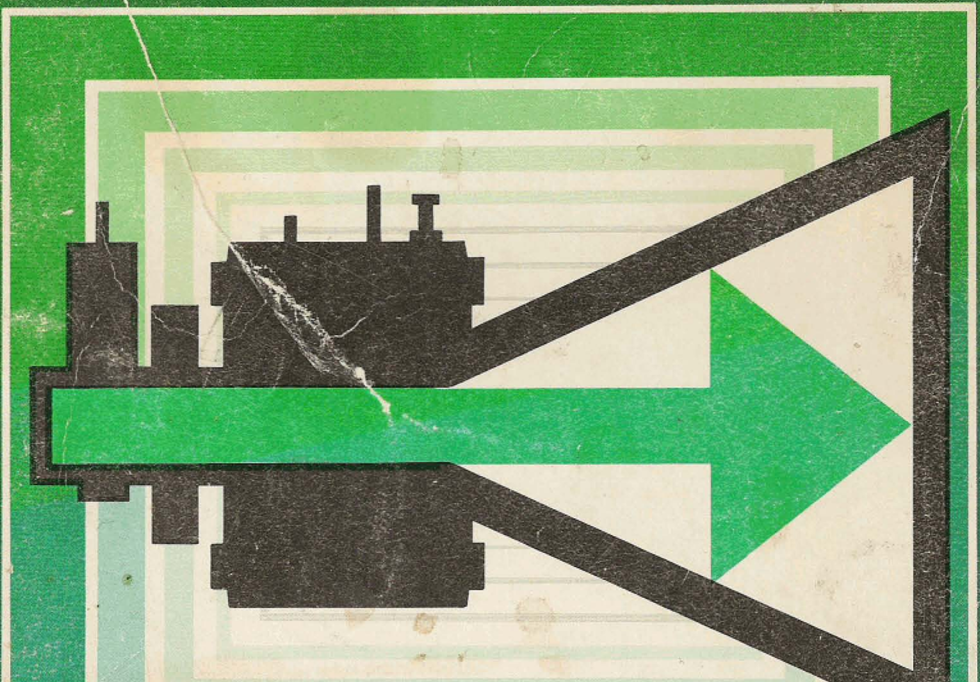
The GUNNPLEXER Cookbook

By Bob Richardson W4UCH



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The Gunnplexer Cookbook

The Gunnplexer Cookbook

A Microwave Primer

for
RADIO AMATEURS
&
ELECTRONICS STUDENTS

by
Robert M. Richardson, W4UCH/2

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The Gunnplexer Cookbook

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This book is dedicated to those outstanding vhf, uhf, and microwave Amateurs whose many contributions to our hobby, avocation, science, and art have led us to the level of today's Amateur microwave technology.

Those outstanding Amateurs, both past and present during the last 30 years include: Ed Tilton-W1HDQ, Denis Heightman-G6DH, Sam Harris-W1FZJ, Rick Emerson-W3OJU, Tom Blevins-W4UMF, Dana Atchley-W1CF, Clair Sutton-W8CMS, Ross Bateman-W4AO, Fred Collins-W1FC, Grid Gridley-W4GJO, Ralph Thomas-KH6UK, John Chambers-W6NLZ, and Bob Cooper-K6EDX/W5KHT, to name a few of the leaders.

Exceptional contributions to 10-GHz Amateur techniques have been made by many of our British cousins who pioneered early Gunn-diode experiments and applications. A special thank-you is due D. S. Evans-G3RPE and G. R. Jessop-G6JP, the editors of the RSGB VHF-UHF Manual, and those British Amateurs who contributed to the microwave section of the RSGM VHF-UHF Manual.

Contents

Foreword

The *Gunnplexer Cookbook* is written for the vhf/uhf radio amateur or electronics student who has at least modest experience assembling vhf converter or receiver kits. The only test equipment required is a grid-dip meter, VTVM or multimeter, a standard broadcast fm receiver, an ordinary TV set, and a good quality high-frequency communications receiver that covers 400 kHz to 30 MHz.

It is much easier to design and build a high-gain video i-f if you have access to a sweep generator and oscilloscope for final alignment. Most amateurs, however, do not have this test equipment available; therefore, the video i-f stages presented in Chapter 15 may be aligned using only a grid-dip oscillator and an fm broadcast receiver. An additional caveat is that, for the same reasons, no machining of the original Gunnplexer/horn antenna module will be necessary.

I have tried to present the subjects in such a way that an isolated vhf/uhf enthusiast, working alone, without help, can build the modules described. At the same time I have tried not to overburden the microwave old-timer who built his first 10-GHz polaplexer transceiver 25 years ago. The line between too much and too little detail is difficult to tread; the reader is asked to be forgiving when the line is too much one way or the other.

Preface

PROPHETS - PIONEERS - PORTENTS

"To predict the future, one must first understand the past." The evolution and development of microwave communications, its history *per se,* is one of the least understood and misconstrued subjects in the lexicon of the average E.E. student and Radio Amateur today. First off, let's try to clarify some of the more popular misconceptions.

Guglielmo Marconi's first major contribution to communications technology was his demonstration of long-wave two-way communications across the North Atlantic in 1901.

WRONG: In 1897 Marconi demonstrated a 1.2-GHz microwave link to the British Post Office. His modulated spark-gap power source covered a 4-mile path and used a Branley-Lodge coherer for the detector.

Longwire antennas and shielded (coaxial) transmission lines preceded parabolic reflectors and waveguide by approximately 30 years.

WRONG: Oliver Lodge demonstrated waveguides to the Royal Institute in London in 1894 and also demonstrated waveguide polarization by rotating the detector 90 degrees. Professor Augusto Righi, Marconi's principal teacher in Italy, developed both parabolic reflectors and refracting microwave lenses during the late 1890s. Heinrich Hertz, even earlier, *circa* 1888, used a parabolic mirror for focusing 420-MHz spark-gap generated rf energy on a nearby dipole antenna with a spark-gap detector.

The first commercial microwave telecommunications link was established between New York City and Boston shortly after World War II.

WRONG: ITT's European R&D houses, LCT (France) and STL (England), established a 1.75-GHz microwave link across the English Channel in 1933 using 33-dB gain parabolic reflector antennas at each end. Though stoutly denied, it is rumored to still be in use today.

The magnetron was invented by Randall and Boot in England during February 1940.

WRONG: The magnetron was invented by Albert Hull in 1921 at the General Electric Research Labs in Schenectady, N.Y. This smooth-bore magnetron was originally invented by Hull as a low-frequency, magnetically controlled amplifier to circumvent the extensive patent litigation, at the time, between DeForest, Westinghouse, and General Electric. In due course, the triode vacuum tube patent problems were resolved, but Hull continued magnetron development through 1925, by which time he was developing over 8 kilowatts power output in the audio and ultrasonic frequency range. Thereafter, the magnetron was virtually forgotten until Randall and Boot invented the cavity magnetron in 1940, which in itself was a spectacular achievement.

After Marconi's historic trans-oceanic communications feat in 1901, he devoted the rest of his life (died 1937), developing long-, medium-, and short-wave communications systems.

WRONG: In an address before the Institute of Radio Engineers in 1922, he stated: "The study of very short electric waves (microwave), although sadly neglected practically all through the history of wireless, is still likely to develop in many unexpected directions and open up new fields of profitable research." Marconi, indomitable genius that he was, then went on to discover microwave troposcatter using his own 3-GHz communication system in 1934.

So much for the anomalies of microwave history and the many popular misconceptions that exist to this day. As the Gunnplexer Cookbook is not a history of microwave technology, we'll skip the very significant contributions of the Varian brothers, inventors of the klystron, (even though our first 10-GHz transceiver, built over 20 years ago, used a surplus 723 A/B klystron); the traveling wave tube, invented by Kompfner; the transistor, invented by Shockley *et al*; the varactor, invented by North *et al*; John Gunn's Gunn diode invention, which made this book possible; plus all the other truly important contributions by so very many others who have brought the state of the art to where it is today.

Acknowledgements

Many individuals have made this book possible, but four stand out above all others:

- Dana W. Atchley Jr., of Microwave Associates, Inc., who brought the Gunnplexer into being through sheer force of character and will, plus a very able supporting cast of company engineers.
- Dr. T. B. Ramachandran, Group Vice President, Microwave Associates, Inc., and producer of over a million Gunn diodes, for his generous financial support directed toward the production of this handbook.
- Margaret C. Merz, whose generosity, foresight, and continued encouragement have kept the author's shoulder to the wheel in the midst of myriad distractions and attractive diversions.
- The author's wife, Nancy C. Richardson, for putting up with such foolishness as parabolic dish antennas in the living room, microwave relay computer data link information on the color TV instead of her favorite program, and for 32 years' of supreme patience and fortitude above and beyond the call of wifely duty.

Let us now get down to business and get to work. I hope you have as much real pleasure building, operating, and improving upon the systems to be described, as I did putting them together and making them play.

Robert M. Richardson W4UCH/2
Chautauqua Lake, N.Y.
February 1981

1

Basic Gunn Diode Theory

A description of negative-resistance microwave devices, Gunn diode fabrication, Gunn diode mounting and tuning, Gunnplexer mixer and isolator, and Gunn oscillator spectral noise.

Since this is a cookbook and not a theoretical textbook, I will touch upon Gunn diode theory very lightly. For those readers who want a more detailed description, the professional literature has many useful articles; Fisk[3] has presented a more modest approach to the subject and includes a detailed list of reference material.

Basically, there are three types of solid-state negative-resistance microwave oscillators in use today: the Esaki or tunnel diode, the Read or IMPATT (Impact Avalanche Transit Time) diode, and the Gunn diode or Transferred Electron Oscillator (TEO). The tunnel diode is characterized especially by its low-noise amplification at microwave frequencies. As such it is widely used in the first rf amplifier stage in microwave receivers for microwave relay links, Doppler navigators, weather radars, etc. Because of its very low power capability it is used only as a receiver local oscillator and never as a power amplifier. (Although

I did use an Esaki diode in a crystal-controlled 50-MHz modulated oscillator powered by a 500 millivolt biochemical fuel cell in 1962.)

IMPATT diodes are the high power members of the Bulk Effect Oscillator (BEO) family, and are currently used to generate peak pulse powers in the 100-watt region. Pulse operation is not allowed in the 10-GHz amateur band, so IMPATT diodes have little interest to amateurs; in addition IMPATTs exhibit high noise, instability, poor linearity, and extreme temperature sensitivity. Their future lies in pulsed radar transmitter applications in the millimeter frequency region where the major problems are, of necessity, acceptable.

Gunn-effect diodes, in the TEO device class, both exhibit low noise, so they can be used for receiver local oscillators, while at the same time serving as the transmitter's rf power generator. Power output of Gunn diodes today is in the 15 milliwatt to 1 watt region. The Gunn diode also exhibits good frequency stability under controlled and stable temperature and voltage conditions. They are widely used in low-power fm and CW radars, microwave data links, intrusion/motion detection alarm systems, parametric amplifier pump sources, and most importantly, the first commercial amateur 10-GHz transceiver (which this cookbook is all about).

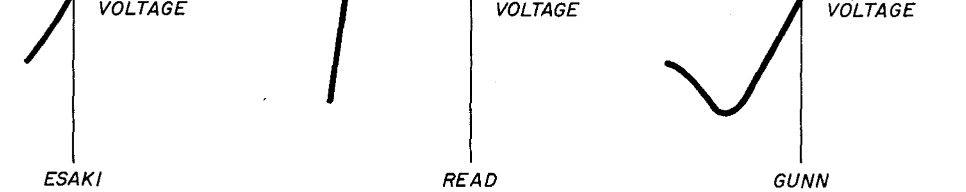

Figure 1-1.
Voltage-current characteristics of Esaki (tunnel) diodes, Read (IMPATT) devices, and Gunn diodes. All are members of the Bulk Effect Oscillator (BEO) family.

Gunn Diode Fabrication

Most of today's Gunn diodes are fabricated from three-layer expitaxially grown gallium arsenide crystals. Indium phosphide Gunn diodes are also manufactured, but gallium arsenide is presently the leader. *Figure 1-2* illustrates the make-up of a typical Gunn diode mounted on a copper heatsink. The resistance of layer I (*figure 2*) is in the range of 0.001 ohms per cm and the size of the gallium arsenide slice may be as large as 1 inch (25 mm) in diameter. Thousands of Gunn diode dice may be obtained from a single slice (after sawing or scribing), but yield varies considerably, requiring thorough testing of each diode. Layer II is an epitaxially grown N-type layer that is doped during growth to obtain a resistivity of approximately 0.5 ohms per cm. This is the active layer of the Gunn diode and its thickness determines the optimum center frequency of operation, varying from 18 μm at 6 GHz to 6 μm at 18 GHz. A typical 10-GHz Gunnplexer diode has a layer II thickness of about 10 μm.

Layer III is only 1 to 2 μm thick and is not actually necessary. It does improve yield and device life, however, by isolating Layer II from impurities introduced during the gold metallization required to bond the diode to the heatsink. The top Layer I is

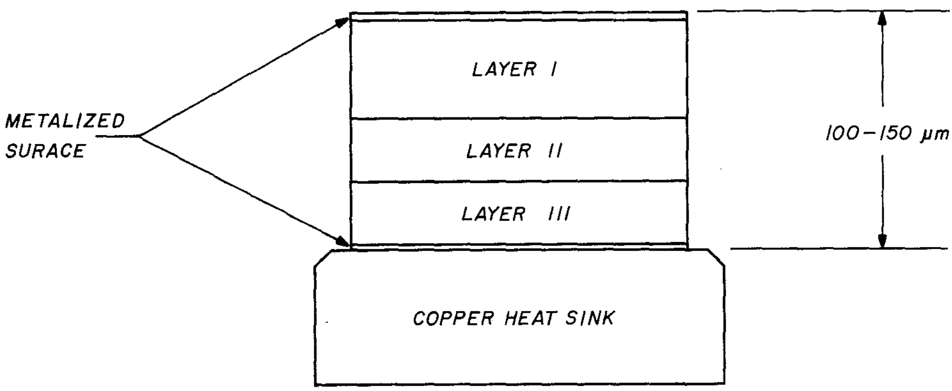

Figure 1-2.

Cross section of a Gunn diode and heatsink mount. Layer I is a low resistivity gallium arsenate substrate approximately 100 μm thick, upon which epitaxial layers II and III are grown in a vapor phase reactor.

also metallized to assure very low thermal and electrical resistance.

The average area of a Gunn diode is about 2×10^{-4} square centimeters. A few hundred on the table in front of you would be swept away as fly-specks if they were not encapsulated; and even encapsulated, they are incredibly small. The average diode package measures only ⅛ inch (3 mm) in diameter by approximately 3⁄16 inch (5 mm) long.

Gunnplexer Diode Mounting

You do not take a Gunn diode, mount it in a section of waveguide with an insulated coupling/mounting post, feed it power through an rf choke, and then measure power output. The dimensions of each part, positions in the cavity, iris-hole coupling size to the waveguide *et al* must be optimized empirically. This is a scientific way of saying that there is a great deal of "cut and try" optimization which is often more "art" than pure science. *Figure 1-3* shows a typical arrangement. By placing a varactor where the tuning slug is shown in *Figure 1-3*, and moving the tuning slug slightly forward of a center between the varactor and Gunn diode/post coupling, a combination of both mechanical and electrical tuning is obtained. Typical gunnplexer tuning characteristics, at a center frequency of 10.250 GHz, are: mechanical, ±600 MHz; and electrical, ±55 MHz.

A front view of the Gunn oscillator and cavity is shown in *Figure 1-4*. The righthand quarter-wavelength rf choke feeds +10 Vdc to the Gunn diode, the lefthand quarter-wavelength choke feeds 1 to 20 Vdc to the varactor diode for electronic tuning. If you look closely between the two choke mounting posts, forward, you can see the top of the mechanical cavity tuning slug.

Gunnplexer Mixer/Isolator

The Gunnplexer oscillator cavity is mounted to a machined aluminum block which holds both the ferrite isolator/circulator and 10-GHz Schottky mixer diode as shown in *Figure 1-5*.

The ferrite isolator decouples the mixer diode from the full output of the Gunn oscillaator, and is positioned so that most of

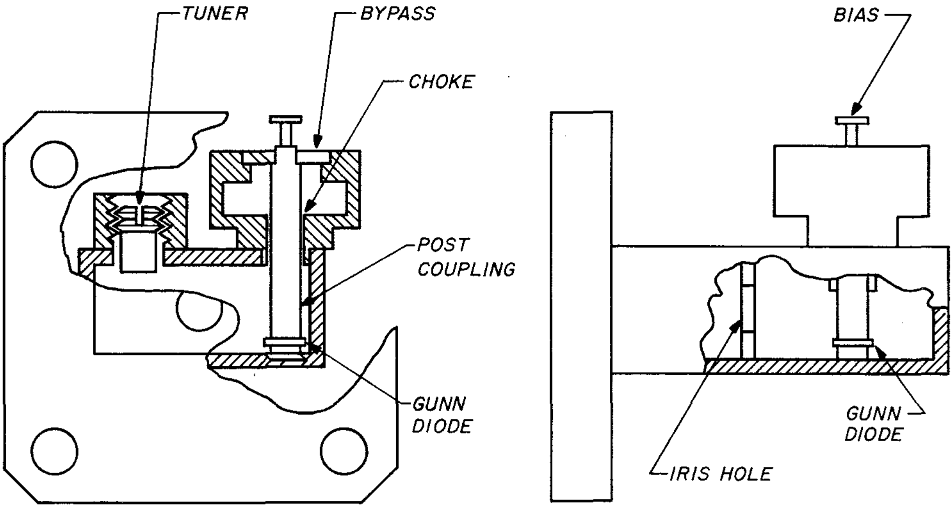

Figure 1-3.

Diagram showing a Gunn diode mounted in a waveguide cavity and designed for direct waveguide mounting. Frequency adjustment is by a mechanical tuning screw.

an incoming 10-GHz signal is intercepted by the mixer diode. The mixer diode output is through the top of the block after passing through an rf choke and 10-GHz bypass capacitor. The operating specifications of the Microwave Associates 10-GHz Gunnplexer are listed in *Table 1.*

Table 1. Operating Specifications of the Microwave Associates 10-GHz Gunnplexer.

Rf center frequency	optional (10.250 GHz desired)
Rf power output	15-40 mW
Tuning: mechanical	±100 MHz minimum
electronic	60 MHz minimum
Temperature stability	-350 kHz per degree C
Power output variation	less than 6 dB with temperature
Frequency pushing	15 MHz per volt maximum
Noise figure	12 dB maximum
Power requirements	

Table 1. Operating Specifications of the Microwave Associates 10-GHz Gunnplexer. (Continued)

Gunn supply voltage	+10 Vdc
Gunn current	500 mA maximum
Varactor voltage	+1 to +20 Vdc
Rf connector	mates with UG-39/U flange
Operating temperature	-30 to +70 degrees C

Gunn Oscillator Noise

All oscillators exhibit a noise spectrum to a varying degree. The Gunn oscillator's noise spectrum is fair to good when unaided by

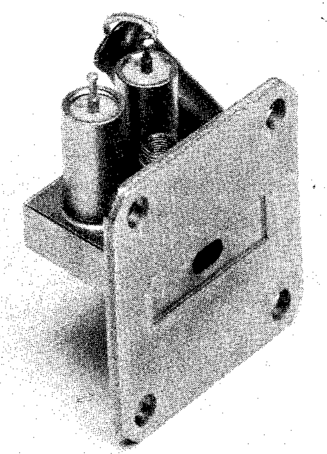

Figure 1-4.
Front views of a Microwave Associates Gunn oscillator cavity. The two tubular objects on the rear of the cavity are quarter-wavelength rf chokes. Power is coupled out of the cavity through an iris.

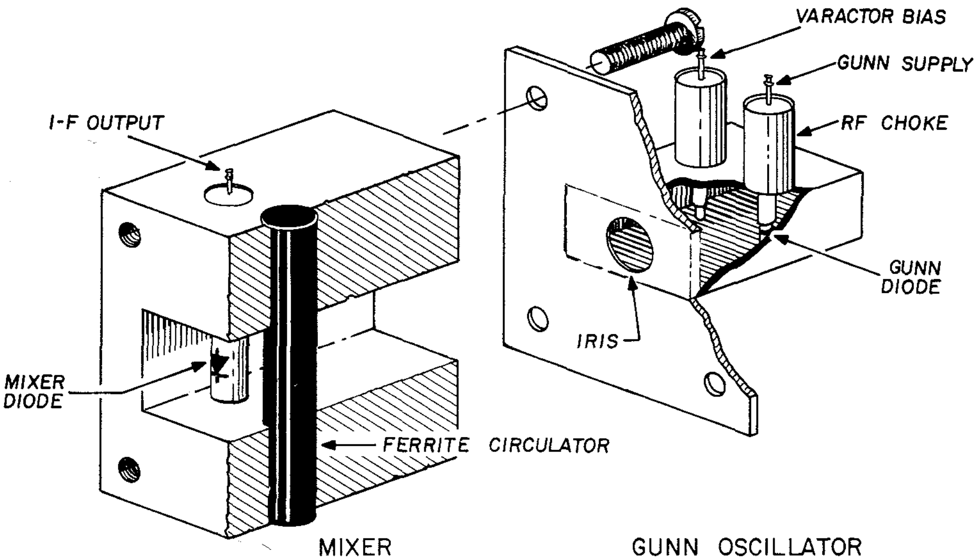

Figure 1-5.
Exploded drawing of the Gunnplexer cavity, ferrite circulator, and mixer diode (drawing courtesy *ham radio* magazine).

phase locking, and is outstanding when phase locked to a harmonic of an ordinary 18- to 19-MHz third-overtone crystal. Rather than fill this section with a plethora of charts and graphs, a few pertinent comments based upon Gunn oscillator a-m and fm noise observations may be more useful.

Microwave Associates has minimized the Gunnplexer's noise output by several methods:

1. Biasing the Gunn diode at optimum turnover voltage, +10 Vdc
2. Maximizing the cavity's quality factor, Q
3. Gunn diode selection

The rest is up to the Gunnplexer's operator who controls ripple on the Gunn diode and varactor power supply voltages, and who may choose to phase lock the Gunn diode to a crystal oscillator harmonic, which virtually eliminates a-m and fm spectral noise.

During wideband fm operation (75-kHz deviation) and narrowband fm operation (15-kHz deviation), with comparable bandwidths of approximately 30 and 200 kHz, respectively, the spectral noise of the Gunn oscillator is not noticeable; it can only be measured with a spectrum analyzer. For the average user, in fact, spectral noise is non-existent. Setting i-f bandwidth to 8 kHz on a high quality communications receiver, the spectral noise is only noticeable in the CW mode. With 2 kHz, 1 kHz, and 400 Hz i-f bandwidth positions, however, the CW note is virtually drowned out in "white noise" and is comparable to a chain-saw running wide open without a muffler in the operating room. No communications of any variety with bandwidths of less than 6 kHz are recommended without the *Crystalmatic* phase lock system *(chapter 12)* or the equivalent. Using the *Crystalmatic* system, 850 Hz or even 170 Hz FSK or CW operation is entirely feasible. A highly pure CW note is easily obtained with either the 400 or 1000 Hz i-f bandwidth.

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2

Gunnplexer Operation

10-GHz propagation, path loss, range vs i-f bandwidth, and carrier-to-noise ratio. Also discusses Gunn diode cavity tuning and Gunnplexer antenna basics.

Propagation on the 10 GHz microwave amateur band (10.0-10.5 GHz) is not greatly different from that experienced on 432 and 1296 MHz amateur frequencies, and is, surprisingly, similar in many aspects to both the 50- and 144-MHz amateur bands. In fact, there are considerably more similarities than differences. E-layer and F-layer propagation are non-existent at 10 GHz, of course, but most of the other modes familiar to vhf/uhf operators do exist. These propagation modes include, but are not limited to, the following:

Reflection. Multipath reflected signals were used for my first 10-GHz contact across Chautauqua Lake, New York, as the two antennas were not properly aligned. As an example of reflection propagation, sheet-metal siding on a barn 1½ miles (2½ km) away will reflect Gunnplexer signals over 30 degrees with insignificant loss.

Refraction. The current 10-GHz amateur distance record set by GM3OXX in Scotland and G4BRS in England during August, 1976, used an over-water ducting mode (just as KH6UK and W6NLZ did between Hawaii and California on both 144 MHz and 432 MHz). Refraction using warm/cold frontal passages is possible on 10 GHz, if you figure out how, where, and when to point a narrow beamwidth antenna. Beacon-type schedules in pre-arranged directions at pre-arranged times will solve this problem if phase-lock frequency control is used so that the transmitting station knows the exact operating frequency, and the receiving station knows exactly where to tune the receiver.

Diffraction. Knife-edge effect exists at 10 GHz, just as it does on the vhf/uhf bands, and the sharper the crest of the hill or mountain, the better. Also, the summits should be clear of trees (or rather, tree leaves).

Absorption/blocking. Regardless of the propagation mode, 10-GHz signals will not pass through a maple tree in full leaf that is 60 feet (20 meters) away from a Gunnplexer with a parabolic reflector antenna. In the winter season, after the leaves are gone, trees are virtually invisible at 10 GHz.

A surprise, at least to me: Moving a Gunnplexer with a parabolic reflector indoors one day, behind ⅜ inch (1 cm) glass sliding doors, I expected the 5½ mile (8½ km) distant Gunnplexer signal to disappear. It did not, but only dropped one S-unit (about 4 dB). Light rain was much worse and attenuated the Gunnplexer signals 10 dB and more (this is why United Air Lines uses only C-band weather radars).

Free Space Attenuation is given by the equation Attenuation (dB) = 96.6 + 20 log frequency (GHz) + 20 log distance (miles). For example, 1 mile at 10.250 GHz = 116.8 dB attenuation; adding 6 dB every time distance doubles,

distance	**attenuation**
2 miles	122.8 dB
4 miles	128.8 dB
8 miles	134.8 dB

A 12 dB Noise Figure with 15 kHz bandwidth represents -120 dBm ENI where ENI = equivalent noise input or absolute threshold. For a 10 dB carrier/noise ratio, a -110 dBm signal is required. Using a 17 dB gain horn antenna, see (Figure 2-1A, maximum operating distance is 102 miles (164 km) for 157 dB total free space attenuation. This is illustrated in *Figure 2-1.*

Note that these calculations are for a 15 kHz i-f bandwidth, which is approaching the minimum that the Gunnplexer spectral

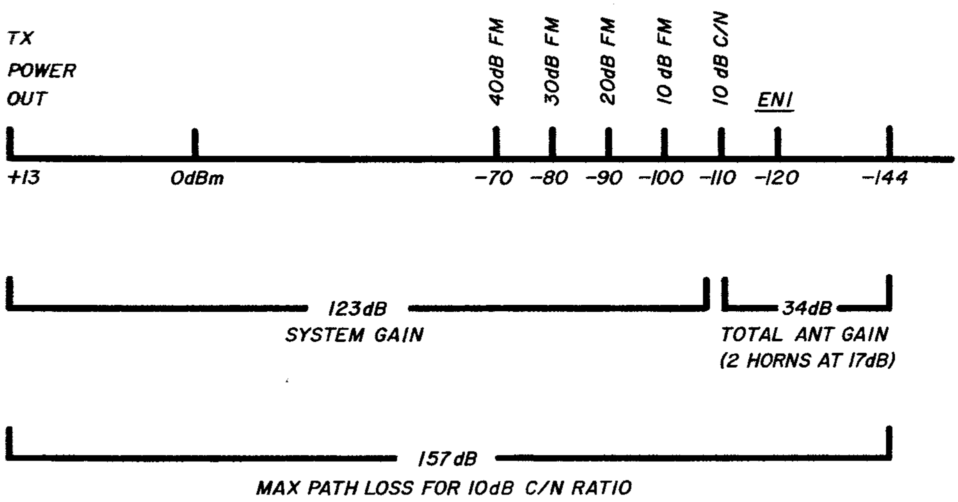


Figure 2-1.

Path performance calculations for a 20 mW (+13 dBm) Gunnplexer operating with a 12 dB noise figure and 15 kHz i-f bandwidth. Maximum path loss for 10 dB carrier-to-noise ratio is 157 dB; with a 17 dB gain horn antenna, this represents a distance of 102 miles (164 kilometers).

noise will allow without phase locking. Also, AFC should be used with narrow-band fm, and proportional temperature control (chapter 5) is recommended so the operator can find the signal to achieve AFC lock-on.

The graph of *Figure 2-2* illustrates free space attenuation vs frequency and path length for the six amateur bands from 1.215 GHz to 24.0 GHz. As the operating frequency is increased, the free space attenuation increases approximately 6 dB per octave (doubling frequency) between isotropic antennas. The key words here are "free space" and "isotropic antenna." Free space means a virtual vacuum and isotropic antenna means that the capture area of the receiving antenna decreases as the ratio of the operating wavelength squared, hence the 6 dB decrease per octave. If you ignore the water vapor absorption line, air density, humidity, fog/clouds, and other factors which increase path loss, this graph should encourage more amateurs to try operating on the microwave bands.

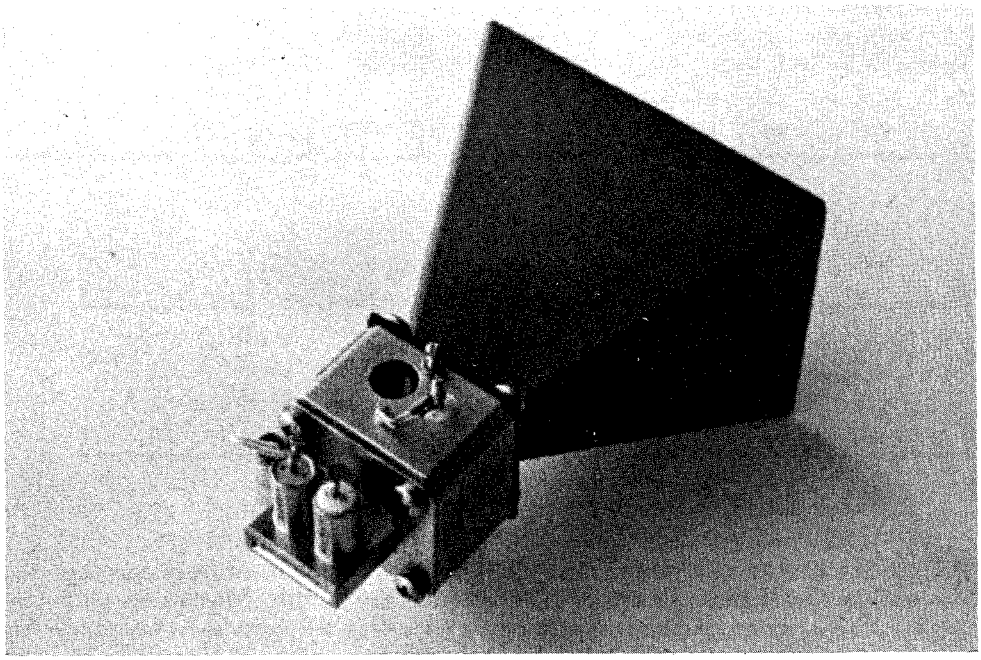


Figure 2-1A. 17dB Gain Antenna.

Communications Range

The graph of *Figure 2-3* clearly illustrates the carrier-to-noise ratio (in dB) that one would find with the three different antennas listed when using a standard fm broadcast receiver bandwidth of approximately 200 kHz, a low noise i-f preamplifier and a Gunnplexer with 15 milliwatts power output.

Figure 2-3 also shows that, by reducing the receiver's i-f bandwidth from 200 kHz to 15 kHz, a 13.33 to 1 ratio, improves the carrier to noise ratio by 11 dB. Now, going from a properly focused 24-inch (61 cm) diameter parabolic reflector to a 48-inch (122 cm) dish provides 6 dB gain. An 8-foot (2.4 meter) parabolic dish would provide 12 dB gain over the 24-inch (61-cm) reflector, but such a large dish is out of the question for most amateurs because of wind loading. It is not difficult to build an 8 foot (2.4

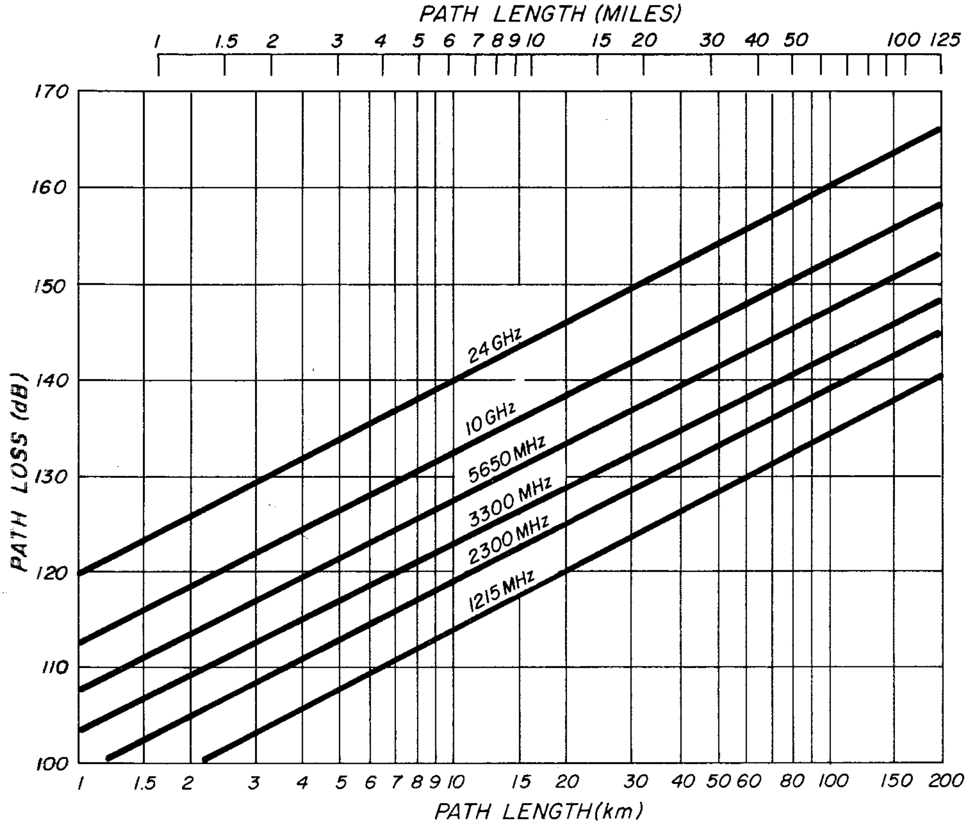


Figure 2-2.

Graph of free space attenuation vs frequency for the amateur bands from 1215 MHz to 24 GHz. Note that path attenuation increases approximately 6 dB each time the operating frequency is doubled.

meter) parabolic reflector using either the petal technique or stressed tubing/screen techniques, but it is difficult to build it strong enough to withstand 60+ mph gusts of wind.

My first 8 foot (2.4 meter) dish antenna, though stressed for 50 mph wind gusts, was scattered far and wide by a thunderstorm. The neighbors were not sure whether an aircraft had exploded or W4UCH's antenna had completely disintegrated; as one of them said, "It was raining aluminum!"

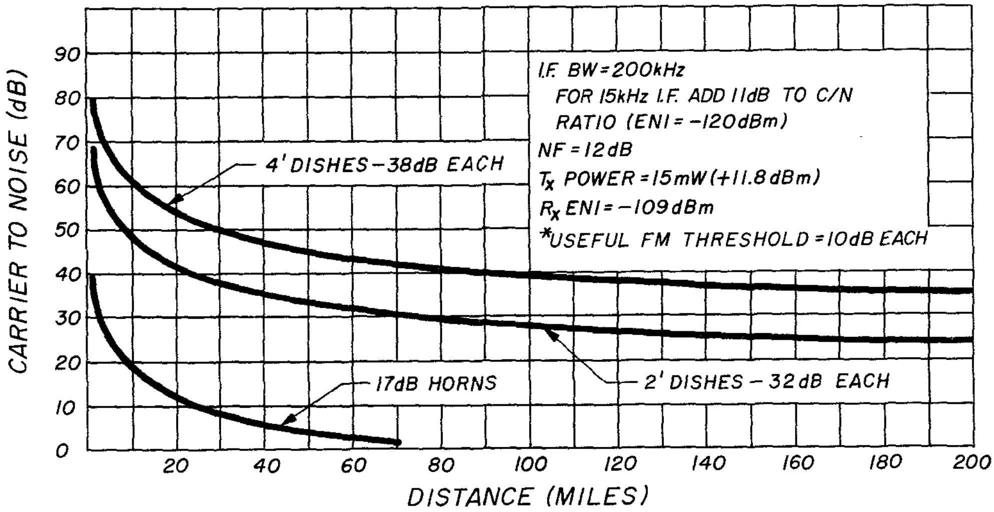


Figure 2-3.

Graph of path distance at 10.25 GHz versus carrier-to-noise ratio for 17 dB gain horn antennas and 24 inch (61 cm) and 48 inch (122 cm) parabolic reflectors. The calculations assume a 200-kHz i-f bandwidth and Gunnplexer power output of 15 mW.

The main point here is that it is much easier and safer (sky-is-falling syndrome) to pick up additional carrier-to-noise dB by reducing i-f bandwidth. Using a small 24 inch (61 cm) parabolic reflector antenna with 850 cycle FSK, CW or Baudot, received with an i-f bandwidth of 1 kHz, yields a better carrier-to-noise signal by +5 dB, than a 48 inch (122 cm) dish at 15 kHz i-f bandwidth, or an 8 foot (2.4 meter) dish at 200 kHz i-f bandwidth.

An additional bonus is that it is considerably easier to orient the 2-foot (61 cm) dish (5 degree beamwidth) when compared to the 4- and 8-foot models with their very narrow beams. Accurate antenna pointing seems extremely simple until you actually try to do it with 1 or 2 degree accuracy; it is definitely not a simple task. Whenever possible, use a phase lock system and keep i-f bandwidths to 15 kHz or less for voice, and 1000 Hz or less for CW and RTTY.

Range vs I-F Bandwidth

Figure 2-4 is a plot of communications range versus bandwidth in free space for "threshold" reception of intelligible speech. Corrected for our real world atmosphere in clear air, perhaps a 10 to 20 per cent reduction is advisable, if all other conditions are perfect and a low noise i-f preamplifier is used. By extrapolating the line for 24 inch (61 cm) parabolic antenna and using 1 kHz i-f bandwidth, the projection yields a threshold range of approximately 8000 to 10,000 miles (13,000-16,000 km). Who will be the first to work California to Hawaii on 10 GHz via two-way ducting? Or Japan to Australia, or New Zealand/South America, or South America/Africa on 10 GHz? Given the right conditions it can (and will) be done.

10-GHz Frequency Plans

There are nearly as many 10-GHz band plans as there are 10-GHz operators and microwave clubs. Most German amateurs operate simplex and have standardized on 10.250 GHz transmit and 10.280 GHz receive (10.220 GHz receive); many microwave enthusiasts in New England have followed suit. Considering the number of 10-GHz operators in the world, or any given locality, and the directivity of the Gunnplexer horn antennas (30-35 degrees), interference should not be a problem for the time being, even if both wideband and narrow band operators adopt the German plan for simplex operation.

I prefer a 29 MHz i-f for narrow-band operation, thus allowing any good quality amateur communications receiver to serve as a tunable i-f. For wideband fm, most fm broadcast receivers will serve as a tunable 98 MHz receiver; used fm auto receivers do the best job because they are usually well shielded; proper power supply bypassing will eliminate all but the most powerful local fm stations. A Gunnplexer with a 10.348 GHz center frequency may be ordered from Microwave Associates, Burlington, MA., or a nominal 10.250-GHz module may be retuned with the mechanical Gunn cavity tuning slug (see Chapter 3 for frequency measurement techniques).

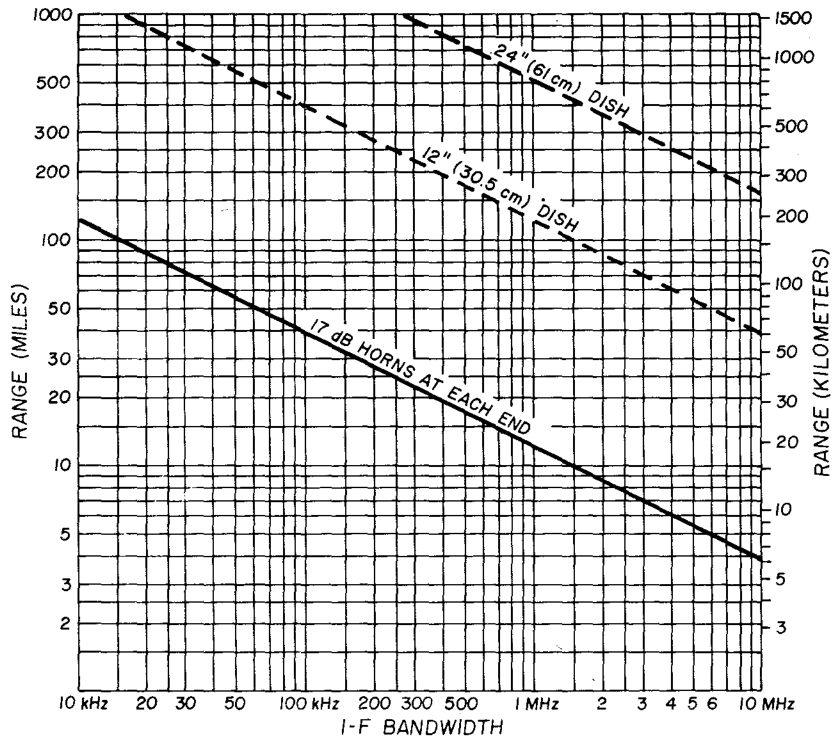


Figure 2-4.

Graph of communications range vs i-f bandwidth for an operating frequency of 10.25 MHz.

A word of caution. Until you master microwave frequency measurement, it is best *not* to adjust center frequency with the Gunn cavity tuning slug unless you have a digital microwave frequency counter. The tuning slug is very sensitive and searching 100 MHz or more for a signal is a bit like trying to find the proverbial needle in a haystack.

Gunnplexer Performance

The performance graphs in *Figures 2-5* and *2-6* were derived by B. Chambers, G8AGN, a member of the RSGB Microwave Committee, using a 25 milliwatt Gunnplexer. *Figure 2-5* illustrates the tremendous frequency range possible using the Gunn diode cavity mechanical tuning slug. *Figure 2-6* is an excellent illustration of both power and frequency output versus varactor voltage. The message is clear, "Keep varactor voltage excursions to a minimum (less than +8 Vdc), and use the mechanical Gunn diode cavity tuning screw if greater tuning range is desired."

Microwave Associates, Burlington, MA 01803, is the exclusive dealer for the Microwave Associates' Gunnplexer. Approximate prices, + $2.00 shipping per order are:

MA 87140-1 15 milliwatt (minimum) Gunnplexer and horn	$119.95
MA 87141-1 (2 each above)	199.95
MA 87140-2 25 milliwatt (minimum) Gunnplexer and horn	170.00
MA 87141-2 (2 each above)	305.00
MA 87140-3 40 milliwatt (minimum) Gunnplexer and horn	205.00
MA 87141-3 (2 each above)	390.00

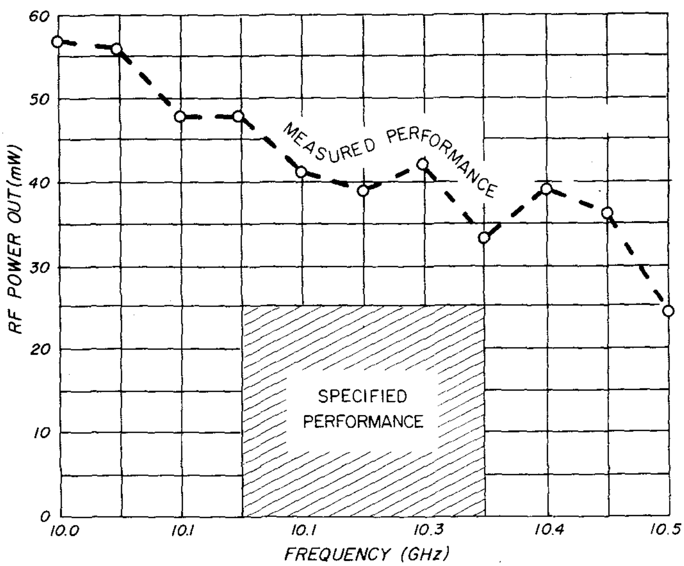


Figure 2-5.
Graph of measured power output vs Gunnplexer tuning.

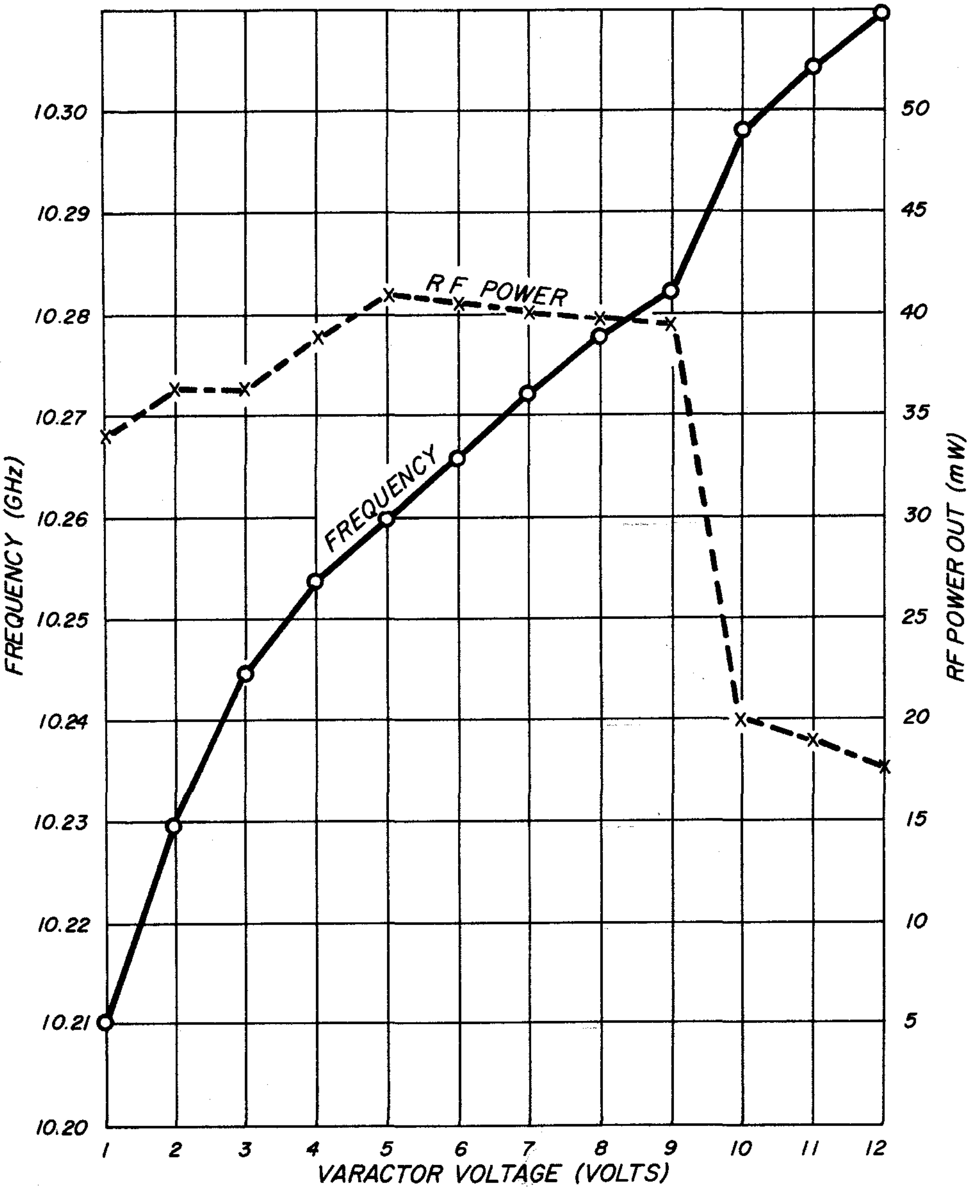


Figure 2-6.
Gunnplexer output power and operating frequency as a function of the varactor tuning voltage.

3

Frequency and Power Measurements

Construction of a simple micrometer-driven frequency measurement table and 10-GHz relative power output dipole/diode attachment.

The use of Lecher wires for wavelength measurements is older than radio communications itself, and is based on the fact that the length of a radio wave can be measured quite accurately by observing the distance between current loops or nulls (maxima and minima) along a two-wire transmission line (Lecher wire). Wireless experimenters in the late 1800s used the Lecher wire system almost exclusively for wavelength/frequency measurements above 100 MHz.

Carrying the Lecher wire principle one step further, a simple reflector located in the near field of a Gunnplexer will cause the mixer voltage output to vary from a maximum to minimum as the reflector or Gunnplexer is moved a physical half wavelength. It's not recommended that you place the reflector too closely (less than 2 feet or 60 cm) to the Gunnplexer or you may permanently damage the mixer diode as I did. Except for the fact that the reflected signal pulls the frequency of the Gunn oscillator output, this would be an excellent way to measure wavelength/frequency. A relatively easy way to resolve this paradox is to vary the distance of a very small dipole/detector in the near-field of the Gunnplexer and measure current loops or nulls. With this technique the signal reflected back into the Gunnplexer is so small it does not measurably effect the Gunn oscillator frequency.

Readers who have access to a microwave digital frequency counter which covers the 10-GHz band may skip this chapter. However, I recommend you read the section on the dipole/detector as this useful device will be used later as a permanently mounted rf monitor inside the outer edge of the Gunnplexer horn antenna.

The wavelength (frequency) measurement table shown in *Figure 3-1*, consists of little more than a 2 or 3 inch (50-75mm) micrometer epoxied to a ½-inch (13-mm) thick plywood base that may be mounted on a tripod. The micrometer piston/arm is inserted into a snug but free to rotate section of brass tubing (the piston) that is held tightly against the moving micrometer piston/arm with rubber bands. This brass tubing drives a plywood float that slides on the plywood base. Another section of brass tubing, *B*, is epoxied to the top of the float (see *Figure 3-2*) which telescopes in and out of another section of brass tubing *C*. Section *C* is epoxied rigidly to the mount which is epoxied to the base. The telescoping section of brass tubing, which has a 10 inch (25 cm) length of ⅛ by ¼ inch spruce epoxied to it, holds the dipole/detector as illustrated in *Figure 3-3*.

The only precautions necessary when building the wavelength measuring table are to make sure that the brass tubing *A*, fits easily on the micrometer piston, and section *B* slides easily without binding in and out of section *C*.

Keep adding rubber bands between the plywood float that *A* is epoxied into, and the end of the table, *E*, until all backlash is eliminated when turning the micrometer, both in and out. One inch (25 mm) threaded standoffs are used to mount the table's sheet aluminum cover as shown in *Figures 3-2* and *3-3*.

The dipole/detector shown in *Figure 3-4*, is, if simplicity has merit, the epitomy of engineering excellence. It is nothing more than a point-contact germanium diode soldered directly across a filed down 200 to 500 pF ceramic disc capacitor. Construction takes only a few minutes and is completed by bending the diode leads to form a dipole about ½ inch (13 mm) wide as shown in *Figure 3-5*. The ceramic disc capacitor is then filed down on each side until one half of each lead is filed away at the center of the disc. Break off the remaining lead on each side and lightly tin each side with a soldering iron (25 watts or less). Then solder the

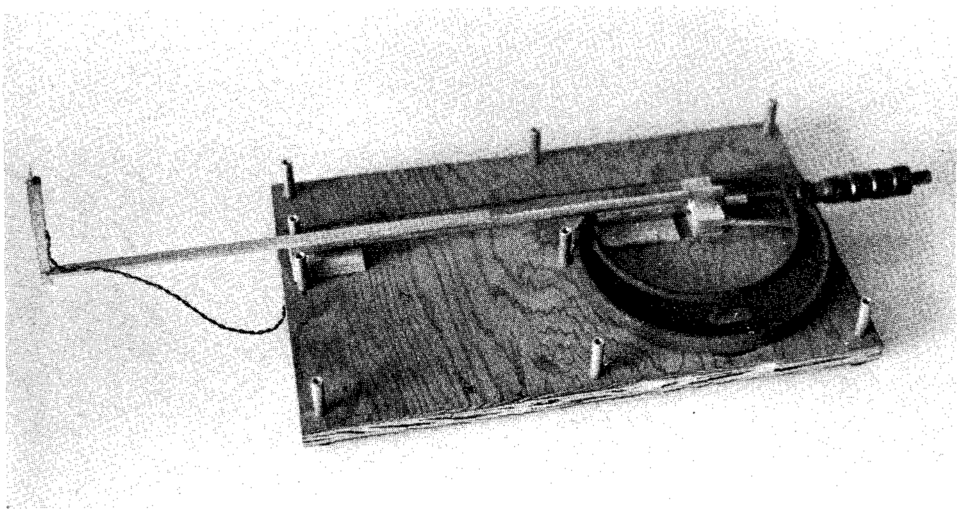


Figure 3-1.

Wavelength (frequency) measurement table consists of a micrometer-controlled dipole/detector assembly which is placed in the near field of the Gunnplexer. Instruction of this instrument is shown in Figure 3-2 and discussed in the text.

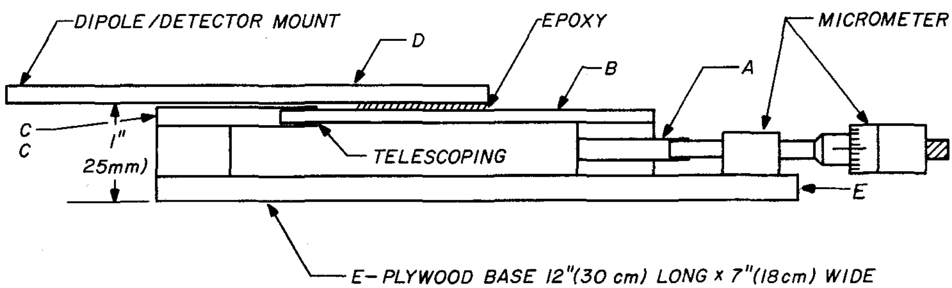


Figure 3-2.

Construction of the wavelength (frequency) measuring table. The micrometer is from Sears (catalog no. 9A387713); the telescoping brass tubing is available at most hobby shops. A photograph of the measuring table with its cover is shown in Figure 3-3.

diode/dipole to each side followed by a small twisted pair of No. 28 (0.3 mm) insulated wire, also to each side. That's all there is to it.

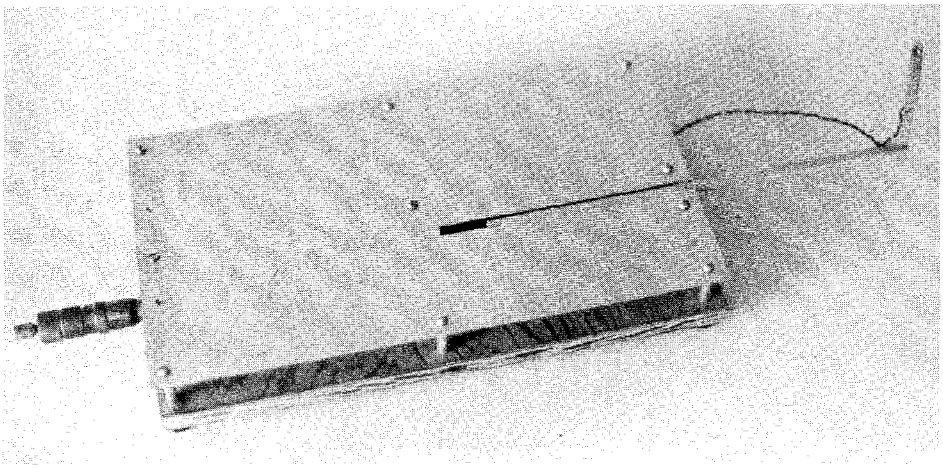


Figure 3-3.
View of the wavelength measuring table with its protective cover. The dipole/detector is at the far right.

It may be necessary to test a few point-contact germanium diodes (200 each for $1.98 from Poly Paks) to select one with high output in the 10-GHz band. The Hewlett-Packard 5082/2835 Schottky diodes are also excellent with outputs in the 5 millivolt range when placed 6 inches (15 cm) away from the mouth of the Gunnplexer horn antenna on the measurement table.

DC Millivoltmeter

Since most radio amateurs and electronics students do not have a dc millivoltmeter with full-scale range of 10 mV or 100 mV, presented here is a unit that may be built in an hour or two for less than $3.00 plus the meter. The circuit is based on the National Semiconductor LM4250 micropower operational amplifier IC and requires only two pen cells for the power supply. It is shown in *Figure 3-6,* built on perf-board, using the LM4250CN mounted in an 8-pin DIP package.

In the dc millivoltmeter schematic *(Figure 3-7)* resistor R_v is 100k ohms for 10 millivolts full scale and 1 megohm for 100

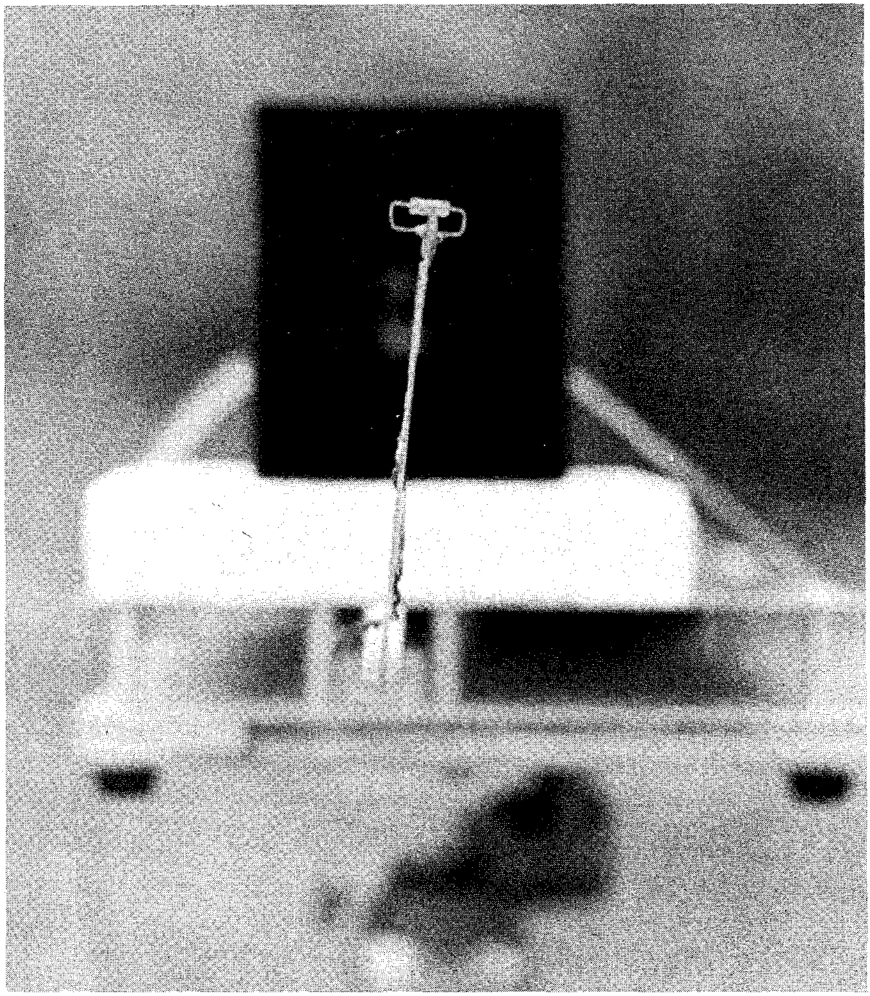


Figure 3-4.
Photograph of the 10-GHz dipole/detector assembly. Construction is shown in Figure 3-5.

millivolts full scale. The 100k pot is for zero adjustments and the 5k pot is for full-scale adjust. The 1.5 Vdc pen cells will last nearly their shelf life if an on-off switch is included. This dc millivoltmeter is also useful as an S-meter amplifier for use with

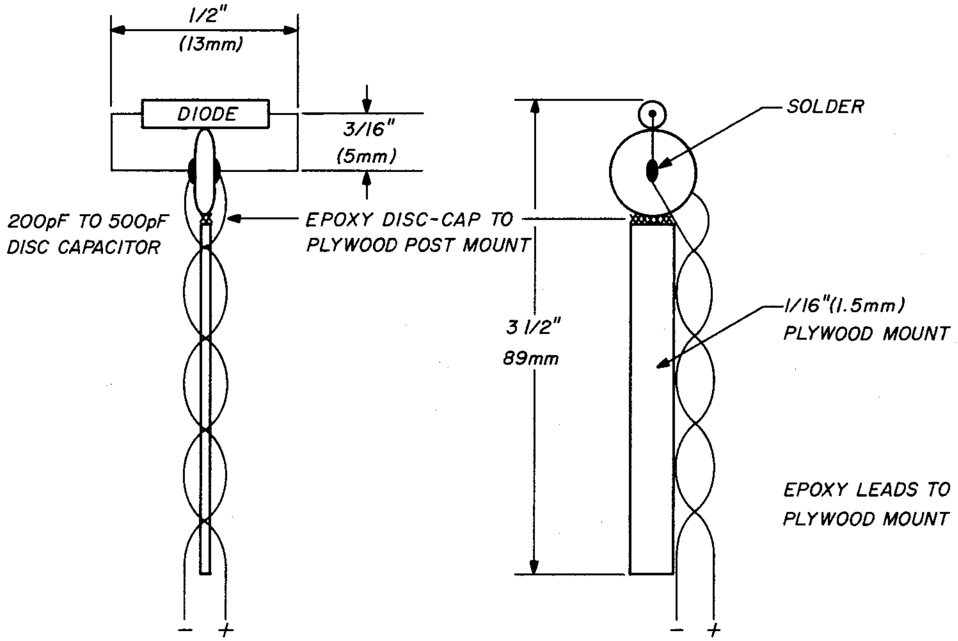


Figure 3-5.

Construction of the 10-GHz dipole/detector assembly. The diode is a low-cost germanium point-contact device which has been selected for high output at 10 GHz; a hot-carrier diode such as the Hewlett-Packard 5082/2835 is also suitable.

standard fm broadcast receivers and will be used later for that purpose (Chapter 9).

Frequency Measurement Practice

A +10 Vdc, 500 mA regulated power supply for the Gunn diode source is needed with exactly +4.00 Vdc for the tuning varactor. If you do not have such a power supply look ahead to Chapter 4 and build one, or assemble the circuit shown in *Figure 3-8.* All that is necessary is a 12-volt storage battery and 3-terminal LM317 adjustable regulator, (or Lambda 1510 fixed 10 Vdc regulator), plus two 500-ohm resistors, a 10-turn 1000-ohm pot, and 10 μF capacitor. This circuit has very high ripple rejection (if you use an ac powered 12 Vdc source).

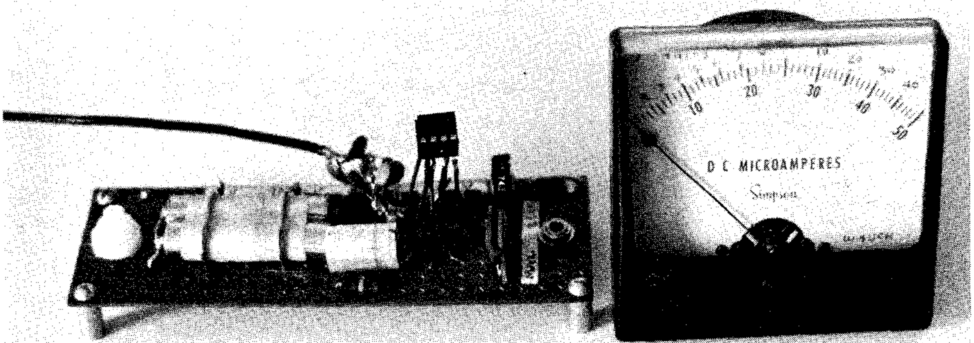


Figure 3-6.
Low-cost dc millivoltmeter which provides full-scale readings of 10 and 100 mV. Schematic diagram of the instrument is shown in Figure 3-7.

The first 1N4002 diode protects the regulator from accidental input short circuits, the second 1N4002 diode serves as protection for accidental input or output shorts, and the 1000 μF electrolytic capacitor is an extra precaution that is probably unnecessary. Most LM317 ICs have less than 2.0 Vdc internal drop so should easily supply +10 Vdc at 500 mA from a 12 volt dc source.

Mount the Gunnplexer on the frequency measurement table with rubber bands and sitting on styrofoam or cardboard blocks as shown in *Figure 3-9.* Pick a warm sunny day, and set the battery powered assembly up outdoors with the Gunnplexer pointing upwards, at nothing at all except sky, because strong reflections of every variety (such as always occurs when used indoors), will make your minimum or maximum readings difficult, misleading, and probably meaningless.

After a 30-minute warm-up period to allow the Gunnplexer case temperature to stabilize as much as possible, adjust the Gunnplexer position on the table as far forward as you can to obtain a voltage null reading on your LM4250 millivoltmeter driven by the dipole/detector. Now move the Gunnplexer rear-

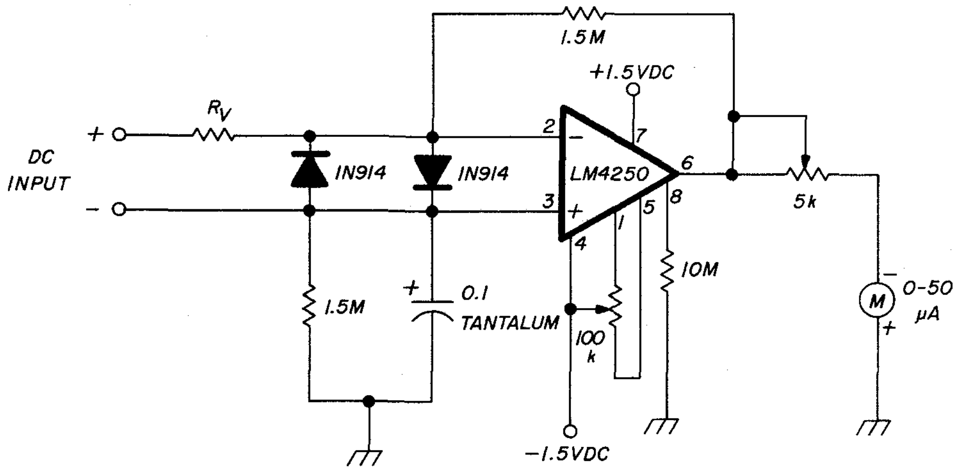


Figure 3-7.
Schematic diagram of a simple dc millivoltmeter with full-scale sensitivity of 10 mV (R_v = 100k) or 100 mV (R_v = 1 megohm). The 100k potentiometer is for zeroing, and the 5k pot is for full-scale calibration.

ward on the table a small amount. The preceding is done with the micrometer turned *in* fully clockwise except for left-hand units. Now slowly bring the dipole/detector in towards the Gunnplexer by rotating the micrometer counterclockwise until you have a voltage null. If all is working well, you should (with practice) be able to locate this null (and relocate it too), within one thousandth of an inch, assuming your micrometer is calibrated in inches. Write down the micrometer reading, and continue turning the micrometer counterclockwise until the second null is located (dead center), and again write down the micrometer reading. You have now measured one-half wavelength of your Gunnplexer's output frequency.

Do this three or four more times, and take the average of the distance between nulls and divide into the constant 5905. The result is your Gunnplexer's output frequency in MHz. A typical run looks like this:

1st reading	2nd reading	3rd reading
0.007″	0.008″	0.007″
0.584″	0.581″	0.582″
0.577″	0.573″	0.575″ (difference)

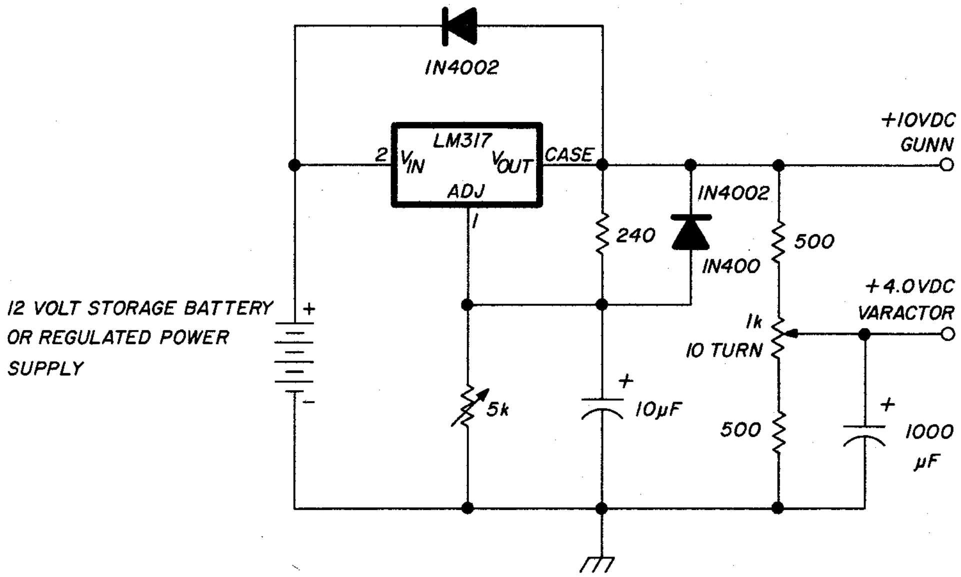


Figure 3-8.
Simple regulated dc power supply for the Gunn diode and tuning varactor. This circuit has high ripple rejection and the voltage regulator IC is protected from input and output short circuits.

Average distance between half-wavelength nulls = 0.575 inch; divided into 5905 = 10.269 to 10.270 GHz. This is excellent for a first try and probably too good to be true, because at 10.250 GHz 0.001 inch half-wavelength difference represents 17 MHz. Experience and more practice will improve your measurements tremendously.

Frequency measurement is not much different from navigating an aircraft or ship. The more practice you have, the more measurements you make and average, the more accurate your frequency determination will be. If you obtain a few "wild ones" by all means throw them out, as something was probably sticking.

An experienced machinist is able to easily read this type of micrometer to 0.0001 inch, using the vernier scale. Considering the wood and rubber band construction suggested here, 0.0001 inch readout is going a bit overboard. If you disregard the mechanical system and its readout errors, however, the next most significant error is due to Gunn cavity temperature control. If you

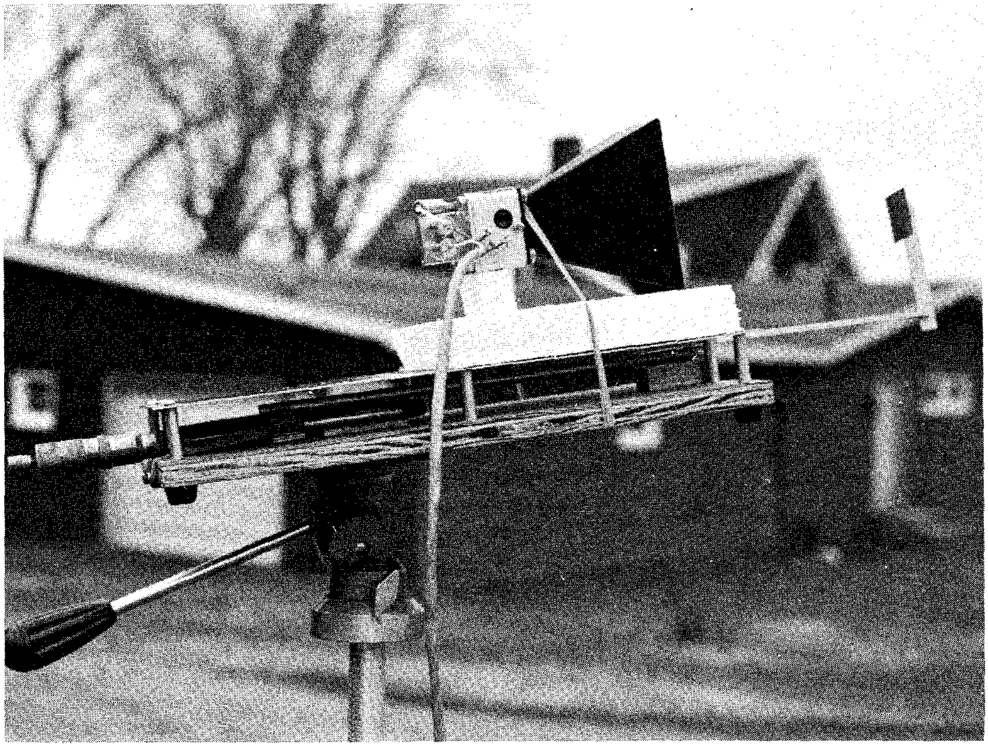


Figure 3-9.

Test setup for measuring the operating frequency of a Gunnplexer (see text). The dipole/detector unit (Figure 3-5) is placed a few inches in front of the Gunnplexer.

wish to experiment, turn off the Gunnplexer for about 30 minutes, allowing it to cool. Now, take another measurement immediately after turning the Gunnplexer back on.

This frequency measurement system is certainly not going to win any ARRL Frequency Measurement Tests, but if you must change the Gunn diode, or varactor diode, or if the Gunn cavity tuning screw has inadvertently been moved, how else can you set your operating frequency if you knew it was somewhere between 9.5 and 10.5 GHz? If you were very lucky, you might find it using a wideband (200 kHz i-f) fm receiver by adjusting the Gunn cavity tuning screw, but 1000 MHz is a pretty large haystack to search through!

Even if you do not build this frequency measurement system, but have taken the trouble of reading this far, it is comforting to know that for the price of a Sears micrometer and a few dollars worth of parts, anyone can build and operate a modestly accurate 10 GHz frequency counter (of sorts).

Bibliography

"Lecher Wires," *Radio Amateur's Handbook*, 30th edition, ARRL, West Hartford, Connecticut, 1953, page 464.

"UHF Slotted Line," *The Radio Amateur's VHF Manual*, 3rd edition, ARRL, Newington, Connecticut, 1972, page 324.

"Wireless Lecher Wires," *The Radio Amateur's VHF Manual*, 2nd edition, ARRL, Newington, Connecticut, 1968, page 291.

"10-GHz Wavemeters," *VHF-UHF Manual*, 3rd edition, RSGB, London, England, 1976, page 8.16.

4

Gunnplexer Power Supplies

Assembly of Gunnplexer power supplies including single 12 Vdc storage battery systems and dual-regulated ac to 12 and 10 Vdc units.

Nothing could be simpler than the regulated Gunn diode and varactor power supply shown in *Figure 3-8*, especially if you substitute a Lambda LAS1410 or LAS1510 3-terminal fixed 10 Vdc regulator for the adjustable LM317. Because of low demand these excellent 10 Vdc regulators, (3 and 1.5 amp capability, respectively) are difficult to obtain unless ordered directly from Lambda sales offices. They have proven extremely reliable, when protected with 1N4002s for inadvertent short circuits, and all I have tried have yielded outputs within 0.05 Vdc of the specified 10 Vdc output from zero to full load when driven by a 12 Vdc source. Extremely conservative equipment designers would probably drive the 10 Vdc regulators with a 15 Vdc supply, but I have found that 12 Vdc is adequate. First I will discuss a 12 Vdc regulated supply, and then the system control module which includes the 10 Vdc regulator.

Figure 4-1 shows the circuit of a 12 Vdc, 3 ampere, regulated power supply. It is installed in a 6 inch (15 cm) wide by 2 inch (5 cm) high by 3½ inch (9 cm) deep vinyl clad aluminum box (same enclosure used for the systems described later). These black boxes from Poly Paks (Poly Paks, P.O. Box 942, South Lynnfield, Massachusetts 01942.) are attractive, are professional looking and are low cost. Radio Shack has a similar size box, no. 270-260, but the Radio Shack unit costs more than twice as much. The only front panel control is an on-off switch at the left (*Figure 4-2*). The two red LEDs at the right are used to monitor bus 1 and bus 2 and serve as crude voltmeters. If one or the other is off, you have a problem. The anodized heatsink on top of the box is for cosmetics only and may be omitted if desired; the Poly Paks enclosure is a more than adequate heatsink for the two LM340K-12 1.5 amp voltage regulators. I used heatsinks because I had them on hand. *Figure 4-3* is an inside view of the regulated power supply. *Figure 4-4* is a bottom view of the regulated power supply.

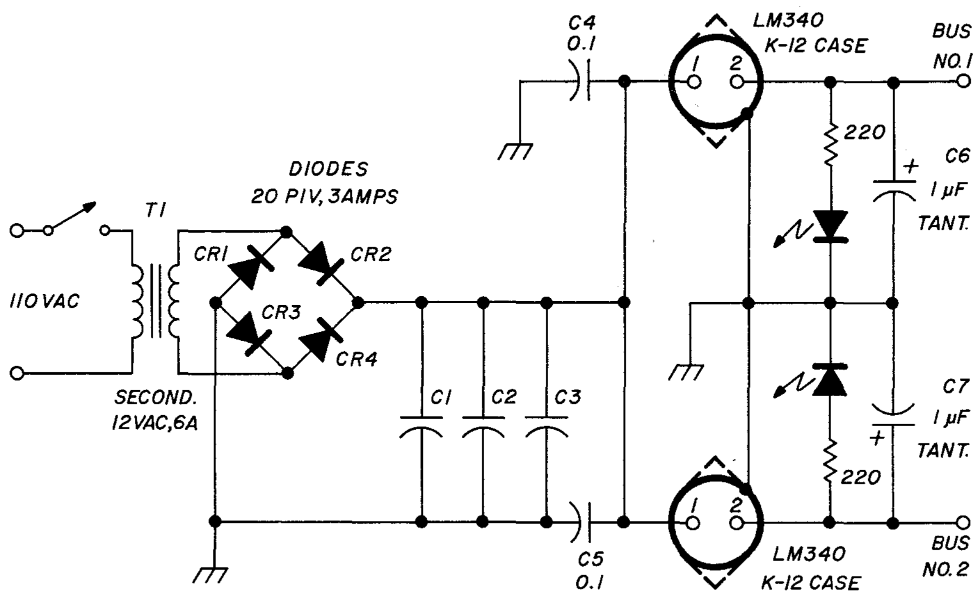


Figure 4-1.
Circuit for a regulated 3 amp, 12 Vdc power supply which uses two LM340-12 voltage regulator ICs. Capacitors C1, C2, and C3 are 2200 μF, 16Vdc, units. Construction of the power supply is pictured in Figures 4-2, 4-3, and 4-4.

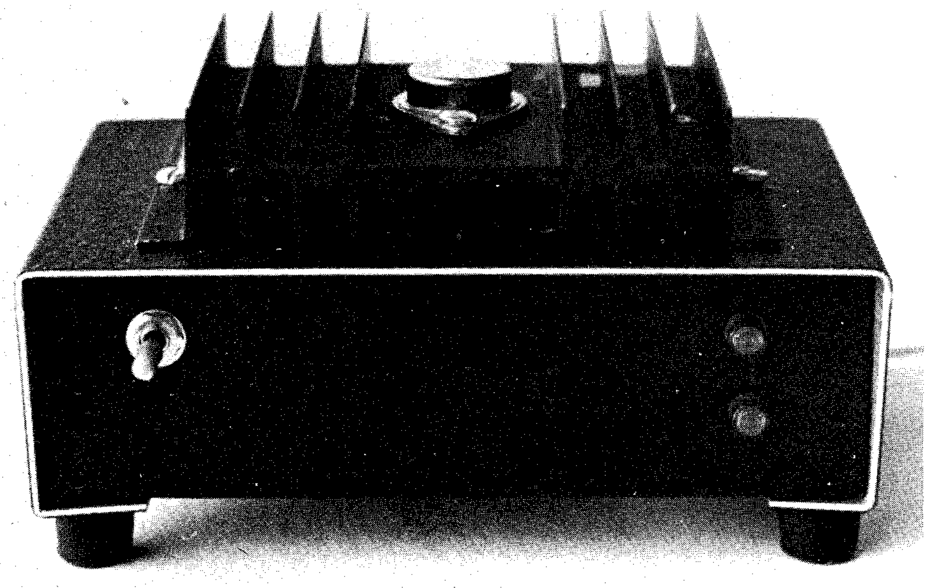


Figure 4-2.
Front panel of the regulated 12-volt power supply. On-off switch is to the left, LEDs to the right. The heatsink is not actually required (see text).

Gunnplexer Power Budget

The largest single power consumer, if you choose to use it, is the proportional temperature control system discussed in Chapter 5. From a cold start it will draw approximately 1 to 1.5 amperes, tapering off to zero to about 200 mA, depending on outside air temperature and how well the Gunnplexer is insulated. A typical Power Budget for the Level I Communications System (Chapter 9) is shown in *Table 4-1.*

Considering the turn-on surge requirement of the temperature control system and growth capability for the Level II narrowband and video systems, it's best to have a surplus of 12 Vdc regulated power. Two LM340K-12 regulators are used both for economy and isolation of the PTC bus from the Gunn diode and varactor bus. Except for cost, a single Lambda 3, 5, or 8 ampere monolithic voltage regulator in a TO-3 package would probably work just as well.

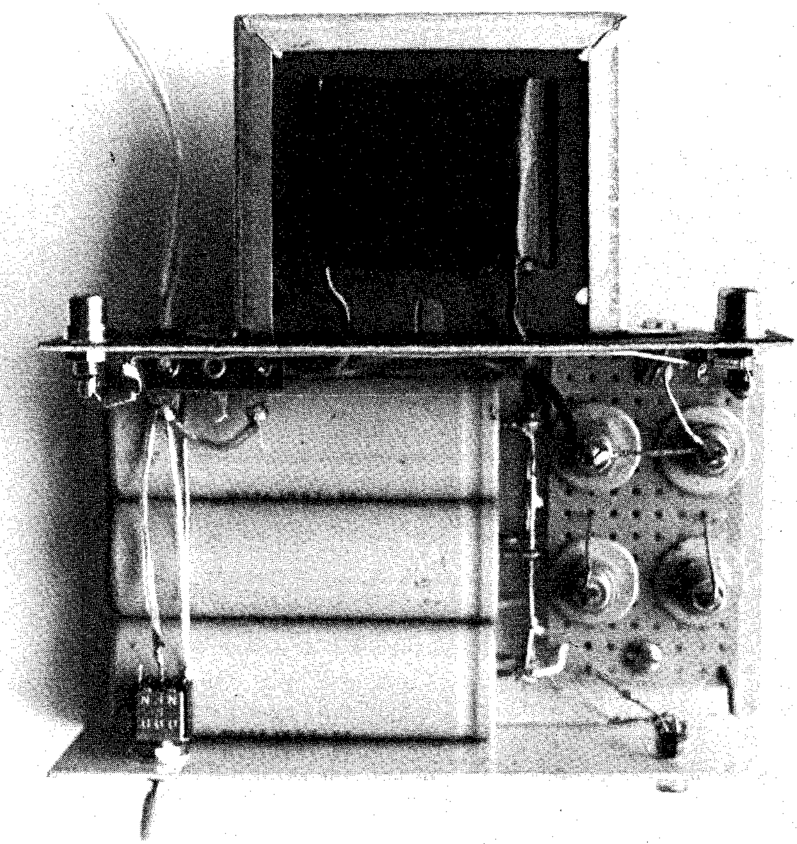


Figure 4-3.
Inside view of the 12-volt regulated supply showing the parts layout. The power transformer is mounted on the rear of the enclosure.

Table 4-1. Typical Power Budget for a Level I Communications System (see Chapter 9).

Gunn diode	500 mA	
Temperature control	200 mA	(average)
Fm receiver	400 mA	
I-f preamplifier	15 mA	
AFC amplifier	15 mA	
Audio amplifier	100 mA	
	1230 mA	(1.23 A)

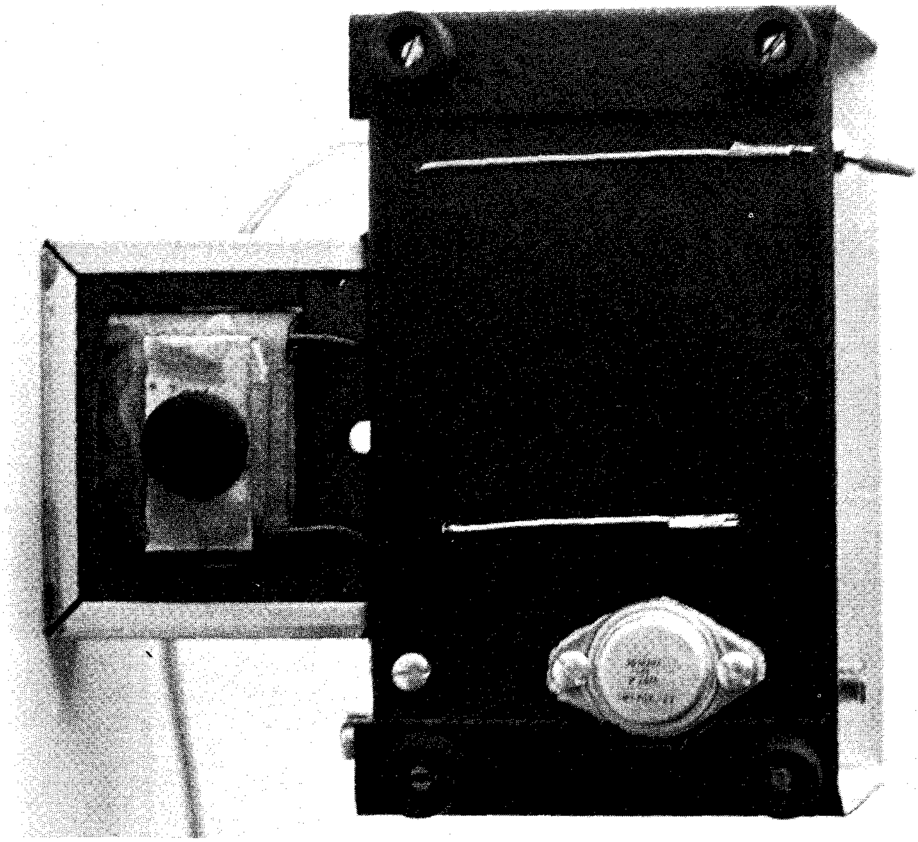


Figure 4-4.
Bottom view of the regulated power supply.

Gunnplexer System Control Module

The Gunnplexer system control module shown in *Figure 4-5* is about the minimum required for reliable wideband portable or hilltop operation. It was designed and built in early 1977 and operated with the 4.5 amp-hour 12 volt Gel/Cell shown with it in *Figure 4-6*. This circuit will furnish 10 Vdc at 500 mA, 2.5 to 7.5 Vdc for manual varactor tuning, AFC jack, PTC current monitor jack, Gunnplexer module temperature sensor voltage source and jack, i-f output jack, MCW tone generator, fm level control, microphone jack, key jack, and a 5-pin DIN connector for the Gunnplexer control cable.

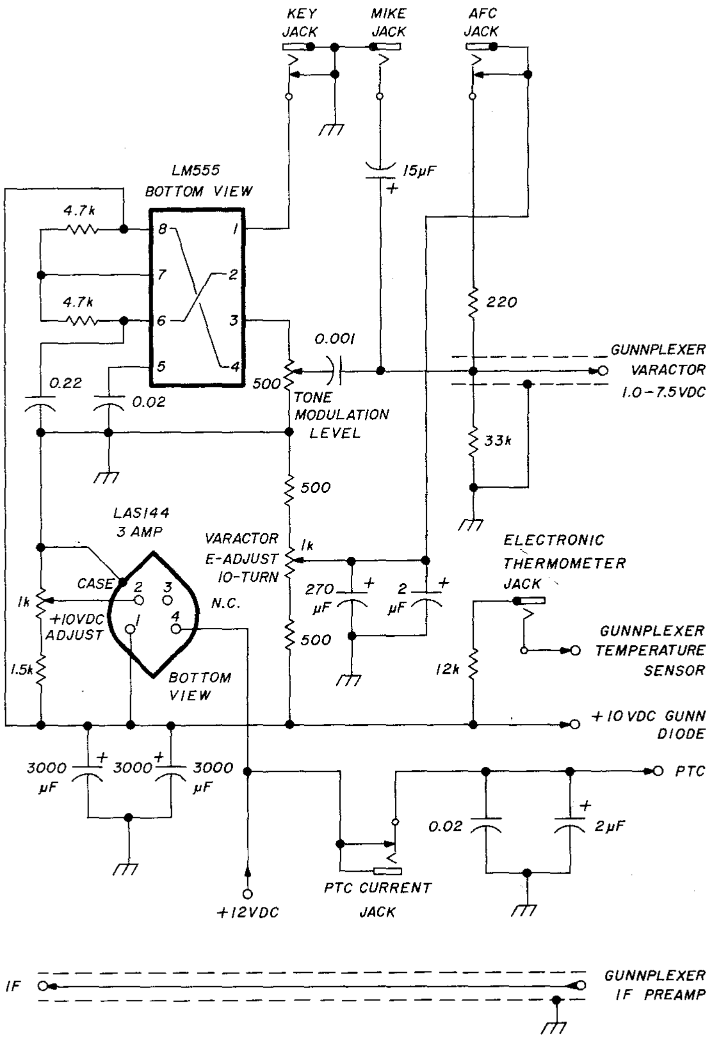


Figure 4-5.

Basic Gunnplexer system control module which provides regulated operating voltages for the Gunn diode and tuning varactor. Also included is a LM555 tone modulator as well as a tuning control and jacks for microphone, AFC, key, i-f output, and PTC current monitoring. Layout and construction of the system is shown in Figure 4-6.

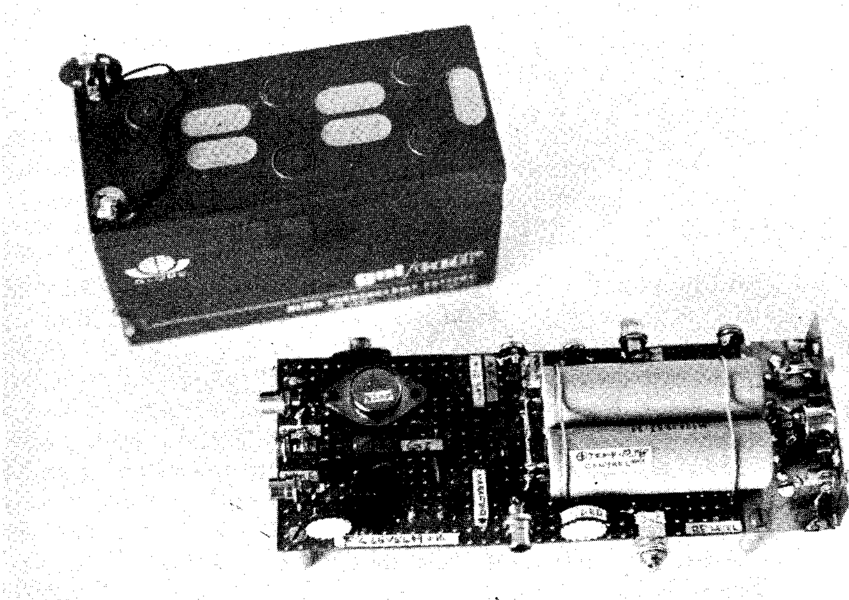


Figure 4-6.

Layout and construction of the basic Gunnplexer system control module. A 12-volt 4½ amp-hour Gel/Cell which has been used with this control system in portable operation is shown in the background.

This 1977 design is based on a Lambda LAS15U 3 ampere voltage regulator, but the National Semiconductor LM317 (1.5 amp), LM350 (3.0 amp), Lambda LAS14U (1.5 amp) or LAS 1510 (1.5 amp) units would work just as well. There are a few surprises here except for the Gunnplexer module temperature sensor line, and possibly the LM555 tone generator.

In early 1977 I had an average MTBF (mean-time-between failure) of about two hours for my first generation proportional temperature control. The problem, as it turned out, was not the high-power transistors, which I originally thought were at fault, but rather a small 500-ohm potentiometer that changed value with temperature. After a few PTC failures at the top of a fire tower, on the top of a mountain, I copied VE5FP's idea of using a low-cost transistor as a thermistor (J.A. Koehler, VE5FP, "Proportional Temperature Control," *ham radio*, January, 1970, page 44). (It is discussed in Chapter 5).

The LM555 tone generator is useful primarily for tuning up two Gunnplexers by yourself and as a remotely keyed beacon identifier; if used for telegraphy, remember that 10-GHz wideband MCW is no more efficient than voice. The circuit uses neither audio amplifiers nor speech processing; this is not to intimate that speech processing is without merit — it definitely has considerable value. With a good quality communications type microphone, however, it has been found unnecessary in normal operation, on both wide and narrow band fm. The Mark II control module uses a mike volume control so you can switch between microphones with varying output levels, yet maintain the same deviation for average voice level.

Except for the enclosure, the Mark II system control module (*Figure 4-7*) is very similar. Front panel controls are, top row left to right: combination on-off switch and mikevideo level, on-off LED, varactor voltage adjust (coarse), tone generator on-off LED, tone generator combination on-off switch and tone level; bottom row left to right: mike/video jack, varactor voltage adjust (fine), and the key jack. The parts layout on perf-board is shown in *Figure 4-8.* A Lambda LAS1510 10 Vdc, 1.5 ampere regulator is used for simplicity and is on the left side of the board mounted on a small shim-brass heatsink. It may be operated with any input voltage from +12 to +25 Vdc. The LM555 tone generator is on the right-hand side of the perf-board. A schematic is shown in *Figure 4-9.*

This systems control module is designed to work with both Level I and Level II Gunnplexer communication systems, either indoors at a fixed station or outdoors in portable operation (*Saranwrap* waterproofing is recommended). Rear panel connectors (*Figure 4-10*) from left to right, top row, see PTC ammeter jack, i-f output to receiver, Gunnplexer rf level test point (from Gunnplexer horn mounted dipole/detector), AFC input from receiver (this is a normally closed-circuit phone jack giving you manual varactor control from the front panel with nothing plugged-in, or full AFC from the receiver/AFC amplifier, if used), +12 Vdc input jack; bottom row, left to right: Gunnplexer temperature sensor output, i-f input from Gunnplexer preamp, 5 pin DIN connector for Gunnplexer cable, varactor voltage test point, and +12 to +25 Vdc input.

The main advantage of the Mark II system control module is the COARSE and FINE varactor tuning controls. The COARSE control allows the varactor tuning voltage range to be set from +1 to +7 Vdc with the FINE tuning control set at mid-range.

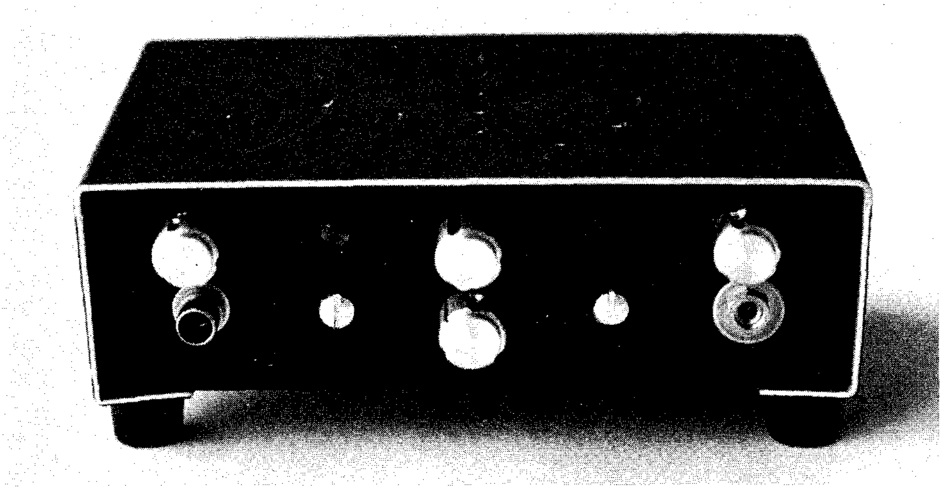


Figure 4-7.
Front panel of the Mark II Gunnplexer system control module. Construction of this unit is shown in Figure 4-8.

After the COARSE adjustment, the FINE tuning control provides an approximately 10 to 1 step down vernier adjustment. The LM555 tone generator, omitted from *Figure 4-9* because of space, is identical to the one illustrated in *Figure 4-5.* The coupling capacitor from the combination microphone and video jack/level control has been increased to 10 μF using a non-polarized (NP) electrolytic for better audio and video response; most polarized electrolytics should work just as well but place the positive terminal towards the varactor and use a 25 WVdc unit. Both the varactor voltage and the Gunnplexer rf level dipole/detector output are brought out to the rear panel through insulated test points. These two test points, though seldom used, save considerable troubleshooting time when all is not as it should be.

Note: the following rear panel jacks are insulated from chassis ground using fiber washers: PTC current, temperature sensor output, AFC input, and the two test points. The 5 pin DIN jack is from Radio Shack. Most purists would object to using a 1000-ohm carbon pot load (the mike/video level control) for terminating the nominal 75-ohm video camera or video source. I should say, true, but it works with no perceptible problems on video coax runs up to 15 feet (4½ meters) long. If your camera or video

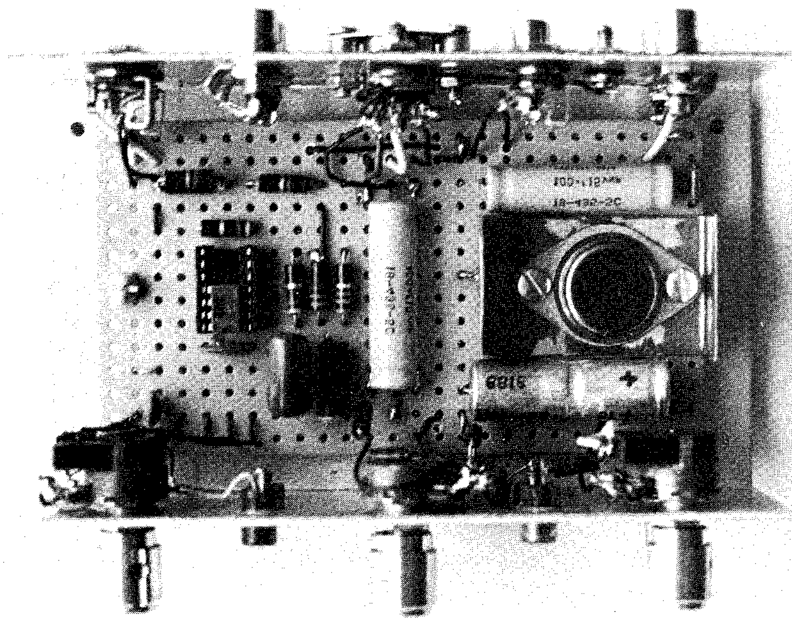


Figure 4-8.
Layout and construction of the Mark II Gunnplexer system control module. Circuit diagram is shown in Figure 4-9.

source gives problems, add a separate 100-ohm carbon pot and jack for video input.

The reason for separate rf jacks for the Gunnplexer i-f and varactor cables is to allow shielded coax transmission lines to be used for these sensitive submicrovolt functions. In metropolitan areas where many 100 kilowatt fm stations may be within direct view of your station, good quality coaxial cable is necessary to prevent fm pickup by the i-f. RG-159/U 50-ohm miniature coax is adequate for the varactor line to the Gunnplexer, but in downtown areas, or on a mountain top shared with a commercial fm transmitter and antenna it is wise to use the best coax you can afford for the i-f line. One excellent variety is RG-142B/U 50-ohm coax which has approximately the same outer diameter as RG-58/U. However, RG-142B/U has a silver-plated solid inner conductor, Teflon insulation, and is covered with two silver-plated layers of tightly woven braid. On top of all this is a tough protective Teflon outer jacket.

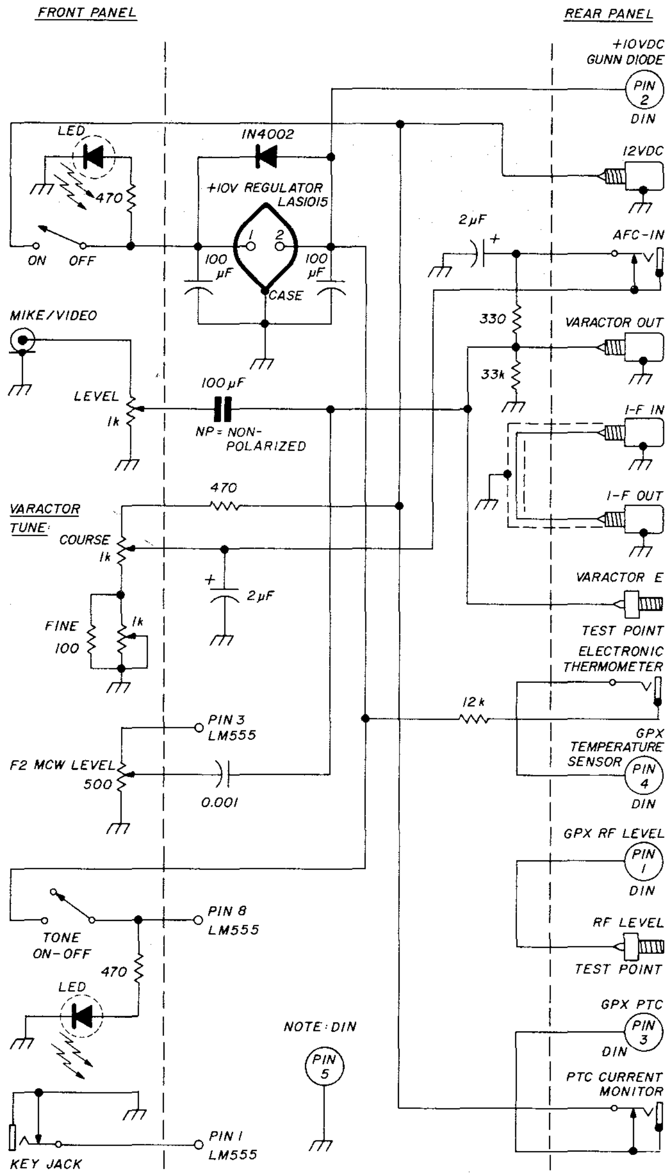


Figure 4-9.

Circuit diagram of the Mark II Gunnplexer system control module. Circuit for LM555 tone modulator, not shown here, is the same as in Figure 4-5. The 5-pin DIN connector is available from Radio Shack (No. 274-005).

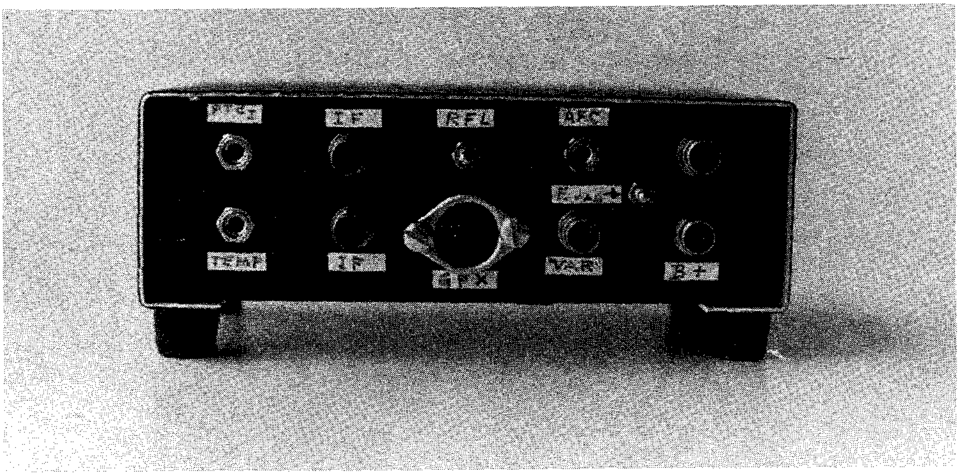


Figure 4-10.
Rear panel of the Mark II Gunnplexer system control module.

Another possibility is to use high quality RG-8/U with tightly woven braid, or still another option, shift your first i-f to another frequency at the low end of the spectrum such as 30 MHz. You could also modify a standard fm broadcast receiver so it tunes from 108 to 128 MHz, with a 118-MHz center i-f.

The simplest solution by far, however, is to use 98 MHz as a first i-f with a high-gain i-f preamplifier that only sees the Gunnplexer i-f output, and follow the preamp with quality coax that does not serve as an fm broadcast antenna.

As is usually the case, however, simplest is not best, so if you use a 95-MHz i-f system you must be prepared to live with strong interference from fm broadcast stations; interference is especially bad in urban areas and during portable mountain-top operation. Even with proper bypassing of all dc leads into and out of the Gunnplexer, and the use of good quality coaxial cable, a 95-MHz i-f is often unsatisfactory.

5

Proportional Temperature Control

Low-cost Proportional Temperature Control (PTC) system for the Gunnplexer that maintains 0.1° to 0.01° Fahrenheit control from 32°F to 90°F (0°C - 32°C) ambient.

Frequency stability and frequency repeatability are extremely important in radio communications. The easiest way to achieve the desired results with a Gunnplexer is to maintain the Gunn diode cavity at a constant temperature regardless of outside air temperature and wind velocity. I will present one approach to solving this problem that was first suggested by W1HR – Proportional Temperature Control (PTC). It requires three inexpensive transistors plus a few parts and was derived from a PTC crystal oven described by a VE5FP. In addition to the PTC assembly, the Gunnplexer module requires a weatherproof and draft-proof enclosure for outdoor operation that is discussed in *Chapter 7*; this combination will maintain Gunn diode cavity temperature at 120 degrees Fahrenheit (49°C), plus or minus 0.1 to 0.01 degree Celsius over the temperature range of +32 to +85 degrees Fahrenheit (0-29°C), and to below zero degrees Fahrenheit (-18°C) with the styrofoam hat shown in *Chapter 7.*

Temperature Control Accuracy

Temperature control accuracy is dependent almost entirely on how well you calibrate the sensor transistor/thermistor, as outlined later. On the other hand, temperature control repeatability depends upon how well you build the Gunnplexer enclosure (*Chapter 7*). Wind drafts and gusts are a major problem for the aluminum Gunnplexer module. A good tight fit of the neoprene seal (piece of an automobile innertube) between the Gunnplexer mounting plate and the Gunnplexer housing is a must; a small wad of putty to seal the cable exit tube also helps. The thermal conductivity of the Gunnplexer module is not all that bad, but the thermal time constant between the Gunn diode cavity and the outer edge of the horn antenna, more than 4 inches (10 cm) away, is measurably long enough to set up a temperature oscillation between heat sources (the Gunn diode and the PTC heating transistor, and the outer section of the horn antenna) if drafts are allowed into the weatherproof Gunnplexer enclosure.

Proportional Temperature Control

The excellent proportional temperature control circuit shown in *Figure 5-1* was designed by VE5FP for use with a crystal oven and was published in the January, 1970 issue of *ham radio*, page 44. In this circuit transistor Q1 is a general purpose PNP germanium transistor which is used, with its base floating, as a thermistor. Q1's collector-emitter current is proportional, though not exactly linearly, to temperature over the range from 70 degrees Fahrenheit to 125 degrees Fahrenheit (21°C - 52°C) if a high quality transistor is used; better quality transistors at Q1 will yield a 10 to 1 current increase over this temperature range.

Transistor Q2 serves as a current amplifier with an output to Q3 that is approximately equal to Q2's common-emitter current gain or beta. Transistor Q3's collector current is determined by both its common collector current gain and the value of resistor R2.

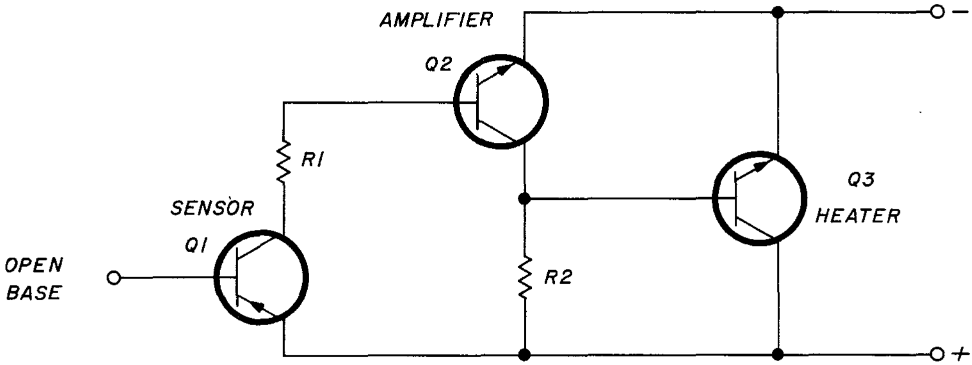


Figure 5-1.

Proportional Temperature Control (PTC) circuit designed by VE5FP. The collector-emitter current of transistor Q1 is proportional to temperature over the range from 70°F to 125°F (21°C - 52°C); transistor Q2 is a current amplifier to drive Q3, a power transistor which is used as a heater.

Assume that Q1's TO-5 package is closely coupled (for heat transfer) to the heatsink of Q3's collector. Therefore, you have a heat transfer servo (feedback) loop in which the temperature sensed by Q1 may be set by the value of resistor R2, and Q3 will provide the heat necessary to maintain this present temperature.

Gunnplexer Heat Sources

Since a Gunnplexer module weighs 14 ounces (400 grams) including horn antenna and has a heat radiating surface area greater than 40 square inches (258 cm^2), it is somewhat larger than VE5FP's crystal oven. The Gunnplexer module, however, has a built-in heat source, the Gunn diode bias supply, which at 10 Vdc at 500 mA contributes 5 watts of heating. Therefore, the external heating requirement is reduced considerably.

An additional assist to the Gunnplexer heating problem is that the Gunn diode cavity is the smallest surface area segment of the total module and is located at the inside end. The majority of heat flow, therefore, is all in one direction, which further simplifies the problem. The biggest help to the PTC designer and builder is the protruding $\frac{3}{32}$ inch (2.5 mm) high nipple underneath the Gunn diode mount on the Gunn oscillator cavity. Here is the ideal location to solder Q3's collector heatsink so the Gunn diode heat source and Q3 heat source are physically separated by only a thin piece of high conductivity brass (see *Figure 5-2*).

Unless you are fortunate enough to have a laboratory standard thermocouple driven electronic thermometer (I did not), you will have to build one. A suitable circuit can be built in a few minutes and requires only a glass thermometer for calibration. The circuit is shown in *Figure 5-3.*

After testing a half-dozen small-signal germanium transistors in the circuit of *Figure 5-3* between the range of 70°F and 120°F (21°C - 49°C), the Radio Shack RS-2007 transistor was found to be the best overall choice. First, the transistor must be germanium in a metal TO-1 or TO-5 package to ensure good thermal

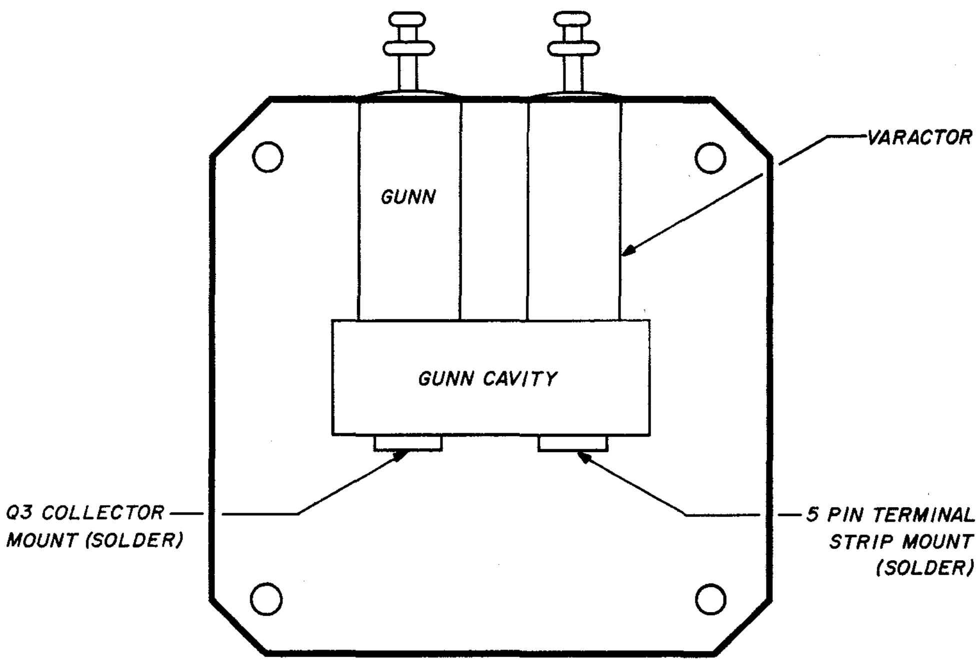


Figure 5-2.

Rear view of the Microwave Associates Gunnplexer, showing the correct placement of the Q3 heater transistor (*Figure 5-1*), left, and the 5-pin terminal strip (see text).

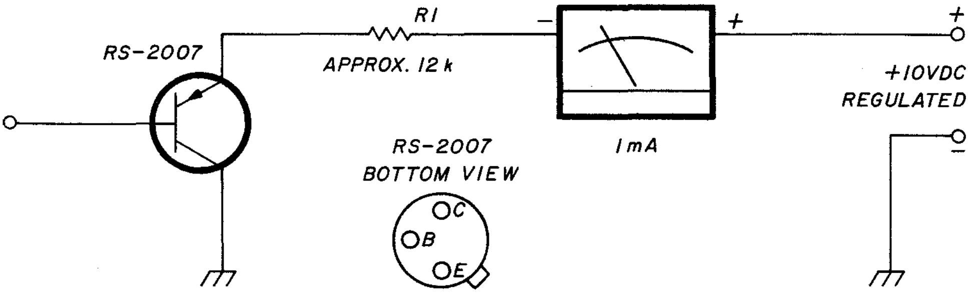


Figure 5-3.

Simple electronic thermometer which is used for calibrating the PTC circuit. The germanium sensor transistor is a Radio Shack RS-2007. The calibration setup is shown in *Figure 5-4*.

conductivity; second, it must operate up to a least 120°F (49°C), the temperature I chose for Gunnplexer operation since the Gunn diode cavity nipple runs about 110°F (43°C) in still air (about 75°F or 24°C ambient) inside a weatherproof Gunnplexer enclosure (see *Chapter 12*).

Fill a glass with hot water, above 130°F (55°C), and pour out all but 2 or 3 inches (5 - 8 cm) of water; wrap a cloth napkin around the glass for insulation. Insert the glass thermometer and the top of the RS-2007 transistor into the hot water as shown in *Figure 5-4*. As the water slowly cools and approaches 120°F (50°C), adjust the 25k pot so the milliammeter reads out slightly less than full scale at exactly 120°F (50°C). Mark this spot on the scale, plus every 2°F (1°C) down the scale as the water cools to the 90°F - 100°F (30°C - 35°C) level as shown in *Figure 5-5*.

You now have a rather accurate homebrew electronic thermometer. The only precaution, and it is an important one, is to check that the RS-2007 transistor used in the circuit is not current saturated at the 120°F (50°C) mark. Add some hot water to the glass to make sure the thermemeter will go above 120°F (50°C) (keep the transistor leads dry), and check to see that your temperature markings from 100°F to 120°F (35°C - 50°C) are almost evenly spaced, as they should be. If the calibration marks are not evenly spaced, try another RS-2007 transistor in the circuit.

The 10°F (6°C) differential from the PTC temperature allows Gunnplexer operation up to about 85°F (29.5°C) ambient, which seldom if ever occurs in my local area. If it is hotter than this

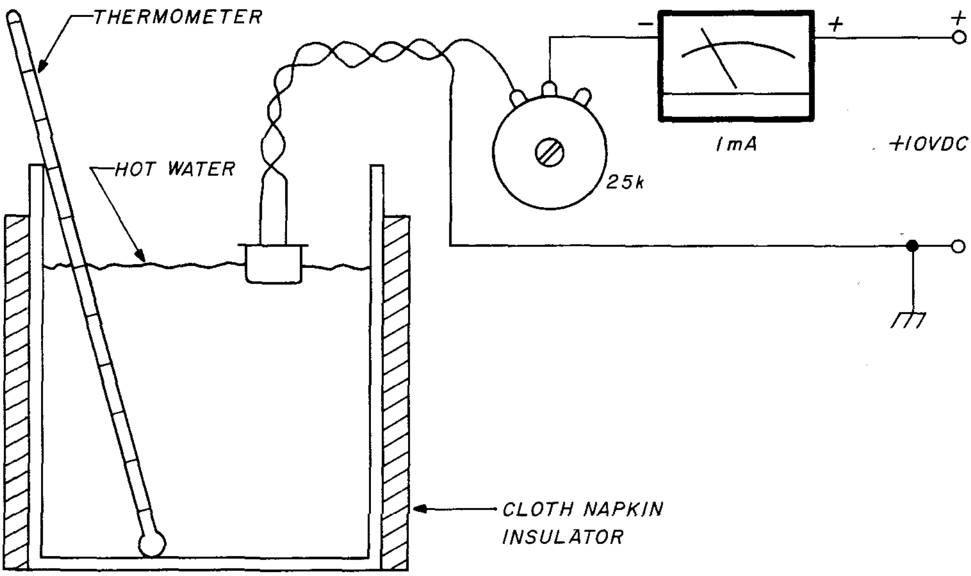


Figure 5-4.
Calibrating the electronic thermometer with a container of hot water and a glass thermometer. See text for correct procedure. The 25k pot sets the full-scale meter reading at 120°F (50°C). See text for correct procedure.

where you operate, I suggest you either move to a more pleasant locale or operate at night. Most of the germanium transistors I tested current saturated in the region of 105°F to 115°F (41°C - 46°C) but the RS-2007 was invariably good to 120°F (49°C).

Electronic Thermometer Calibration

Solder a twisted pair of no. 22 (0.6 mm) insulated solid hookup wire to the emitter and collector of the RS-2007 as shown in *Figure 5-3* and temporarily solder in a 25k pot for R1. The meter I used was a full-scale 1.5 mA meter purchased at a hamfest; any 1 mA movement will work as well. Rubber cement a blank paper scale on the meter face and carefully trace out the meter scale line, but with no values. Borrow or buy a glass thermometer that is calibrated in Fahrenheit up to at least 130 degrees (or up to 55° Celsius).

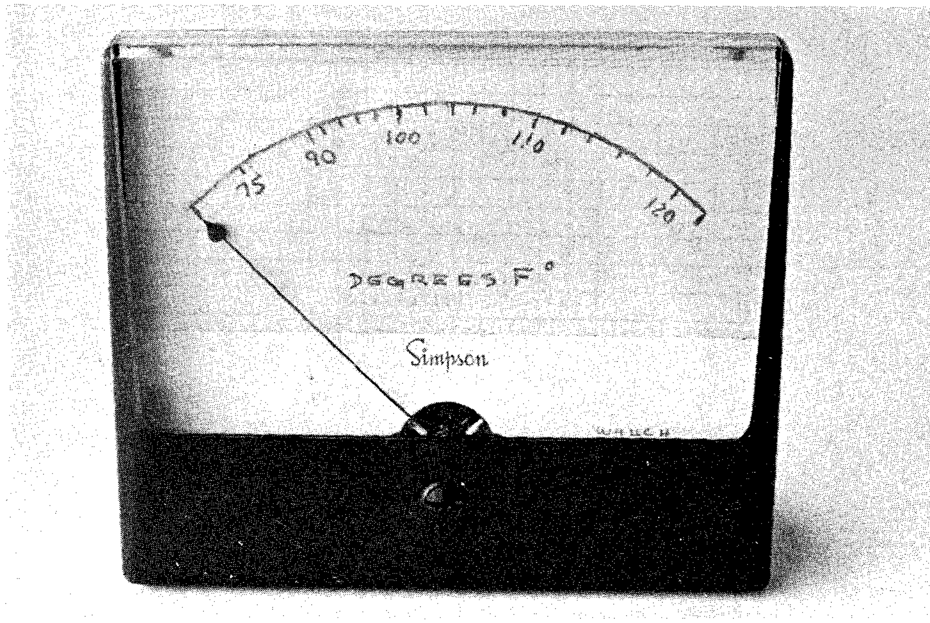


Figure 5-5.

Photograph of the 1 mA meter used in the electronic thermometer built by W4UCH. Note that the spacing between calibration marks is quite linear over the desired temperature range.

Note that some RS-2007 transistors have the base grounded to the case, and some do not, but five out of the six RS-2007s I have calibrated so far worked just fine and required a resistance value within 500 ohms of each other for R1 to readout exactly 120°F (50°C).

Now, measure the resistance of the 25k pot setting you made at the 120°F (50°C) temperature level and make up exactly the same value resistance using fixed ¼ or ½ watt resistors. Repeat the entire process using another RS-2007; this will be used for Q1 in the Gunnplexer PTC circuit shown in *Figure 5-6.*

Proportional Temperature Control Circuit Layout

The entire PTC circuit is built on the Gunn diode cavity with the metal heatsink (collector) of Q3 soldered directly to the Gunn

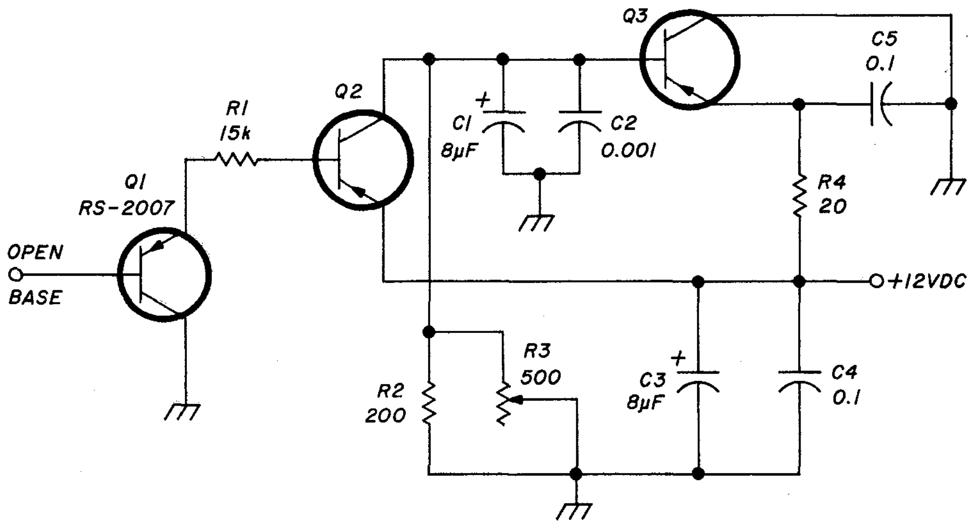


Figure 5-6.

Schematic of the Proportional Temperature Control (PTC) circuit for Gunnplexer operation. Q1 is a Radio Shack RS-2007; Q2 and Q3 are 12-watt PNP transistors in a TO-220 case (Poly Paks 92CU3068). Both C1 and C3 are tantalum capacitors, and R5 is a miniature ½-watt potentiometer.

diode nipple on the bottom of the Gunn diode cavity as shown in *Figure 5-2.* Transistor Q2 is mounted directly on top of Q3, with Q2's collector lead soldered directly to Q3's base lead, which holds it in position. Resistor R4 consists of two 10-ohm, ½-watt resistors in series and is included to limit the peak turn-on surge current to Q3 to approximately 500 mA. It may be left out of the circuit for cold weather operation when the full 1 amp heating capability of Q3 is needed.

R2 is a 200-ohm, ½-watt resistor in parallel with the small ½-watt potentiometer, R3, to keep the pot within its power rating. R2's value will vary when using different Q2 and Q3 transistors with different values of forward current gain. R3, the 500-ohm pot, sets the temperature that the closed loop PTC circuit will maintain. Transistor Q4, shown in *Figure 5-7,* is the sensor transistor/thermistor for your electronic thermometer that allows you to remotely monitor the Gunn diode cavity temperature.

Circuit layout is not particularly critical so long as the PTC assembly, built on and around the Gunn diode cavity, is fairly

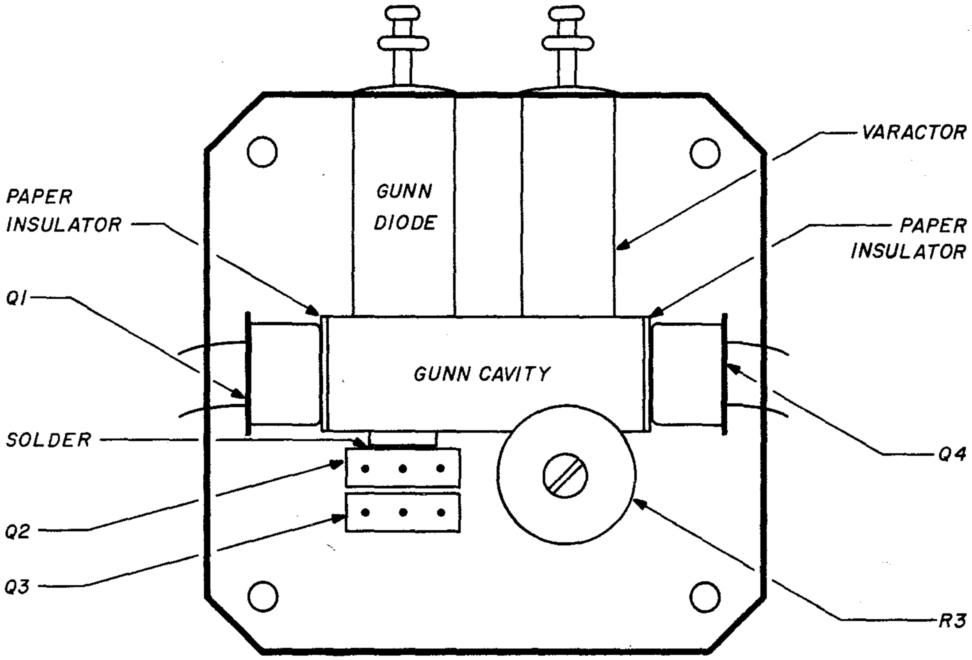


Figure 5-7.
Suggested parts placement for the PTC circuit (*Fig 5-6*) on the 10-GHz Gunnplexer module (see text).

compact so it will easily fit inside the Gunnplexer's weatherproof enclosure. Transistor/thermistor Q1 and Q4 are epoxied, with a thin paper insulator in between, to the sides of the Gunn oscillator cavity, ¼ inch (6 mm) from the rear end, as shown in *Figure 5-7.* The thin paper insulator is very important as some RS-2007 sensor transistors have the base grounded to the case. This thin paper insulator does not seem to harm the thermal conductivity significantly, as two of mine have it, and work as well as those without it. It is convenient to install the R3 pot facing to the rear as shown in *Figure 5-7* so it may be adjusted, if necessary, through the rear of the weatherproof Gunnplexer enclosure after installation.

With the proportional temperature control circuit installed and 10 Vdc to both the Gunn diode and PTC ready to go, put a Turkish towel over the Gunnplexer module on the workbench and turn on the power. Make it a habit to point the Gunnplexer horn antenna away from you and make sure that no solid metal reflectors are within a few feet of the Gunnplexer output (to protect the mixer diode). It is also good practice, and a good habit, to stay out of any concentrated rf field at uhf and microwave frequencies.

With a multimeter set to the 5 or 10 amp scale check PTC current at turn-on time. With R3 in the center of its range, PTC current should be around 500 mA with R4 installed. Reduce your multimeter range to 1 amp full scale. In 10 to 20 minutes the PTC current should stabilize between 50 and 200 mA, depending upon ambient temperature, and your electronic thermometer should read somewhere between 100°F (43°C) and full-scale. Adjust R3 to increase or decrease the Gunn cavity operating temperature of 120°F (50°C). This may take another 5 to 10 minutes.

If all is well, you should be able to remove the Turkish towel insulation from around the Gunnplexer module and watch the PTC current rapidly increase as your circuit tries to compensate for the radiated heat loss. It should hold to 120°F (50°C) if ambient temperature is at least 75°F (24°C) in a draft-free room. Once the PTC current stabilizes again, try fanning the Gunnplexer module. PTC current should immediately (within a second or two), rise to compensate for the additional heat loss, and then return slowly to the draft-free level. Try changing or eliminating R4 as it limits the maximum current drawn by Q3. With a bit of experimenting you will find the optimum value for the transistors you are using.

Other PTC Applications

Once you have completed a trouble-free PTC circuit and have the satisfaction of watching the circuit do what it is supposed to, many other PTC applications will come to mind. Perhaps even VE5FP's original crystal oven. My enthusiasm for the circuit was so great that I considered trying to make a ¾ inch (19 mm) square by 1 inch (25 mm) high PTC crystal oven that would snap over a HC-25/U crystal used in the VHF Engineering TX-432 1 watt 432-MHz transmitter board (see photo in *Chapter 10*). This consideration turned into reality or I would not have mentioned it.

My reasoning went like this: if an RS-2007 transistor is willing to behave like a thermistor with its base floating (collector-base and emitter-base junction diodes in series), might not an ordinary point-contact germanium diode or general purpose silicon switching diode exhibit the same behavior? The answer turned out to be "yes" for both types of diodes. The silicon switching diodes exhibited thermistor behavior over the range of +300°F (150°C) and up, and selected point-contact germanium diodes had excellent thermistor characteristics in the desired temperature range from 100°F to 120°F (38°C - 50°C). My source of point-contact germanium diodes was a low-cost bag of germanium diodes from Poly Paks; the "scientific" methodology used to test them was to place a lighted cigarette close to each diode that was attached to a Hickok 455 multimeter that measured reverse resistance on the X100k ohms scale with a 30 Vdc battery source.

The circuit of the HC-25/U slip-on PTC circuit is shown in *Figure 5-8.* The point-contact germanium diodes that worked best in this circuit all had reverse resistance readings in the 100k to 600k ohm range as measured with the multimeter. The fixed value resistor R1 was substituted for the 20k pot after determining the value required for operation at 110°F (43°C).

Construction of the slip-on HC25/U PTC circuit is shown in *Figure 5-9.* First epoxy a thin sheet of insulating paper to the inside edge of transistor Q1's heatsink to prevent the metal crystal case from short circuiting Q1 to Q2. The plastic bodies of transistors Q1 and Q2 are epoxied together while being held together with rubber bands and a Saranwrapped HC-25/U is held between their heatsinks to assure proper spacing. Sensor diode CR1 is then soldered in place, cathode to Q2's heatsink (common ground) and anode to Q1's base. Leads of Q1 and Q2 are then bent over and connected as shown in *Figure 5-8.* Capacitor C1 is included to prevent the PTC from oscillating more than the crystal. The thin, 1/16 inch (1 mm) thick brass tubing that is a press fit on an RS-2007 transistor is then carefully soldered on Q2's heatsink. It serves to hold the temperature meter's sensor for calibration The balsa wood case is then temporarily slipped over the assembly with the 20k pot externally sitting on the top.

Before testing this PTC slip-on device, you have to build another electronic thermometer, this one for portable operation as

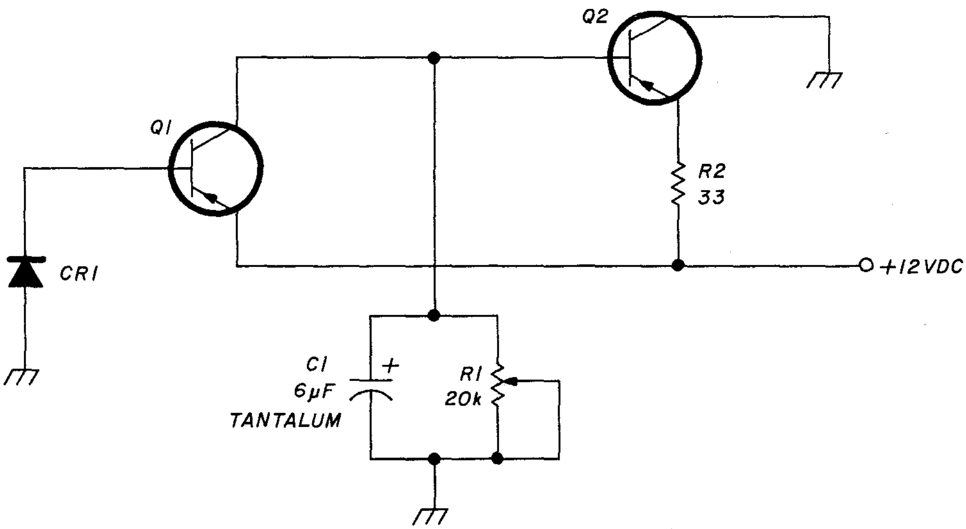


Figure 5-8.

Proportional Temperature Control circuit which is used as a slip-on oven for HC-25/U crystals. CR1 is a point contact germanium diode; PNP transistors Q1 and Q2 are Poly Paks 92CU3068. Construction is shown in *Figure 5-9*.

shown in *Figure 5-10.* It will be used to calibrate the PTC and may be used later wherever temperature measurement is required.

The RS-2007 temperature sensor and meter are calibrated essentially the same way as shown in *Figure 5-4.* Note in *Figure 5-11* that the temperature meter reads 140°F (60°C) full scale. Operation of this particular RS-2007 transistor was nearly linear up to that temperature, but only 120°F (50°C) is required.

Miniature RG-159/U coaxial cable is used for the lead between Q1 and the meter case. The normally open mini-phone jack on the case serves as the on-off switch. Q1 is mounted on the end of a 5 inch (7.5 cm) long piece of ⅜ inch (10 mm) diameter wood dowel with a piece of foam rubber insulation Scotch taped around the bottom of Q1 to reduce heat out-flow from the leads. The wood dowel and miniature coax are wrapped with black vinyl insulating tape for a professional appearance.

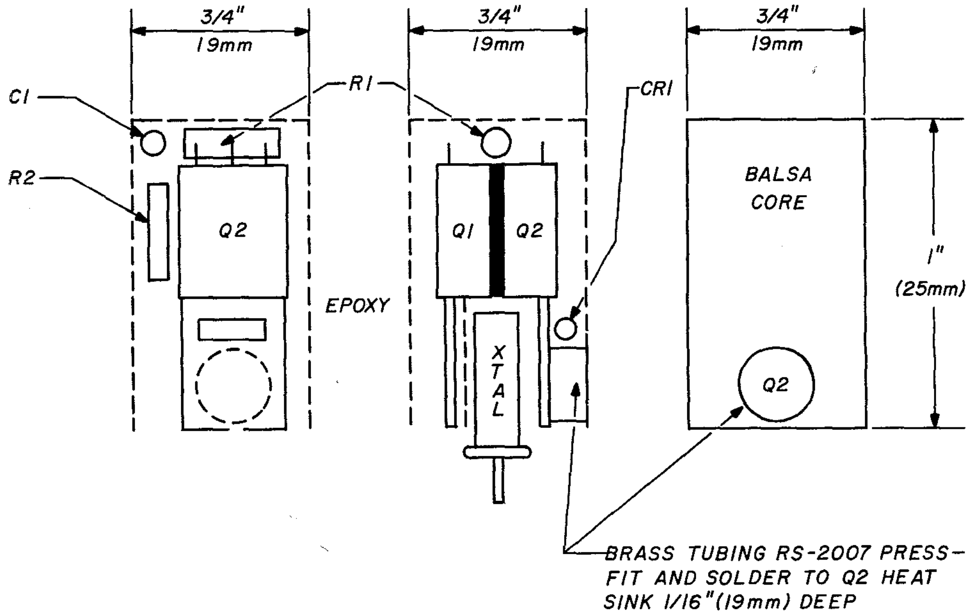


Figure 5-9.

Parts layout for the HC-25/U slip-on PTC circuit. Schematic is shown in *Figure 5-8*.

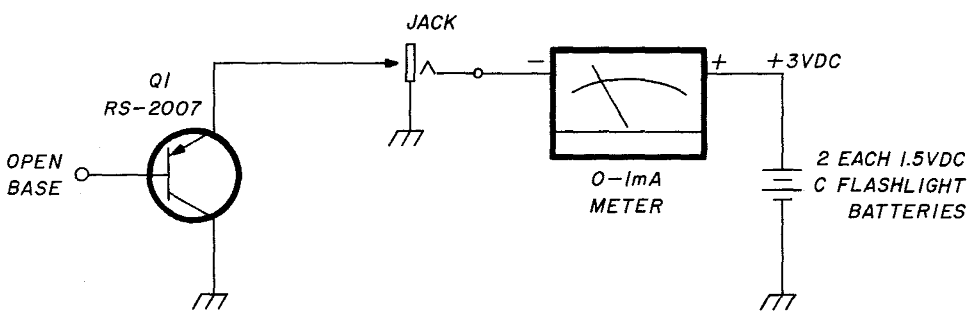


Figure 5-10.

Schematic for a portable electronic Tempmeter which may be used for setting up Proportional Temperature Control Circuitry. Completed Tempmeter and probe are shown in *Figure 5-11*.

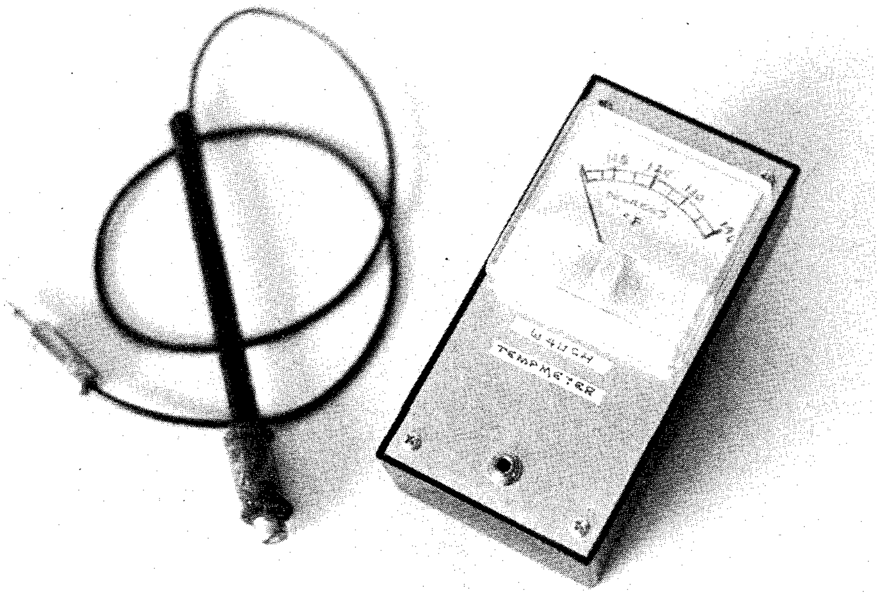


Figure 5-11.
Photograph of the portable Tempmeter built by W4UCH for setting up Proportional Temperature Control circuits.

PTC Crystal Oven Calibration

With the thermometer probe firmly implanted in the press-fit brass tubing on the Q2 side of the PTC, apply 3 Vdc to the circuit. If all is well, the temperature and PTC current should stabilize in about 5 minutes. Adjust R1, the 20k pot until the thermometer is stable at 110°F (43°C). Disconnect power for about 5 minutes to allow the crystal and PTC to cool a bit; then re-connect the 3 Vdc power source. The readout should slowly climb back to 110°F (43°C) and stabilize. Now measure the value of the 20k pot and permanently solder in a fixed resistor of similar value between the leads on the top of Q1 and Q2.

This exercise has a practical purpose and will be used in Chapters 10 and 12 to stabilize the 528th harmonic of a TX-432's 18-19 MHz crystal oscillator that will be used to both calibrate the Gunnplexer and to phase-lock the Gunn diode to this crystal. Plus or minus 50-Hz drift at 19 MHz represents a total excursion of 52.8 kHz on the 10-GHz band which is unacceptable for any type of narrow-band operation (1000 Hz bandwidth or less).

6

I-f Amplifiers

Design and construction of low-noise i-f amplifiers which may be mounted on the Gunnplexer module.

As I mentioned in *Chapter 2*, there are almost as many 10-GHz band plans as there are Gunnplexer operators. The 10.250 GHz transmit and 10.280 GHz (or 10.220 GHz) receive plan which originated in Germany has now spread to much of England, and many of the operators in New England have followed suit. Recently, a number of 10-GHz wideband fm operators have begun using a 111-MHz i-f with one station on 10.250 GHz, and the other on 10.361 MHz or 10.139 MHz, which allows the use of re-tuned standard fm broadcast receivers.

The 108 to 111 MHz region is occupied by Instrument Landing Systems (ILS) localizer transmitters throughout the world, so unless you are close to an airport with ILS (especially on the front- or back-course approach or departure paths) you should not experience any significant interference problems. (This assumes that the retuned fm broadcast receiver is sufficiently selective and will discriminate against nearby strong signals and reciprocal mixing; most low-cost fm portables popular for 10-GHz i-f systems do not meet these requirements. Therefore, in most two-way 10-GHz communications systems the use of a 111-MHz i-f results in unsatisfactory operation. The use of a 30-MHz i-f system by all microwave enthusiasts is highly recommended. *Editor*) The next frequency segment above 111 MHz is assigned internationally to Visual Omni Range (VOR) aircraft navigation systems with a minimum frequency separation of 50 kHz. With their limited bandwidth transmission, VOR transmitters (25 watts or less and usually on the highest hill or mountain) should not cause significant problems for video bandwidth receivers, but will undoubtedly be annoying if allowed to feed through the i-f of either wide- or narrow-band voice transmissions.

Two different i-f preamplifiers will be presented; they are both capable of approximately 20 dB gain (depending upon bandwidth), may be built for any intermediate frequency with appropriate frequency scaling, and are small enough to be installed inside the weather-proof Gunnplexer enclosure described in *Chapter 7.*

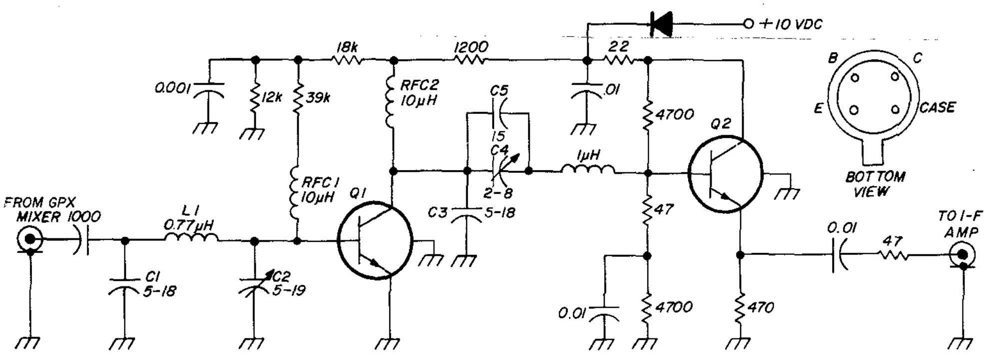
Microwave Associates Preamplifier

The low noise *ne plus ultra* 30-MHz Gunnplexer preamp designed by Microwave Associates engineers is shown in *Figure 6-1.* The printed-circuit version of this preamp shown in *Figure 6-2* was designed and built by W1HR. (J. R. Fisk, W1HR, "Low-Noise 30-MHz Preamplifier," *ham radio,* October, 1978, page 38. Text and illustrations provided courtesy W1HR and *ham radio* magazine.)

The circuit is based on two low-noise Microwave Associates NPN silicon planar transistors. These transistors exhibit excellent noise figure *vs* current characteristics, which results in extremely low noise figure and wide dynamic range. The circuit of *Figure 6-1* provides 19 dB gain with a noise figure of about 1.1 dB; compression of 1 dB occurs at an output of -7 dBm. The 3-dB bandwidth of the preamplifier is 10 MHz, and the input is designed to match the 200-ohm source impedance of the Gunnplexer mixer diode.

The noise figure of the Schottky mixer diode in the Gunnplexer is specified at 12 dB maximum, but many units are better than this. With careful design, proper impedance matching, and the use of an i-f preamplifier with a 1.0 to 1.5 dB noise figure, some users have reported system noise figures well below 10 dB. This represents a significant increase in reliable communications range.

The design of the input matching circuit is extremely important for good gain and low noise figure. For the Microwave Associates 42001-509 transistor the input impedance for optimum



L1 0.77 μH (8 TURNS AIRDUX 610T OR 17 TURNS NO. 28 [0.3 mm] WOUND MICROMETALS T-25-6 POWDERED-IRON TOROID)

L2 1.0 μH (10 TURNS AIRDUX 610T OR 20 TURNS NO. 28 [0.3mm] WOUND ON MICROMETALS T-25-6 POWDERED-IRON TOROID)

Q1 MA 42001-509 (MICROWAVE ASSOCIATES)

Q2 MA 42003-509 (MICROWAVE ASSOCIATES)

RFC 10 μH (51 TURNS NO. 32 [0.2 mm] ON 100K, 1-WATT RESISTOR, OR 20 TURNS NO. 28 [0.3mm] WOUND ON FT-230-06 FERRITE BEAD)

Figure 6-1.

Low-noise preamplifier has a noise figure of 1.1 dB and a 3 dB bandwidth of 10 MHz. Gain is 19 dB. Total current drain with a +10 Vdc power supply is 13 mA. (*courtesy Ham Radio magazine*)

noise figure is 100 + j37 ohms at 30 MHz; the input pi network (C1, L1, C2 in *Figure 6-1*) transforms this to the 200-ohm source impedance of the Gunnplexer mixer diode. The output of the first stage is matched to the approximately 50-ohm input of Q2 with C3, C4, C5, and L2.

A full-size printed-circuit board for the low noise 30-MHz preamplifier is shown in *Figure 6-3*; the component placement is shown in *Figure 6-4*. Note that the rf choke in the base circuit of Q1 (RFC1) is mounted on the foil side of the board; this is to prevent unwanted coupling to RFC2, which is located nearby. When winding the toroid coils, be sure to spread the windings evenly over the circumference of the form. By trimming ¼ inch (6 mm) from each side of the PC board, the preamp will fit neatly inside the weather-proof Gunnplexer enclosure described in *Chapter 7*.

For best operation the preamplifier should be adjusted for minimum noise figure, but this is not possible if you don't have access to noise-measuring equipment. Tuning the preamplifier for maximum gain will degrade noise figure slightly, but noise performance will still be better than that available with most 28-MHz receivers or 30-MHz i-f strips.

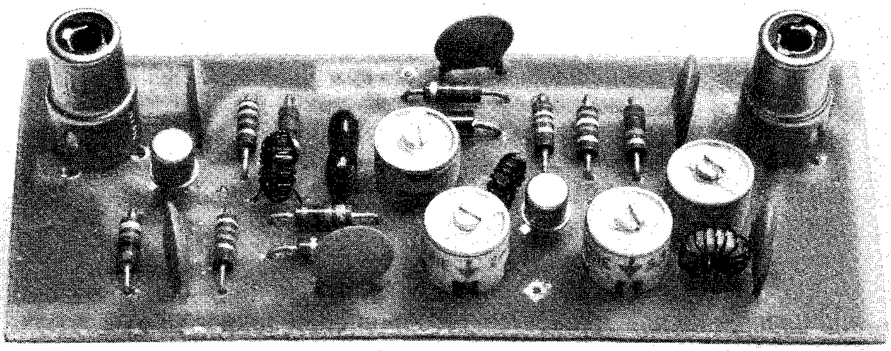


Figure 6-2.
Printed-circuit version of the Microwave Associates preamplifier built by W1HR. Printed-circuit layout and component placement are shown in Figures 6-3 and 6-4. (*courtesy Ham Radio magazine*)

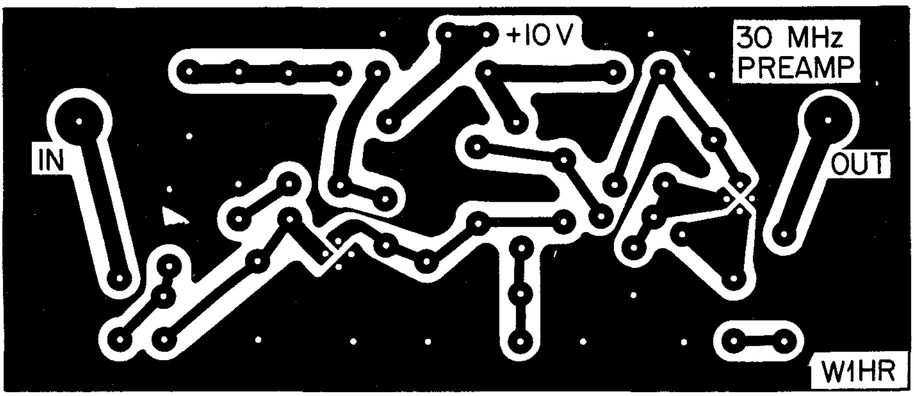


Figure 6-3.
Full-size printed-circuit layout for the low-noise 30-MHz preamplifier. Component placement is shown in *Figure 6-4.* (*courtesy Ham Radio magazine*)

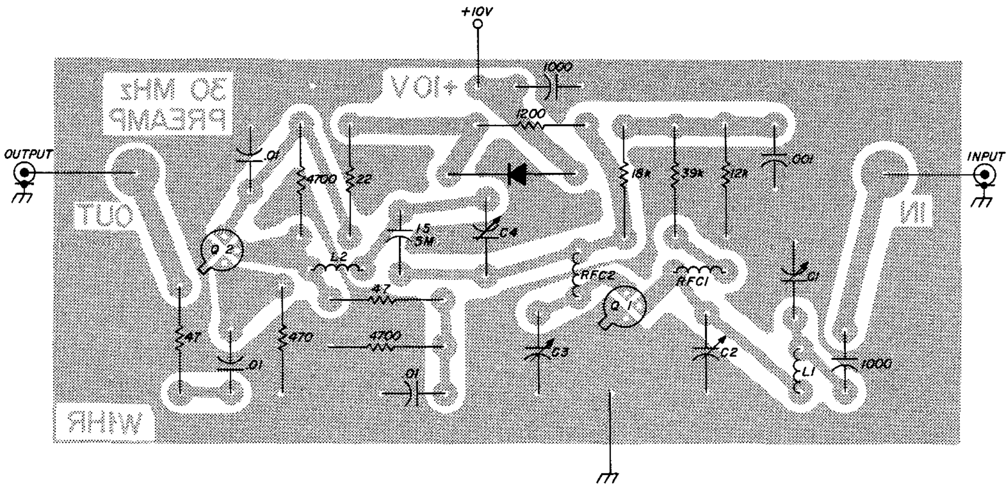
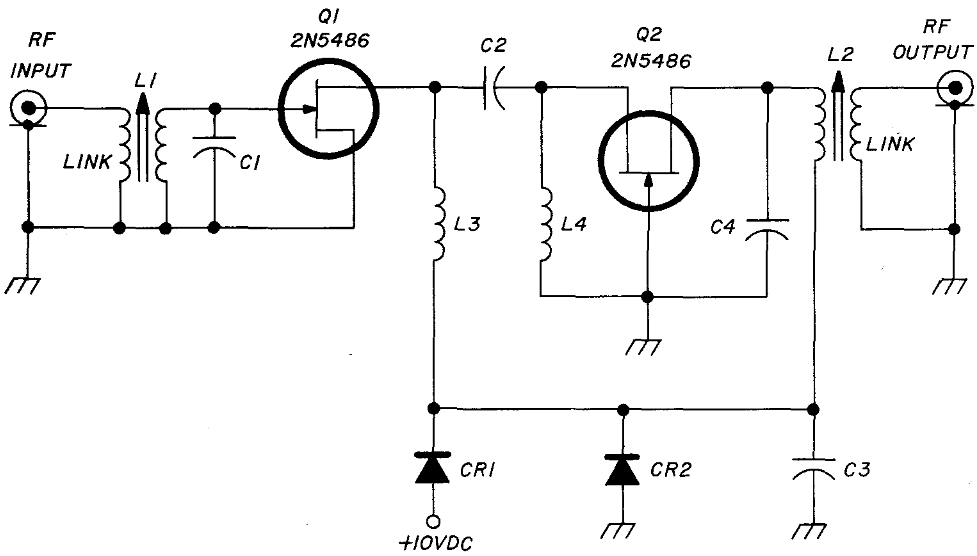


Figure 6-4.
Component layout of the 30-MHz preamplifier. Note that RFC1 is mounted on the foil side of the board to prevent coupling to RFC2. (*courtesy Ham Radio magazine*)

Hamtronics Cascode Fet Preamp

The Hamtronics (Hamtronics, Inc., 65 Moul Road, Hilton, New York 14468.) cascode fet preamplifier (model P-8) shown in *Figure 6-5* is available in kit form and can be built to cover any frequency range from 20 MHz to 170 MHz. Typical component values for center frequencies of 30 MHz and 111 MHz are listed under the schematic. Noise figure is 2 dB or less; gain was measured to be greater than 15dB at 98 MHz. The printed-circuit board for the Hamtronics preamp measures only ¾ inch (19 mm) wide by 2½ inches (64 mm) long. It is easily mounted on the Gunnplexer module with loops of no. 16 (1.3 mm) bus wire which have been soldered to the ends of the circuit board. The mounting arrangement used by W4UCH is shown in *Figure 6-6.*

Construction of the Hamtronics preamp is straightforward and requires little time. I have built two of these units with absolutely no difficulty. However, I do recommend the use of a 1N4148 diode across the +12 Vdc supply line (CR1 in *Figure 6-5*) to protect the 2N5486 fets from voltage transients.



PART REF	30 MHz	111MHz
C1	47pF	6.8pF
C2,C3	0.001 µF	220pF
C4	33pF	5pF
L1 LINK	2 5/6 TURNS	11 5/6 TURNS
L1 SECONDARY	8 5/6 TURNS	4 1/6 TURNS
L2 PRIMARY	12 1/2 TURNS	6 1/2 TURNS
L2 LINK	4 1/6 TURNS	3 5/6 TURNS
L3,L4	15µH	1µH

Figure 6-5.
Schematic diagram of the Hamtronics P8 cascode fet preamplifier which may be set up for any operating frequency from 20 MHz to 190 MHz. Component values for center frequencies of 30 to 111 MHz are listed above; values for other operating frequencies are included with the kit. Diode CR1 is recommended to prevent damage from supply voltage transients; CR2 protects the circuit from reversed power-supply polarity.

For best matching to the Gunnplexer mixer diode for optimum mixer noise figure, I used 3 5/6 turns for the input link on inductor L1 (terminals 5 and 6) at either 98 or 111MHz. A short length of RG-159/U coax, about ¾ inch (19 mm) long, connects

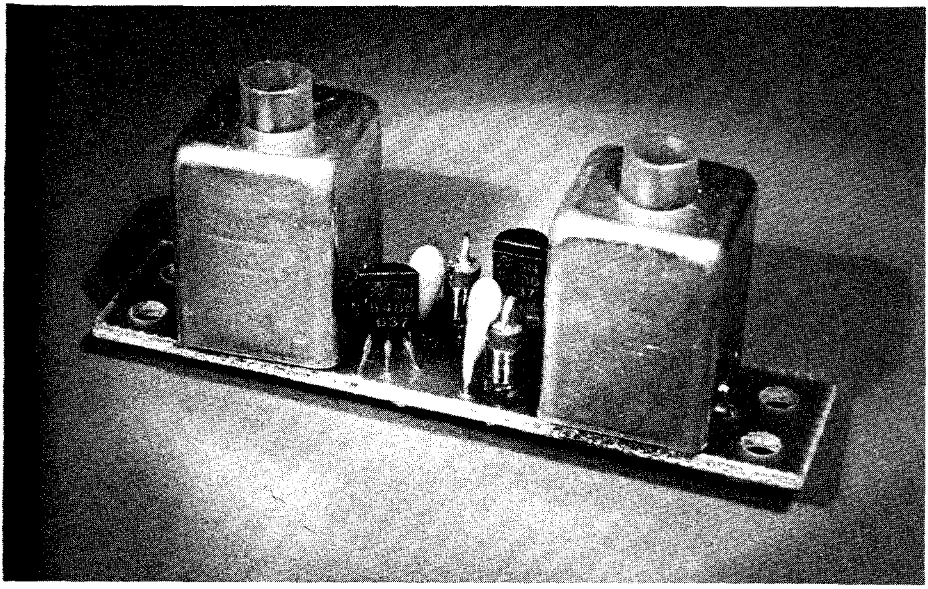


Figure 6-6.

Photograph of the Hamtronics cascode fet preamplifier. This preamp is available as a kit and comes complete with tuning instructions for any operating frequency from 20 MHz to 190 MHz. (Photo courtesy Hamtronics).

the mixer diode output terminal to the preamp input. Remove the 1000-ohm resistor across the Gunnplexer mixer output terminal; the protective diode, also across the mixer output terminal, is good insurance for mixer diode protection, but contributes about +1 dB to the mixer noise figure. It should be removed for serious long range work, and then special care taken to avoid strong reflections near the mouth of the horn antenna; otherwise the mixer diode may be damaged.

If you choose a 111-MHz center i-f and plan to use the wideband video or computer data link covered in *Chapter 15*, the Hamtronics preamp should be broadbanded by stagger tuning L1 and L2 at 116 and 106 MHz respectively. Before installing the preamp on the Gunnplexer module, apply +10 Vdc to the preamp and with a 200-ohm resistor across its input and an fm receiver connected to the output, adjust L1 and L2 for the flatest response you can obtain across 106-116 MHz using a dip meter as the frequency source. A short length of hookup wire should be an adequate antenna with the dip meter 20 or 30 feet (10 meters) away. For wideband fm voice, no video, tuning the i-f to a relatively flat 110-114 MHz should be adequate.

I-F Preamplifier Installation

Install the preamp on the Gunnplexer module; do not forget to remove the 200-ohm loading resistor across the input as illustrated in *Figure 6-7.* To decouple and bypass any local fm station pickup on the +10 Vdc power line that feeds both the Gunnplexer diode and the preamplifier, install a 1 michrohenry choke with 1000 pF disc capacitors on each side of the choke on the +10 Vdc feed on the Gunnplexer module. A similar choke and bypass capacitors should also be installed at the varactor terminal.

Solder a 5-pin terminal strip to the nipple of the varactor diode mount on the bottom of the Gunn diode cavity as shown in *Figure 5-2.* This terminal strip is an excellent spot to terminate the 4-wire Gunnplexer control cable, plus two coax leads for the varactor and i-f, and mount the decoupling chokes and bypass capacitors. The mounting lug soldered to the varactor nipple is a good common ground; soldering a no. 16 (1.3 mm) bus wire to it, extending 1 inch (25 mm) to each side, provides a common ground bus for the 1000 pF bypass capacitors.

Conclusion

Both preamplifiers will work exceptionally well on their respective intermediate frequencies. The Microwave Associates design exhibits a better noise-figure at 30 MHz than the Hamtronics i-f preamp in the 100 MHz region. For narrow-band modulation systems, by all means use the preamplifier designed by Microwave Associates with a 30-MHz i-f. For wideband fm and video computer data links, try the Hamtronics preamplifier first, and then step up to the low-noise Microwave Associates preamp as you gain experience. In either case, use the lowest noise figure you can afford.

Building a very wideband (approximately 10 MHz) i-f amplifier with 50 to 60 dB gain and reasonably flat response at 30 MHz is well beyond the capabilities of most radio amateurs. It is

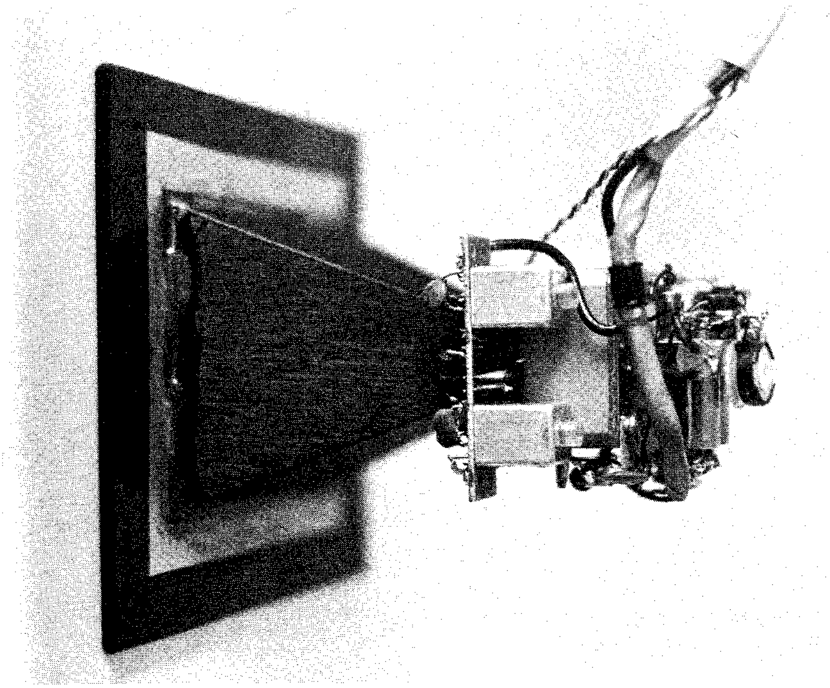


Figure 6-7.

Photograph of a Hamtronics preamplifier, center mounted on a Gunnplexer module. Components to the right (rear of Gunnplexer) are part of the Proportional Temperature Control circuitry.

certainly not impossible, but it would require extensive laboratory resources plus considerable time and investment.

7

Weatherproof Enclosure and Tripod/Rotator Mount

Details of an economical weatherproof Gunnplexer enclosure and tripod mound, covered with iron-on Monocote mylar.

Except for portable hill-top operation on clear sunny days using wideband fm, the serious Gunnplexer operator needs an equipment enclosure that will withstand inclement weather of all varieties and also serve as a temperature insulating housing in cold weather. The enclosure discussed in this chapter is easy to fabricate without special tools and serves the purpose well. Two have been built; both have survived 18 months of extreme weather conditions including temperatures from zero to 85°F, ice storms, 280 inches (7 meters) of annual snowfall, and thunderstorms with wind gusts over 60 mph (95 km/h). They are designed for tripod mount, antenna rotor/mast mount, and parabolic reflector mount. The latter is covered in Chapter 11.

Construction

The enclosure is a truncated pyramid with trapezoidal sides as shown in *Figure 7-1.* This configuration has considerable strength, is easy to build, and keeps parabolic reflector shadowing to a minimum. The front and rear segments are made from ⅛ inch (3 mm) thick five-ply aircraft-grade birch plywood. The sides utilize two laminated sheets of ⅛ inch (3 mm) thick medium to hard balsa wood that are epoxied together with each sheet's grain oriented at right angles (90 degrees) to the other, for a total thickness of ¼ inch (6 mm). The ¼ inch (6 mm) thick balsa walls, both sides plus top and bottom, give excellent thermal insulation. The small rear segment of ⅛ inch (3 mm) plywood may have a sheet of ⅛ (3 mm) balsa epoxied to the inside for further insulation. The external covering consists of iron-on *Monokote* mylar that has its own thermoplastic adhesive. *Monokote* is extremely durable, almost indestructible, and provides a professional looking finish.

The enclosure consists of the two parts shown in *Figure 7-2*, with the Gunnplexer module epoxied to the outer mounting rim which is hollow in the center. Included, but not shown in *Figure 7-2* is a 1/16 inch (1.5 mm) neoprene (old automobile inner-tube) gasket that goes between the segments for a waterproof fit. The two segments shown in *Figure 7-2* are held together with eight no. 4 (M3) by ½ inch (12 mm) sheet-metal screws.

All parts for the enclosure should be available from most well stocked model airplane hobby shops. (For Gunnplexer enthusiasts who live in remote areas, all components for the weatherproof enclosure are available from Hobby Lobby International, Route 3, Franklin Park Circle, Brentwood, Tennessee 37027, telephone (615) 834-2323.) An alternative is to build the enclosure from ordinary ¼ inch (6 mm) exterior plywood. There is no reason why it should not work almost as well, but it is considerably easier to cut balsa wood with an X-Acto knife and balsa wood is a better thermal insulator. In addition, balsa is significantly lighter in weight so it is easier to mount the Gunnplexer enclosure 14 to 16 inches (35 - 40 cm) away from the parabolic reflector (*Chapter 11*).

Step. 1. Use a piece of flat plywood or soft pine lumber as a building board; cover with *Saranwrap* to keep epoxy off the board. With a sharp X-Acto knife cut out eight halves of the enclosure sides as shown in *Figure 7-3*, then epoxy the halves together. Use common pins or T pins to hold the halves absolutely flat on the

Figure 7-1.
Homebuilt Gunnplexer enclosure is easy to build and weatherproof. Complete construction details are given in the text. It is shown here on a tripod mount.

building board while the epoxy sets. Scrape the excess epoxy off the joint before it sets because another layer of balsa will be laminated on top of each side, and a smooth tight fit is desired.

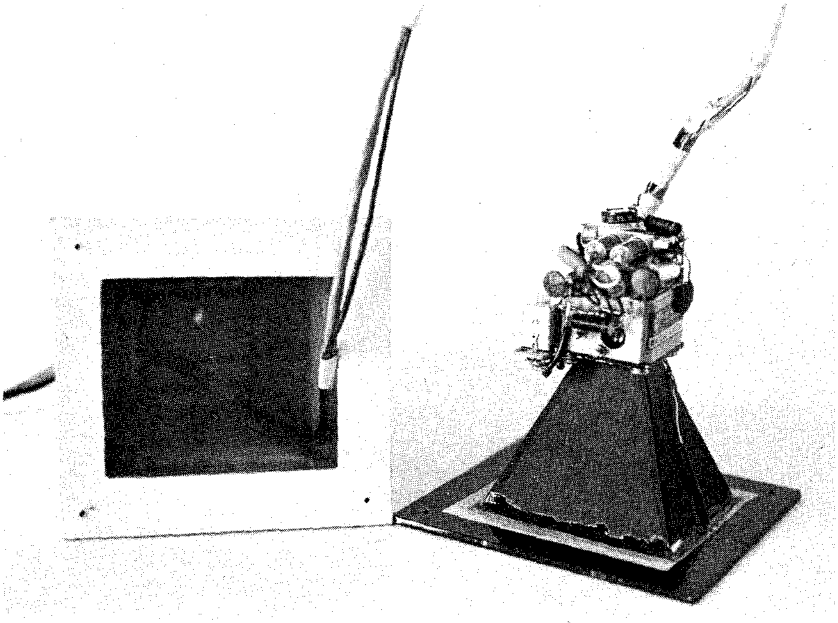


Figure 7-2.

The two segments of the Gunnplexer enclosure: the outer rim with the Gunnplexer module epoxied to it (right), and the truncated pyramid cover (left).

Step 2. Cut sheet balsa pieces to cover the four semi-finished enclosure sides, but with the grain crosswise (90 degrees). Mix only enough epoxy to do one side at a time, and work quickly as the recommended 5-minute epoxy sets quite rapidly. Pin together to ensure a tight fit and wipe off any excess epoxy at the edges.

Step 3. Pin one side to the building board. Using homebrew 90-degree balsa squares to obtain a true vertical (see *Figure 7-4*), epoxy two sides to the pinned down side.

Step 4. Epoxy in the triangular cross-section balsa reinforcing strips as shown in *Figure 7-4.* After the epoxy sets, remove pins and assemble and pin down the remaining side on the building board. Repeat Steps 3 and 4.

Step 5. Take a 12 inch (30 cm) square sheet of no. 180 sandpaper and pin or epoxy it to a flat board. Move the partially finished assembly lightly over the sandpaper until the edges at the front

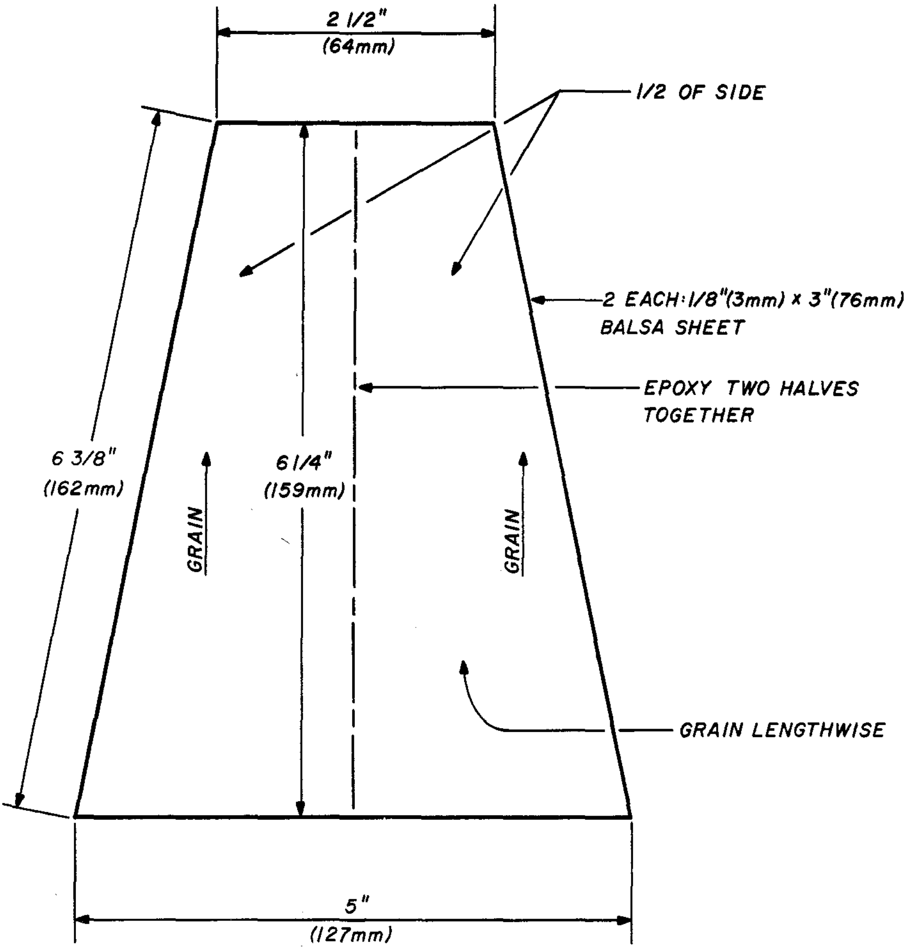


Figure 7-3.

Layout of the enclosure sides; material is ⅛ inch (3 mm) thick balsa wood. Eight pieces are required.

and rear of the assembly are truly flat so the front and rear plates shown in *Figure 7-5* will fit perfectly.

Step 6. Cut rear plate, front plate, and front mounting flange from ⅛ inch (3 mm) thick, five-ply plywood as illustrated in *Figure 7-5.* Approximately $^{3}/_{16}$ inch (5 mm) from the outer circumference of the rear and front plates, drill $^{1}/_{16}$ inch (1.5 mm) diameter holes

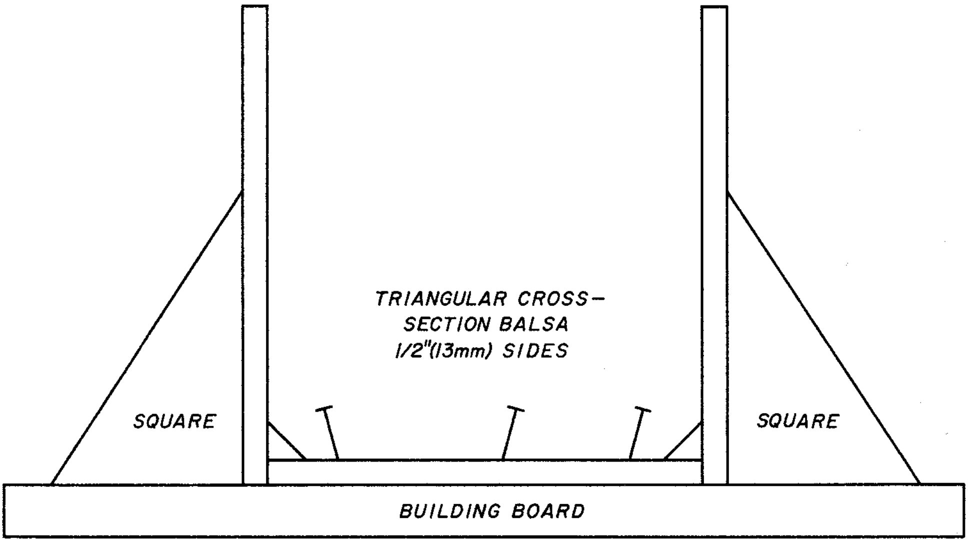


Figure 7-4.

Building board with 90-degree balsa wood squares to obtain a true vertical when the sides are glued together. Triangular reinforcing strips are also shown.

by $^1\!/_{16}$ inch (1.5 mm) deep, spaced about ¼ inch (6 mm) apart. Do the same around the enclosure's front and rear plate edges on one side. These small holes will give the epoxy a better grip between each plate and each end of the enclosure.

Epoxy the front and rear plates to the enclosure. Be sure to center the plates as there should be approximately $^1\!/_{32}$ to $^1\!/_{16}$ inch (1 - 2 mm) overhang on each side which will be sanded off later.

Step 7. Center the front mounting flange over the front plate assembly and drill the mounting flange for eight mounting holes as shown in *Figure 7-5*; the holes should be in about ½ inch (12 mm) from the circumference. Either no. 4 or no. 6 (M 3.5) by ½ inch (12 mm) sheet-metal screws will do the job. Drill a $^7\!/_{16}$ inch (11 mm) diameter hole ¾ inch (19 mm) in from the end of the plate on the bottom of the enclosure. This will be for the $^7\!/_{16}$ inch (11 mm) diameter brass tubing that is used for the Gunnplexer control cable exit; water will not flow up hill and the tubing may be hermetically sealed with a small wad of putty. Temporarily

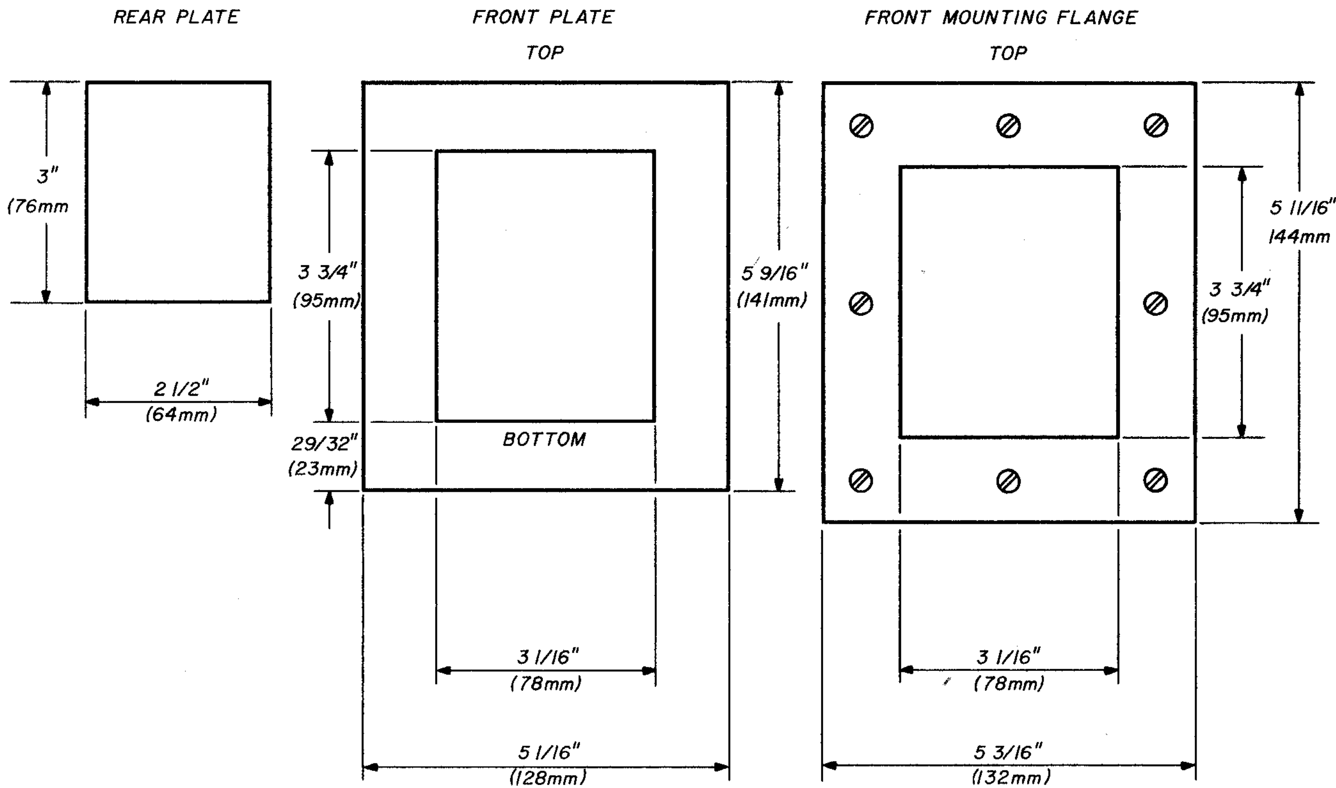


Figure 7-5.

Layout of the rear plate (left), front plate (center), and front mounting flange (right). Material is ⅛ inch (3 mm) aircraft grade plywood (see text). One each is required.

mount the mounting flange to the front plate assembly with sheet-metal screws. With either a sanding block or belt sander, carefully sand the plates and mounting flange flush with the balsa enclosure sides. Note that five-ply plywood sands much slower than balsa, so use extreme care.

Step 8. Disassemble the front mounting flange from the enclosure assembly. Using the mounting flange as a template, lay out a gasket on a piece of old automobile inner tube, then cut out the gasket with scissors. Use a pointed soldering iron to burn holes through the neoprene gasket for the eight mounting screws.

Step 9. With the front mounting flange flat on the building board, check to see the Gunnplexer horn antenna sits loosely in the flange mounting hole so epoxy can fill the void. If tight, sand the hole until there is at least 1/32 inch (1 mm) clearance on all sides. Using no. 120 sandpaper, lightly roughen up the outer 1/8 inch (3 mm) of the Gunnplexer aluminum horn antenna so the epoxy has something to grip. Place the Gunnplexer horn antenna in the mounting flange hole (on *Saranwrap*) and fill the void with a large quantity of epoxy. Wipe off any excess epoxy with a scrap of balsa wood to ensure a good tight fit on the gasket and enclosure's front mounting plate.

Step 10. If you are an old timer at building model airplanes this is the easiest step of all; i.e., finishing the enclosure with Topflite *Monokote* mylar thermoplastic-adhesive covering. The Gunnplexer enclosure is covered with one or two layers of *Super Monokote* 204 (white) on the sides and rear plate, plus two layers of *Super Monokote* 208 (black) on the front panel mounting flange. It may be applied with an ordinary electric iron, or better yet, a *Sealector* iron with a shoe-shaped heating element which is Teflon covered to reduce scratches. With a bit of practice either will work well. Experiment with the thermostat temperature setting; too cool will give poor adhesion (causing wrinkles), and too hot will overly shrink the *Monokote* (melting holes in it). Many youngsters have mastered the technique, so it is not overly difficult.

Overlap each edge of the enclosure and mounting flange approximately ½ to ¾ inch (12 - 19 mm). This seam will be virtually invisible when complete. The only caution for newcomers to this technique is when applying the second layer of *Monokote.* If trapped air bubbles between layers are to be avoided, this is rather difficult to do without a bit of practice. Rather than go into a long dissertation on how it is done, try the easy way out: use a common pin and prick each air bubble on the top layer of *Monokote*; then, iron smooth as silk.

Step 11. This step finishes the enclosure. Select a section of- 7/16 inch (11 mm) diameter brass tubing and cut a 1 inch (25 mm) length with a hacksaw or tubing cutter. Install the tubing in the 7/16 inch (11 mm) hole drilled in *Step 8* and epoxy in place. Be sure to leave about ⅝ inch (16 mm) of the tubing protruding from the bottom of the enclosure.

Tripod Mount

The tripod mount is built from leftover ⅛ inch (3 mm) thick five-ply plywood. First, cut out seven plywood rectangles 1-¾ by 1 inch (44 x 25 mm), and one 2-¾ inch (70 mm) plywood disc. Epoxy six of the rectangles together. After the epoxy has set, drill a 9/32 inch (7 mm) diameter hole through the center of the laminated rectangles. With a ½ inch (12 mm) bit, drill a ¼ inch (6 mm) deep hole in the top of the rectangles to hold the ¼-20 nut that is the international standard thread for camera tripods. Coat the threads of a 1-½ inch (35 mm) long ¼-20 bolt with Vaseline. Now partially fill the ½ inch (12 mm) hole with epoxy; also coat one side of the seventh rectangle with epoxy. Very quickly bolt the assembly together as shown in *Figure 7-7A* before the epoxy begins to set; remove the bolt in 5 minutes.

Carefully mark the saw line on each side of the partial tripod mount assembly as shown in *Figure 7-7B.* Make sure the ¼-20 nut is on the bottom side of the assembly. Using either an X-Acto razor saw or ordinary hacksaw, very slowly cut the assembly in half. Finish sanding the assembly.

Drill four equidistant holes ¼ inch (6 mm) in from the circumference of the 2-¾ inch (70 mm) diameter round plywood mounting plate as shown in *Figure 7-6* to accommodate either no. 4 or no. 6 (M3.5) ½ inch (12 mm) sheet-metal mounting screws. Place the rear edge of the round mounting plate on the bottom of the Gunnplexer enclosure about 1- 1/16 inch (27 mm) in from the rear of the enclosure. Drill mounting holes through the enclosure, and on the inside of the enclosure epoxy two each ½ × 2 inch (12 × 50 mm) scraps of five-ply plywood over the mounting holes to serve as grip plates/doublers for the mounting screws. Re-drill the mounting holes. Center the partial tripod assembly on the round mounting plate and epoxy. Two coats of varnish or epoxy will waterproof the completed tripod assembly (see *Figure 7-8*).

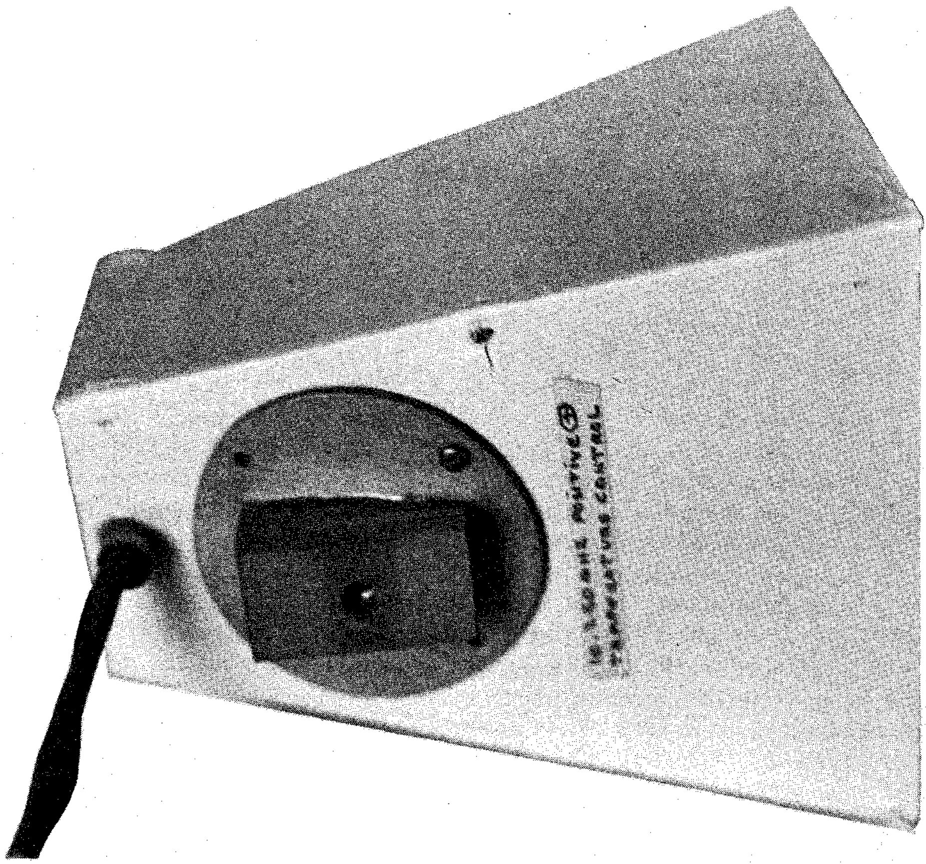


Figure 7-6.

Bottom view of the Gunnplexer enclosure showing the tripod mount and the $\frac{7}{16}$ inch (11 mm) tubing to pass the control cable.

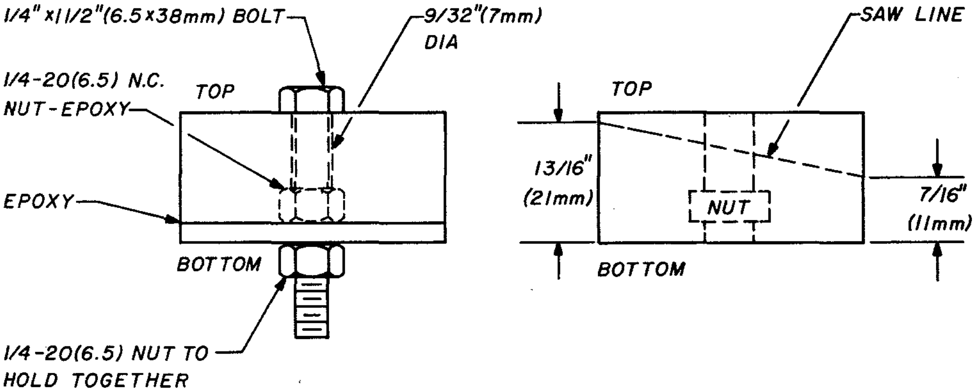


Figure 7-7.

Construction of the tripod mount. Six sections of ⅛ inch (3 mm) thick plywood are laminated together at A with epoxy. After completely dry, mark the saw line shown in B and carefully cut the assembly in half.

Antenna Mast/Rotor Mount

The antenna mast/rotor mount is quite simply a 4 inch (10 cm) by 5 inch (12.5 cm) plate of ¼ inch (6 mm) plywood (or two laminated pieces of ⅛-inch (3 mm) five-ply plywood). The plate is drilled for two 1-½ inch (38 mm) U-bolts and attached to the Gunnplexer enclosure rear plate with four no. 6 (M3.5) sheet-metal screws. It is a good idea to epoxy a ⅛-inch (3 mm) thick plywood doubler on the inside of the Gunnplexer enclosure rear plate for added strength.

An unintentional drop test was performed on this mount, Gunnplexer, and enclosure when the assembly was dropped accidently 35 feet (10.7 meters) from the roof to the grass below. Amazingly, it landed on the mount end of the assembly, bounced, and suffered no damage whatsoever except for a few grass stains. *Figure 7-9* is a drawing of the mount.

The antenna mast/rotor mount may be used with the Styrofoam hat described in the next section by using no. 6 (M3.5) sheet-metal screws, 1-½ inches (38 mm) long and inserting 1 inch (25 mm) tubular spaces through the Styrofoam which covers the enclosure's rear plate. The spacers may be made from any scrap tubing with ¼ to ½ inch (6 - 12 mm) diameter.

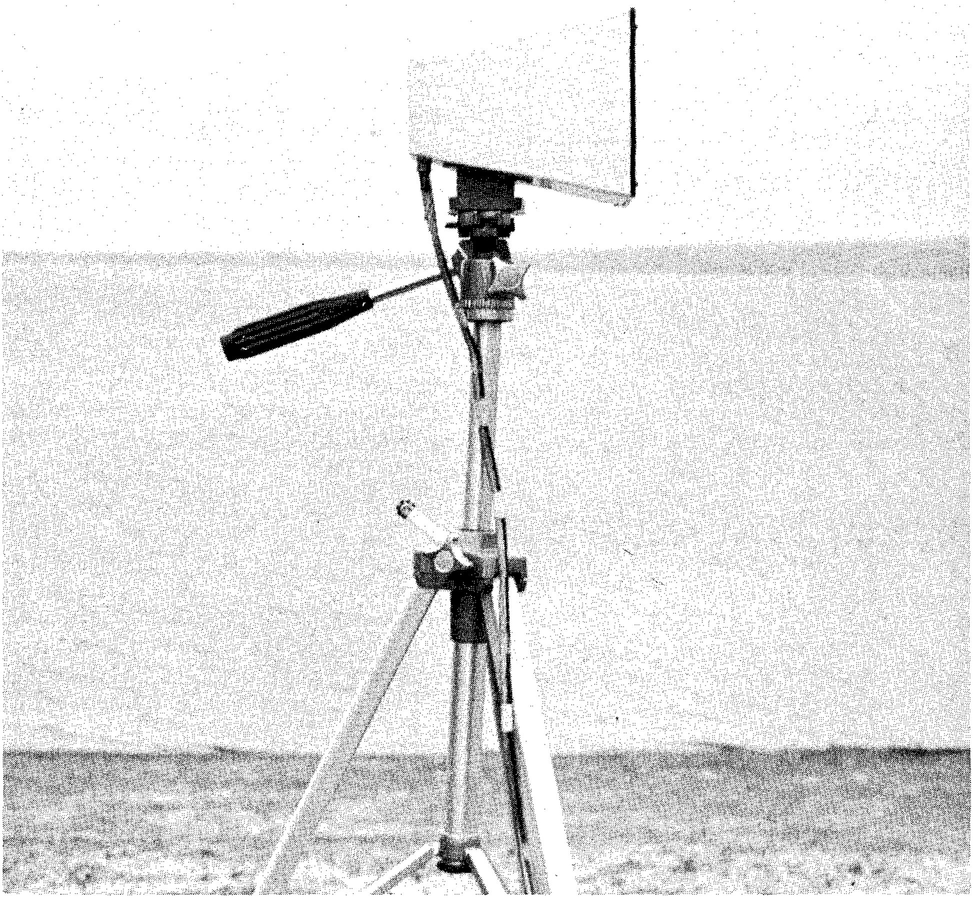


Figure 7-8.
Side view of the completed Gunnplexer enclosure and tripod mounting assembly.

Styrofoam Cold-Weather Hat

The 5 watts of heat generated by the Gunn diode (500 mA at 10 Vdc), plus the 12 watts of heat (maximum) contributed by the

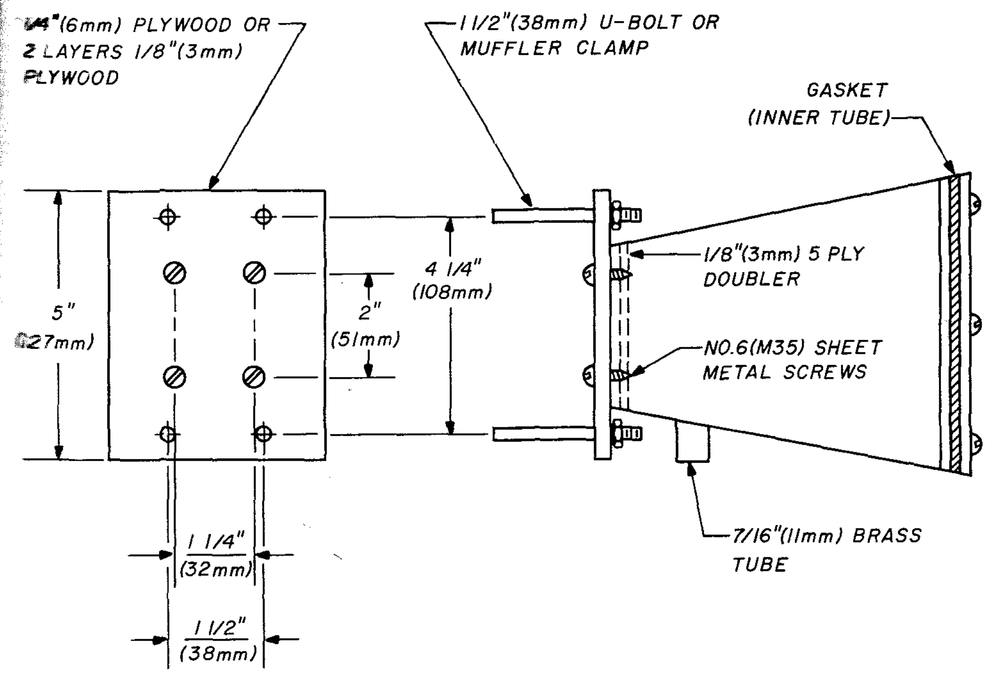


Figure 7-9.

Construction of the antenna mast/rotor mount for the Gunnplexer enclosure. The 1-½ inch (38 mm) U-bolts are used to attach the Gunnplexer enclosure to the antenna mast.

PTC doesn't leave much surplus capacity for cold-weather operation. At outside air temperatures below 32°F (0°C), using the standard Gunnplexer enclosure described earlier, the heating capacity becomes a negative number. The Gunnplexer operator has two choices: either use a higher capacity heating transistor in the PTC that will handle 4 to 6 amps, or further insulate the Gunnplexer enclosure.

I chose the second option because running 4 to 6 amp heating lines seemed absurd, the inside rear of the Gunnplexer enclosure is rather cramped for space and a much larger heating transistor would be a difficult fit, and a Styrofoam cold-weather hat may be built in a short time for a dollar or two. Finally, the cold-weather hat is by far the simplest solution.

Nearly all building supply stores and lumber yards now stock 2 foot (61 cm) by 8 foot (2.4 meters) by 1 inch (25 mm) thick Styrofoam insulating panels; the price is $2 to $3 a sheet. As this is usually the minimum size panel, you will have enough left over to make 15 more Gunnplexer Styrofoam hats - or one giant beer cooler!

Construction

Lay the Gunnplexer enclosure on the Styrofoam sheet and trace out the 2 sides and front with a felt tip pen. Add about ⅛ inch (3 mm) to each line for a loose fit. Also trace out the enclosure's top and add 1-⅛ inch (29 mm) to each side and the front. Purists use a transformer-driven hot nichrome wire for cutting Styrofoam, but not being very pure, I used a serrated bread knife — it will do an excellent job if you proceed slowly.

Check the sides, top, and front for a loose fit and first epoxy the sides to the top, and then the front to the sides and top as shown in *Figure 7-10.* If you wish, make the bottom edge of the sides, front, and rear an extra inch lower to further reduce heat loss; remember, however, that the heat rises so the improvement will be very small. Also, if you plan to use the Gunnplexer enclosure on the antenna mast/rotor mount, add a Styrofoam insulating plate that may be held in position with eight no. 6 (M3.5) 1-½ inch (38 mm) sheet-metal screws. Now place the partially finished rear end of the hat on the Styrofoam sheet and trace out the rear panel. Cut and epoxy the rear panel in place completed unit shown in Figure 7-11.

Construction hint: 5-minute epoxy is an excellent solvent for building grade Styrofoam insulation, so it should be applied as follows. Mix epoxy 1 to 2 minutes; spread a very thin coat on each side to be joined. Wait a minute or two until the epoxy just starts to become "stringy," and then very quickly swab a 1⁄16-inch (1.5 mm) thick layer of epoxy on the joint and quickly press the pieces together. You will obtain a very strong and well insulated joint.

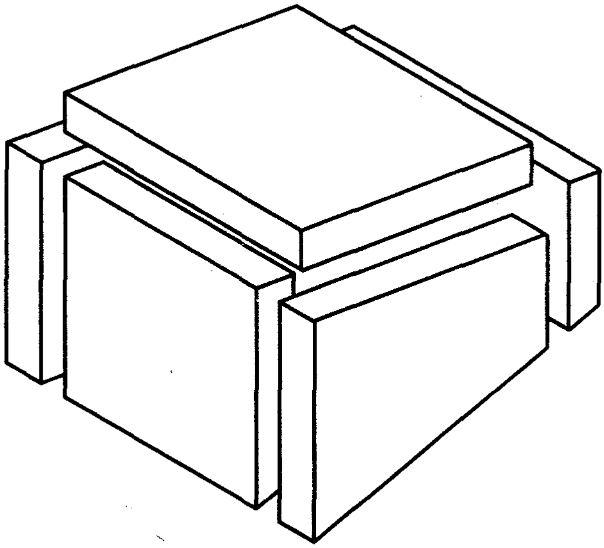


Figure 7-10.
Five pieces of 1-inch (25 mm) thick Styrofoam insulating sheet are used for the cold-weather hat. See text for layout instructions.

Cold Weather Hat Operation

At any outside free air temperature above approximately 50°F (10°C) the hat will not work because the heat generated by the Gunn diode (PTC automatically fully cutoff) will hold the Gunnplexer temperature at 120°F (50°C) or higher with the hat in place. The hat should be used only when the temperature is expected to reach freezing or below. The unit has been tested down to zero Fahrenheit (-18°C) at which point PTC current stabilized at 600 mA. The lower temperature limit is estimated to be about -30°F (-34°C). If your location has colder temperatures, I suggest a move to a more moderate climate.

For dry operation, the cold-weather hat does not have any measurable attenuation to the 10-GHz Gunnplexer signal; by this I mean I am not able to notice any signal loss. When wet, the attenuation varies between 3 and 6 dB. This may be reduced

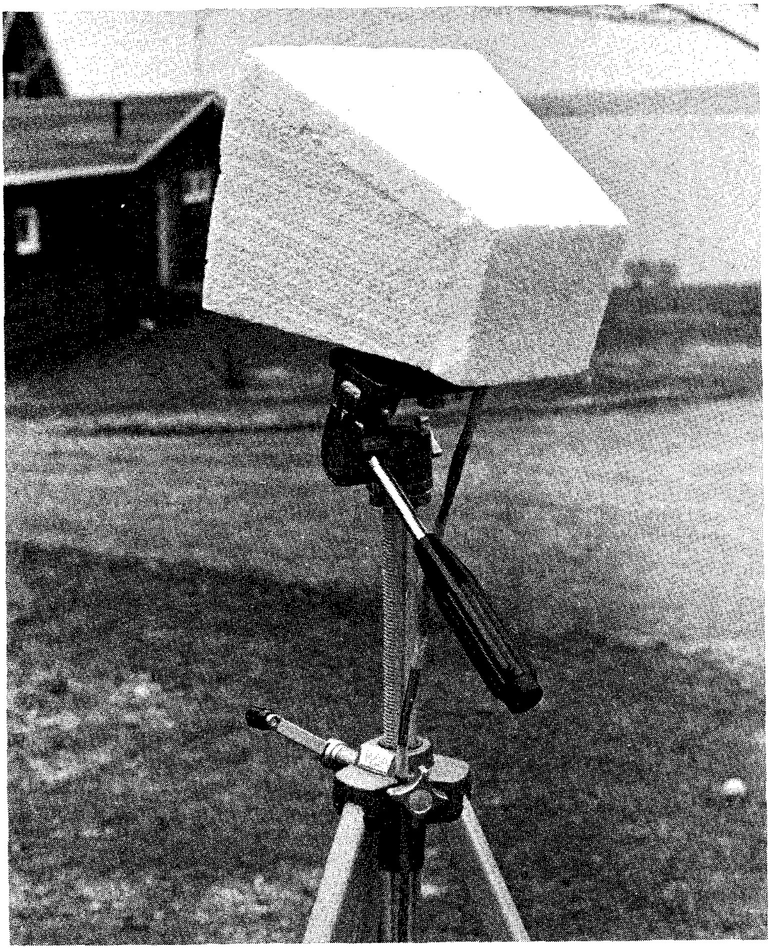


Figure 7-11.

View of the tripod-mounted Gunnplexer enclosure with the Styrofoam cold weather hat in place. This insulating cover allows temperature stabilization o the Gunnplexer to below zero Fahrenheit (-18°C).

considerably, almost eliminated, by using the rainwater repellen spray developed by Boeing for use on the 747 and other aircraft. have used this water repellent many times and it works very well A much simpler solution is to wrap the front of the Styrofoam ha with *Saranwrap* held in place with a rubber band; it work remarkably well, sheds water like a duck, and is almost free.

8

Automatic Frequency Control

Automatic frequency control peculiar to Gunnplexer operation. Some ideas and circuits for AFC -compatible discriminators. IC and transistor circuits for AFC amplifiers are presented with notes on how to use them.

Automatic frequency control on the amateur high-frequency and vhf bands was virtually unknown until the recent popularity of ¾-meter repeater operation. The 1976 edition of *ARRL's The Radio Amateur's Handbook*, fifty-third edition, does not mention the subject, even though thirty-eight pages are devoted to frequency modulation and repeaters. The 1974 edition of the ARRL book, *FM and Repeaters for the Radio Amateur*, devotes only three paragraphs to AFC . This is not meant as a criticism of the ARRL editors, since I have ardently supported ARRL for thirty years and continue to do so; it is only to point out that AFC has not been widely used, nor required, in most amateur radio applications. Even with Gunnplexer 10-GHz wideband fm operation, AFC is not a "must" item, although it is of considerable convenience. For most types of Gunnplexer narrowband fm communication with 15-kHz deviation or less, AFC is almost a virtual necessity. As such, I will try to cover AFC operation from "go," up to building a few easily constructed AFC circuits with 16-40 dB loop gain.

AFC Systems

Most AFC systems are nothing more than a closed servo loop that a) senses the fm detector (discriminator) output frequency change of the received signal (or local) oscillator drift with respect to the received signal), and b) outputs an error voltage which is roughly proportional to the frequency offset. This sounds just like any one of many fm discriminator circuits to generate audio and it is, except that it is bypassed for audio frequencies; thus its output measures only carrier frequency change (hopefully). If this carrier-frequency-change voltage output is fed back to the receiver local oscillator (usually to a varactor) to bring the detected frequency difference back to zero, we have a complete closed AFC servo loop.

That is all there is to it. Many sophisticated texts tend to complicate the AFC process; but in reality, it is simplicity, period. A few new terms are used: "capture range," which is the maximum frequency difference in which a receiver with AFC must achieve initial lock-on to a new signal; "lock range," which is the maximum frequency differential (plus and minus) that a captured signal may change and which the receiver AFC will continue to track automatically; and AFC time constant, which is the speed at which an AFC loop will correct the receiver local oscillator for any detected frequency change.

A truly fast AFC time constant would correct oscillator frequency for audio-frequency-rate deviation, thus delivering virtually zero audio output, which is not exactly desired. A slow AFC loop would allow the received signal carrier to drift so far off center frequency that considerable audio distortion would result. This, too, leaves something to be desired. A compromise between too fast and too slow action is used.

The Proportional Temperature Control (PTC) servo loop covered in *Chapter 5* and the AFC servo loops in this chapter use the same principle of operation. The AFC loop is many orders of magnitude faster than the proportional temperature control loop, so you might well ask, "Why have both?" The answer to this reasonable question is that the PTC holds your frequency relatively close to where you want to be, and the AFC corrects for the other station's frequency drift if it does not have PTC. Even if it does have PTC, AFC is a real aid and virtual necessity for narrowband operation.

AFC dynamic range and loop gain roughly define the variation in received signal level that the AFC circuit will accommodate. Some of the newer active tracking filters, which incorporate phase-locked loops, will maintain lock on coherent signals down to 20 dB below the average noise level – real black magic that we will save for a later volume of the Gunnplexer Cookbook. The foregoing rationalized definitions may drive some experienced AFC engineer/scientist types up the wall; sorry about that. They may skip the rest of this chapter.

Gunnplexer AFC Considerations

The Gunnplexer varactor that varies Gunn-diode output frequency has a near infinite (high) input impedance and may be tuned by any dc voltage between +1 to +20 Vdc. Specified center frequency, as delivered from the factory, is at a nominal +4.0 Vdc varactor voltage with +10 Vdc for the Gunn-diode bias supply. Outside air temperature is not specified, so we assume 72°F (22° Celsius). The varactor high input impedance is a blessing in that we have only to furnish a voltage source to tune it. It is a curse in that its high impedance makes it susceptible to inductive coupling of almost any variety. To minimize inductive pickup, always keep varactor feed impedances as low as possible, always use shielded coax for varactor feedline (over a few inches), and use as much bypass capacitance as possible.

For clarity (hopefully to avoid confusion), we will assume that the Gunnplexer with AFC is at 10.250 GHz, and the other Gunnplexer is always higher in frequency and has no AFC. If both stations had their AFC *ON* simultaneously, they would chase each other up and down in frequency, never locking, with no meaningful signal output. A solution to the dual AFC paradox is presented in *Chapter 12*, where both stations are phase locked to a PTC crystal oscillator harmonic to eliminate (almost) the drift problem.

Another assumption is that the local oscillator of the 10.250 GHz Gunnplexer tunable i-f receiver is always on the high side of the i-f (as most all are). This allows us to use an inverting AFC amplifier (up is down and down is up). A switch-selectable inverting or noninverting amplifier designed by DJ700 is also presented.

Almost any dc voltage amplifier with adjustable output in the +1 to +10-volt range will work as an AFC amplifier driving the high-impedence Gunnplexer varactor. Complexity may vary from the very simple single LM3900 and 2N3563 AFC amplifiers illustrated in *Figures 8-1* and *8-2*, to the highly sophisticated, single-slice, microprocessor-controlled AFC amplifiers used in communications satellites. We will stick to the simple variety, because they do the job adequately for both the Level I and II communications systems, the Crystalmatic phase-lock system, and video data links for TV and/or computers.

The LM3900 Norton Operational Amplifier

The LM3900 op amp was one of the first single-voltage operational amplifiers. It is extremely reliable and a mountain of applications literature exists for it. It is capable of up to 70 dB

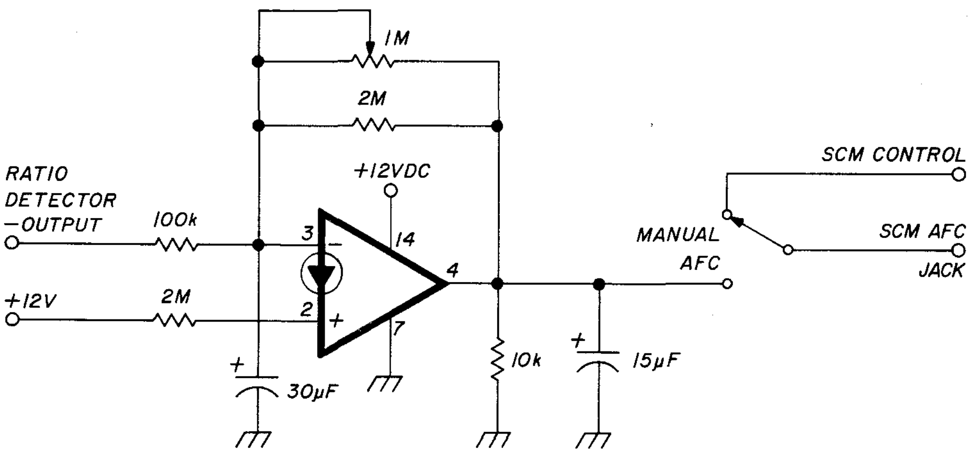


Figure 8-1.

AFC amplifier using the LM3900 IC. The 2-meg resistor on pin 2 provides offset bias, which is needed when the device is in the inverting configuration. Another bias voltage of about 500 millivolts is also required for linearity, which is provided by the ratio detector of *Figure 8-3*.

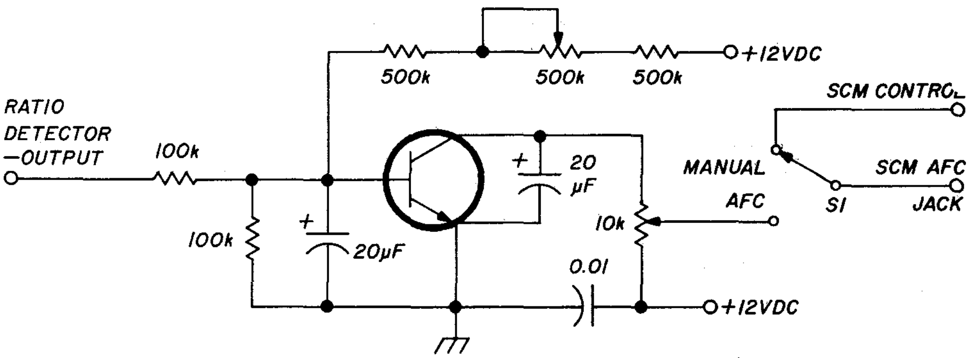


Figure 8-2.
An AFC amplifier using a 2N3563 transistor. It also is an inverting amplifier with about the same time constants as the amplifier of *Figure 8-1*.

voltage gain, may be operated as an inverting or noninverting amplifier, is inexpensive ($1 or less), and with its four op amps on a single 14-pin IC, it is capable of just about any linear op amp application desired. An excellent report on LM3900, covering applications data of every type imaginable, is available from Radio Shack (no. 62-1373) at $2.75. It is a part of the National Semiconductor *Linear Applications Handbook*, Volume I.

The LM3900 provides voltage output up to source voltage minus 1 volt, which more than meets our needs using a regulated 12 Vdc power supply. It has an output impedance of 8k, which is low enough for our purposes, and it works quite well with a series input resistor of 100k that does not significantly load down the output of any fm discriminator.

Discriminators and AFC Amplifiers

Most fm discriminators have zero Vdc output when tuned dead center on the carrier frequency. The LM3900 op amp in the inverting configuration needs a small offset bias, as it will track to only 100 millivolts. The circuit shown in *Figure 8-1* provides this offset bias through the 2-megohm resistor on pin 2. Since the discriminator output is zero at the carrier center frequency, we must introduce about 500 millivolts bias to give the LM3900 a linear voltage to track that does not pass through zero. The ratio detector shown in *Figure 8-3* provides that bias as we tap off the minus side of the ratio detector's 1N60 diode.

Another method of obtaining offset biasing from an fm discriminator is to deliberately mistune the discriminator transformer to obtain approximately 500 millivolts output. This method is discussed in *Chapters 12—14*, where a separate i-f is used exclusively for the Crystalmatic system, and the deliberate mistuning does not impinge on or distort the audio signal.

The ratio detector circuit shown in *Figure 8-3* is from the Radio Shack 12-1345 fm Car Radio Converter. With the addition of an LM380 audio amplifier and LM3900 AFC amplifier, it comprises a complete Gunnplexer tunable i-f receiver and is described in *Chapter 9.*

Consider *Figure 8-1.* Nothing could be much simpler than this AFC amplifier. In the manual tune position the Gunnplexer varactor is fed +4 Vdc from the System Control Module's regulated power supply (with the coarse tuning control set at mid position). The Gunnplexer's tunable fm i-f receiver is then tuned up and down 10 MHz from the 98-MHz center frequency until the other Gunnplexer signal is found. Switch S1 then transfers varactor control to the AFC amplifier and the 1-meg pot is adjusted for lock on. With a weak-to-medium strength signal, the AFC amplifier will capture the other Gunnplexer signal when tuned within 500 kHz of its i-f. Once captured, you can tune your fm receiver from 88 to 108 MHz and the AFC amplifier, through

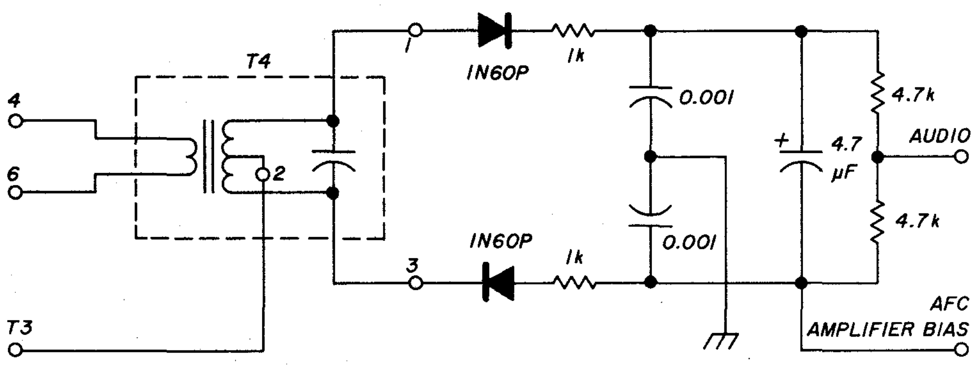


Figure 8-3.

Ratio detector circuit taken from the Radio Shack 12-1345 fm Car Radio Converter. Note that the bias voltage for the AFC amplifier of *Figure 8-1* is obtained from the negative side of the bottom 1N60 diode.

varactor control, will keep the signal locked on unless you live close to a 100-kW fm station whose signal is leaking into your i-f strip and is stronger than the Gunnplexer signal at the detector.

Overload From fm Broadcast Stations

The closest fm station to my location is 25 miles (40 km) away and poses no problem. If your problem seems overwhelming, go back and double check to see that all lines are well shielded and adequately bypassed for rf pickup. Try a 12-volt battery power supply to make sure the fm station's signal is not sneaking into your system through the 110-Vac power line, as power lines make excellent fm-station antennas in metropolitan areas. If all else fails, realign your fm receiver and tune 108 to 128 MHz and be sure to let the other Gunnplexer operators know about your new i-f. All it takes to move a nominal 10.348-GHz signal to 10.361 GHz to yield a 111-MHz i-f is about 1 volt dc varactor change.

The amplifier shown in *Figure 8-1* has an average voltage gain of 16 dB. The voltage gain is determined solely by the ratio of the feedback resistance between terminals 3 and 4 (average 600k) to the input resistance, 100k at terminal 3. Therefore, *600/100 = ratio of 6:1 = approximately 16 dB voltage gain.* All this is fine and good except that the input and output impedances are different, so it is a rather meaningless exercise.

Especially note the AFC amp input and output electrolytic bypass capacitors. The input time constant of 0.3 second is set by the combination of the 100k resistor and 30 μF capacitor. This time constant is slow enough so that any audio frequency variations will have no effect yet is fast enough that any frequency drift of either Gunnplexer oscillator is automatically compensated. The 15-μF capacitor across output terminal number 4 bypasses any local 60-Hz hum.

Transistor AFC Amplifier

For those wishing to experiment, *Figure 8-2* illustrates a single 2N3563 NPN transistor amplifier. It, too, is an inverting amplifier with approximately the same time constants as the LM3900 of *Figure 8-1.* The AFC capture range of the 2N3563 AFC amplifier in

Figure 8-2 is about 200 kHz, and its lock range is from 94 to 106 MHz on the Radio Shack receiver with a medium-to-strong Gunnplexer signal.

DJ700 Op Amp AFC System — Inverting and Noninverting

Here is a useful and interesting AFC circuit designed by Klaus Hirschelmann, DJ700 from Mainz, West Germany (*Figure 8-4*). DJ700 is one of the real Gunnplexer pioneers in western Europe. It is an excellent design that, with its 100k input resistor, should work with any fm receiver discriminator. Switch S1 allows selection of either inverting or noninverting AFC amplifier output, which is indeed a convenience for contest work. The S1 center position is AFC *OFF*, allowing manual setting of varactor voltage with the 5k pot. Another interesting feature of Klaus' design is that it covers the full +1 to +20 Vdc Gunnplexer varactor voltage range if a well-regulated, ripple-free, +20 Vdc power supply is available. If you don't have +20 Vdc regulated, the top of the 5k pot may be connected to the +12 Vdc regulated power supply and resistor *R* changed to 440 ohms (two 220 ohm resistors in series).

Conclusions

For those who wish to go further into AFC work and dig deeper into the subject, try these experiments:

1. A high-gain Darlington transistor pair AFC amplifier.
2. Slow sawtooth generator for automatic scan and capture.
3. Sample and hold varactor *E* memory for fading signals.

For wideband fm voice or video operation, AFC is nice to have, but certainly not necessary. Remember that each Gunnplexers' tunable i-f receiver may have its AFC turned *ON* to its own local oscillator, but not to the Gunnplexer varactor, at the same time. For narrowband operation either AFC or Crystalmatic is a must accessory for all practical purposes. There are numerous ways to generate the AFC voltage. These vary from taking an fm receiver's high-level AFC output (if it has one) and feeding it

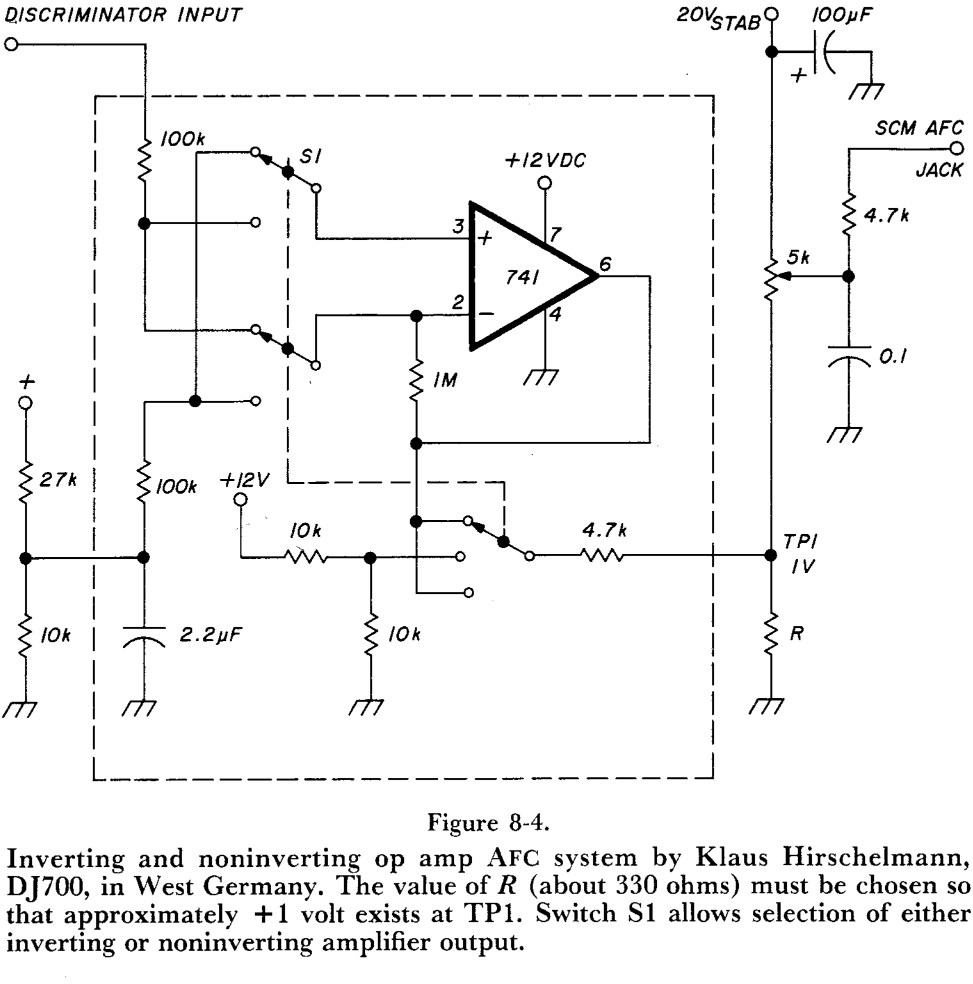


Figure 8-4.
Inverting and noninverting op amp AFC system by Klaus Hirschelmann, DJ700, in West Germany. The value of *R* (about 330 ohms) must be chosen so that approximately +1 volt exists at TP1. Switch S1 allows selection of either inverting or noninverting amplifier output.

directly to the varactor, on up to dual-sense AFC amplifiers such as the DJ700 op amp and the Crystalmatic system.

For serious DX operation using simplex it is my best guess that 10.250 GHz will become the universally accepted calling frequency. As such, choice of i-f, whether 29 MHz, 30 MHz, 98 MHz, 111 MHz, or 113 MHz, is up to the operator, as it makes no difference to the other station. All Gunnplexers, if mechanically tuned to 10.250 GHz at 1.5 Vdc varactor input, will easily tune any of these i-fs with less than the full +20 Vdc applied to the varactor. *Ipso facto*: use any or all of the foregoing intermediate frequencies you wish.

Knowing exactly where 10.250 MHz is located, and ensuring that your signal is "on it," is the real key to serious Gunnplexer operation; it separates the men from the boys with their toys. The crystal-controlled weak-signal source covered in *Chapter 10* is a low-cost solution to this problem.

9

Level I Communications Systems

Circuits and techniques for getting started. How to use fm receivers from Delco and Radio Shack for tuneable i-f strips. A 30-MHz i-f wideband receiver is included for serious DX operation.

Any enterprising electronics buff can purchase a pair of Gunnplexers (for instance 10.250 GHz and 10.348 GHz), open the box in the morning, and from absolute scratch be on-the-air the same afternoon with two operating Gunnplexer transceivers. All it takes are two standard-broadcast 88-108-MHz portable fm receivers (as tunable i-f strips), a 12-volt battery power supply (no voltage regulators needed), a crystal or dynamic microphone for audio, some resistors and pots, and two capacitors. See schematic shown, Figure 9-1. Three 10-ohm, ½-watt resistors in parallel provide approximately 10 Vdc for the Gunn diode source; and two potentiometers provide both COARSE and FINE tuning for the Gunnplexer varactor. RG-159/U minicoax should be used from the Gunnplexer mixer diode coupling capacitor to the fm receiver to minimize local fm broadcast station interference. This ultimately simple circuit can be lashed up in an hour or so for both Gunnplexer units. It will work fine if you only wish to work a few miles on sunny days when everything is going your way.

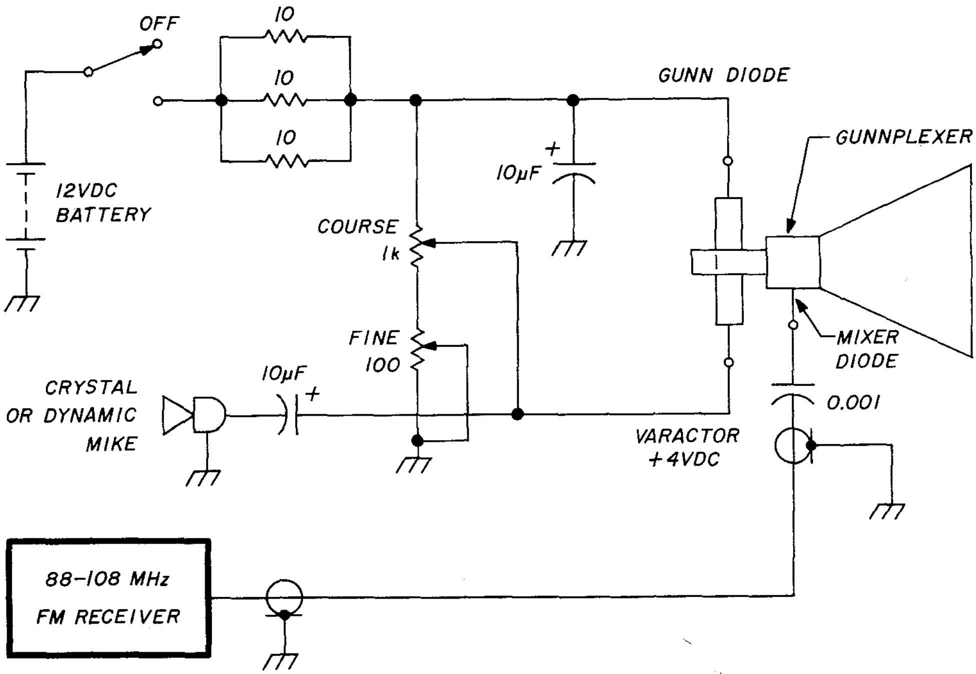


Figure 9-1. Ultimately Simple GPX Transceiver

The "ultimately simple" Gunnplexer transceiver consists of a standard fm-broadcast portable receiver (tunable i-f strip), battery supply, crystal or dynamic microphone, the Gunnplexer, and a few discrete components. Range will be limited to only a few miles with this setup under ideal conditions.

After 15-20 minutes warmup it works quite well and only requires occasional retuning on wideband fm. It certainly won't set any DX records but will at least give you a legal 10-GHz two-way contact in a vhf contest, if that's your only objective. That's about its full capability, although range can be extended considerably with the Hamtronics P8 i-f preamp described in *Chapter 6.* It is to the 10-GHz amateur band what the old combination modulated oscillator-superregenerative receiver hilltop units were 40 years ago on the 5- and 2-½-meter bands. It works under *ideal* conditions, but that's all. In no sense of the word is it a *communications system.* The Gunnplexer can be mounted on top of the fm receiver with wood blocks and rubber bands.

Level I Communications System

Here is our definition of a communications system. It is a system that will work reliably day or night, rain or shine, winter or summer. It has reasonable frequency stability, and at the very least has a modicum of frequency repeatability when turned on and warmed up for day or night operation or winter or summer operation; *i.e.*, it will operate any time under most any weather conditions.

It should also include a frequency-calibration capability, which is covered in *Chapter 10*, so that when you advise another station you'll be transmitting on 10.250 GHz, within reasonable tolerances that is exactly where you'll be. A Gunnplexer communication system that meets these minimum requirements is what separates the men from the boys with their toys. That type of system, using wideband fm, is what this chapter is all about.

Getting Started

The last paragraph's definition of a Level I communications system sounds like a pretty big order, actually it contains only the minimum requirements for a remotely mounted Gunnplexer unit capable of reliable operation. If you have constructed the system control module (SCM) in *Chapter 4*, the proportional temperature control (PTC) subassembly in *Chapter 5*, a simple low-noise i-f preamp in *Chapter 6*, and the weatherproof Gunnplexer enclosure-mast mount in *Chapter 7*, then you will have completed 90 per cent of the work required for a reliable Level I communications system.

All that remains is to mount the Gunnplexer enclosure on your antenna mast and rotor, run the cables into your operating area, plug in a microphone and standard fm broadcast receiver, and you're on-the-air. That's all there is to it — for a beginning.

Figure 9-2 shows a cheapy Panasonic fm receiver and an early prototype SCM that will do the job. The Gunnplexer AFC voltage was tapped off the AFC switch on the receiver front panel, and with a resistor and potentiometer to set the AFC level, provided +4.0 Vdc AFC voltage to control the Gunnplexer varactor on moderate-to-strong 10-GHz signals.

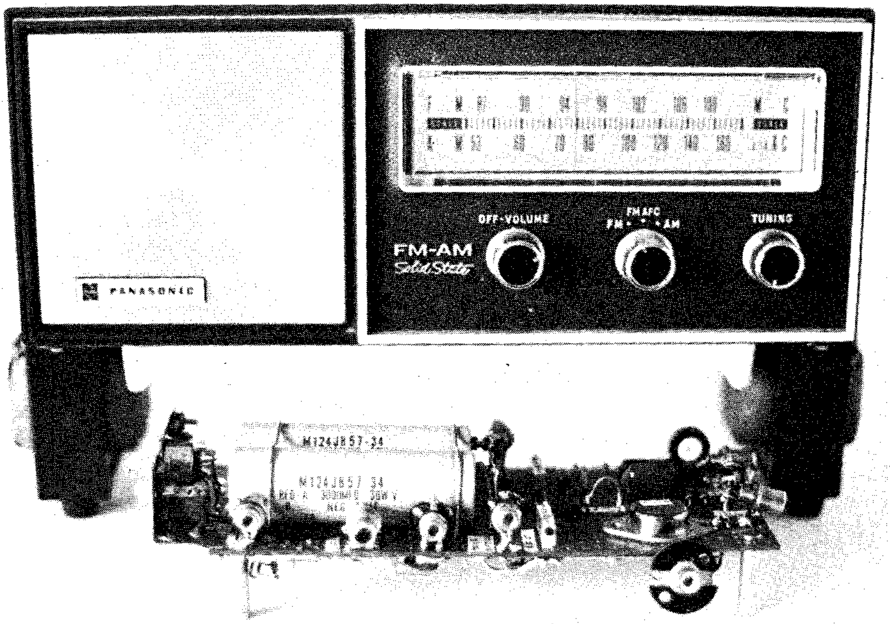


Figure 9-2. Panasonic FM Receiver & Prototype SCM Module

This low-cost Panasonic receiver was used as a tunable i-f amplifier for a preliminary Level I communications system. Also shown is a prototype system control module (SCM). Such simple arrangements are fine if you're not close to a high-power fm broadcast station.

The little Panasonic receiver worked as the Gunnplexer's tunable i-f. I built the system as a fun project just to see how very simple a Level I communications system could be assembled. However, the project was discarded because 1) the receiver plastic cabinet couldn't be easily shielded, and 2) the one local fm station plus two 100-kW fm stations in Buffalo, New York, some 65 miles (104 km) away, leaked through and captured the AFC loop when tuned through the fm stations' frequency.

The two 6-volt, 6-amp filament transformers used as props for the fm receiver (*Figure 9-2*) were used to isolate this transformerless receiver when working on it (see *Figure 9-3*).

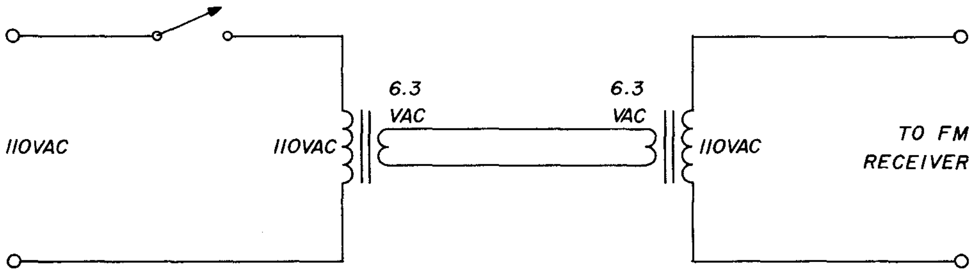


Figure 9-3.
The two filament transformers supporting the Panasonic fm receiver in Figure 9-2 were used in this circuit to provide isolation while working on the receiver.

So much for inexpensive unshielded household fm receivers. They work okay if the 10-GHz stations you're trying to work don't lead you close to an i-f with an fm station on or close to it. One alternative is to realign the fm receiver to tune 108-128 MHz, realign the Gunnplexer preamp, and have the Gunnplexer stations you're working move up (if you are on 10.250 GHz) to around 10.361 GHz for a 111-MHz or higher i-f. A much better alternative is presented in the following paragraph.

Shielded Level I Communications System — Mark I

A quick trip to the local auto junkyard yielded a well-shielded Delco model 05CFPI a-m/fm receiver (A copy of the schematic may be obtained from the good people at Delco Electronics, P.O. Box 737, Kokomo, Indiana 46901) for $1.00. This receiver came from a vintage Cadillac of around 1968-70. I removed the audio subassembly and installed a single LM380 IC audio amplifier to decrease dc power requirements (see the LM380 audio amp for the Mark II version later in this chapter). I installed a Z-28 rf choke and two .001 μF disc cap bypass capacitors in the +12-Vdc power supply line for good measure, but these probably were not needed, as this radio is shielded like a battleship. It's just that I was still gun shy of any rf pickup after the plastic Panasonic receiver episode.

The Delco 05CFP1 fm Receiver

As shown in *Figure 9-4*, this excellent Delco fm receiver uses an AFC loop in its local oscillator and delayed AGC in its rf amplifier. With the PTC in the Gunnplexer module *ON*, Gunnplexer stability is outstanding, and AFC for the Gunnplexer varactor is unnecessary when working another Gunnplexer station with PTC: the Delco receiver's AFC will compensate for the 20-30 kHz drift encountered which, during wideband fm operation, has no noticeable effect.

The AFC amplifier described later in this chapter for the Mark II version may be used if desired by connecting the AFC amp to the minus side of the ratio-detector output. Also, the millivoltmeter covered in *Chapter 3* makes an excellent S meter when set for the 1-volt dc range and connected to the AGC voltage doubler rectifier junction between DS27 and DS28 in the Delco receiver. This S meter is shown on top of the receiver in *Figure 9-5.*

Making It rf Tight

With a battery or good power-supply filtering, you can almost park next to a 100-kilowatt fm station antenna without i-f feedthrough. The receiver steel cabinet is solidly constructed and is a thorough rf shield. The only fm station pickup will probably be on the i-f coax line between the Gunnplexer housing and fm receiver if low-cost, poorly shielded coax is used. So much of the low-cost coax available today has the *very minimum* amount of copper shielding in it that one might as well use unshielded, single pair telephone wire!

If your coax is as tight as a Sherman tank and fm station interference is still getting into the i-f receiver, try using shielded coax for the 10-Vdc Gunn-diode supply and tempmeter lines. Alternatively, realign the fm receiver to tune above the commercial fm band, as mentioned earlier in this chapter. Remember, fm station rf can't penetrate well-sealed steel boxes, although at times it appears to do so. If you purchase or wind a good supply of Z-50 rf chokes with .001 μF disc caps on each end and use *very short* leads to ground, you'll find and eliminate the interfering signal.

Shielded Level I Communications System — Mark II

The Radio Shack 12-1348 fm car converter ($29.95) (The 12-1348 converter is still available as of October, 1979. Editor) makes one of the best wideband fm tunable i-f amplifiers for the Level I communication system that can be purchased today. If fits into the palm of your hand, runs for days on a few pencells (with pilot light removed), and with the addition of an LM380 IC audio amplifier and LM3900 AFC amplifier matches or exceeds the performance of many fm receivers in the over-$100 class when used as a Gunnplexer tunable i-f. See *Figure 9-6.*

A 0-50 microammeter, left, is used as an optional S meter. The fm converter is mounted on ¼ inch (6-mm) standoffs attached to two 3 by 6 inch (77 by 153 mm) G10 double-sided printed circuit boards soldered together to form a base mount. The AFC and audio amp ICs are mounted on the bottom. The rear of the unit (not shown) houses six RCA phone jacks and two insulated mini phone jacks. Four of these jacks are mounted on the rear of the fm converter case, for +12 Vdc to the converter, AFC out to the LM3900 AFC amplifier, audio out to the LM380 audio amplifier IC, and i-f input from the Gunnplexer control module. The other two phono jacks mounted on the PCB baseboard are for +12 Vdc input and speaker output. Two insulated mini phone jacks are used for varactor voltage/varactor input from SCM and raw S-meter output. A schematic of the unmodified fm converter is shown in *Figure 9-7.*

The Radio Shack 12-1348 Converter

Get out your magnifying glass and take a look at the Radio Shack fm converter schematic. It is a clear-cut, straightforward circuit design with more features than a casual glance would indicate. Highlights are: three-gang variable tuning capacitor with two gangs tuning the rf input frequency (rf amplifier and mixer inputs), varactor-tuned AFC loop, 10.7-MHz two-pole ceramic filter between mixer output and IC i-f amplifier input, three separately tuned i-f transformers, transformer-tuned ratio detector, 5.9-Vdc zener voltage regulation for the entire circuit, with a total current drain of only 14 mA (less pilot light); and

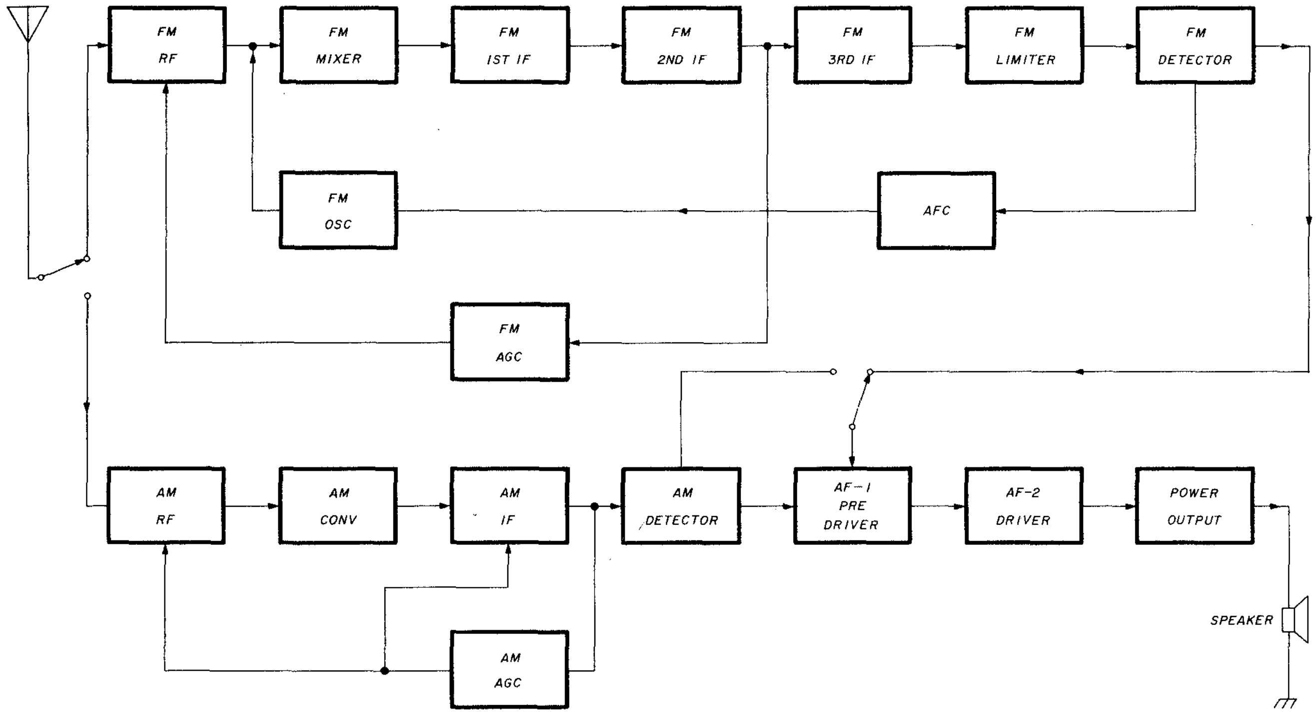


Figure 9-4.

The Delco O5CEP1 receiver has an AFC loop in its local oscillator circuit and delayed AGC in its rf amplifier. The receiver has excellent stability.

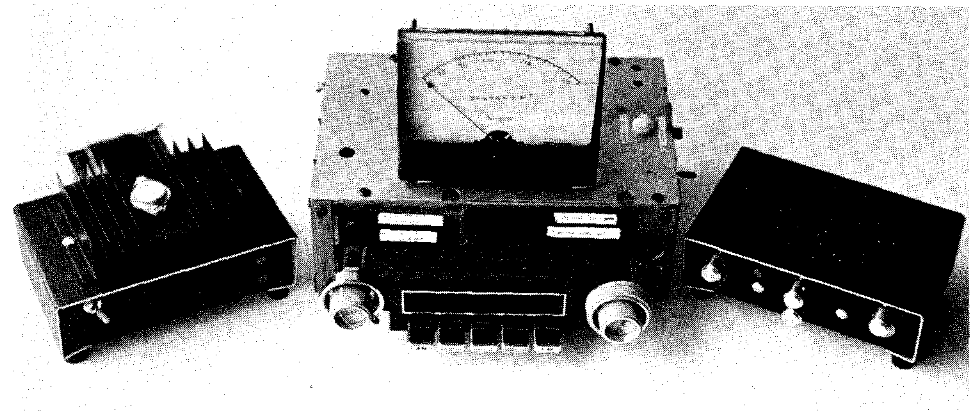


Figure 9-5. 12 Vdc Supply, Delco FM/AM Receiver & SCM

Shielded Level-I communications system Mark I showing, from left, a 12-volt power supply, the Delco receiver, and SCM. The S meter was described in Chapter 3.

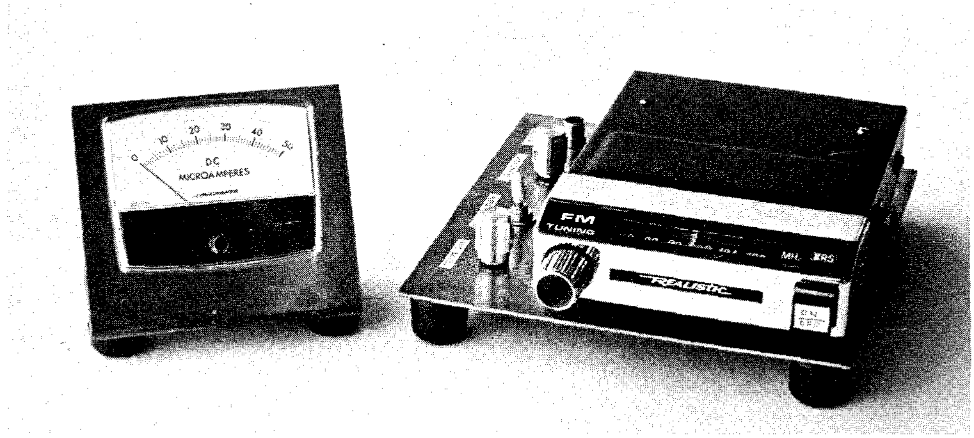
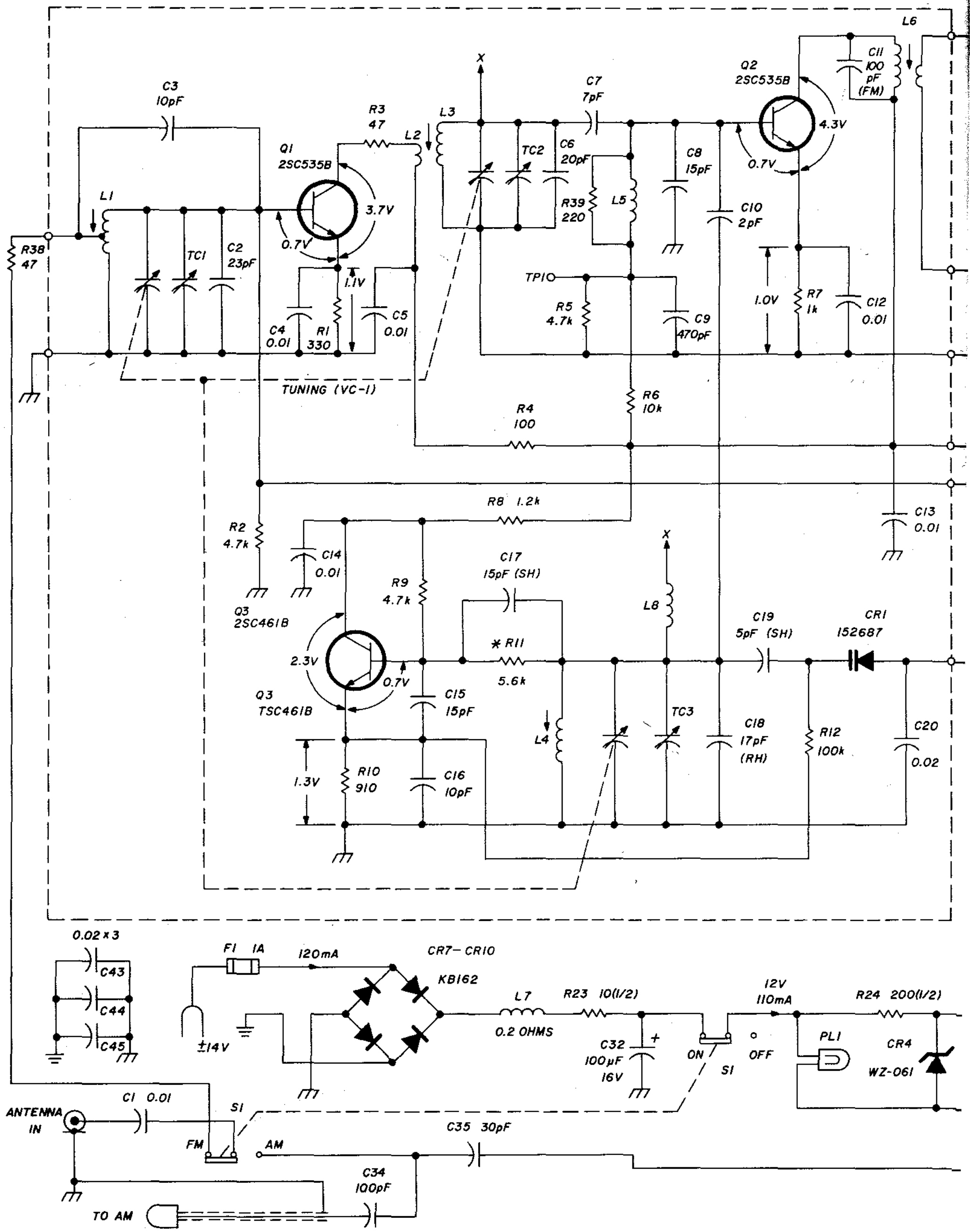


Figure 9-6. Radio Shack FM Converter with AFC & Audio Amps

The shielded Level-I communications system Mark II. The Radio Shack 12-1348 FM car converter has built-in AFC; the converter is mounted on two 3 by 6 (77 by 153 mm) G10 double-sided PC boards soldered together to form a baseplate. Microammeter at left is used as an optional S meter.


C3 10pF
R3 47
L2
L3
X
C7 7pF
Q2 2SC535B
L6
C11 100 pF (FM)
Q1 2SC535B
TC2
C6 20pF
C8 15pF
4.3V
0.7V
L1
3.7V
R39 220
L5
C10 2pF
R38 47
TC1
C2 23pF
0.7V
1.1V
TP1
1.0V
R7 1k
C12 0.01
R5 4.7k
C9 470pF
C4 0.01
R1 330
C5 0.01
TUNING (VC-1)
R6 10k
R4 100
R8 1.2k
C13 0.01
R2 4.7k
C14 0.01
C17 15pF (SH)
R9 4.7k
Q3 2SC461B
L8
C19 5pF (SH)
CR1 152687
* R11
2.3V
5.6k
0.7V
Q3 TSC461B
C15 15pF
TC3
L4
C18 17pF (RH)
R12 100k
C20 0.02
1.3V
R10 910
C16 10pF
0.02 x 3
C43
C44
C45
F1 1A
120mA
CR7 — CR10
KB162
±14V
L7
0.2 OHMS
R23 10(1/2)
C32 100μF 16V
12V 110mA
ON
OFF
S1
R24 200(1/2)
PL1
CR4
WZ-061
C1 0.01
ANTENNA IN
FM
AM
C35 30pF
C34 100pF
TO AM

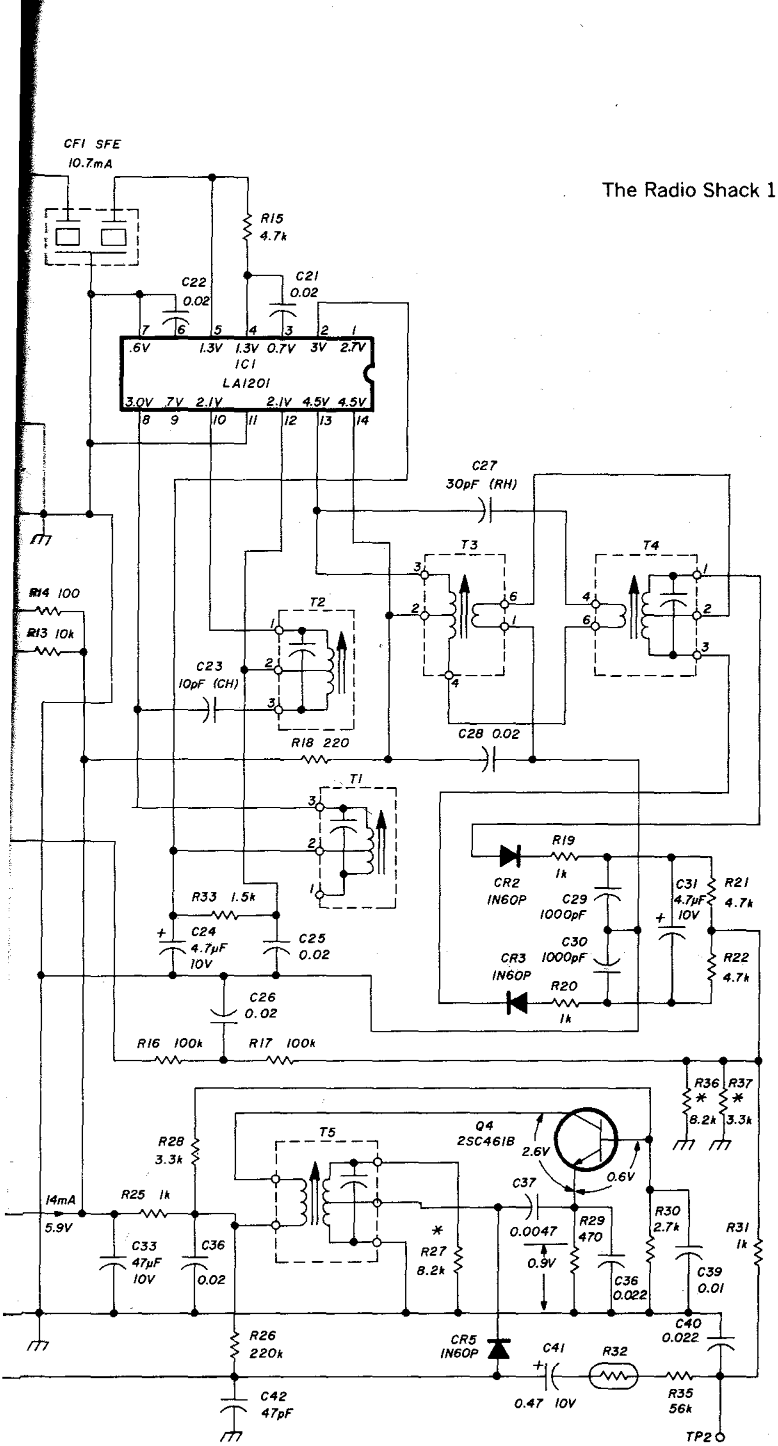


Figure 9-7.
Schematic of the Radio Shack 12-1348 fm car converter. Many excellent features are included in this low-cost circuit (see text).

lastly, voltage polarity input protection through the bridge rectifier on the dc input line.

Everyone makes an error sometimes, and the bridge circuit accepts either polarity voltage input, thus deferring one's error for another day. Additionally, this little $29.95 gem is mounted in a well-shielded steel case with secondary steel shielding of the rf and mixer stages.

A number of low-cost fm receivers and converters were checked out before this project began. Not one came close to having all the features of the 12-1348 in its price class. A general comment about most Radio-Shack engineered products is in order, even though I have no connection whatsoever with this corporation: "Whether it is a $2000 and up TRS-80 microcomputer system, or a $29.95 fm car converter, most Radio Shack-engineered products will give you considerably more value and features per dollar than any other similar product line. Thank you, spirit of Charles Tandy." End of free commercial.

For either fixed station or portable use, it's wise to leave the pilot light in the circuit for operating convenience, as the total current drain is only about 100 mA with it on.

Modifications to the Radio Shack fm Converter

1. Open both sides of the case and remove the front dial cover. Remove 1k resistor *R25* to disable *TR4*, the a-m oscillator as it serves no purpose in our application.
2. Remove RG-174/U coax +12-Vdc line and fuse holder that comes out of the left rear side of the case.
3. Drill four 9⁄32 inch (7 mm) diameter holes in rear of chassis as shown in *Figure 9-8.* Disconnect leads to old connectors and remove.
4. Install four chassis-mount (threaded) RCA phono jacks in holes just drilled.
5. Solder +12 Vdc phono jack to top (+ side) of diode bridge rectifiers *D7-D10.*
6. Solder *AFC out* phono jack to junction of *R20, C30, C31,* and *R22,* which is the minus side of the ratio-detector output.

7. Lift off side of *R32* going to *C41* and solder to *AUDIO-OUT* phono jack.
8. Solder *C1* antenna side to *I-F IN* phono jack.
9. Solder one ¼-watt, 15k resistor to junction of *R19* and *C29* (+ side of ratio detector output). Solder another ¼-watt, 15k resistor to the junction of *R20* and *C30* (- side of ratio detector output).
10. Solder a 6-inch (153 mm) length of no. 28 (0.3 mm) twisted pair (color coded) to each of these resistors. Bring the pair out through the grommet on the rear of the chassis. This pair will serve as a simple but effective "S" meter connection to drive a 0-50 microammeter. It connects to the insulated S meter mini phone jack shown in *Figure 9-9.* Observe correct polarities. For a much better zero reading S meter circuit, use the design on page 256, figure 8-24C, in the 1976 *ARRL Radio Amateur's Handbook.*
11. Add a 0.001 μF disc cap from the +12 Vdc phono jack input to ground to bypass any stray rf pickup.
12. Drill and tap for 6-32 (M 3.5) threads four holes on the bottom cover ½ inch (12.5 mm) in from each corner. These will be used for mounting the converter on ¼ inch (6.5 mm) spacers on the base plate.

This completes modifications to the fm converter.

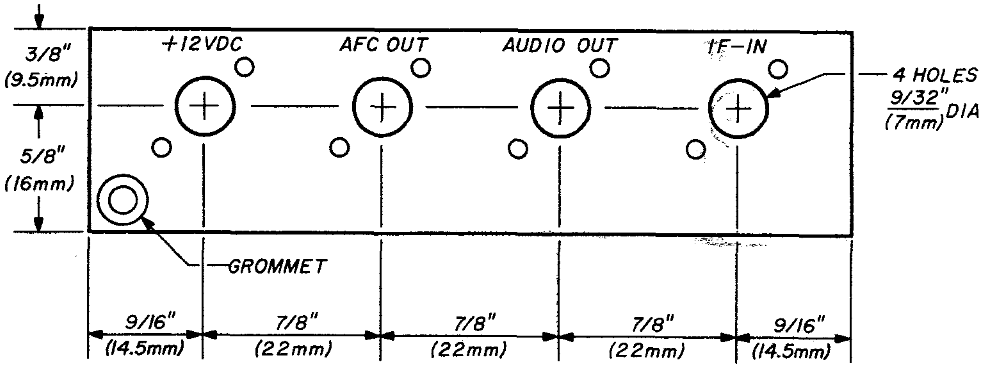


Figure 9-8.

Modifications to the Radio Shack 12-1348 fm converter for making the Level-I communications system Mark II.

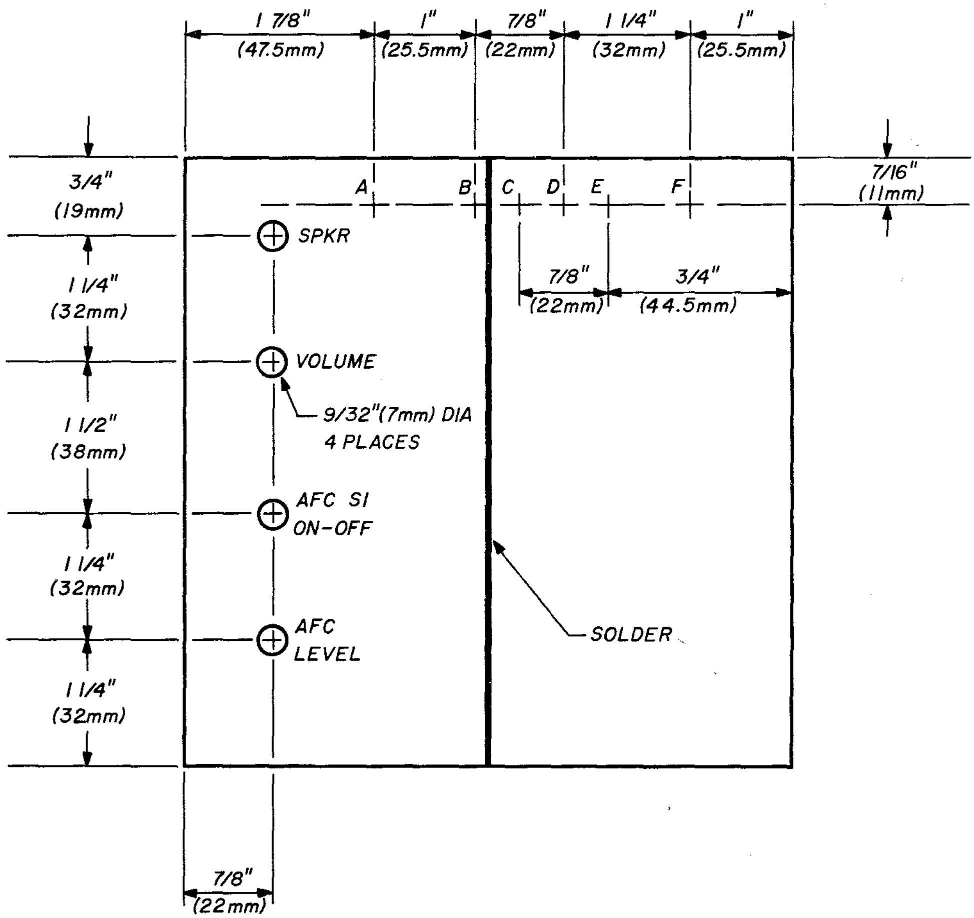


Figure 9-9.
Baseplate layout. Dimensions for holes A through F are given in the text.

Baseplate Layout

Solder two 3 by 6 inch (76.5 by 153 mm) double-sided G10 printed circuit boards together as shown in *Figure 9-9*. Refer to *Figure 9-9* for the following dimensions and hole sizes:

1. ⅜-inch (9.5-mm) diameter hole for S-meter insulated mini phone jack; varactor *E* input from SCM and Gunnplexer varactor *E* out to SCM.
2. ⅜-inch (9.5-mm) diameter hole for insulated mini phone jack to S meter.
3. ⅛-inch (3-mm) diameter hole for RG-159/U audio output to LM380; phono plug to rear of converter phono jack.
4. 9⁄32 -inch (7-mm) diameter hole for chassis-mount phono jack—12 Vdc input.
5. ⅛-inch (3-mm) diameter hole for RG-159/U from converter to LM3900; phono plug to rear of converter AFC output phono jack.
6. ⅛-inch (3-mm) diameter hole for RG-159/U +12 Vdc to converter; phono plug to rear of converter phono jack.

Figure 9-10 is a bottom view of the base plate, the LM380 audio amplifier, and the LM3900 AFC amplifier, both mounted on a perf-board subassembly. The bottom of *Figure 9-10* is the front, and the top of *Figure 9-10* is the rear, of the Radio Shack converter Level I assembly. A schematic of the LM3900 AFC and LM380 IC amplifier subassemblies, which mount on the perf board shown in *Figure 9-10*, is illustrated in *Figure 9-11*.

Some Final Hints

There is nothing sneaky or tricky about these IC amplifiers. The 0.001 disc cap on the 100k input resistor to pin 3 of the LM3900 AFC amplifier bypasses any stray rf from nearby 2-meter walkie-talkies, as does the 0.001 disc cap on output pin 4. The 16 and 20 μF electrolytics on the AFC amplifier output line set the AFC loop time constant to a reasonable value, as a too-fast time constant introduces audio distortion and a too-slow time constant will cause a drifting signal to be lost.

The LM380 IC audio amplifier is one of my favorite chips. The 6.8k ohm resistor and 0.1 μF disc cap in the audio line to the volume control on pin 6 shape and set the audio signal from the Radio Shack fm converter to the LM380 for best communications fidelity. Audio quality is excellent.

Don't overlook the LM380 note in *Figure 9-11*. Be sure to ground pins 3, 4, 5, 10, 11, and 12 to either a heavy piece of bus

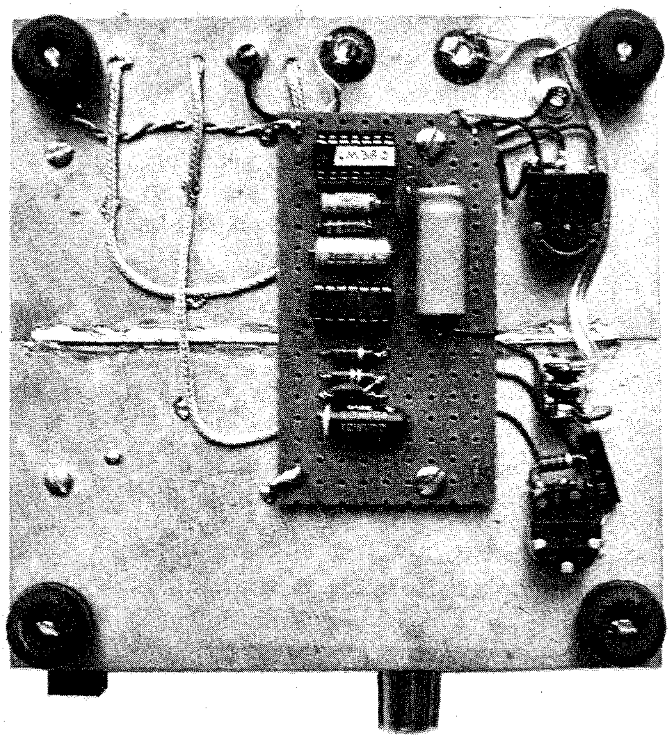


Figure 9-10. Base Plate, AFC & Audio Amplifiers Bottom View
Bottom view of the baseplate showing the AFC and audio amplifiers.

bar, or better yet, to a 1-inch (25-mm) square piece of 0.16-inch (4-mm) thick brass to serve as a heat sink, especially if you want to run the LM380 audio at the 1- or 2-watt level.

Summary

Either the Delco fm auto receiver, or the Radio Shack fm converter will serve you well for simple wideband fm Gunnplexer operation. They may be used for either fixed-station operation (hopefully with the $6.00 Snow-Sled parabolic reflector covered

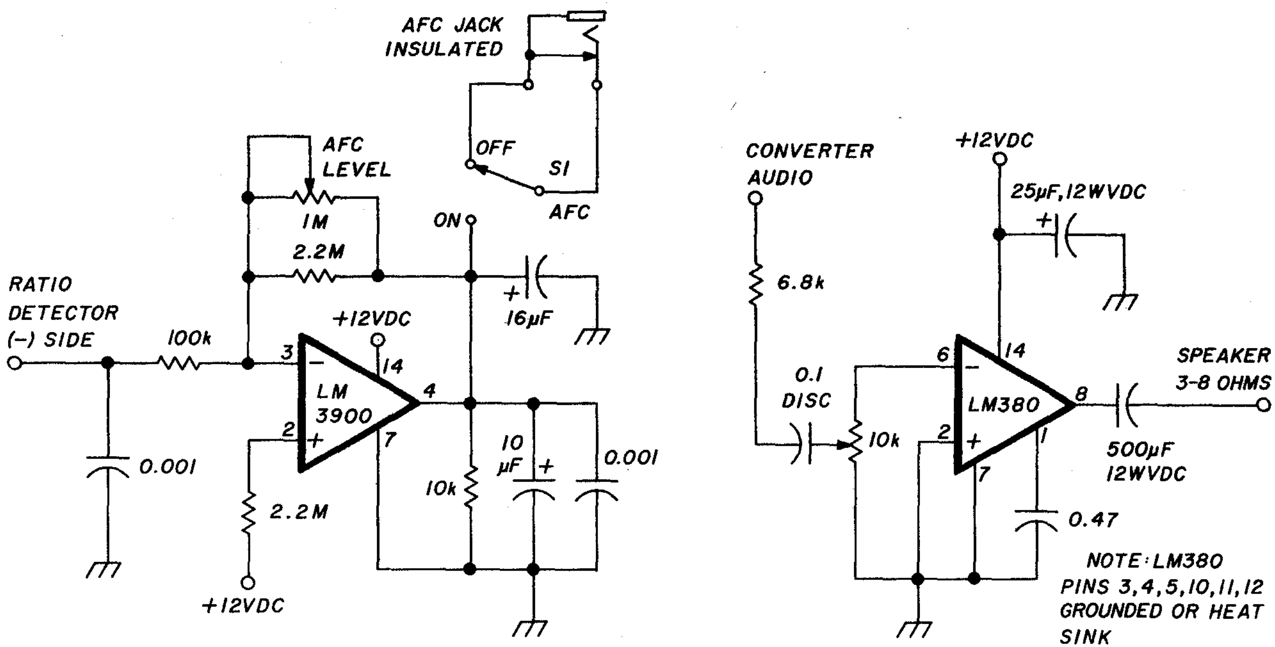


Figure 9-11.
Schematic of the LM3900 AFC amplifier and LM380 audio amplifier, which mount on the perf board shown in Figure 9-10.

in *Chapter 11*) or in portable operation for VHF contesting or field-day events using either the simple horn antenna or the parabolic dish reflector.

Except on the coldest days when PTC current may run up to 1 ampere, each of the Level I communication systems' current drain will not exceed 700 mA allowing use of storage batteries as small and light as the 4.5 ampere-hour 12-Vdc gel cell, which makes it easy to pack the whole kit and caboodle up a mountain top or fire tower.

The PTC assembly, which may be built and tested in a few hours, is probably the single most important subassembly of the entire Level I system, because it allows you (and the stations you're trying to work) to know exactly where you are in the 10-GHz band (after calibration with the crystal-controlled weaksignal source in the next chapter).

Both the Delco and Radio Shack tunable i-f receivers may be realigned in a few minutes to tune above the 108-MHz fm broadcast band. The author and editor strongly recommend you use the 30-MHz i-f wideband fm receiver for serious DX operation, thus avoiding any i-f feedthrough problems.

Gunnplexer 30 MHz i-f Wideband fm Receiver

It has been a long time (over 20 years) since mobile communications services in the 30-50-MHz band used wideband fm versus today's narrowband fm. It is indeed difficult to find a clean used 30-50-MHz wideband fm receiver of any variety.

So let's build a new 30-MHz wideband fm receiver that's electronically tuned plus or minus 2 MHz from both 10.250 GHz and 10.280 GHz using the Gunnplexer varactor diode as the tuning element. Actually, Gunnplexer tuning may be over *any* 10-GHz frequency desired that produces a 30-MHz i-f.

This receiver may be constructed in a single day and has a parts cost of approximately $25 including the standard PolyPaks black box. Most importantly, it allows the Gunnplexer user in metropolitan areas to avoid the irritating feedthrough problems caused by local high-power fm broadcast stations that often occur when using 88-108 MHz as the Gunnplexer i-f with tunable fm receivers (as well as similar overload problems when some retuned *low cost* and poorly designed fm receivers are used in the 108-118 MHz tunable i-f range).

Two important advantages are gained using the 30-MHz Gunnplexer i-f:

1. 30 MHz will probably become the world standard i-f for Gunnplexer duplex operation with the calling station on 10.250 GHz and the responding station on 10.280 GHz (or 10.220 GHz).
2. A 30-MHz i-f allows easy Gunnplexer frequency shift for simplex operation; that is, transmitting on 10.250 GHz and receiving on 10.280 GHz requires only about +4.3 Vdc shift to the Gunnplexer varactor.

A block diagram of the 30-MHz i-f wideband fm receiver is shown in *Figure 9-12.* A photo of the complete assembly mounted on perf board is shown in *Figure 9-13.* Parts layout is shown in *Figure 9-14. Figure 9-15* shows the schematic and parts values for the VHF Engineering RF28 converter. Parts layout is not especially critical and may take most any form you wish.

Notes on the RF28 Converter

The RF28 schematic (*Figure 9-15*) shows component values for an early 1977 model. By all means use the values shown on the schematics for newer models. Coil *L2* and capacitor *C4* are not used in this version to obtain slightly greater rf-amplifier gain, and the extra bandwidth they provide is not needed. They may be included if you wish.

The RF28 is an excellent little crystal-controlled converter for the $13.50 price and performs comparably to factory-built units selling for four to five times as much. The rf amplifier is a low-noise N-channel field-effect transistor in grounded gate configuration. The mixer is a dual-gate MOSFET offering extremely broad dynamic range; that is, no overload with accompanying spurious outputs caused by strong local signals yet capable of extremely efficient conversion with weak signals close to the noise level.

The third overtone 40.7-M Hz crystal oscillator is in one of the simplest and easiest starting circuit imaginable. It is the old tuned-grid tuned-plate circuit from vacuum-tube days applied to an NPN transistor.

The RCA 3089E shown in *Figure 9-16* has just about everything except bells and whistles. The mini ⅜ inch (9.5 mm) square

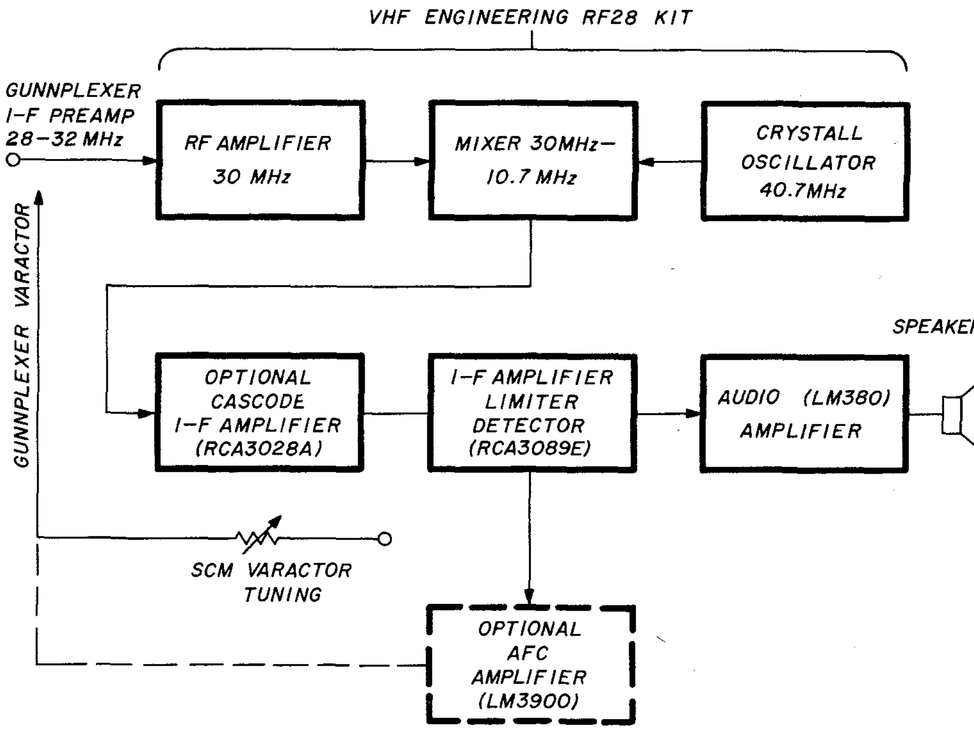


Figure 9-12. 30 MHz i-f Wideband FM Receiver-Block Diagram

30-MHz i-f wideband fm receiver. Rf amplifier, mixer, and crystal oscillator comprise the Vhf Engineering model RF28 kit. Mixer output drives an optional RCA 3028A i-f amplifier, which drives an RCA 3089E "all-purpose" IC (three stage i-f amplifier, limiters, phase-quadrature fm detector, squelch amplifier, first-stage audio amplifier, and first-stage AFC amplifier). The 3089E drives an LM380 audio amplifier and optional LM3900 AFC amplifier. A schematic of the 3089E IC is shown in Figure 9-16.

10.7-MHz i-f transformer is available separately from Hamtronics, but most any variety will work. The resistor and capacitor values shown on the CA3089E audio output, pin 6, were adjusted for best sounding audio while listening to a 5.5-mile (8.8 km) distant Gunnplexer that was transmitting Rock music from a nearby transistor radio picked up by its microphone. The Rock music sounded terrible. After changing the resistance and capacitance values a few times, I ended up with the 3.3k resistor and 0.1

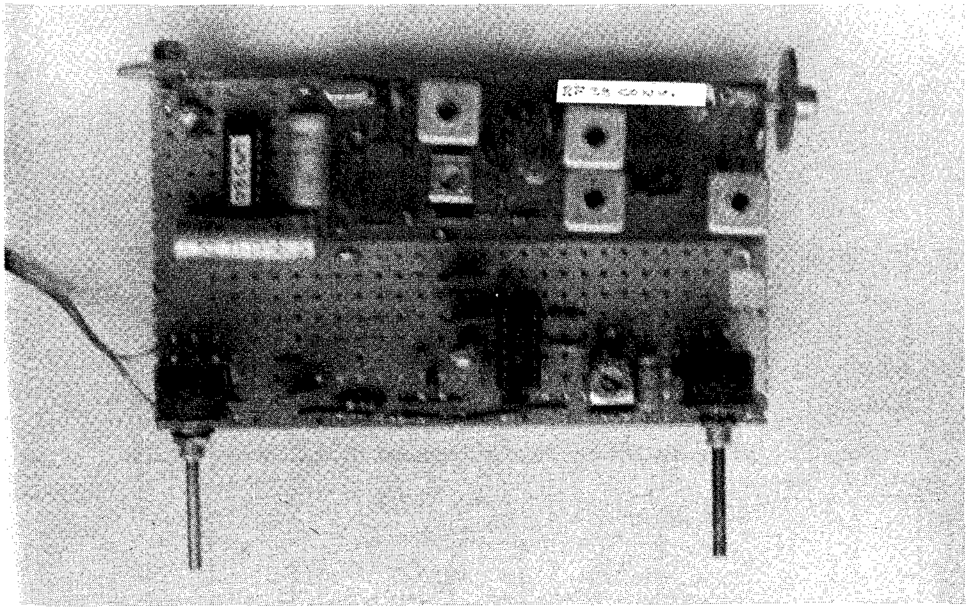


Figure 9-13. 30 MHF IF Wideband FM Receiver Top View-Photo

Top view of the RF28 kit installed in a section of perf board containing the CA3089E and LM380 ICs before it was installed in the Poly Paks black box.

μF disc capacitor in *Figure 9-16* for best quality sound, which improved from terrible to only dreadful. On voice alone it sounded quite good. Try adjusting these values to suit your own fancy.

The circuit shown so far is more than adequate for receiving moderate-to-strong signals in the 5.5 plus mile (9km) range. To really soup it up to work DX as far as any line-of-sight path conceivable with wideband fm, add an RCA 3028A IC i-f amplifier stage, as shown in *Figure 9-17*. This IC i-f amplifier costs $1.25 (from ADVA Electronics), and in the cascode configuration shown in *Figure 9-17*, provides 50-dB voltage gain: 2.5 cents per dB, which equals some kind of record! If you plan to work Gunnplexer wideband fm during the ARRL VHF contests, by all means spring for it and you'll hear the weak ones even if they don't hear you!

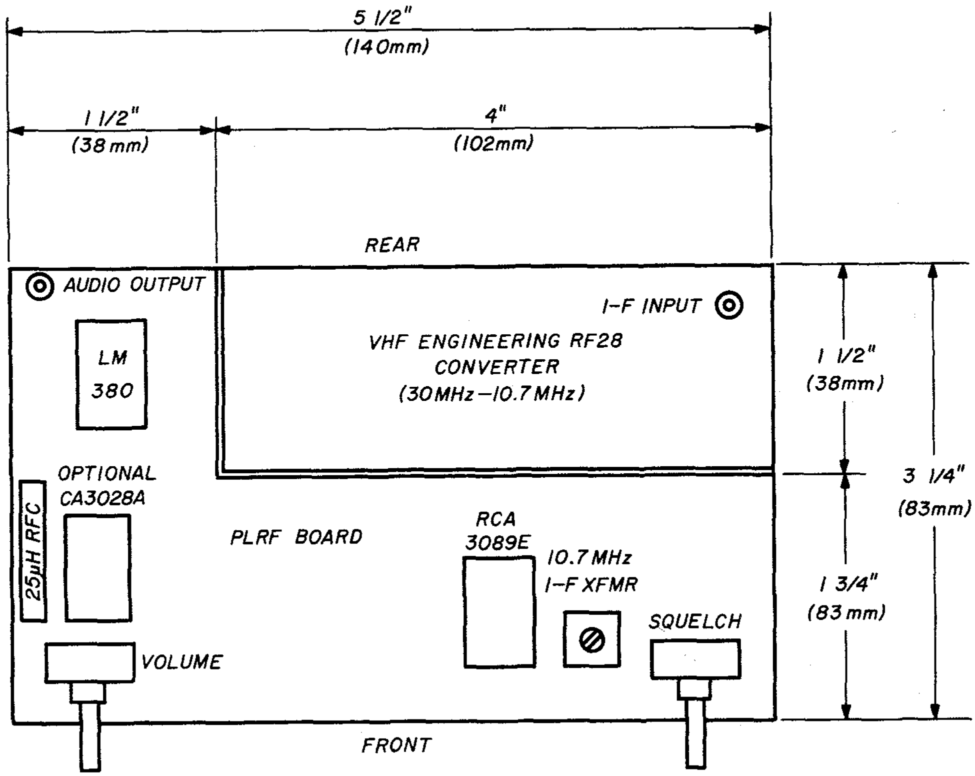


Figure 9-14.
Layout of the 30-MHz i-f wideband fm receiver. Dimensions are not critical.

Putting It All Together

There's nothing sneaky or tricky about this very simple, yet very effective Gunnplexer wideband fm receiver. If you choose to use the CA3028A extra i-f amplifier stage (the author recommends it), it should be placed 2-¾ inches (70 mm) to the left of the CA3089E, right behind the volume control as shown in *Figure 9-14* (with 25 μH rf choke on its left) to avoid any feedback or regeneration problems with these high-gain ICs.

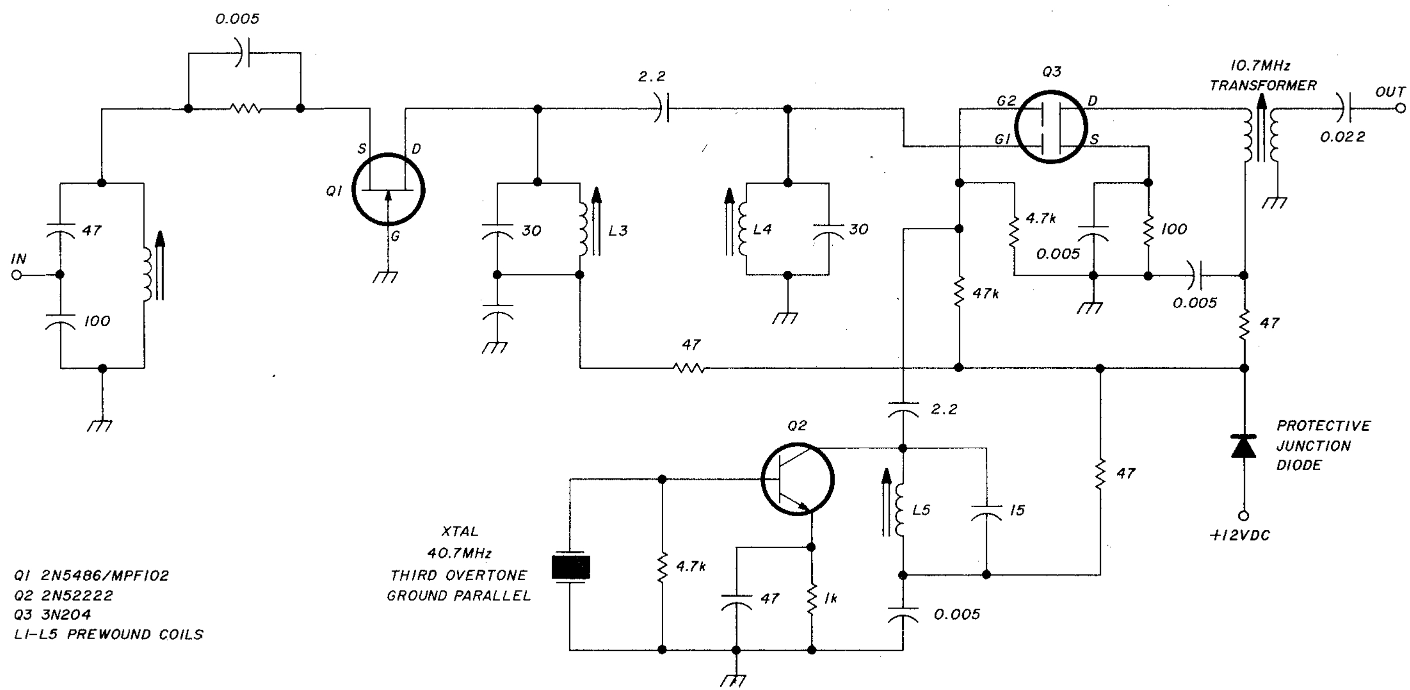
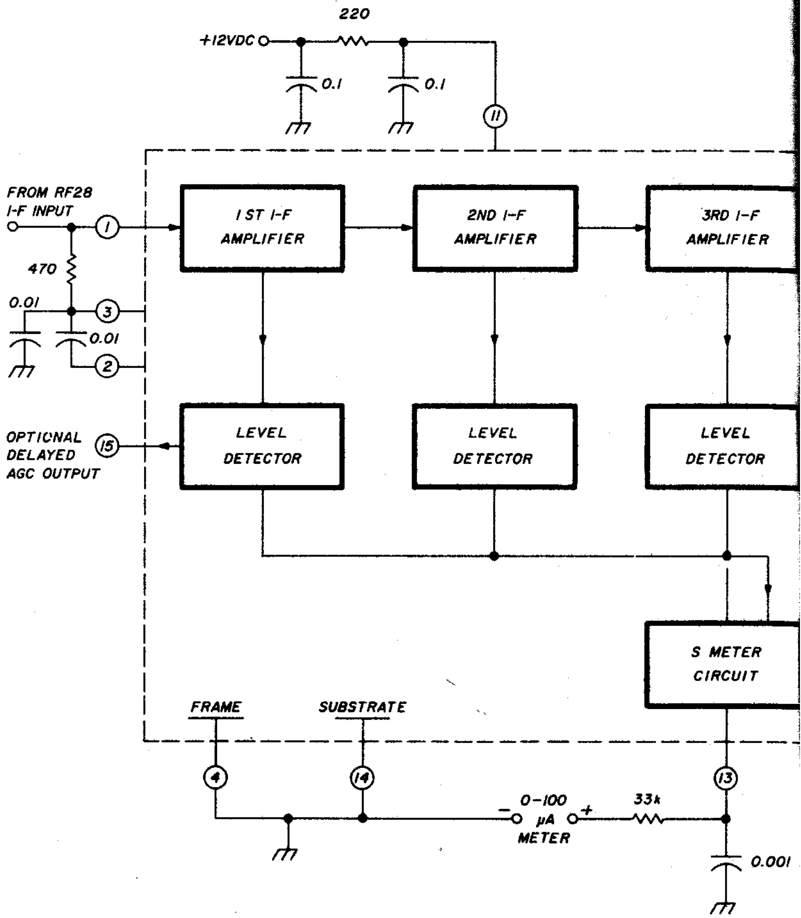


Figure 9-15.

The RF28 30-10.7-MHz converter schematic. Component values are for an early 1977 model. Use the values shown on schematics for later models.


220
+12VDC
0.1
0.1
11
FROM RF28
I-F INPUT
1
470
0.01
3
0.01
2
1ST I-F
AMPLIFIER
2ND I-F
AMPLIFIER
3RD I-F
AMPLIFIER
OPTIONAL
DELAYED
AGC OUTPUT
15
LEVEL
DETECTOR
LEVEL
DETECTOR
LEVEL
DETECTOR
S METER
CIRCUIT
FRAME
SUBSTRATE
4
14
13
0-100
μA
METER
33k
0.001

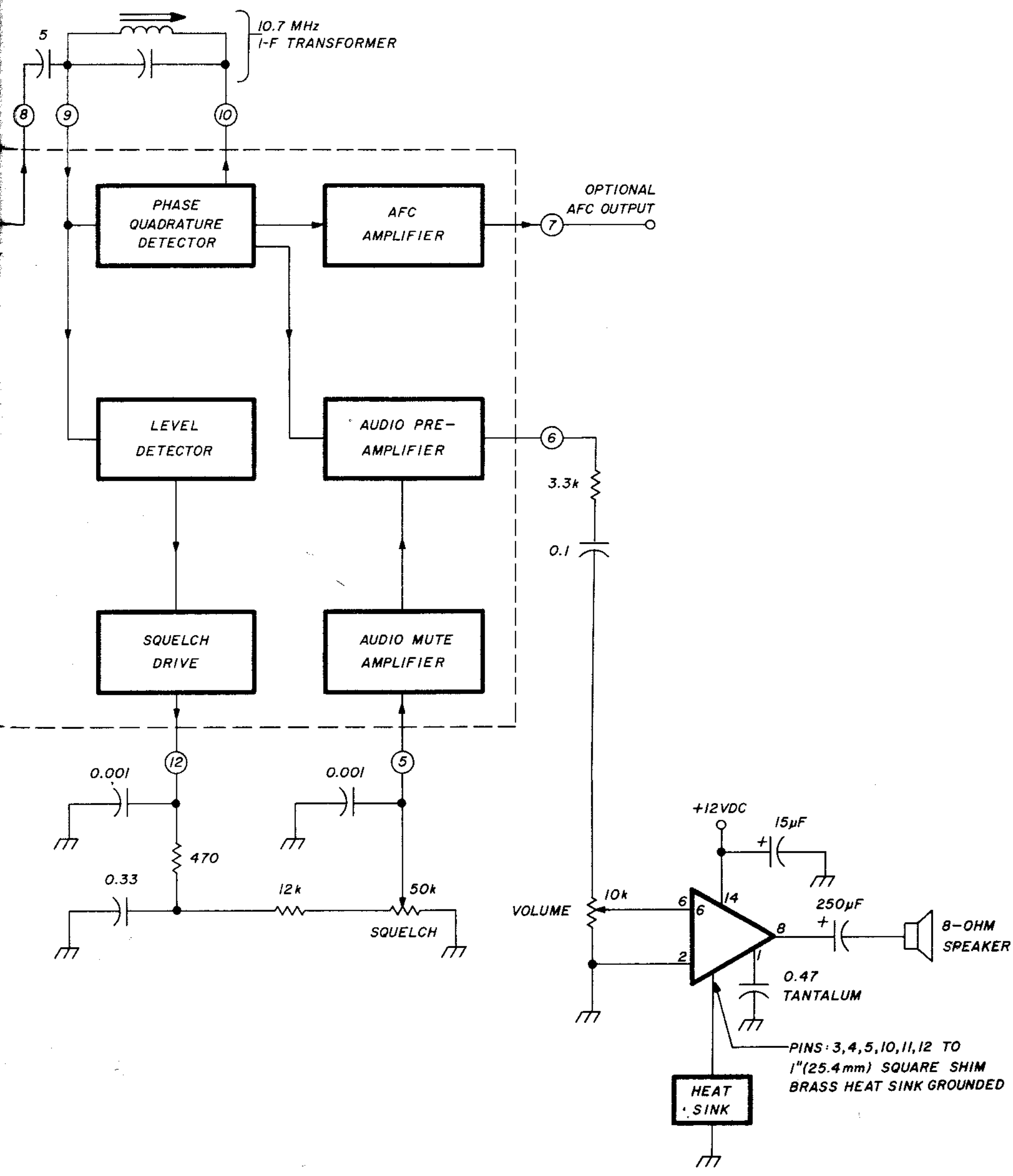


Figure 9-16.

Schematic of the RCA 3089E "does most everything" IC and the National LM380 audio amplifier. The RC combination on pin 6 of the 3089E resulted from experiments for best audio quality, ranging from Rock Music to voice.

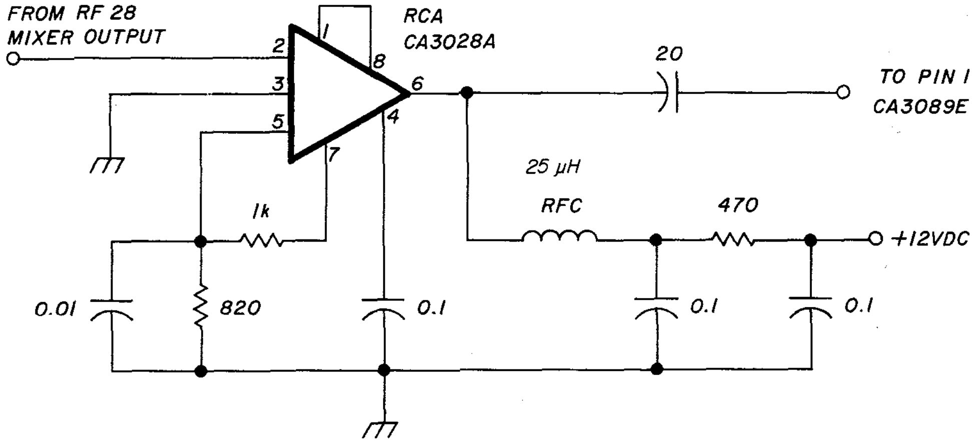


Figure 9-17.

Add the RCA CA3028A IC i-f amplifier to the RF28 30-10.7 MHz converter for extended line-of-sight range. You can get 50-dB voltage gain for only about $1.25 (device available from ADVA Electronics).

Tuneup is straightforward and may be done with a grid-dip oscillator as the signal source on 30 MHz and the CA3089E S meter as an output indicator. Adjust *L1*, *L3*, *L4*, and the 10.7-MHz i-f transformer for maximum output, constantly moving the grid-dip oscillator farther away from a cliplead antenna on the RF28 rf input to avoid overloading. A real purist (the author), would use his communications receiver to calibrate the grid dip oscillator *exactly* on WWV at 10 MHz or 15 MHz so that the grid-dip oscillator second or third harmonics fall *exactly* on 30 MHz during tuneup.

The CA3089E transformer should be tuned for best-sounding audio with a modulated GDO. Either AFC amplifier covered in *Chapter 8* may be used by connecting the CA3089E AFC amplifier output from pin 7 directly to the AFC amplifier input. If you will only be working other Gunnplexer stations with proportional temperature control installed (and you have it too), the AFC amplifier option isn't necessary, because once both Gunnplexers have warmed up and are temperature stabilized, their frequency stability will be such that only an occasional retuning will be necessary on wideband fm.

Operating with the 30-MHz i-f Wideband fm Receiver

You're probably wondering where the tuning dial is located. It is certainly a reasonable question. Answer: There isn't any tuning dial. All tuning is done with the system control module COARSE and FINE varactor tuning potentiometers for 10.250-GHz operation and two new COARSE and FINE tuning potentiometers for 10.280 GHz operation that you will install on the front panel of the 30-MHz i-f wideband fm receiver.

How do you know what frequency you're operating on? Answer: You don't. If you constructed *Chapter 3's* micrometer frequency measurement table, you'd have an idea where you are within possibly 10-15 MHz, but you wouldn't know exactly on what frequency you were operating. This subject provides a super lead-in to the next chapter, which covers 10-GHz crystal-controlled weak-signal sources.

Let's steal a few bytes from the next chapter for the moment. Two $5.00 crystals plus *Chapter 10's* weak-signal source will very nicely allow you to spot your Gunnplexer on both 10.250 and 10.280 GHz; *i.e., crystal frequency* × 528 = 10 GHz output frequency. Let's assume you're using a nominal 10.250 GHz Gunnplexer that was adjusted at the factory to this frequency, with +4.0 Vdc to the Gunnplexer varactor and that you have installed the simple circuit illustrated in *Figure 9-18* to allow you to switch instantly to either 10.250 or 10.280 GHz.

Adjusting the 10.250 and 10.280-GHz Switching Circuit

There are probably as many ways of calibrating this simple switching system as there are Gunnplexer enthusiasts who build it. They will vary from the obvious (a microwave signal generator and digital microwave frequency counter) to the innovative (the 22nd harmonic of a grid-dip oscillator using 465.909 MHz) and a 100:1 prescaler, to a Heathkit digital frequency counter. For those without access to any special test equipment, the following method, using *Chapter 10's* crystal-controlled weak-signal source, is probably the quickest and least painful.

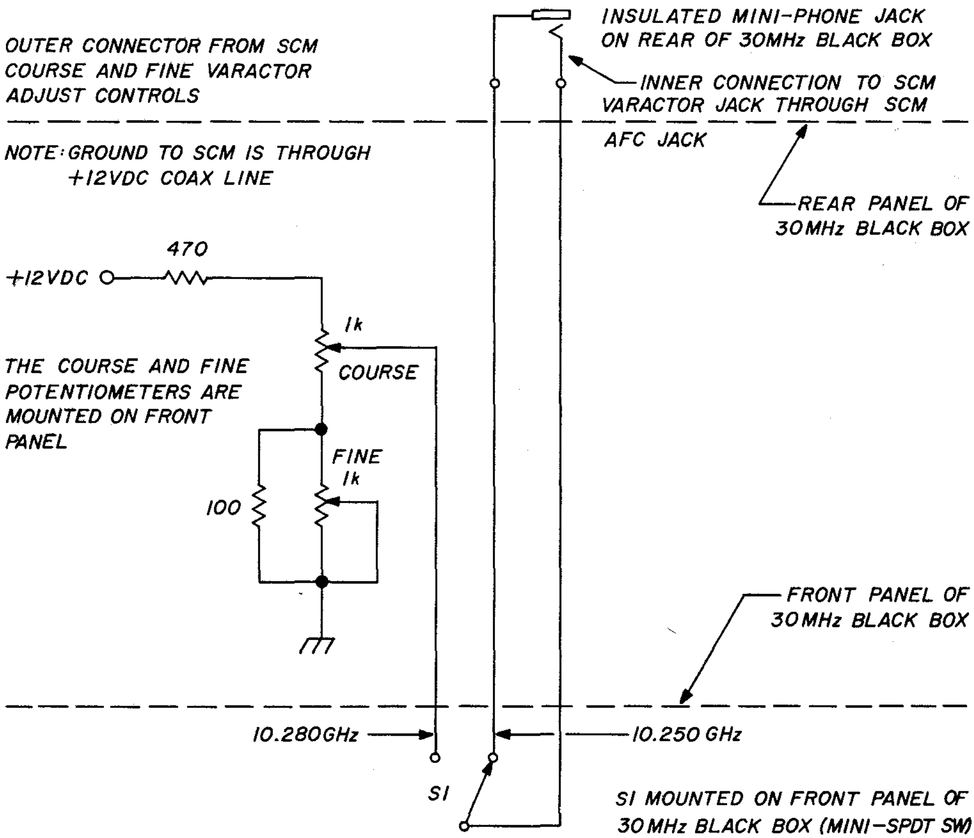


Figure 9-18.

Switching circuit for either 10.25 or 10.28 GHz. It may be installed between the rear and front panel of the 30-MHz black box. Adjustment and calibration are discussed in the text.

1. With a 19.469697-MHz crystal (× 528 - 10.280 GHz) in the weak-signal source, allow 5-10 minutes for it to warm up and stabilize. If you have a digital frequency counter, adjust the crystal oscillator trimmer capacitor, *C33*, for exactly 116.818182 MHz (*crystal frequency* × 6) at the junction of *C14*, *R6* and the base of *Q3* on the TX432. If you don't have a digital frequency counter, tune in the 19-MHz crystal signal on a general-coverage communications

receiver, and adjust the crystal trimmer as close to the correct frequency as possible after calibrating the receiver on WWV's 20-MHz signal. You certainly will not have "lab standard" frequency accuracy at 10.280 GHz, but you will be more than close enough.

2. Allow your nominal 10.250-GHz Gunnplexer to warm up and stabilize. Set *S-1* on the front panel of the 30-MHz wide-band receiver to the 10.250 GHz position. Adjust the coarse and fine varactor tuning controls on the SYSTEM CONTROL MODULE until you have the signal from the weak-signal source. Write down the Gunnplexer varactor voltage (to a millivolt if you have a digital VOM, or as accurately as possible if you don't have one). The Gunnplexer varactor voltage will be slightly lower than +4.0 volts (usually) if you use *Chapter 5's* proportional temperature control, since the original factory calibration was done at room temperature and the PTC is holding the Gunnplexer at 120° F (44° C).
3. Repeat steps 1 and 2 using a 19.412879-MHz crystal (× 528 = 10.250 GHz) in the weak-signal source and switch *S-1* on the 30-MHz wideband fm receiver in the 10.280 GHz position, but now use the COARSE and FINE controls on the 30-MHz receiver front panel to tune in the weak-signal source *instead* of those on the system control module. Write down the Gunnplexer varactor voltage at the SCM test point.
4. For illustration let's use *4.0-Vdc Gunnplexer varactor voltage = 10.250 GHz Gunnplexer output and 8.286 Vdc varactor voltage = 10.280 GHz Gunnplexer output.* This Gunnplexer frequency output versus varactor voltage gives a slope of 7 MHz per volt, which was the average obtained on the first three Gunnplexers tested. If your slope is different, don't worry about it because the variation between individual Gunn diodes and Gunnplexer varactors is considerable. Remember, you're using a 10-GHz transceiver module that costs approximately $100 instead of $10,000, so don't be critical (thank you, Microwave Associates).
5. A frequency/voltage slope of 7 MHz per volt yields the following outputs at the frequencies noted, which allows you to tune plus and minus 2 MHz from each center frequency. There is no reason why you can't tune plus or minus 10 MHz, 20 MHz, or any range you wish. The only

limitation is *frequency change rate.* If you tune too fast, you'll miss hearing a signal as you pass by it; and if the tuning range is too wide, it will take a lot of time to tune the full range.

Table 9-1. Varact or voltage change as a function of tuning.

Tuning (MHz)	Gunnplexer Frequency (GHz)		Varactor Voltage (Vdc)
minus	10.248	=	3.714
center	10.250	=	4.000
plus 2	10.252	=	4.286
minus 2	10.278	=	8.000
center	10.280	=	8.286
plus 2	10.282	=	8.572

As you can see from *Table 9-1,* approximately 572 millivolts Gunnplexer varactor voltage change gives a 4-MHz tuning range. A digital voltmeter with millivolt readout connected to the system control module Gunnplexer varactor voltage test point would make a simple tuning indicator but would require a look-up table to ascertain exact frequency. It's a relatively simple matter to design and build a direct digital frequency readout for any frequency/ voltage slope using a relatively inexpensive analog-to-digital converter, a few junk-box parts, and those handsome 1 inch (25 mm) LED displays. Such a system will be included in Volume II of the Gunnplexer Cookbook.

For those who wish to dig deeper into the subject of analog-to-digital converters, an excellent article for those new to the subject is covered in the January, 1979, issue of *ham radio.* It is entitled, "Digital Readout For The Ham-3 Rotator," pages 56-59, by Doug Grant, K1DG. It is a very good primer on the subject of A/D converters.

10

10-GHZ Weak-Signal Source

Construction details for a weak-signal source that uses the *VHF Electronics TX-432 narrowband transmitter kit and a times-22 diode frequency multiplier.

This is one of the most fun and worthwhile chapters of the Gunnplexer Cookbook. Fun because the circuits developed for generating a crystal-controlled, 10-GHz-band weak-signal source are absurdly simple to build; and worthwhile because such a signal source will allow you to know your operating frequency as accurately as on the low-frequency bands. Furthermore, evolution of these circuits led to the *Crystalmatic* phase-lock system covered in *Chapter 12.*

Frequency multipliers using crystal diodes are almost as old as radio itself. Frequency multipliers with relatively high efficiency when used as X22 multipliers, and using the diode as a folded-dipole antenna or waveguide radiating source, haven't been published (to my knowledge), especially when using the Poly Paks (200 for $1.98) point-contact germanium diodes. I have used low-cost germanium diodes in passive frequency-multiplier applications for over 20 years. Perhaps the most widely known application is incorporated in my U.S. Patent 3,098,971, which is the

*NOTE: Or Hamtronics T450 UHF Exciter Kit @ $44.95

basic patent for all passive diode-generated harmonic communications systems, including the widely used F1 to F2 microwave antishoplifting system (over 50 million tags produced to date). Another pleasant surprise using the weak-signal source to be described was that it could be received 1-½ miles (2.4 km) across Lake Chautauqua when fed into a 25-inch (64-cm) parabolic reflector and narrowband fm was used with a 29 MHz i-f. The S3 to S5 signal was not exactly overwhelming over this path, but was R5 copy.

General Comments

For a crystal-controlled 1-watt rf source, I chose the VHF Engineering TX-432 narrowband fm transmitter kit for a number of reasons. It's in the $49 price class, puts out a very clean narrowband fm signal when properly tuned and used with an amplifier or tuner, and may easily be built and tested in an evening. I've built five TX-432s in the past three years with only one problem and that was of my own making; *i.e.*, when using hex allen wrenches instead of the correct-size plastic tuning tool, I managed to break a few of the ferrite coil slugs. This was my fault and not that of the TX-432, which is an excellently designed and well-crafted kit.

A Bird Thruline™ wattmeter with either the 1- or 5-watt slug that covers the 400-100 MHz range will make alignment somewhat easier but isn't necessary, as an ordinary no. 12 pilot light bulb will suffice. The only tools required are a pair of heavy scissors or sheet-metal shears for cutting the 0.010 or 0.016-inch (0.25 or 0.4 mm) sheet brass (even an old tin can will do — discussed later in this chapter), and a 50-watt soldering iron such as the Ungar 4036S, for soldering the brass waveguide and pyramidal horn together.

Objectives of this chapter include the following: assemble a TX-432 with a 19.227273-MHz crystal with 1-watt output on 461.450 MHz (crystal frequency X24), which drives a Poly Paks point-contact germanium diode (with simple matching network) in a soldered-up waveguide/horn antenna configuration. This diode's 22nd harmonic (22 × 461.450) will be used on 10.152 GHz to provide a weak-signal source for a 10.250-GHz Gunnplexer, thus delivering an i-f output on 98 MHz. If you wish to use an i-f other than 98 MHz, order a fundamental-mode crystal in an HC25/U holder with a frequency equal to desired 10-GHz frequency divided by 528 (24 × 22). A ±0.005 per cent tolerance should be adequate, as the TX-432 crystal trimmer will bend its frequency quite a bit. If you use the TX-432 crystal proportional temperature control (PTC) covered in *Chapter 5*, you'll find the 10-GHz 528th crystal harmonic stabilizing after about ten days aging and yielding a near-ideal marker during summer and winter, day and night.

The TX-432: Circuit Description and Assembly

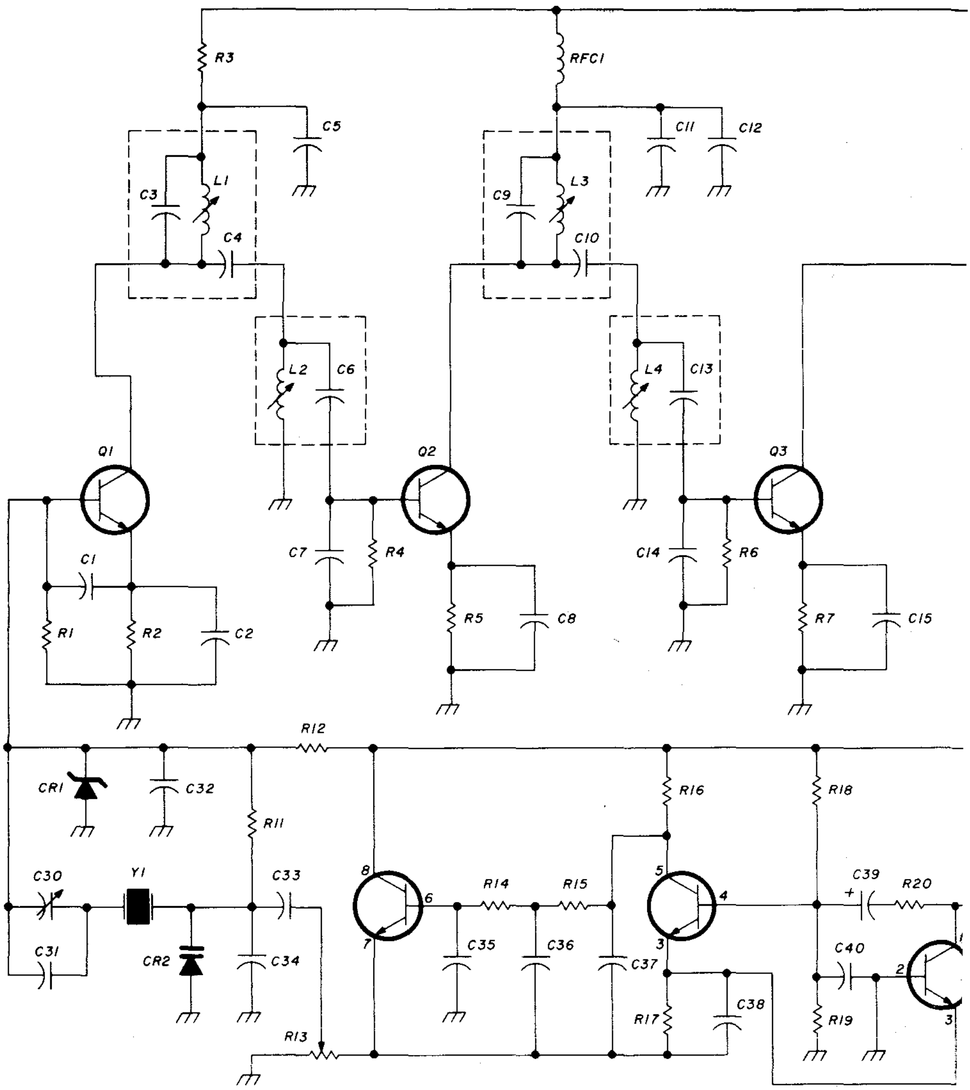
The instructions with the TX-432 are clear and explicit. It takes real effort to make a mistake as the coils, L1 through L6, are prewound on the slug-tuned coil forms. About the only precaution required is to positively make sure of the disc cap values before soldering them in. This isn't difficult as the instructions identify those with nonstandard marking. Tune up is straightforward using test points at each stage. The last doubler stage and final-amplifier input stage are somewhat sensitive to tuning but may be quickly aligned using a flashlight bulb or Thruline™ wattmeter with dummy load.

Circuit description. Let's run through the circuit of this simple but highly efficient 1-watt, crystal-controlled, narrowband fm ¾-meter transmitter (narrowband or wideband fm on 10 GHz with the multiplier).

The first five NPN audio-stage transistors (*Figure 10-1*), are mounted on a single 14-pin DIP IC: an RCA CA3086. The first-stage audio preamp includes a pre-emphasis network, R-25 and C-45 which is designed to be driven by a medium-to-high impedance dynamic or crystal microphone. If you use a low-impedance dynamic mike (PM speaker variety), bypass these two components with a jumper.

The following two NPN transistors are connected as diode limiters/clippers with suitable filtering, which hold the audio drive level to the fourth NPN transistor to 0.6 volt peak-to-peak. Output from the fourth transistor, an amplifier, drives the final audio output transistor, which is in emitter-follower configuration, serving as an active filter.

Potentiometer R13 controls the audio-voltage level applied to varicap CR2 (50-100 pF), which serves as both an rf ground and


R3
RFC1
C5
C11
C12
C3
L1
C4
C9
L3
C10
L2
C6
L4
C13
Q1
Q2
Q3
C1
C7
R4
C14
R6
R1
R2
C2
R5
C8
R7
C15
R12
CR1
C32
R16
R18
R11
C30
Y1
C33
R14
R15
C39
R20
C31
CR2
C34
C35
C36
C37
C40
R17
C38
R19
R13
8
6
7
5
4
3
2
3
1

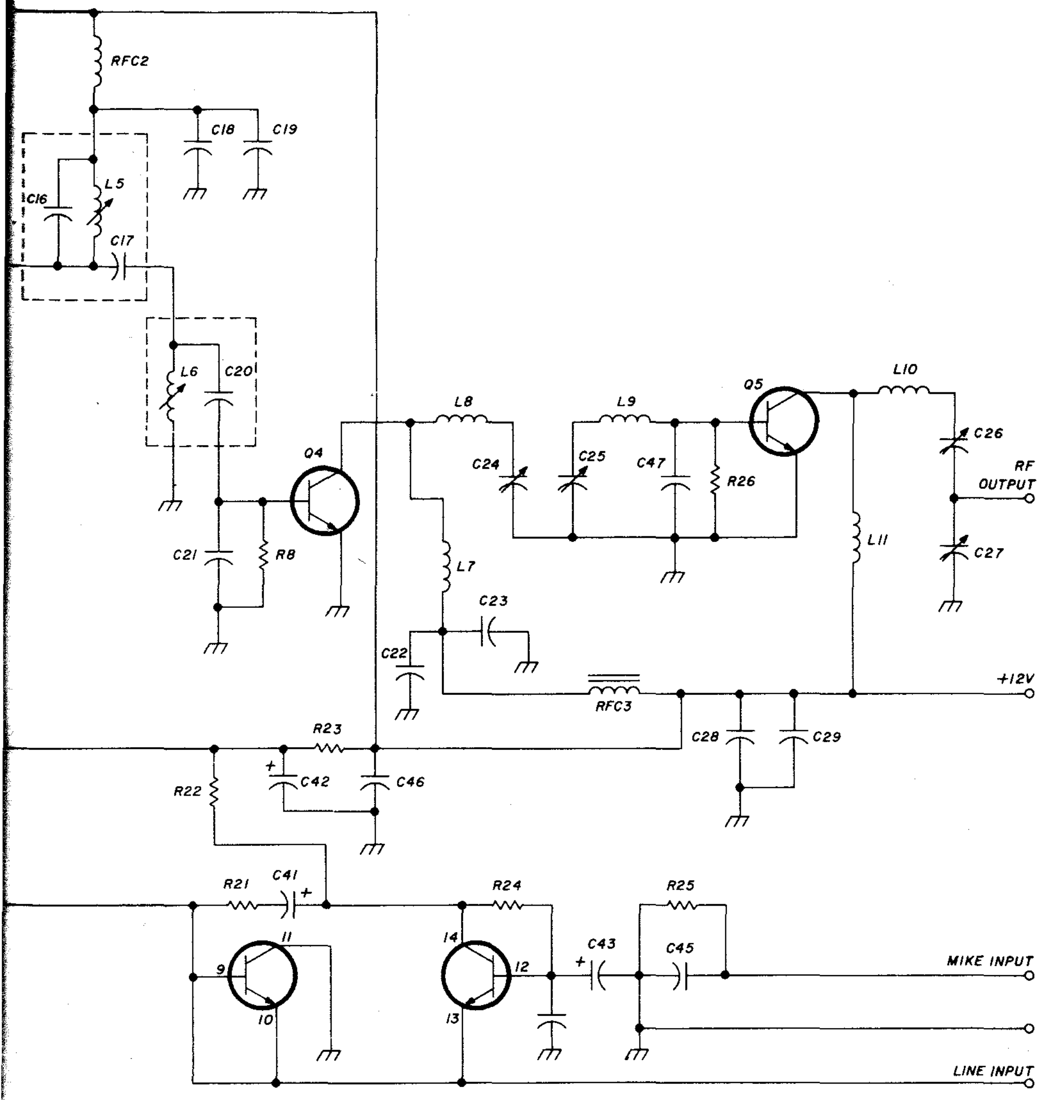


Figure 10-1. VHF Engineering TX-432 Schematic

Schematic of the VHF Engineering TX-432 narrowband fm transmitter kit, which forms the basis of the 10-GHz weak-source. It drives a poly Paks point-contact germanium diode in an X22 frequency multiplier to provide a weak-signal source for a 10.250-GHz Gunnplexer to deliver i-f output at 98 MHz.

phase modulator for the 19-MHz crystal, thus setting the deviation. The convenient miniature trim pot, R13, depending upon its setting, allows the TX-432 and X22 10-GHz multiplier/horn antenna assembly to operate either as a wideband or narrowband fm transmitter.

C30, a 22-pF ceramic trimmer capacitor, allows you to trim (net) the crystal exactly on frequency. If you use the proportional temperature control (PTC) HC25/U crystal oven covered in *Chapter 5* and can borrow a digital frequency counter for calibration, you should be able to hold frequency output on 10 GHz to ±200-500 Hz after a few weeks of crystal aging. Crystal calibration should be accomplished every month or so thereafter if you're doing truly narrowband work and must know exactly where you are.

Transistor Q1 is a combination crystal oscillator and tripler. The crystal oscillates on its fundamental frequency and may be heard on a general-coverage receiver, even though Q1 output is at 3× the crystal frequency. As the objective is a 10-GHz weak-signal source, and it's presumed you've built at least one of the wideband fm receivers in the last chapter, it's assumed you desire a frequency output of 10.152 GHz which, of course, yields a 98-MHz i-f when received on a nominal 10.250-GHz Gunnplexer. The frequency table would then look like this when using a fundamental-cut, ground parallel at 20 pF crystal of 0.005 or 0.0025 per cent tolerance on 19.227273 MHz in an HC25/U holder:

Q1 tripler (MHz)	Q2 doubler (MHz)	Q3 doubler (MHz)
57.6818	115.363	230.727

Q4 doubler (MHz)	Q5 amplifier (MHz)	X22 multiplier (GHz)
461.454	461.454	10.152

Transistors Q2, Q3, and Q4 are frequency doublers. Note the double-tuned shielded circuits between each stage to ensure a relatively clean signal on the desired frequency. As mentioned earlier, the two series-tuned circuits between Q4, the last doubler, and Q5, the 2N5913 final amplifier, are rather sensitive to tuning but they do the job of impedance matching and filtering undesired harmonics quite well in this inductively coupled bandpass configuration.

Final amplifier Q5, using grid-leak bias (or more correctly, base-leak bias) and running class C, generates sizeable harmonics with its L-tuned output network and no antenna tuner. This is just "fine business" for this application. Final tune up using a no. 12 pilot light bulb is straightforward using the test points specified in the instructions.

10-GHz horn antenna and multiplier assembly. Solder a chassis-mount female BNC connector to the edge of the TX-432 PCB as shown in *Figure 10-2* to mount the 10-GHz horn antenna/multiplier assembly. If you have access to a Bird Thruline™ wattmeter, an almost perfect 50-ohm dummy load for 461 MHz may be made by soldering five ½-watt 330-ohm resistors around the periphery of a male BNC connector and the opposite ends to a piece of no. 16 (1.3 mm) hookup wire going to the connector center pin. The number 330 divided by 5 doesn't exactly equal 50, but the inductive reactances and stray capacitances work out to a near-perfect 50-ohm load that will handle a watt or two.

The X22 10-GHz Frequency Multiplier

Many different types and varieties of crystal diodes will work as good X22 multipliers to 10 GHz. Two-dozen Schottky, silicon, germanium, and cheapy varactor diodes were tested. Surprise of surprises: the Poly Paks 92CU2614 point-contact germanium diodes (selected devices) were as good as many of the $3.00-and-up surplus X-band diodes, such as the 1N21D, when used in the multiplier circuit.

The rudimentary but efficient circuit shown in *Figure 10-3* produces S9 plus 20 dB signals at 100 yards (90 meters) range on 10.152 GHz using a narrowband fm tunable i-f and has been received at 1-mile (1.6-km) range with an S3 to S4 signal when feeding a 25-inch (63-cm) sort-of-parabolic reflector. The SWR at 461 MHz input is between 1:1 and 1.2:1 at 700 milliwatts input.

Originally three ⅛-inch (3-mm) diameter holes were drilled and three 4-40 (M3) nuts were soldered in the center of the waveguide, spaced 3/16 inch (5 mm) apart, beginning 11/16 inch (17.5 mm) from the rear of the waveguide to point A (*Figure 10-3*). (These may be seen in *Figure 10-2*.) Three 4-40 by ½ inch (M3 by 12.5 mm) machine screws in these holes were supposed to aid in

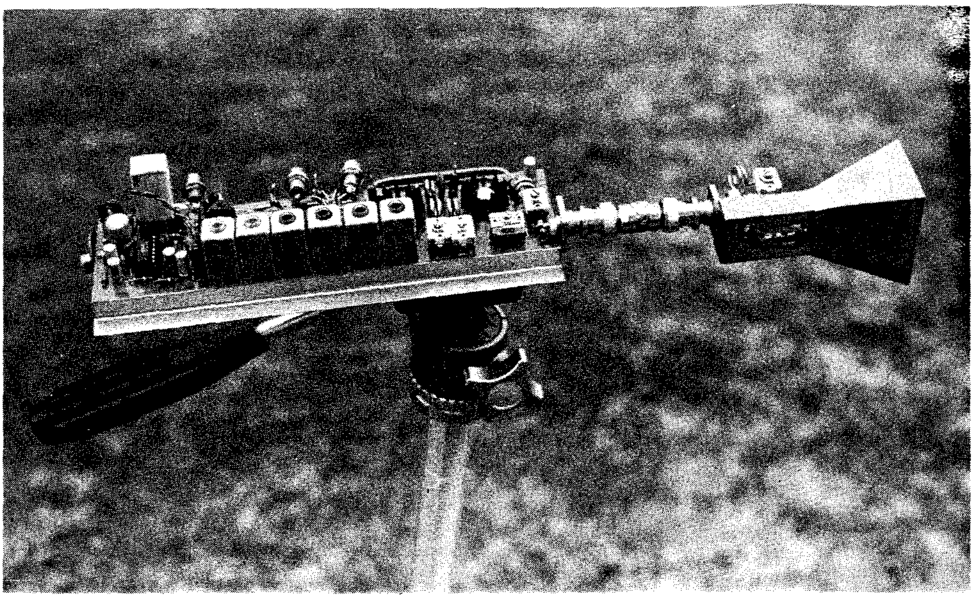


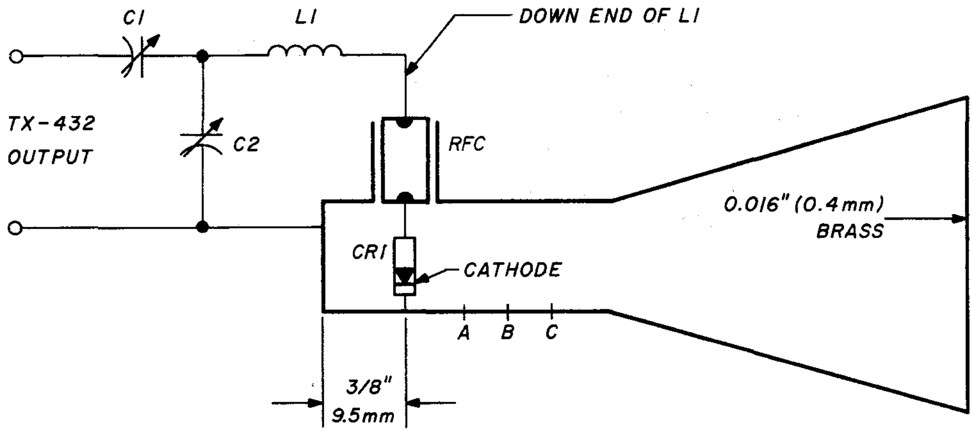
Figure 10-2. TX-432 and 10 GHz Horn Antenna/Multiplier Assembly
The TX-432 fm transmitter and 10-GHz horn antenna-frequency multiplier assembly, which is mounted on a tripod. The text gives details on assembly and mounting to provide a sturdy arrangement for portable or fixed-station use.

matching the multiplier diode to the waveguide and horn antenna but were found to be unnecessary as the match luckily turned out to be near perfect.

Waveguide/Horn Antenna Fabrication

Brass is an ideal waveguide/horn antenna material with 0.016-inch (0.5 mm) sheet brass near optimum for moderate stiffness yet is easy to work with. Even sheet brass as thin as 0.010 inch (0.26 mm) could be used. Or you could use the sheet metal from most any tin can.

A brief reminiscence about cavity material at frequencies above 1 GHz may be of interest. A few years ago I built duplicate 1296-MHz cavity amplifiers in the 25-50 watt output range using 7289 ceramic triodes (*73 Magazine*, April 1978). In one amplifier I



CI ARCO 401
C2 ARCO 402
RFC 1/4"(6.5mm) BRASS LUG WRAPPED WITH SCOTCH TAPE IN 5/16"(8mm) BRASS TUBE
LI 2 TURNS NO.16(1.3mm) WIRE 1/2"(12.5mm) 1/4"(6.5mm) ID
CRI SELECTED POLY PAKS NO. 92CU2614 GERMANIUM DIODES

Figure 10-3.

The X22 10-GHz frequency multiplier. Construction is discussed in the text. The crystal diode is a Poly Paks 92CU2614 point-contact germanium, which was test-selected. Dimensions A, B, C are discussed in the text.

used sheet brass for the cavity walls; in the other I used an ordinary Purina cat food can for the cavity walls. No measurable or discernible difference occurred in efficiency (which was quite good) or in power output between each amplifier! I'm not recommending that all future microwave cavities, waveguide, or horn antennas be constructed from ordinary cat-food cans. The main thrust of this reminisence is that, if you don't have sheet brass available, ordinary tin can sheet metal will not only work, but will work quite well, if you *roll it flat* and closely follow dimensions.

Making the waveguide. It's easiest to lay out the waveguide design directly on the sheet brass with a scribe or sharp nail. (See *Figure 10-4*) Cut with heavy scissors or sheet-metal shears. Bend the material 90 degrees on the dotted lines shown in *Figure 10-4.* If you don't have a sheet-metal finger brake, ordinary pliers or a vise will do almost as well with this light-gauge metal. Tack solder the edges at the middle and open end on all four sides.

Don't be afraid to use plenty of *Nokorode* soldering paste to make the job easier. The paste may be cleaned off later with acetone, gasoline, or lighter fluid. Now solder each of the four seams and joints completely. Solder the 11/32 -inch diameter by ¼-inch long (8.5 mm by 6.5 mm) tubing at A, *Figure 10-4.*

Horn antennas. Use a fine file or sandpaper block to smooth all cut-out edges so they are square (*Figure 10-5*). Pound out any dings or

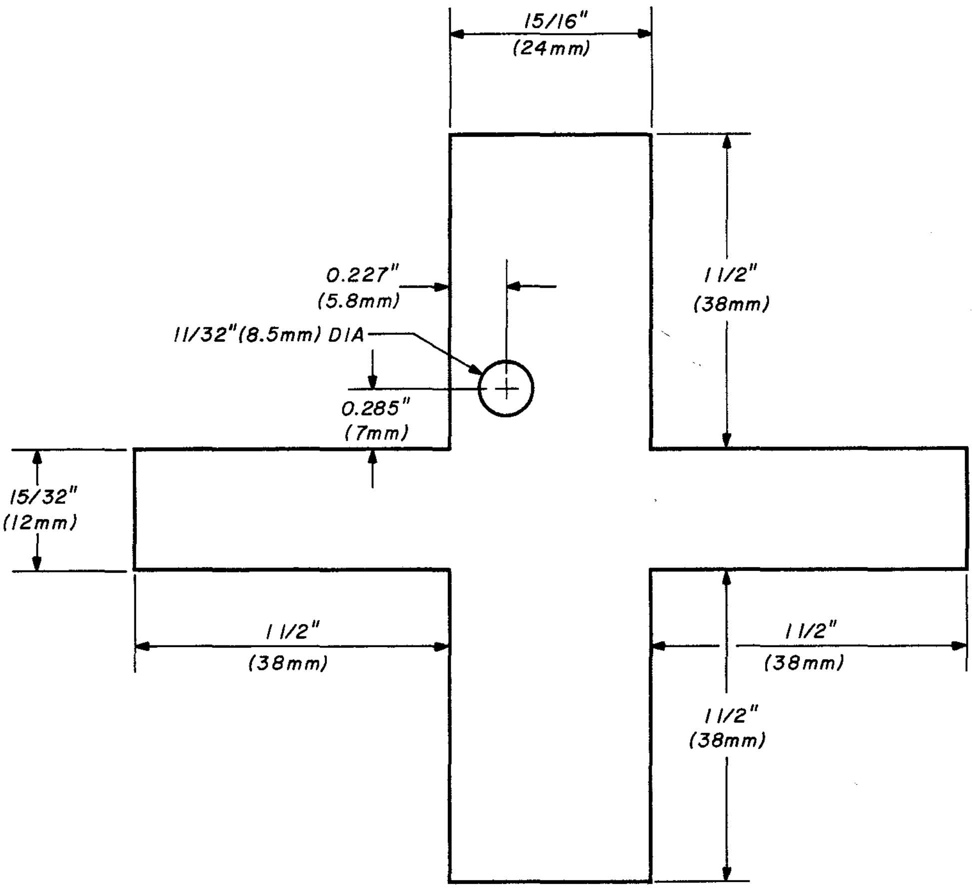


Figure 10-4. Waveguide layout.

You can use brass sheet or tin from ordinary food cans without any sacrifice in performance. Follow construction information.

bends with a wood block so that all surfaces are *truly flat.* With a short length of 2 by 4 inch wood block as a 90-degree square, tack solder **A** to **B** on the inside then solder the entire seam. Use plenty of soldering paste. Repeat with the other **A** and **B** pieces. Now solder the two halves carefully together. If you first lightly tin each inside seam about 1/16 inch (1.5 mm) in from the edge the job will be easier.

Use a fine file to make all the inner soldered edges of the horn smooth and flush. Tack the horn antenna to the waveguide on all four corners, then solder all four seams. File smooth all inside seams of the horn-to-waveguide solder joint. Finish file and sand all outer seams smooth as shown in *Figure 10-6.*

The frequency-multiplier trimmer capacitor in *Figure 10-6* on the top is C2, the Arco 402. The adjustable side of the capacitor is soldered directly to the waveguide outer wall. Solder a chassis-mount BNC female connector directly to the rear edge of the waveguide, as shown in *Figures 10-2* and *10-7.* Make this a good

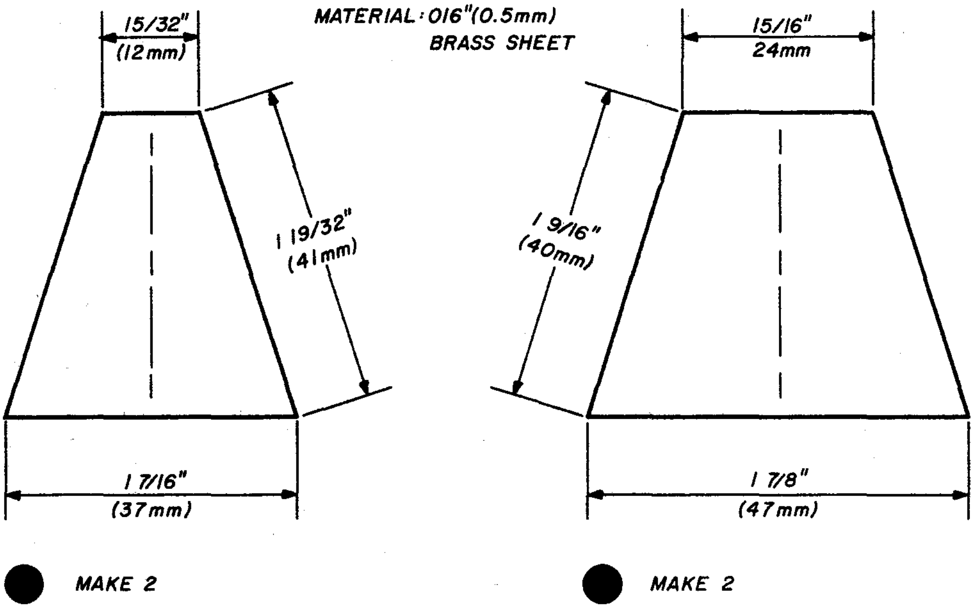


Figure 10-5. Horn Antenna Layout
Horn antenna layout. Two each are required.

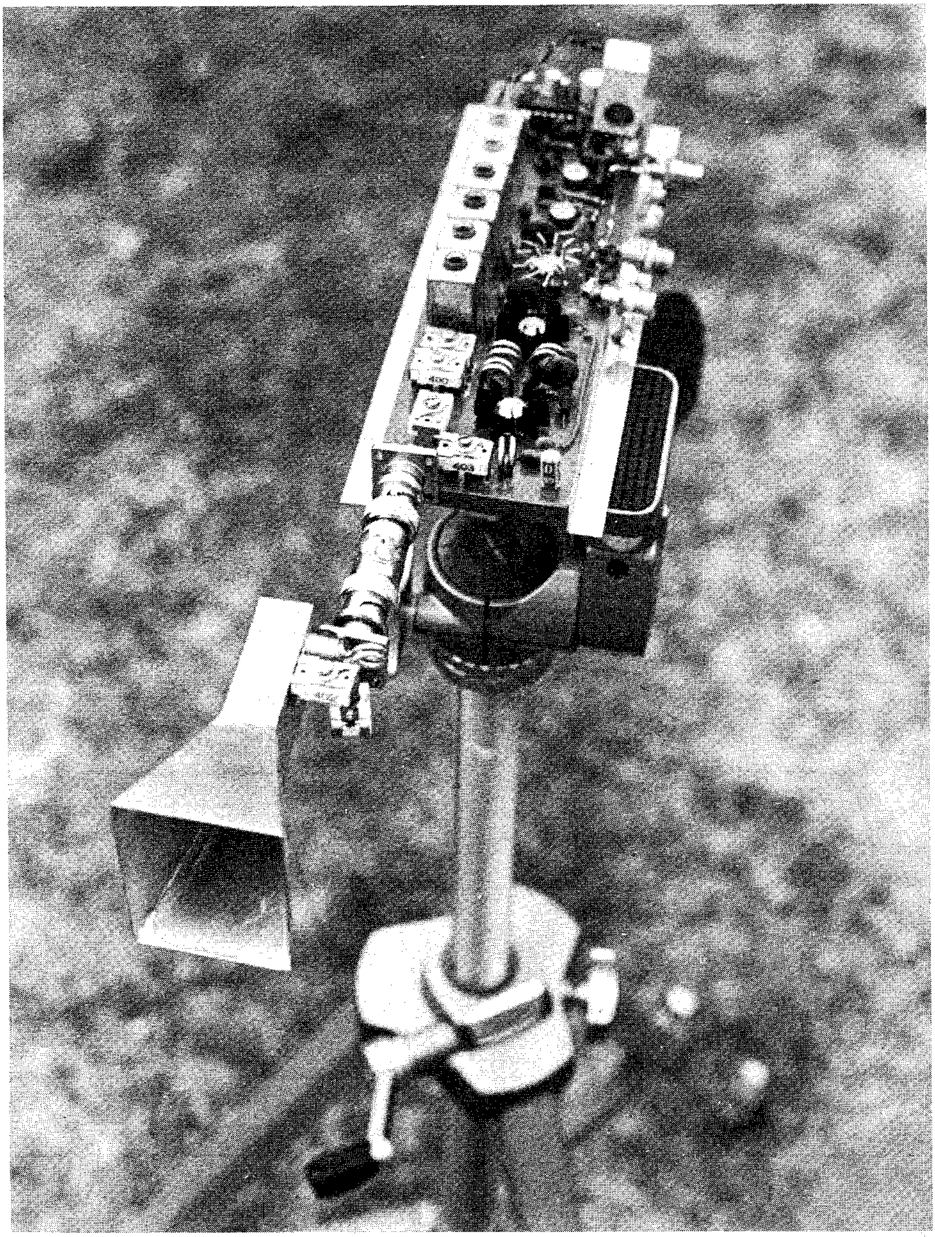


Figure 10-6. Horn Antenna/Multiplier/TX-432 Front View
Front view of the horn antenna, frequency multiplier, and TX-432 transmitter.

solid solder joint, as it carries the entire weight of the multiplier-horn assembly when connected to the TX-432 with a BNC male-to-male adapter.

If you don't have a BNC male-to-male adapter, they're easy to make. Use two ordinary male BNC-to-coax connectors and remove the threaded coax fitting. File the coax end of each connector to base metal. Measure the distance from male face-to-face when held together. Solder a piece of no. 16 (1.3 mm) wire between each center pin so that total length equals the face-to-face distance.

Press fit one center pin and wire into one connector so the center pin is flush with the connector face. With this connector vertical on a flat surface, slowly press fit the other connector onto its center pin until it's flush with its face, at which point (if you measured correctly) both BNCs should be flush. Solder together.

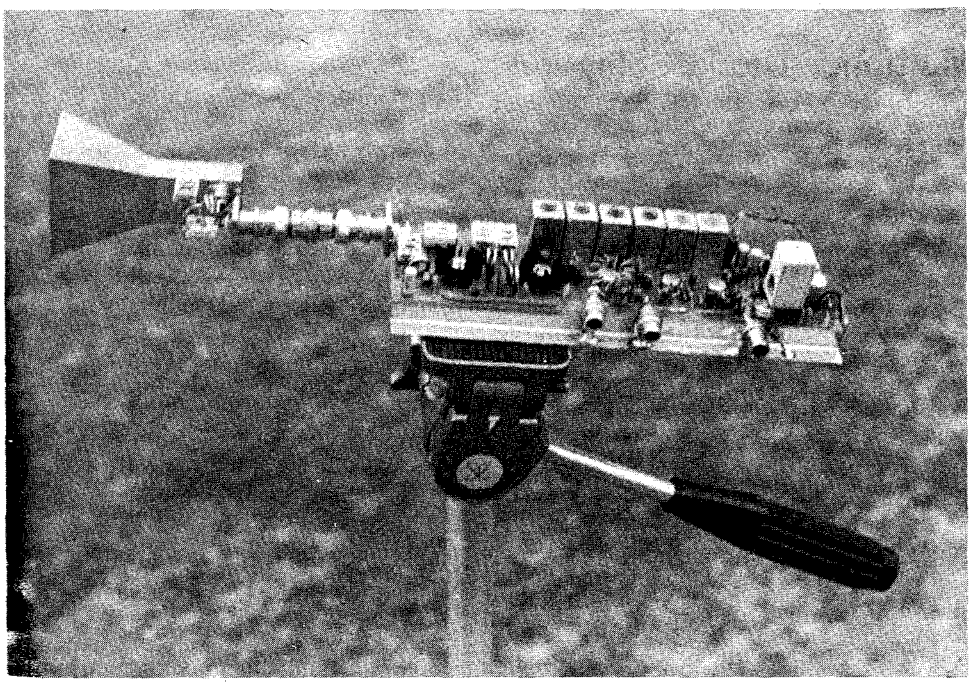


Figure 10-7. Horn Antenna/Multiplier/TX-432 Side View

Side view – horn antenna, multiplier, and TX-432. Mechanical rigidity is important. See text for details on soldering.

Don't use *Nokorode* paste this time because you can't clean the inside. Solder C1, the Arco 401 trimmer capacitor, to the BNC chassis mount center connector and the other end to C1 and C2. *Figure 10-7* shows the C2 position.

Wind L1 with no. 16 (1.3 mm) hookup wire on a ¼-inch (6.5 mm) diameter drill bit: two turns spaced one wire diameter with ¼-inch (6.5 mm) leads at each end. One end goes down to C3 and the other end out to C1, C2 junction. Drill a 1/32-inch (1-mm) diameter hole through the waveguide wall opposite the center of C3's tubing mount. Cut a ¼-inch (6.5-mm) piece of ¼-inch (6.5-mm) brass rod for C3. Drill each end about 1/16 inch (1.5 mm) deep with a 1/16-inch (1.5-mm) diameter drill bit. Tin each hole just drilled. Solder the "down" end of L1 to one end of C3 and wrap C3 with Scotch tape to ensure a loose press fit into the C3 tubing holder. You're now ready to select diodes for the X22 frequency multiplier.

Multiplier Diode Selection

By using Poly Paks 92CU2614 point contact germanium diodes at 200 for $1.98, you can afford to blow and/or throw away a few diodes in selecting the best ones. Blowing $10-$12 diodes is no fun at all and can ruin your whole day, which is why this cheapy, less-painful approach is used. If you work for an X-band diode factory and can get all you wish free, use your own diodes and skip the rest of this chapter.

Here are two general selection rules that will save considerable time:

1. The point-contact germanium diodes with the best X22 10-GHz output all had measured forward resistances of 5 ohms or less and reverse resistances greater than 1 megohm as measured on a Hickok or Simpson VOM.
2. All diodes with high 10-GHz output did not reach maximum output until 5-10 seconds after 461 MHz was turned ON.

Item 2 leads me to believe there's a mechanism at the point-contact junction between the cat-whisker and germanium pellet that is temperature dependent, which I don't claim in any way whatsoever to understand. What I do understand is that diodes that came ON instantly were always 10-30 dB down in 10-GHz output compared with those that have the time delay. Understanding why this occurs might be intellectually satisfying but would not increase 10-GHz output.

Select a half-dozen or so Poly Paks diodes that meet item 1 above and have a go at it as follows:

1. Trim each diode leads to 3/16 inch (5 mm) long and tin. Use needle nose pliers to conduct heat away from the diode.
2. Solder the anode end of the diode to the center of one end of C3.
3. Carefully insert diode and C3 into the brass tube on the waveguide, making sure the diode lead comes out of the 1/32-inch (1 mm) diameter hole on the other side of the waveguide. Solder this lead.

If all is well, the diode should be approximately dead center in the waveguide. Diode polarity probably makes no difference but I've always inserted them with cathode down, soldered to the waveguide wall.

Tripod mounting the TX-432/multiplier/horn assembly is the most convenient for most applications although there's no reason why the assembly couldn't be mounted in a waterproof Monokote-mylar-covered balsa wood assembly for permanent outdoor installation. For tripod mounting solder a 2-inch (51-mm) wide strap of 0.016-inch (0.5 mm) brass or tin can across the bottom of the TX-432 flanges about 1 inch (25 mm) from the rf output end of the PCB. Solder a 1/4-20 (M6) nut to the center of the strap for the tripod mounting screw.

Initial Test

With the 10-GHz weak-signal source about 6 feet (1.8 meters) away from a 10.250-GHz Level I Gunnplexer, set the Gunnplexer varactor voltage at 4.0 Vdc. Turn on the weak-signal source and hope for the best. If you don't have a Bird Thruline™ wattmeter, set C1 and C2 on the X22 multiplier about one turn out from full in. Tune your fm i-f receiver up and down 4 or 5 MHz. You should be able to find the weak signal.

If you're lucky and do find the 10-GHz 22nd harmonic of the TX-432 output on the first try, adjust the multiplier C1 and C2 for maximum output and the TX-432 C26 and C27 for maximum

10-GHz output. Repeat this tuning procedure until no further increase in the 10-GHz harmonic is obtained.

Further Assistance

If you can't find any glimmer of a 10-GHz harmonic and can't borrow a Thruline™ wattmeter, take a few steps backward and try another multiplier diode. Perseverance will usually prevail. Also, try slowly varying the Gunnplexer varactor voltage between about +3.0 to +5.0 volts while listening for the 10-GHz harmonic on the wideband fm tunable i-f, as the Gunnplexer diode is probably running at a slightly higher temperature than when it was calibrated at the Gunnplexer factory. This is because the diode is in the insulated Gunnplexer enclosure, and also because of the PTC circuit if you are using it.

If, after testing five or six diodes in the 10-GHz multiplier without finding any harmonic at all, you probably have a problem. Check the Scotch tape insulation around C3 for a possible short circuit. Also check to make sure that C1 is an Arco 401 and C2 is an Arco 402, as they might have been reversed. Retune the TX-432 for approximately 1-watt output into a no. 12 pilot light and try again.

Should fate still not be smiling upon you, try substituting a 1N21 or 1N23 diode, any variety. They are more expensive but most will work the first try. Another alternative is to borrow a Bird Thruline™ wattmeter with a 5E 5-watt slug that covers 400-1000 MHz and try the following tuneup procedure.

Connect the TX-432 directly to the input of the Thruline™ wattmeter and the multiplier/horn assembly directly to the wattmeter output. With 0.7 to 1.2 watt forward power, adjust the multiplier C1 and C2 for minimum reflected power. With a good multiplier diode you should be able to bring reflected power down to almost zero. About 0.1 watt reflected power or less is an excellent match and should give you a booming 10-GHz harmonic signal. If reflected power can't be reduced to 0.5 watt or less, keep changing diodes until you have four or five diodes that do so. Keep a record of each diode's 10-GHz signal output as seen on the fm receiver S meter.

If all else fails, (you might have a sack full of *all* bad diodes — perish the thought), try ordering a few World War II surplus

1N21D diodes from G & G Electronics in New York City (see end of chapter) and start again with refreshed spirits and diodes.

Frequency Calibration

Method 1. Using a general-coverage shortwave receiver, first calibrate it on WWV's 20-MHz signal. Then, with a clip lead for an antenna near the TX-432's Q1 transistor, adjust C30, the crystal trimmer, for output to 19.2273 MHz as close as possible. With X528 frequency multiplication this will not furnish a laboratory standard output on 10.152 GHz but will be considerably better, by many orders of magnitude, than the micrometer frequency measurement table in *Chapter 3.*

Method 2. Borrow a digital frequency counter and clip it onto the junction of C14, R6, and the base of Q3 on the TX-432. If you're using the PTC on the TX-432's HC25/U crystal, allow 10-20 minutes warmup time. Then adjust C30 for a frequency reading of 115.3636364 MHz and you'll be right on 10.152 GHz.

You'll be pleasantly surprised at the long-term stability of the weak-signal source 10-GHz frequency output, especially if it's kept out of drafts, or better yet, installed in a small insulated balsa wood enclosure. For really precise frequency measurement the weak-signal source should be recalibrated *every month or two.*

Summary

Your 10-GHz weak signal source has a number of applications beyond that of a crystal-controlled frequency marker. Two of my favorites are described below.

It will serve as a 10-GHz wideband fm transmitter on short ranges. In narrowband fm transmitter service it will provide a readable signal up to a mile or so.

The weak-signal source is an ideal aid for aligning large-diameter, very narrow-beam, 10-GHz parabolic reflector antennas. Using a surveyor's transit, place a stake a few hundred yards (300 meters or so) from the large parabolic dish/Gunnplexer antenna tower at the exact compass heading you wish. (I use the north star to obtain true north, but a surveyor's compass will suffice.) Keep the stake in the clear to avoid multipath reflections.

Carefully rotate the parabolic dish to each side of the weak-signal-source direct path and mark the half-power points on each side. By dividing these half-power points exactly in half, and pointing the large dish in this direction, you'll have gained an azimuth-pointing accuracy to within a few hundredths of a degree.

Radio astronomers can't do much better!

1N21D diodes, approximately $3.00 each	G & G Electronics, 45-47 Warren Street New York, New York 10007
92CU2614 germanium diodes, 200/$1.98	Poly Paks P.O. Box 942 South Lynnfield, Massachusetts 01940

Parts sources

TX-432B transmitter
kit: $49.95

Optional alternate to TX-432B:

T450 UHF Exciter kit: $44.95	Hamtronics, Inc. 65 Moul Road Hilton, New York 14468

11

Parabolic Reflectors and Mounts

Design and construction of two homebrew parabolic reflectors for the 10-GHz baı.d. Data for determining design parameters for a 96-inch (244-cm) diameter dish. Feed systems. Construction of a 25-inch (64-cm) parabolic dish and tripod/mast mount.

In a book such as this, which is aimed specifically at Gunnplexer applications, it's difficult to arbitrarily decide how deep to go into theoretical aspects. This is a "Cookbook"— it's neither a textbook nor a handbook. Cookbooks provide the user with "recipes." This chapter is a modest exception to the Cookbook rule, since most electrical-engineering students and Radio Amateurs have little experience in microwave parabolic-reflector antenna design and construction. The exposure of many readers to the subject is limited to a single sophomore year physics course in optics. A goodly number of readers' exposure to parabolic reflectors is limited to buying a replacement sealed-beam headlight for a car.

The objective of this chapter is to present enough parabolic-reflector theory, plus Cookbook design and construction data, to entice the reader to dig deeper into the subject. A good place to start is reference 1, the *VHF/ UHF Manual*, third edition, published by the Radio Society of Great Britain, by Dain Evans,

*NOTE: Or Hamtronics T450 UHF Exciter Kit @ $44.95

G3RPE, *et al.* Reference 1 is a bargain at $12.95 and may be ordered from the *Ham Radio Bookstore*, Greenville, New Hampshire 03048. Pages 8.50 through 8.70 cover the subject thoroughly and allow you to design virtually any type of parabolic reflector antenna desired.

Parabolic-Reflector Antenna Theory

A parabolic curve is a cross-section of a cone formed by a plane that intersects the cone parallel to one side. A properly constructed antenna parabolic reflector, in the receive mode, will focus electromagnetic energy from a distant source at a single point (the focal point). In the transmit mode (the physical law of reciprocity prevailing), it will radiate a plane wave that emanates from its focal point focused at an infinitely distant point.

The gain of a properly constructed parabolic reflector antenna, whose diameter is at least ten wavelength at the operating frequency, is expressed by:

$$G = K(4\pi A/\lambda^2) \qquad (1)$$

where

G = antenna gain

K = efficiency, per cent

λ = wavelength

A = dish area = πR^2 (R = dish radius)

Antenna efficiency, K, is typically 50 per cent (0.5) for amateur antennas (and also for many commercial ones). Assume a parabolic dish of 21-inches (53 cm) diameter and an operating frequency of 10.25 GHz (wavelength of 1.152 inches or 29 mm).

Translating dish diameter into area and solving *eq. 1* yields a power gain of 1638 times that of an isotropic antenna (one that radiates equal power to all surfaces of a surrounding sphere). In terms of dB the gain is 32 dB – quite a bit!

The following table relates typical parabolic antenna gain to its 3-dB and 10-dB down beamwidth in degrees:

gain (dB)	3-dB beamwidth (deg.)	10-dB beamwidth (deg.)	gain (dB)	3-dB beamwidth (deg.)	10-dB beamwidth (deg.)
10	60	90	35	3.0	5.0
15	30	60	40	1.7	3.0
20	17	30	45	0.9	1.7
25	9	17	50	0.5	0.9
30	5	9	55	0.3	0.5

This table illustrates the fact that, for parabolic antennas with less than 30-35 dB gain, we can point our dish quite easily using a Boy-Scout compass if we know the desired true heading and correct for local magnetic deviation. [East is least (-) and west is best (+).] Add or subtract deviation as appropriate for your location to obtain true heading. For parabolic antennas with more than 35-dB gain we do indeed have a pointing-accuracy problem which we will try to solve in the last section of this chapter.

Reflector Calculations

The formula in *Figure 11-2* will allow you to calculate the parabolic curve for any size reflector with a given focal length. Choice of focal length is not arbitrary and may vary anywhere from dimension **C**, a focal-plane feed that is even with the rim of the parabolic dish, out to about one dish diameter, which yields a focal-length-to-diameter ratio, *f/D*, of 1. Except when using *Snocoasters,* (*Snocoaster* is a toy sled made of aluminum, which is available from Sears, Roebuck and Company) *Snosleds*, garbage-can lids, or dishes that are free, you have a choice of *f/D*. Selection of this ratio is a compromise between a) ease of reflector construction, b) ease of feed construction, c) feed efficiency, and d) antenna sidelobe radiation.

As 10-GHz-band occupancy is somewhat less than that of the 2-meter band with its wall-to-wall repeaters, you can neglect minor sidelobe radiation. The key word here is "minor" as any sidelobe radiation results in wasted power. At Gunnplexer power levels you can ill afford to throw any away intentionally. Minor side lobes are not all bad and do have one redeeming virtue: *i.e.*, if your parabolic reflector is slightly misaligned (as mine was in a recent VHF contest), you might luckily still make the desired contact through one of the sidelobes.

Focal-plane feed sounds like a neat idea but is difficult to implement efficiently, as the feed must illuminate 180 degrees, and considerable power is wasted. A good compromise for Amateur-constructed parabolic dishes would have *f/D* ratios in the 0.5-0.85 range for ease of construction and feed with only minor sidelobe radiation.

TRS-80 Computer Program

Using the parabolic curve formula in *Figure 11-2* we'll let our TRS-80 microcomputer do some work for a change instead of having the Electric Pencil (TM) do all its word-processing programming. The simple BASIC program that follows will let your computer a) compute the values for *x* and *y* for the *Figure 11-2* parabolic-curve formula for any size dish, with any *f/D* ratio, and b) print them out in any increments you wish. The computer runs on the following pages are for a 96-inch (244-cm) diameter parabolic reflector and are printed out in 2-inch (51-mm) increments beginning at the center of the dish and proceeding outward. The *f/D* for each run is: 0.25 (focal-plane), 0.33, 0.50, 0.66, 0.85, and 1.

Program

```
10   REM PARABOLIC CURVE CALCULATION PROGRAM
20   REM THE GUNNPLEXER COOKBOOK BY W4UCH
30   REM APRIL 1, 1978
40   REM X=(Y*Y)/(4*D)*FD COMPUTES PARABOLIC
     CURVE
50   REM Y=DISTANCE FROM CENTER OF DISH
60   REM X=DISTANCE FROM REAR PLANE OF DISH TO
     DISH SURFACE
70   REM A=FOCAL LENGTH OF DISH
75   INPUT"F/D RATIO      " ; FD
80   INPUT"DISH DIAMETER — INCHES      " ; D:A=D*FD
90   INPUT"RADIUS INCREMENTS DESIRED — INCHES
     " ; I:Y=I : CLS
100  X=(Y*Y)/(4*A)
110  PRINT"Y=" ; Y, "X=" ; X
120  IFY=D/2 THEN GO TO 120 : REM=END
130  Y=Y+I : GO TO 100
```

f/D = 0.25; dish diameter = 96 inches (244 cm)

Y = 2	X = .0416667
Y = 4	X = .166667
Y = 6	X = .375
Y = 8	X = .666667
Y = 10	X = 1.04167
Y = 12	X = 1.5
Y = 14	X = 2.04167
Y = 16	X = 2.66667
Y = 18	X = 3.375
Y = 20	X = 4.16667
Y = 22	X = 5.04167
Y = 24	X = 6
Y = 26	X = 7.04167
Y = 28	X = 8.16667
Y = 30	X = 9.375
Y = 32	X = 10.6667
Y = 34	X = 12.0417
Y = 36	X = 13.5
Y = 38	X = 15.0417
Y = 40	X = 16.6667
Y = 42	X = 18.375
Y = 44	X = 20.1667
Y = 46	X = 22.0417
Y = 48	X = 24

f/D = 0.33; dish diameter = 96 inches (244 cm)

Y = 2	X = .0315657
Y = 4	X = .126263
Y = 6	X = .284091
Y = 8	X = .505051
Y = 10	X = .789142
Y = 12	X = 1.13636
Y = 14	X = 1.54672
Y = 16	X = 2.0202
Y = 18	X = 2.55682
Y = 20	X = 3.15657
Y = 22	X = 3.81944
Y = 24	X = 4.54546
Y = 26	X = 5.3346
Y = 28	X = 6.18687
Y = 30	X = 7.10227
Y = 32	X = 8.08081
Y = 34	X = 9.12248
Y = 36	X = 10.2273
Y = 38	X = 11.3952
Y = 40	X = 12.6263
Y = 42	X = 13.9205
Y = 44	X = 15.2778
Y = 46	X = 16.6982
Y = 48	X = 18.1818

f/D = 0.5; dish diameter = 96 inches (244 cm)

Y = 2	X = .0208333
Y = 4	X = .0833333
Y = 6	X = .1875
Y = 8	X = .333333
Y = 10	X = .520833
Y = 12	X = .75
Y = 14	X = 1.02083
Y = 16	X = 1.33333
Y = 18	X = 1.6875
Y = 20	X = 2.08333
Y = 22	X = 2.52083
Y = 24	X = 3
Y = 26	X = 3.52083
Y = 28	X = 4.08333
Y = 30	X = 4.6875
Y = 32	X = 5.33333
Y = 34	X = 6.02083
Y = 36	X = 6.75
Y = 38	X = 7.52083
Y = 40	X = 8.33333
Y = 42	X = 9.1875
Y = 44	X = 10.0833
Y = 46	X = 11.0208
Y = 48	X = 12

f/D = 0.66; dish diameter = 96 inches (244 cm)

Y = 2	X = .0157828
Y = 4	X = .0631313
Y = 6	X = .142045
Y = 8	X = .252525
Y = 10	X = .384571
Y = 12	X = .568182
Y = 14	X = .773359
Y = 16	X = 1.0101
Y = 18	X = 1.27841
Y = 20	X = 1.57828
Y = 22	X = 1.90972
Y = 24	X = 2.27273
Y = 26	X = 2.6673
Y = 28	X = 3.09343
Y = 30	X = 3.55114
Y = 32	X = 4.0404
Y = 34	X = 4.56124
Y = 36	X = 5.11364
Y = 38	X = 5.6976
Y = 40	X = 6.31313
Y = 42	X = 6.96023
Y = 44	X = 7.63889
Y = 46	X = 8.34912
Y = 48	X = 9.09091

f/D = 0.85; dish diameter = 96 inches (244 cm)

Y = 2	X = .0122549
Y = 4	X = .0490196
Y = 6	X = .110294
Y = 8	X = .196078
Y = 10	X = .306373
Y = 12	X = .441177
Y = 14	X = .60049
Y = 16	X = .784314
Y = 18	X = .996247
Y = 20	X = 1.22549
Y = 22	X = 1.48284
Y = 24	X = 1.76471
Y = 26	X = 2.07108
Y = 28	X = 2.40196
Y = 30	X = 2.75735
Y = 32	X = 3.13725
Y = 34	X = 3.54167
Y = 36	X = 3.97059
Y = 38	X = 4.42402
Y = 40	X = 4.90196
Y = 42	X = 5.40441
Y = 44	X = 5.93137
Y = 46	X = 6.48284
Y = 48	X = 7.05882

f/D = 1; dish diameter = 96 inches (244 cm)

Y = 2	X = .0104167
Y = 4	X = .0416667
Y = 6	X = .09375
Y = 8	X = .166667
Y = 10	X = .206417
Y = 12	X = .375
Y = 14	X = .510417
Y = 16	X = .666667
Y = 18	X = .84375
Y = 20	X = 1.04167
Y = 22	X = 1.26042
Y = 24	X = 1.5
Y = 26	X = 1.76042
Y = 28	X = 2.04167
Y = 30	X = 2.34375
Y = 32	X = 2.66667
Y = 34	X = 3.01042
Y = 36	X = 3.375
Y = 38	X = 3.76042
Y = 40	X = 4.16667
Y = 42	X = 4.59375
Y = 44	X = 5.04167
Y = 46	X = 5.51042
Y = 48	X = 6

Interpretation of Results

Let's summarize the message that all this computer-generated data is trying to tell us. First we'll look at it from the structural and mechanical rigidity viewpoint, and in the next section of this chapter, from the feed-system aspect.

As far as mechanical rigidity for a given material thickness is concerned the focal-plane dish, with its focal-length-to-diameter (*f*/*D*) ratio of 0.25 and a depth of 24 inches (61 cm) at the center of the dish, is the big winner in the 96-inch (244-cm) diameter reflector contest. Unfortunately it's also the most difficult to feed with any efficiency.

Looking at the data sheets, we find that, as *f*/*D* increases, the depth of the parabolic reflector at the center decreases quite rapidly, which requires considerably more external structural support to maintain reasonable rigidity: i.e.,
f/*D* = *0.33* has depth of 18 inches (459 mm),
f/*D* = *0.5* has depth of 12 inches (306 mm),
f/*D* = *0.66* has depth of 9 inches (230 mm),
f/*D* = *0.85* has depth of 7 inches (179 mm),
and *f*/*D* = *1.0* has a depth of 6 inches (153 mm).

Any aeronautical engineer will tell you that, as the aspect ratio (wingspan divided by mean chord) increases, the wing structural integrity (for a given material weight) decreases inversely as the square of the aspect ratio. In a few words: a low-aspect-ratio delta wing will withstand tens of gs more loading for a given material weight than a high-aspect-ratio sailplane wing using the same material and of the same weight.

Although none of us will be flying any of these parabolic dishes, the same rule is true for parabolic antennas. Wind, snow, and ice loading will do their very best to destroy dish geometry, with resulting gain losses and other problems such as collapsing, falling on your car, or causing flying fragments to litter neighbor's yards.

Care and Feeding of 10-GHz Parabolic Antennas

In the best of all possible worlds, you'd simply go up into the attic (in the summertime) and swipe one of your childrens' 25-inch (64-cm) diameter aluminum *Snocoaster* snow sleds for a parabolic reflector. The reason for this comment is that, if you have an existing parabolic dish, there's little you can do to change the optimum feed system, since it's determined solely by the *f/D* ratio, without exception. You *can* change the *f/D* of an existing parabolic dish by cutting down its diameter.

A case in point: a much beat-up, dented, and battered 8-foot (2.4 m) diameter focal-plane (*f/D = 0.25*) dish is scrounged by the user. If this dish were sabre-sawed to 4-foot (1.2 m) diameter, its *f/D* would double to 0.5, which is easy to feed, and the number of dents (area) to be pounded out would be reduced from about 48 square feet (4.3 square meters) to 12 square feet (1 square meter). Each time a dish diameter is doubled or halved, its gain goes up or down 3 dB.

The Shadow Problem

Every feed system shadows a portion of the dish to a greater or lesser extend, depending on the feed-system area. A frequent question is: "How much parabolic antenna gain is lost by having the 3 by 3-½-inch (77 by 89-mm) Gunnplexer horn and wood Gunnplexer mount assembly in front of the 25-inch (64-cm) diameter *Snocoaster* dishes shown in *Figure 11-1*?" The answer: gain loss due to shadowing is so small that it's almost impossible to measure. For instance, a Cassegrain feed system with a subreflector approximately one-third the diameter of the main dish reduces gain only by 1 dB. For all practical purposes, dish shadowing may be ignored if the shadow diameter is less than *33 per cent of the main parabolic reflector.*

Power Distribution

Figure 11-3 illustrates two possible methods of distributing rf power across the face of two identical parabolic reflectors.

Figure 11-1.
Author Richardson and homebrew 25-inch (64-cm) diameter parabolic reflector antennas for the 10-GHz band. The reflectors were made from toy sleds *Snocoaster* manufactured by the Mirro Aluminum Company. The sleds are available from Sears, Roebuck and Company and J. C. Penney Company. The sleds are aluminum and are near-perfect paraboloids. The dishes in the photo provide about 30 dB gain and have a focal-length-to-diameter ratio (f/D) OF 0.5.

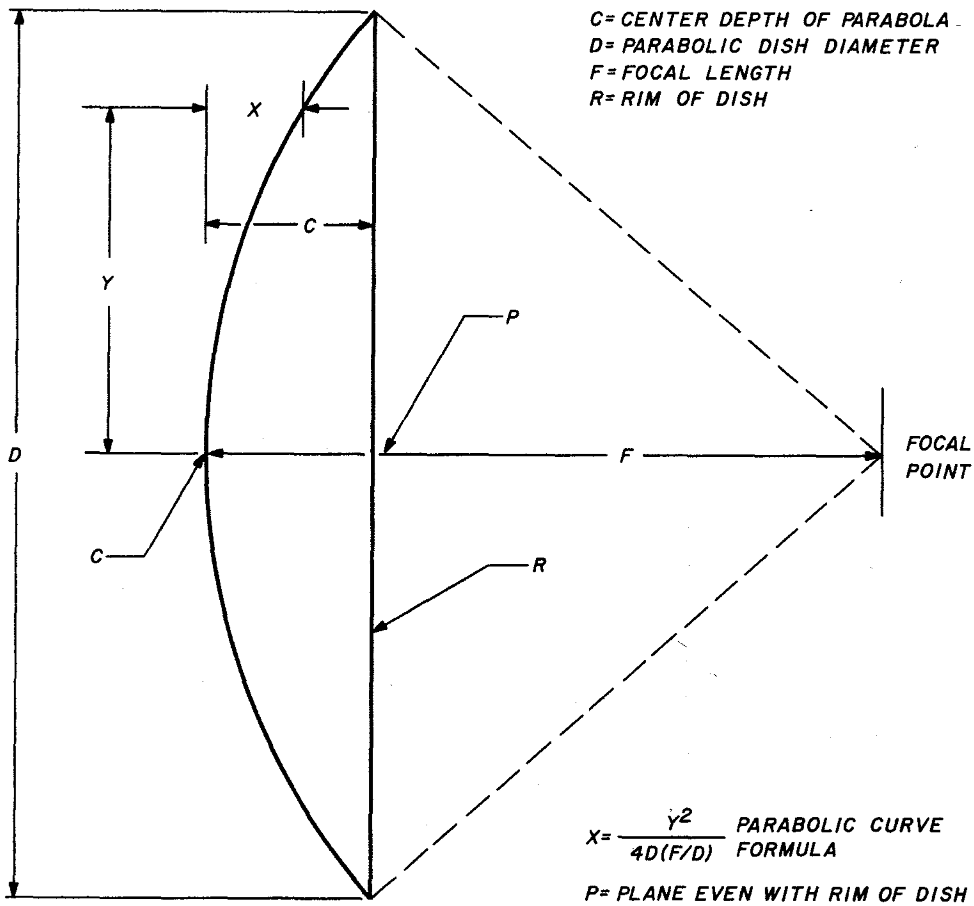


Figure 11-2.

Parabolic-reflector measurements may be determined from this drawing. The formula allows calculation of the parabolic curve for any size reflector with a given focal length.

Reflector **A** has the 10-dB-down rf points from the feed coincident with the dish outer edge, while reflector **B** has the 3-dB-down rf points from its feed coincident with its outer edge. Which is best? Despite appearances, the concentration of most all the rf power on reflector **A** is by far the best and most efficient. Again, we have a compromise between too-wide or too-narrow illumination.

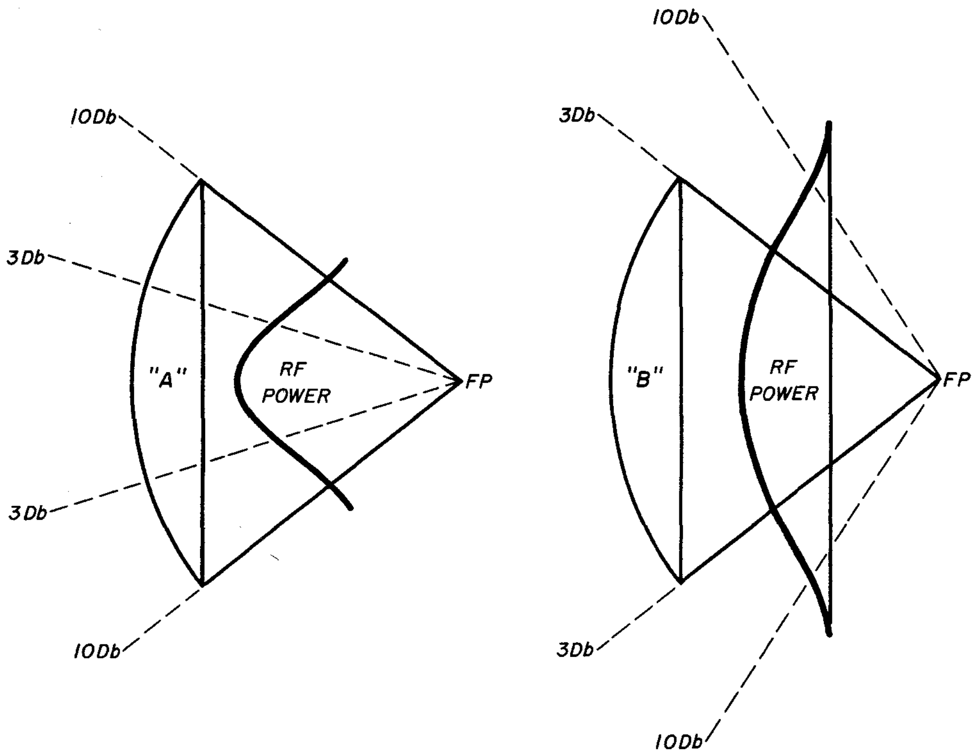


Figure 11-3.

Two methods for distributing rf power across two identical parabolic reflectors. *A* shows the 10-dB down points from the feedpoint coincident with the dish outer edge; *B* shows the 3-dB-down points from the feedpoint coincident with the dish outer edge. Reflector *A* is by far the most efficient.

With a properly designed feed, reflector (A will invariably yield an efficiency of 50 per cent or better, (which was used earlier in the gain equation), while reflector (B will have an efficiency in the 25-per cent ballpark. At Gunnplexer power levels you can ill afford to throw away intentionally any rf power or antenna gain, so henceforth the (A system, which has the 10-dB-down rf-power points coincident with the edge of the reflector, will be used.

The Phase-Center Problem

Ideally all rf energy from the feed system should come from a single point in space (the focal point of the parabolic reflector). In the real world such is not the case, as the feed size is always a major portion of a wavelength; also the (H-) and (E-) plane rf sources emanate from different points. These points are called the phase centers. To further complicate matters, the Gunnplexer rf source, the Gunn diode, and the Gunnplexer mixer diode, for the incoming signal, are separated by approximately 1-⅜inches (35mm), which is well over a wavelength. So now we have a number of different phase sources stirring up the pot.

Things are never as bad as they seem. Through judicious design, Microwave Associates has skillfully juggled the physical layout of the Gunnplexer module so that the phase centers appear to be at (or close to) a single point in the parabolic dish. And this is what counts.

Later in this chapter, when the focal length of the 25-inch (64 cm) *Snocoaster* dish is measured, not one but two points in space occur where the reflector gain peaks. These points are about 3 inches (76mm) apart. Although they may appear to have different phase centers, they're really two different compound focal points caused by mixing of parabolic and circular (and other) curves near the dish outer edge. No matter; the dish works great and gives a gain of approximately 30 dB. The $6.00 price works out to 5-dB per dollar.

Optimum-feed Beamwidth As A Function of f/D

The optimum-feed beamwidth in degrees at both the 3- and 10-dB down points, for illuminating a parabolic reflector whose edges intercept the beam at the 10-dB-down level for *f/D* ratios of 0.25 to 1.1, is shown in the following table.

f/D	3-dB beamwidth (deg.)	10-dB beamwidth (deg.)	f/D	3dB beamwidth (deg.)	10db beamwidth (deg.)
0.25	155	180	0.70	46	83
0.30	120	165	0.80	40	73
0.40	83	150	0.90	35	64
0.50	65	120	1.00	31	57
0.60	54	97	1.10	26	52

This table is most heartening for the Gunnplexer enthusiast, as it vividly illustrates the excellent match between an unmodified Gunnplexer and the "mostly parabolic" *Snocoaster* dish.

We'll use 21 inches (53 cm) for calculating the dish diameter with the *Snocoaster* and ignore the outer 2 inches (51 mm) with its more circular curve, which gives the dish more rigidity when riding it down snow-covered hills. The empirically measured optimum focal length of the *Snocoaster* is 16-⅜ inches (42 cm) from the dish center to the Gunnplexer mixer diode. Calculating $f/D = 16.375/21 = 0.8$, and referring to the table above, calls for a feed source with a 40-degree beamwidth at the 3-dB-down points. This is indeed amazing, as an unmodified Gunnplexer with horn antenna has a 30-40 degree beamwidth at the 3-dB-down points, thus giving us a near-perfect match.

Selecting A 96-inch (244 cm) Diameter Parabolic Dish f/D and Feed System

Numerous options of f/D ratios were printed out earlier in this chapter. If ease of feed were the only consideration, we'd logically choose the dish with an $f/D = 0.85$, which would be an excellent match to the unmodified Gunnplexer with horn combination, just like the *Snocoaster*. Spacing between the center of this dish and Gunnplexer diode would be $0.85 \times 96 = 81.6$ inches (207 cm), which is not unreasonable. As mentioned earlier, this dish's shallow center depth of 7 inches (179 mm) is a disadvantage in terms of the amount of extra structural support required to keep it from blowing apart in the first thunderstorm.

My choice for f/D ratio of the 96-inch (244 cm) parabolic reflector would be the 0.5-unit for two reasons:

1. The center depth of this reflector is 12 inches (31 cm), which gives a reasonable aspect ratio with which to work. This curvature allows stressed-skin construction to keep down weight and keep external structural braces to a minimum.
2. The 0.5-f/D ratio yields a 48-inch (122 cm) focal length measured from the dish center to the Gunnplexer mixer diode. This is a conveniently short distance and makes mounting the Gunnplexer and weatherproof enclosure an easy task.

Modifying the Gunnplexer Horn Feed

The 65-degree, 3-dB-down beamwidth feed, which the table above calls for with this *f/D* ratio, may be obtained easily by hacksawing off the outer 1-$^{15}/_{16}$-inch (49-mm) rim of the Gunnplexer horn antenna as shown in *Figure 11-4*, or better yet, by constructing the small horn in *Figure 11-5*.

Improved Horn Feed

Slightly improved (almost perfectly even) illumination of the 96-inch (244-cm) diameter parabolic reflector with the 0.5-*f/D* ratio may be obtained by making the flange-mounted horn antenna shown in *Figure 11-5*. It may be constructed from 0.016-inch (0.5-mm) sheet brass using identical construction methods to those given in *Chapter 10* for building the weak-signal-source horn

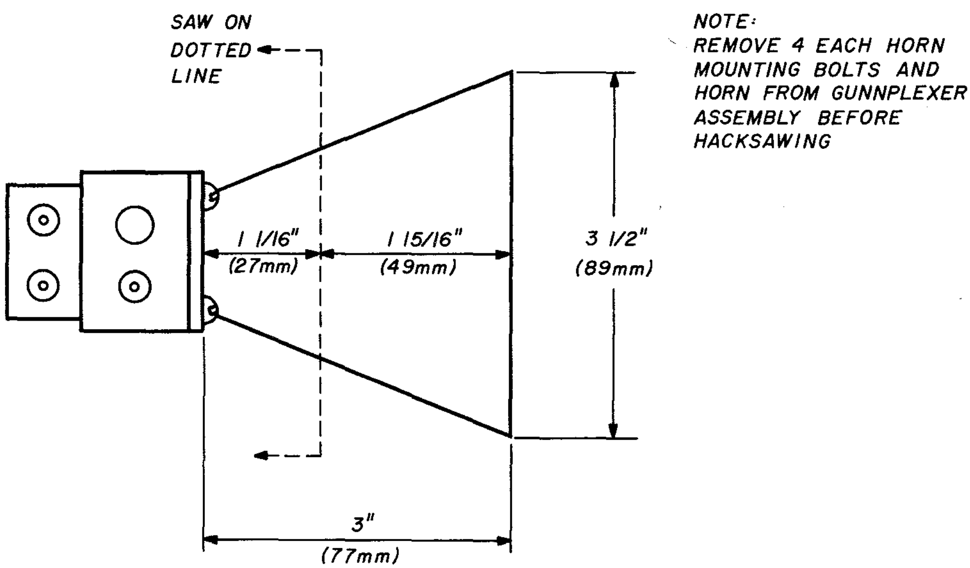


Figure 11-4.

The Gunnplexer horn feed must be modified to obtain the 65-degree, 3-dB-down beamwidth feed for an 0.5 *f/D*. The outer 1-$^{15}/_{16}$-inch (49-mm) rim of the horn is hacksawed off as shown.

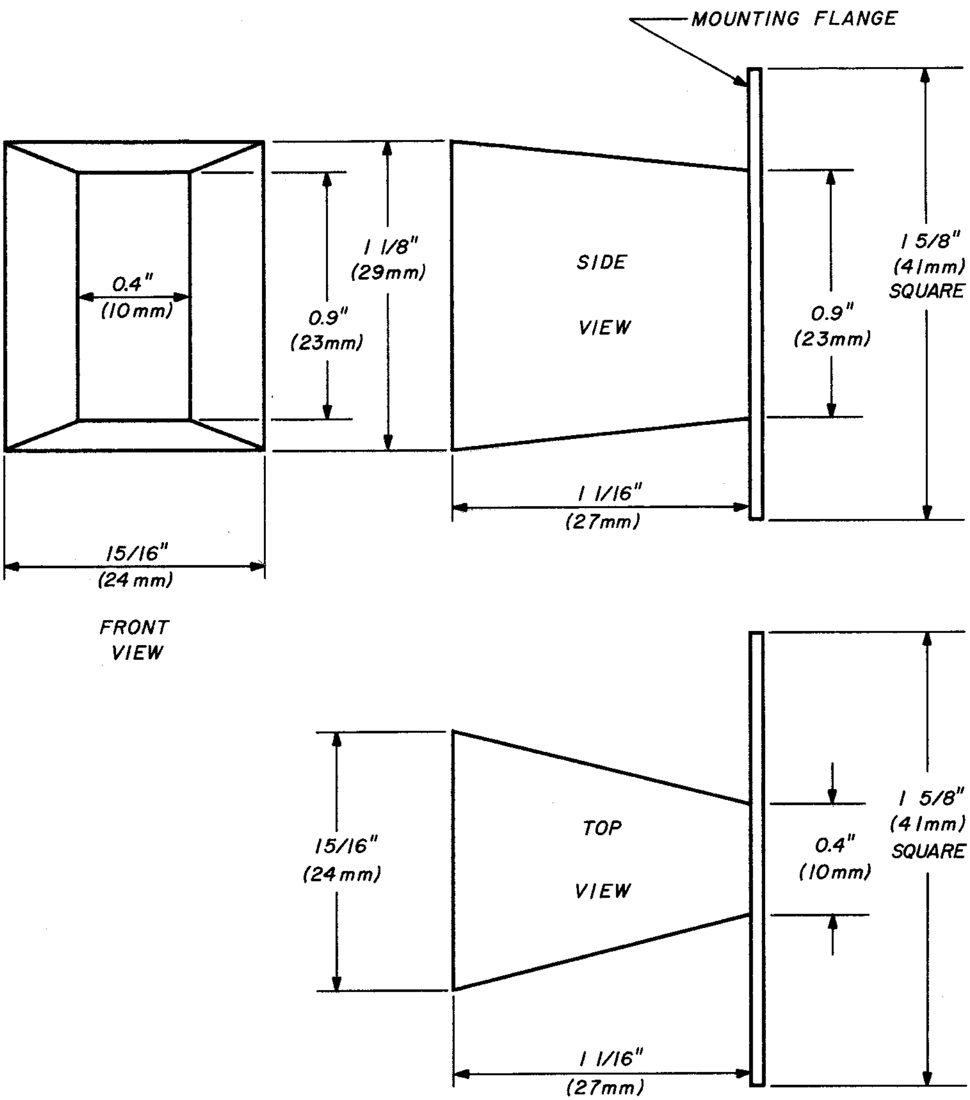


Figure 11-5.

Improved flange-mounted horn antenna that will provide better illumination than the modified Gunnplexer horn in Figure 11-4. This assembly is recommended over the modified version because the reflector will be almost perfectly illuminated in both *E* and *H* planes. An additional 1-2-dB gain will result.

antenna. Its primary advantage over the sawed-off horn in *Figure 11-4* is that the 96-inch (244-cm) parabolic reflector is almost perfectly illuminated in both *E* and *H* planes, which will give an additional 1-2 dB gain.

Anyone making the effort required to construct a parabolic reflector of this size would do well to spend an additional hour or two to build this feed horn rather than use the modified horn in *Figure 11-4.*

The mounting flange should preferably be of 1/16-inch (1.5-mm) or heavier brass to eliminate any tendency to warp while being soldered. The flange opening, 0.4 inch × 0.9 inch (10 × 23 mm) should be a perfect fit with the Gunnplexer module. Use the Gunnplexer horn antenna mounting flange as a template. This horn antenna design is provided by reference 1. This is the feed-horn antenna to be used for the 96-inch (244-cm) fiberglass parabolic dish now under construction.

25-inch (64-cm) Parabolic Reflector Tripod/Mast/ Mount

The world is full of many wonderful things, with a few exceptions. One notable exception is naturally occurring perfect paraboloids made of aluminum with a 25-inch (64-cm) diameter. The Mirro Aluminum Company of Manitowoc, Wisconsin probably has the closest thing to a perfect aluminum 25-inch (64-cm)-diameter parabolic dish that is priced at a level most anyone can afford ($6.00 in 1977). A number of microwave antenna manufacturers offer 24-inch (61-cm) parabolic dishes with a few dB more gain than the *Mirro* dish, but lowest price noted is over $150, which for about 3-dB more gain than *Mirro*'s dish, works out to $50 per dB. That's no bargain at all, so we'll stick to the *Mirro* marvel. (The Mirro 25-inch (64-cm) dishes are sold by both Sears, Roebuck and Company and J.C. Penney stores: Sears, Roebuck and Company catalog 79N85063L, 25-inch Aluminum Coaster, $6.97 (in 1978). J.C. Penney Company catalog 654-003358, 25-inch Snocoaster, $6.99 (in 1978).)

As mentioned earlier, these dishes are almost perfect paraboloids, except for the outer 2-inch (51-mm) radius. Because of this departure from a perfect parabolic curve, it's wise to measure the focal point using a Gunnplexer at 10.250 MHz. To make this measurement we need a stable mount for the dish. That's why we build the mount first.

This tripod mast mount is designed for single-axis azimuth rotation on an antenna rotor mast (but may be modified for elevation rotation too, if desired) and for three-axis adjustment when used with a modestly priced camera tripod.

Materials List for Tripod/Mast Mount

16-inch (41-cm) length of 1 × 3-inch (25.5 × 77 mm) pine

8-½ × 18-inch (22 × 46 cm) sheet of ¼-inch (6.5 mm) thick double-tempered *Masonite*

four ¼ 20 × 1-½ inch (M6 × 38 mm) nuts, bolts, and washers

two 1-½ inch (38 mm) ID *U* bolts for mast mount

six-inch (153-mm) length of yellow pine [1 inch (25.5 mm) diameter broom handle].

ten No. 10 (M5) sheet-metal screws 1-½ inch (38 mm) long and washers

The recommended tripod is a Sears, Roebuck and Company 3HA8465 ($44.95 each). It's Sear's top-of-the-line camera tripod and is sturdy enough to handle the 25-inch (64 cm) dish and Gunnplexer assembly in modestly high winds if each of the tripod legs is well secured to 8-inch (204 mm) cinder blocks (use masonry nails in the cinder blocks and heavy nylon cord to tie down the ends of the tripod legs. Less expensive tripods will work until the first high wind gusts hit the dish.

Building Frame and Mount

The right-hand dish in *Figure 11-6* shows the H-shaped frame and parabolic-reflector mount. For the antenna rotor and mast mount, a 6-inch (153-mm) square piece of ¼-inch (6.5-mm) thick *Masonite* is screwed onto the H-frame rear, with the 1 ½-inch (38-mm) U bolts centered at top and bottom about ¾ inch (19-mm) in from the edges. Mount the 6-inch (153-mm) square *Masonite* plate to the H-frame back, using three no. 10 × ½-inch (M5 × 38-mm) sheet-metal screws on each side. See *Figure 11-7.*

Figure 11-6. Tripod/Mast Mount & 25''D. Parabolic Reflectors
The 25-inch (64-cm) diameter reflectors and their tripod/mast mounts. The mounts are made from a Sears, Roebuck and Company camera tripod. Design will withstand modestly high winds if each tripod leg is secured to concrete blocks.

The H frame is made from two pieces of 1 × 3 × 8-inch (25.5 × 77 × 204 mm) pine cut as shown in *Figure 11-8.* Each of these pieces is notched ½ inch (12.5 mm) deep × ¼-inch (6.5-mm) wide for the center of the H, which is a 3 × 5 inch (77 × 128 mm) piece of *Masonite.* This piece of *Masonite* has a ½-inch (12.5-mm) hole in its center. Mount a ¼-inch (6.5-mm) sheet-metal washer, with a ¼-20 (M6) nut brazed or soldered to the washer, over the hole in the *Masonite.* Use liberal amounts of epoxy. This washer and nut will be used to attach the assembly to the tripod.

The *Masonite* center of the H will have a better grip onto the wood sides of the H if the *Masonite* edges are drilled 1/16-inch (1.5 mm) deep with a 1/16-inch (1.5-mm) diameter drill every ¼ inch

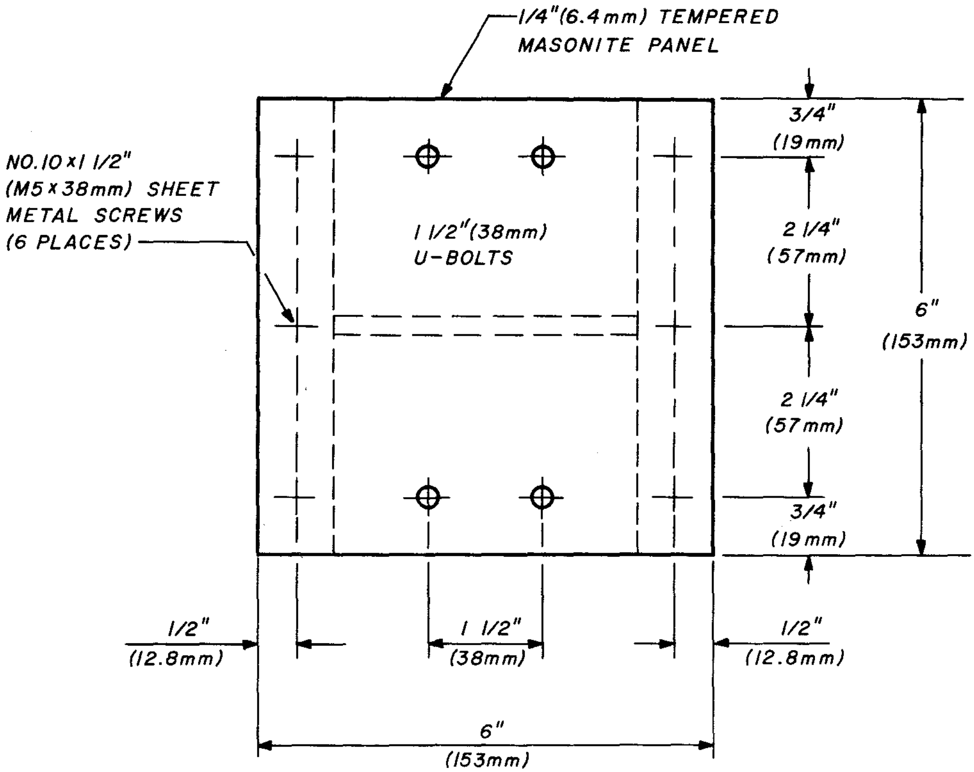


Figure 11-7. Antenna Rotor/Mast Mounting Plate

Details for making the antenna rotor/mast mounting plate for the 25-inch (64-cm) diameter *Snocoaster* parabolic reflectors.

(6.5 mm) or so, before being epoxied. Cut four each 1-inch (25.5-mm) lengths of hard pine broom handle. Drill out the centers with a 9/32 -inch (7-mm) diameter drill.

Now comes the hard part: Hacksaw a 10-degree angle (from either flat end) on each piece; or better yet, sand the 10-degree angle with a belt or disc sander. The reason for this bevel is that we're trying to fit the flat H frame and its plate to the parabolic curve of the 25-inch (64-cm) dish without warping or distorting its surface when we tighten the mounting bolts. See *Figure 11-9.* The 10-degree beveled edge of the broom handle spacers goes against the *Masonite* mounting plate, not against the dish.

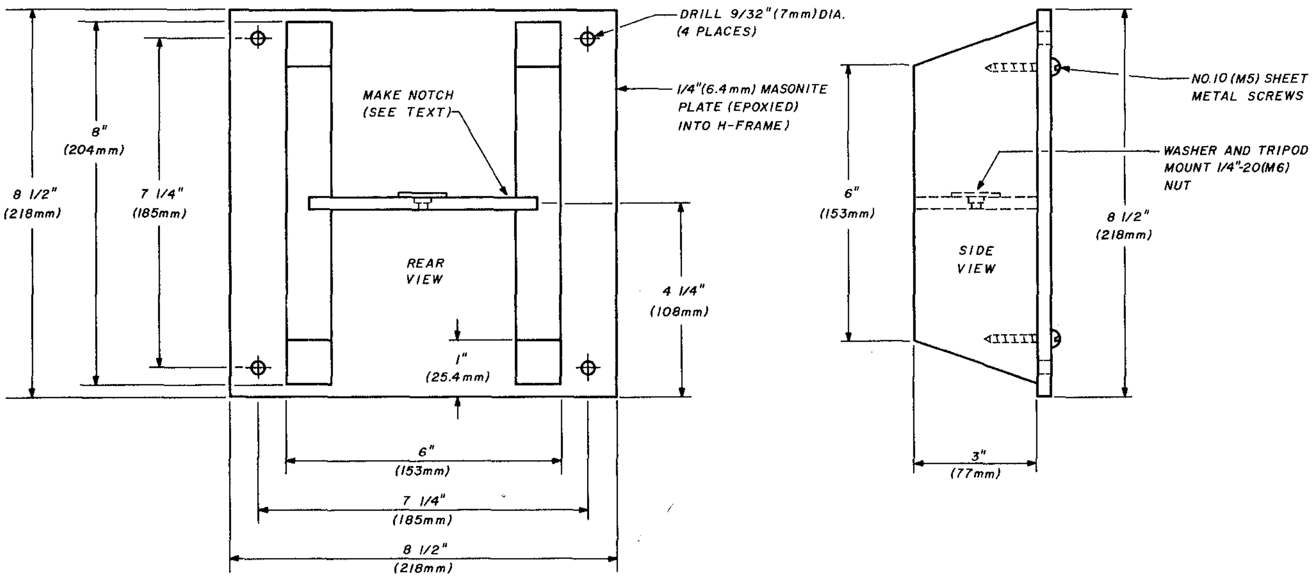


Figure 11-8.
Construction details for the *H* frame and plate, which is used for the 25-inch (64-cm) diameter dish.

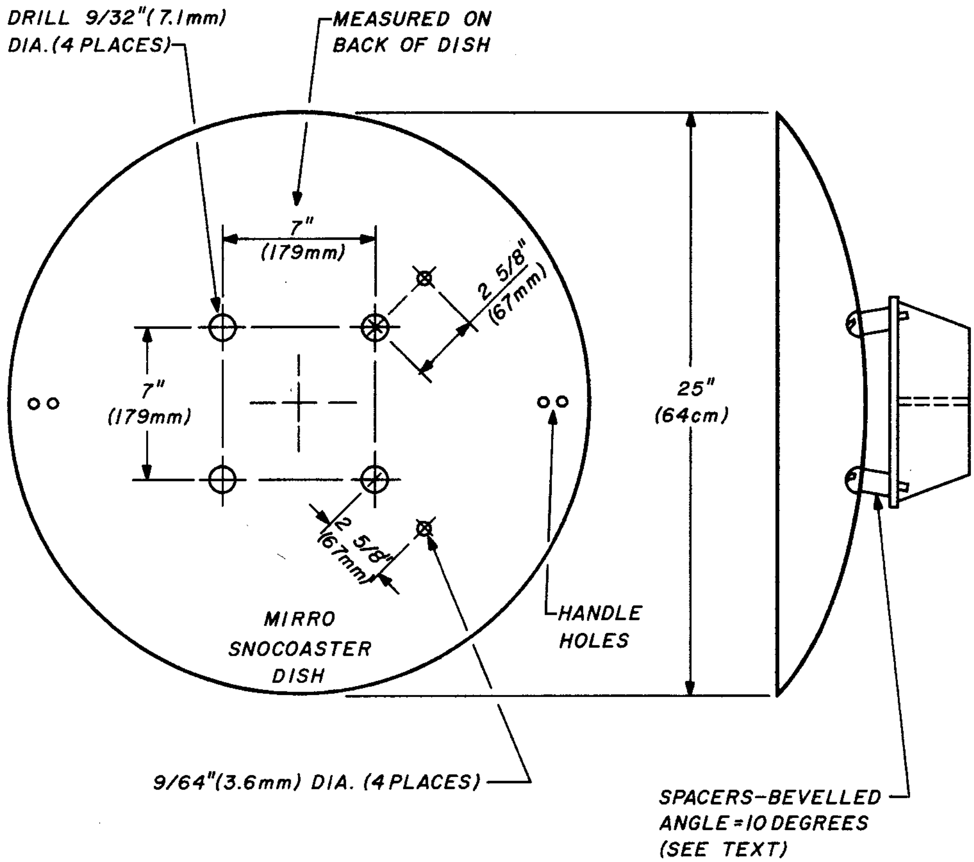


Figure 11-9.
Details for the 25-inch (63-cm) diameter dish mounting spacers.

The easiest way to lay out the points for drilling the four dish-mounting holes is to draw a line between the *Snocoaster's* hand-hold holes on each side of the dish. Drill out the rivets. Use a piece of straight ¼-inch (6.4-mm) thick lath as a ruler since it will bend to fit the dish curve.

Draw the line on the back of the dish. Then, with a plastic square, lay out a perpendicular line from the center of the dish on each side of center that is 3½-inches (89-mm) long upwards and 3½-inches (89-mm) long downward. You will now have a perfect square 7 inches (179 mm) on a side, which is centered on the dish center.

Center punch these points and drill the four mounting holes. Now drill the four 9/64 -inch (3.6-mm) diameter holes for the Gunnplexer standoffs. Using the lath as a ruler layout a line from the center of the dish that passes through the center of each hole just drilled. Mark a point 2-5/8-inches (67-mm) outward past each hole center. Center punch and drill a 9/64 -inch (3.6-mm) hole for the Gunnplexer enclosure standoff mounting bolts. Assemble the dish and mount. Make sure that the spacer beveled angles are positioned as shown in *Figure 11-9.*

Measuring Focal Point of the 25-inch (64-cm) Snocoaster Parabolic Dish

I assume you've built at least one of the Level I Communication Systems presented in *Chapter 9* and either have another Gunnplexer or have built the weak-signal source in *Chapter 10* to furnish a 10-GHz signal. We'll now set up a mini 10-GHz antenna range and physically vary the distance of our Gunnplexer receiver in its enclosure from the 25-inch (64-cm) parabolic reflector to determine empirically the dish focal point.

The mini antenna range shown in *Figure 11-10* can be assembled and set up in a few minutes. The test bed for sliding the Gunnplexer assembly back and forth is nothing more than two 2 × 4 pieces of lumber about 2-3 feet (0.6-0.9 meter) high that are pounded into the ground, with a piece of 3-foot (0.9-meter) long 2 × 4 lumber nailed on top.

Adjust the tripod height so that the center of the Gunnplexer horn antenna is dead center with the 25-inch (64-cm) dish reflector. Square everything so that it's either level or on a true vertical. The signal source should be located 100-200 feet (30-60 meters) in front of the dish. The less obstructions around the better, as we want to measure the direct signal and not a multi-path signal from the signal source. Typical S-meter readings *versus* distance of the Gunnplexer enclosure face from the center of the parabolic dish are shown below on the first run:

spacing inches	(mm)	S reading (dB over S9)
7	(179)	20
8	(204)	28
9	(230)	27
10	(255)	42
11	(281)	36
12	(306)	29
13	(332)	48
14	(357)	47
15	(383)	43
16	(408)	48
17	(434)	46
18	(459)	44
19	(485)	44
20	(510)	45
21	(536)	46
22	(561)	46
30	(765)	39
34	(867)	38

In this first run three peaks occurred at 13, 16, and 21-22 inches (352, 408, and 536-561 mm). The latter peaks were caused by multipath propagation. The signal source was moved further away for lower readings. An average of these runs is:

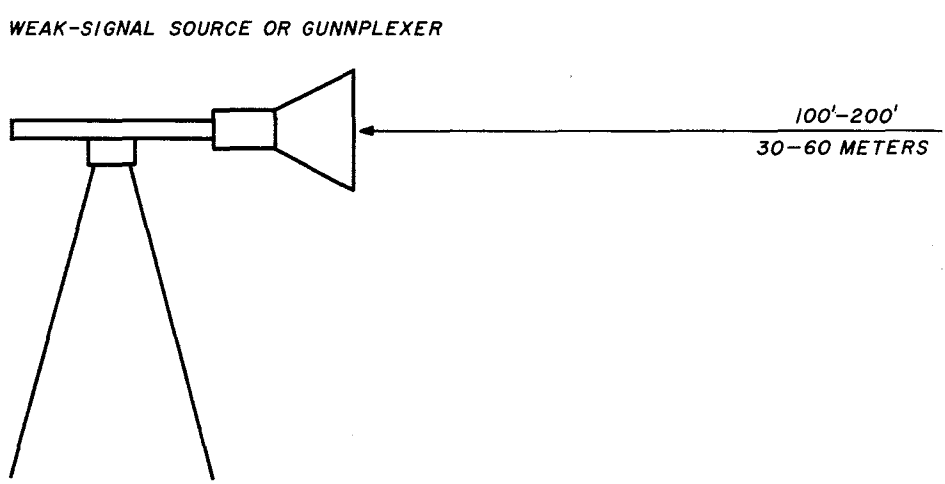
spacing inches	(mm)	S reading (dB over S9)
12 7/8	(328)	0
12 15/16	(330)	2
13	(332)	13
13 1/16	(333)	5
13 1/8	(335)	0
16 3/8	(418)	0
16 7/16	(419)	5
16 1/2	(421)	12
16 9/16	(422)	3
16 5/8	(424)	0

The 13 dB over S9 at 13-inch (332-mm) spacing was the most consistent high reading, with the second-place winner being at

16½-inch (421-mm) spacing, which was usually 1-2 dB down from the 13-inch (332-mm) number. The latter spacing from the face of the Gunnplexer enclosure to the center of the dish is my favorite not only because of its apparent 1-2-dB gain advantage, but because it also makes the Gunnplexer assembly tied to the 25-inch (64-cm) dish less unwieldly with better balance than the 16½-inch (421-mm) spacing. Not all *Snocoaster* parabolic dishes have exactly the same parabolic curve, so it's wise to measure the focal length of each separately. It takes only a few minutes once you're set up.

Gunnplexer Standoffs for the 25-inch (64-cm) Parabolic Dish

Most every hardware store stocks hardwood dowels from ¼-inch (6.4-mm) diameter and up. I chose the ⅜-inch (9.5-mm) diameter dowels two years ago for my 13-inch (332-mm-spaced Gunnplexer and 16½-inch (421-mm) spaced Gunnplexer enclosure standoff dowels illustrated in *Figure 11-11.* Both have withstood the test of



time (with three coats of white *Hobbypoxy* on them) without significant warping or bending. I recommend the ½-inch (12.5-mm) diameter dowels for standoff supports. Dimensions for the 13-inch (332-mm) long standoffs are given in *Figure 11-12.*

Making the Dowel Standoffs

1. Use a coping or jig saw to quarter the first 6-⅞ inches (175 mm) of each standoff dowel as shown in **B** of *Figure 11-12.* Remove one of the quarters with an *Exacto* knife or thin-blade pocket knife.
2. Cement the remaining three quarters of the dowel back together with 5-minute epoxy. Drill three ⅛-inch (3-mm) diameter mounting holes as shown.
3. Carefully drill the other end of the rod 1-inch (25.5-mm) deep using a no. 28 (3.6-mm) drill. Coat 1 inch (25.5 mm) of a 2-inch (51-mm) length of 6-32 (M 3.5) threaded rod with 5-minute epoxy.

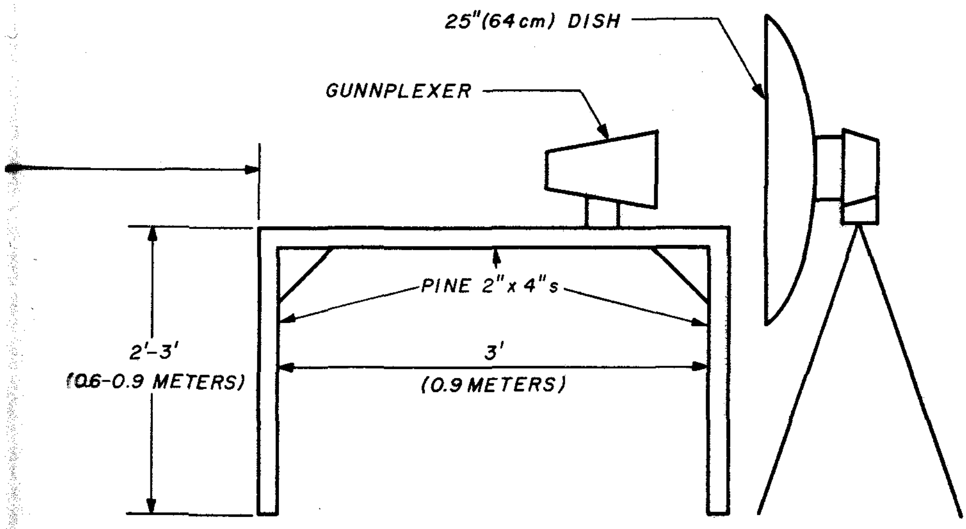


Figure 11-10. Mini-Antenna Range To Measure Dish's Focal Length
A mini antenna range layout for measuring dish focal length.

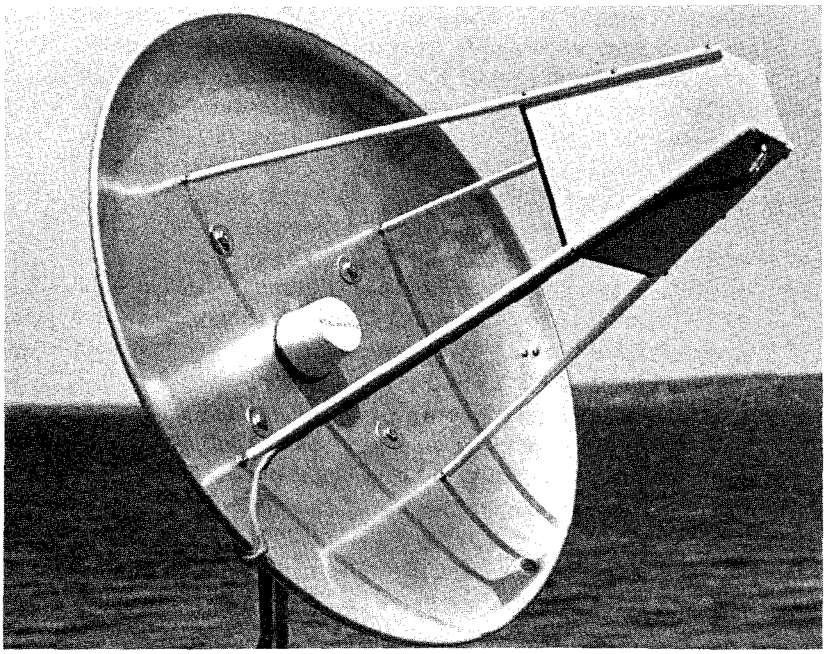


Figure 11-11. Detail View-GPX Enclosure & Standoff Dowels
Close-up of the Gunnplexer enclosure and standoff dowel assembly.

4. Apply a few drops of epoxy on the hole in the end of the dowel and quickly insert the threaded rod into the dowel. Let the epoxy harden overnight.
5. Give each dowel rod two or three coats of *Hobbypoxy* white epoxy coating for a good weatherproof finish. (Equivalent coating material may be used.)

Final Assembly

1. Place each standoff dowel rod on each mounting edge of the Gunnplexer enclosure. Use a sharp nail to make a mark on the Gunnplexer enclosure edge for the mounting-screw holes.
2. Drill each of these marks through with a no. 52 (1.6-mm) diameter drill at a 45-degree angle.

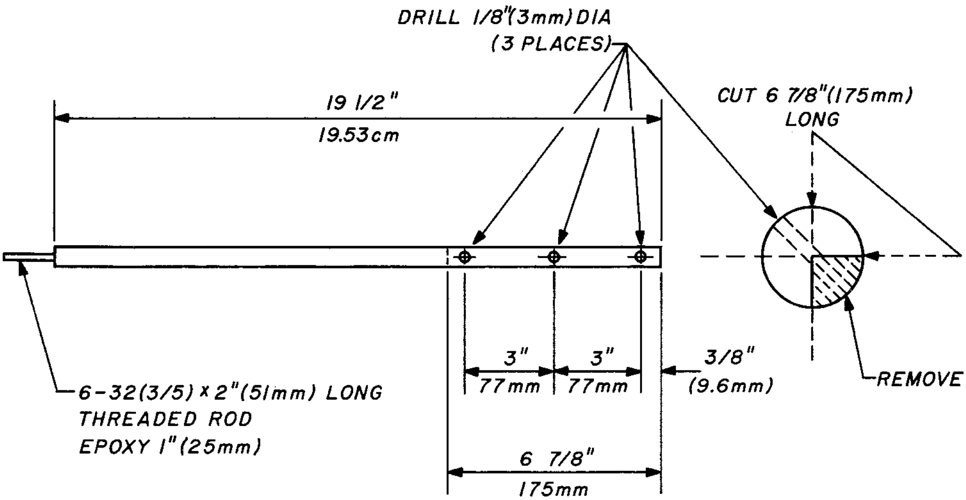


Figure 11-12.
Construction details for the standoff dowels (25-inch or 64-cm diameter parabolic dish).

3. Apply a few drops of cyanoacrylate (*Magic Glue*) into each of the 12 holes. Let set for an hour.
4. Mount the four standoff dowels to the enclosure with no. 4 sheet-metal screws by ½-inch (12.5-mm) long.
5. Run a 6-32 (M3.5) nut all the way up each threaded rod. Using small washers, install the Gunnplexer enclosure with its standoffs on the *Snocoaster* dish. Adjust so that the face of the Gunnplexer enclosure is exactly 13.0 inches (33 cm) away from the center of the dish. Make sure that each standoff is *exactly* the same length so that the Gunnplexer is truly centered on the dish face.

Building a 96-inch (244-cm) Diameter Fiberglass Parabolic Reflector

This section is only a brief synopsis of the subject, as it was originally planned to be included in *Volume II* of the Gunnplexer

Cookbook. Nevertheless, after many phone calls and letters from friends who knew I was designing and beginning construction of a 96-inch (244-cm) diameter dish for 10 GHz, I decided to include this short section in Volume I, which may give you some food for thought on the subject.

Very few microwave buffs comprehend the enormous size of a 96-inch (244-cm) diameter parabolic reflector. (That's 8 feet, or 2.4 meters!) We're used to thinking of a 96-inch (244-cm) long 2-meter Yagi antenna as rather small, which indeed it is. The following facts may give you some perspective on the subject; they're not meant to scare you away from the task of building such an antenna, but possibly they'll provide you with some design and construction ideas that you'll improve upon when building your own big dish.

Wind Loading

We will consider the reflector from the aerodynamic viewpoint as a flat plate when calculating wind loads. When wind direction is toward the rear of the dish, loading is slightly less. When the wind is 90 degrees to the plane of the dish, wind loading is only a fraction. But let's consider the worst-case condition because if it can happen, it will.

Drag (loading) increases as the square of the (wind) velocity. As such, every time velocity doubles, drag increases four times:

wind/gust velocity		**loading**	
mph	**(km/h)**	**pounds**	**(kg)**
12	(19)	273	(123)
25	(40)	1092	(491)
50	(80)	4368	(1966)
100	(160)	17472	(7862)

The average summertime thunderstorm often has horizontal peak gust velocities in the 50-70 mph (80-112 km/h) ballpark at the surface, so we're looking at peak loads on the 96-inch (244-cm) diameter reflector of well over 2 tons (1816 kg), and that's a bunch. If we were dealing only with a propellor on a wind generator, we could feather it, brake it to a stop, or fold it back when wind velocity exceeded a preset limit. It's very difficult to brake a large parabolic dish to a stop, so let's look at our options:

1. The dish could indeed be feathered by turning it so the face is vertically up or down, but this isn't easy.
2. Dismantle it and simply not use it except in calm air.
3. Mount it flush against a building, although it's not very easy to turn buildings.
4. Build it strong enough to take 50-70 mph (80-112-km/h) gust loads and mount it on a well-guyed and strong tower.
5. Build it strong enough to take 50-70 mph (80-112-km/h) gust loads, but mount it close to the ground and use multiple external braces and supports that can be moved when either azimuth or elevation must be changed.

I chose option 5 because it's easiest to implement and allows a relatively light weight dish to be built.

Construction Options

Here again are a number of options:

1. Use an existing 96-inch (244-cm) diameter parabolic dish for the mold. I don't have one, so this is out.
2. Make a sand mold, as briefly outlined in the RSGB *VHF/UHF Manual*. This would probably work for lower microwave frequencies, but 1/16 -inch (1.5-mm) accuracy for 10 GHz would be difficult.
3. Make a 90-degree plywood/screen/parging plaster mold and build one ¼ section of the parabola at a time.

Option 3 is my own idea so I like it best. (Same basic system used by WB6IOM in 1968 to build a 16-foot dish for 1296-MHz moonbounce; see *ham radio*, August, 1969, page 8.) It's the easiest solution that will yield a dish of ± 1/16 inch (±1.5 mm) accuracy, which we need at 10.250 GHz.

The 96-inch (244-cm) Diameter Dish Design

Figures 11-13 and *11-14* show the dish design. The rear view shows the four 90-degree segments assembled. Both edge spars of each segment were made of 5 to 9 ply by ½ -inch (12.5-mm) thick marine plywood (shaded areas, *Figure 11-13*). The 90-degree mold was made of plywood ribs, shaped to an approximate 0.5 *f*/ *D*-ratio parabolic curve, that radiate outward from the center. The ribs were covered with hardware cloth and fine screen. They were well braced to prevent flexing. Parging plaster was then carefully built up on the screen-mesh assembly until a 90-degree plywood female parabolic curve could be smoothly rotated over the mold with virtually zero clearance. Thus I had a near-perfect male mold with less than 1⁄16 -inch (1.5-mm) error. Also, because the mold was only one-quarter revolution of the paraboloid, the mold maker (me) was less likely to run out of patience and do a sloppy job.

Construction Procedures

When everything looks and measures perfectly, proceed as follows.

1. Apply a separator coat to the male mold. It should look glass smooth, such as a telescope lens.
2. Next, apply the gel coat. When set, use epoxy to apply narrow strips of perforated *Reynolds Wrap* (aluminum foil) that has been acid etched on both sides for good chemical bond.
3. Use a squeegie to form the *Reynolds Wrap* absolutely flush with the gel coat, allowing about ¾-inch (19-mm) overlap of each foil strip.
4. Use layers of heavy fiberglass cloth and resin to build up to ⅜-inch (9.5-mm) thickness. These parts are tied into the rear supports.

The dotted lines in *Figure 11-14* are for an extra center spar in each of the 90-degree segments and are not shown. Also not shown is the 1-inch thick by 3-inch (25.5 by 77-mm) high laminated rim of the dish that surrounds each segment. It is made

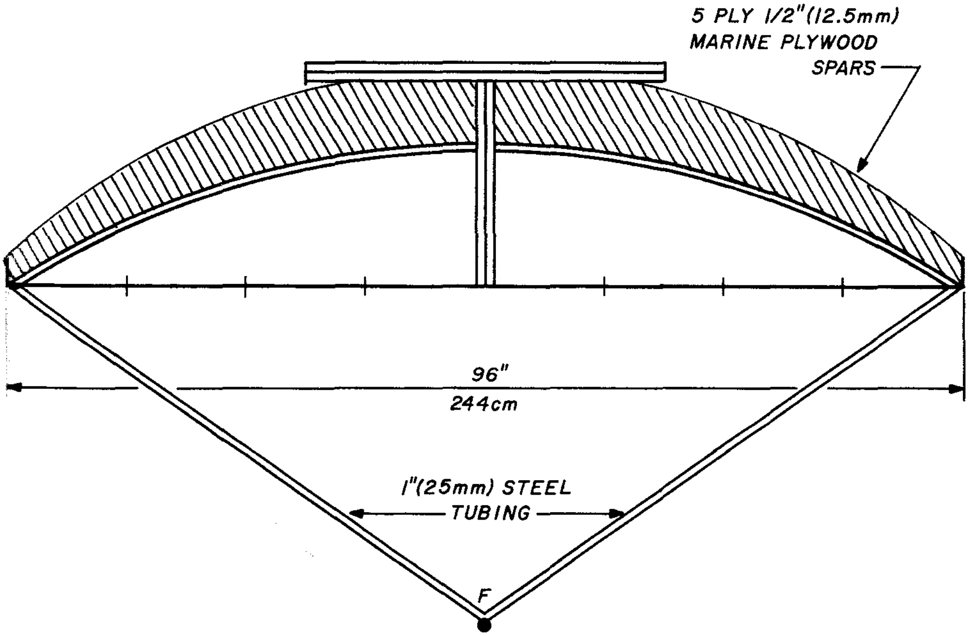


Figure 11-13.
Side view of a 96-inch (244-cm) diameter fiberglass parabolic reflector; perforated household aluminum forms the conducting surface on this design.

from 3 ply ⅛-inch (3-mm) thick birch aircraft plywood. It, too, is tied into the structure with fiberglass cloth and resin.

This brief synopsis of Volume II's chapter on building a 96-inch (294-cm) diameter fiberglass parabolic dish should give you some ideas for your own design. *Volume II* contains photos and drawings of each step for both the parabolic dish and moveable mount.

Homebrew Alignment System and Techniques

Using the Sears 3HA8465 camera tripod, we'll build a simple surveyor's transit that will allow alignment of a narrow-beam-width parabolic antenna to a true heading of about ±0.2 degree.

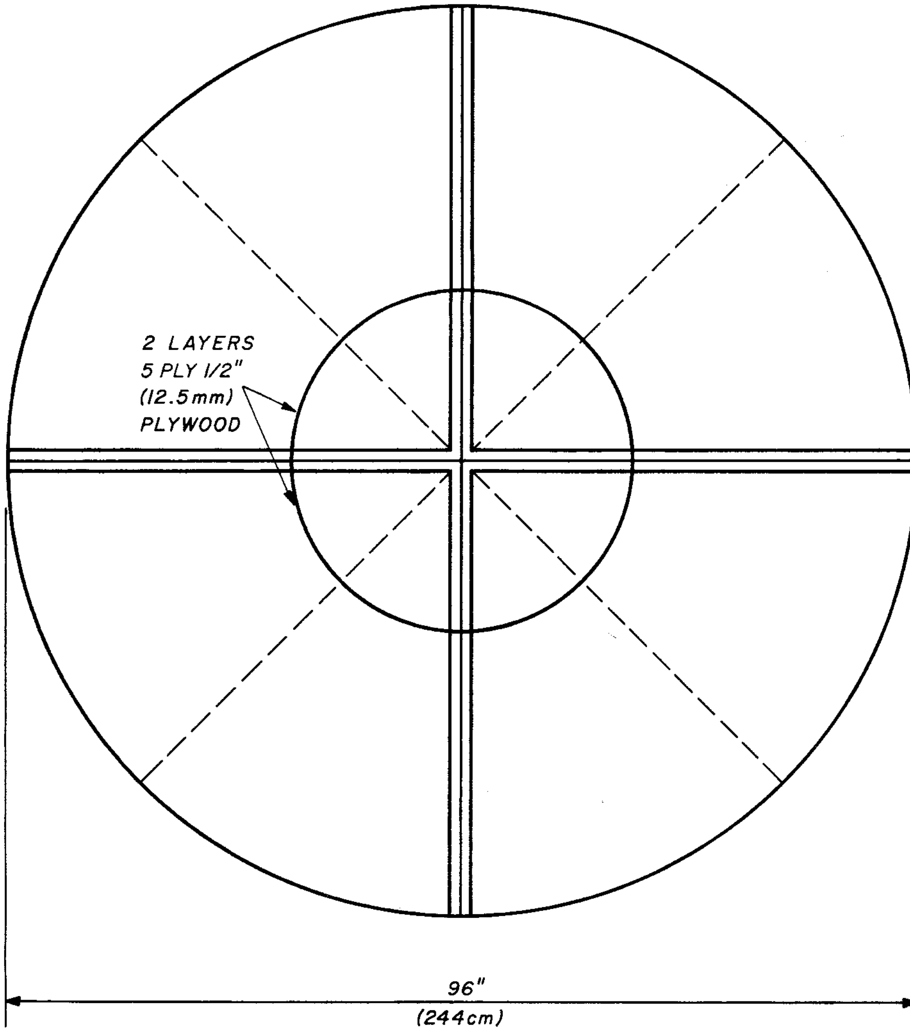


Figure 11-14.

Rear of the 96-inch (244-cm) diameter parabolic dish made of Reynolds Wrap household aluminum foil applied to a homebrew parabolic dish made of plywood. Dotted lines represent extra spars in the 90-degree segments of the dish. Materials are available in most hardware stores.

Construction Procedures

1. Purchase an inexpensive steel tape measure replacement insert.
2. Using a sabre saw, carefully cut out a 14- 11/32 -inch (36-cm) diameter disc from 1/4-inch (6.5 mm) exterior grade plywood.
3. Drill exact center of the disc 1/4-inch (6.5-mm) diameter and insert a 1/4-20 (M7) by 1½-inch (26-mm) long bolt through the hole. Use 1-inch + OD fender/body washers on each side. Firmly tighten nut.
4. Put bolt at center of plywood disc into heavy-duty drill or drill press. With disc turning, carefully sand off 1/64 inch to 1/32 inch (0.5-1 mm) with stationary sanding block. Stop every minute or so and measure disc circumference with steel tape. When circumference equals exactly 45 inches (114 cm), stop sanding.
5. Rubber cement white bond paper onto plywood disc face.
6. Cut off tape measure at 45 inches (114 cm). Temporarily Scotch-tape the steel tape to the plywood disc circumference with markings on the inside just a hair above the edge so you can see the 1/8-inch (3-mm) division lines. 8 × 45 = 360. Hence, every 1/8-inch (3 mm) mark equals 1 degree.
7. Mark all 360 degree marks around disc circumference and draw lines with a straight edge to each 10-degree mark. Number the 10-degree marks accordingly.
8. Redrill the plywood center 15/16 inch (12 mm) diameter. Press fit and epoxy a 1/4-20 (M7) nut exactly into center of hole.
9. Drill the center of the 1/4-20 (M7) bolt on the tripod mounting plate 1/16 inch (1.5 mm) deep with no. 60 (1 mm) drill. Be sure to center punch first.
10. Make up a balsawood/plywood U-shaped cradle about 10 to 12 inches (25-30 cm) long to firmly hold a low-cost 4 to 6 power 3/4 -inch (19-mm) 0.22 caliber rifle telescopic sight.
11. Epoxy the small pointed end of a nail exactly into the bottom center of the scope cradle so that it just barely fits into the tripod mounting bolt hole drilled in step 9.

12. Epoxy piano wire pointers about 1-2 inches (25.5-51 mm) long into the bottom front and rear centers of the scope cradle so that the total length from end to end is 14 9/32 inches (37.3 cm). With the scope cradle center nail just into the tripod, mount the mounting bolt. Pointers should indicate exactly 180 degrees difference when aligned.
13. Make a plumb bob from a heavy weight and attach it to the bottom of the center tripod post center.

Alignment Techniques

I assume you'll place your homebrew transit at the exact spot (in the horizontal plane) where the center of the front face of your parabolic dish will be located. A few feet of error will have negligible effect if you set the bench marks listed below at least 100 feet (30.5 meters) away. The further away the better.

1. With the plywood azimuth disc bolted onto the tripod, level the disc using a carpenter's level by adjusting the tripod's leg lengths. Rotate the disc and level ±90 degrees and keep adjusting the legs until you have a true level; (the tripod mounting head must be perpendicular to the tripod axis of azimuth rotation).
2. Wait for a clear night, then center Polaris, the north star, in your scope sight.
3. Next day drive a stake into the ground 100 feet (30.5 meters) or so away for a *true-north* benchmark.
4. With the scope on your true-north benchmark, adjust the plywood disc azimuth/compass rose so that front and rear piano-wire pointers read exactly zero and 180 degrees respectively. Now tighten the locking nut so that the plywood azimuth table is locked on exactly onto true north.
5. Carefully rotate scope and cradle to the desired true heading, keeping the bottom nail in the cradle centered on the top of the tripod mounting bolt.
6. Have a friend drive a benchmark stake about 100 feet (30.5 meters) away from you to mark the *desired* true heading.

7. Install the parabolic dish and Gunnplexer assembly. Align using the weak-signal source and procedure described in *Chapter 10*.

That's about all there is to it. You now have the capability of aligning your narrowbeam dish to an accuracy of about 0.2 degree true heading, assuming you can visually divide the ⅛-inch (3-mm) 1-degree markers into five parts. Either aeronautical sectional charts (large scale) or regional charts (medium scale), may be ordered from U.S. Coast & Geodetic Survey, Washington, D.C.

This isn't a navigation course, merely a Gunnplexer Cookbook, so I won't go into the intricacies of navigation. With either of the above charts (you may glue as many as you wish together to cover the distance desired), you can easily determine the true heading from your Gunnplexer location to any point in the western hemisphere. If you plan to work greater distances, use a globe.

Reference

1. Dain Evans, G3RPE, *et al*, *VHF/UHF Manual*, 3rd edition, Radio Society of Great Britain, London.

12

Crystalmatic Phaselock System

Simple and reliable circuit to phase lock the Gunnplexer diode oscillator output to a harmonic of a low-frequency crystal oscillator. Minimizing Gunn-diode oscillator noise. The phase-lock system. *Crystalmatic* frequency multiplier and antenna. Tuning procedures. A modulator for the *Crystalmatic* system.

The primary objective of this chapter is to develop an easy-to-build, simple, and reliable circuit that will a) phase lock the Gunnplexer's oscillator output to a harmonic of a low-frequency crystal oscillator and b) virtually eliminate close-in Gunn diode fm spectral noise. There are many ways to accomplish the objective with either digital or analog circuitry that has been around for many years. An important consideration is that the Gunnplexer oscillator/mixer module not be cobbled-up, hack-sawed or machined in the process, as most Gunnplexer users don't have machine-shop facilities. A system has been developed that meets the objectives within the set limits. The system operates just as well, and in some cases better than, custom Gunnplexer systems in the over-$1000 price class.

Gunn Diode Spectral Noise Review

The end of *Chapter 1* briefly mentioned the spectral noise of a 10-GHz Gunn-diode oscillator. By spectral noise we mean rf output on frequencies other than the desired frequency, or undesired a-m of the carrier, which is a rather straightforward definition. With the Gunnplexer we may ignore a-m noise, as it's usually 110-dB down or more at 100 Hz away from the carrier. Also most residual a-m will be removed by the receiver limiter stages. We'll concentrate on the fm spectral noise between the carrier and 3-kHz out that exhibits 1/f behavior, which is typical of most all semiconductor diodes.

The most common means of minimizing Gunn-diode oscillator noise are to:

1. Adjust the Gunn-diode bias (power-supply) voltage to the frequency turnover point: i.e., the highest frequency output while varying Gunn-diode bias from about 9.5 Vdc to 10.5 Vdc, with varactor voltage constant at 4.0 Vdc.
2. Increase the Gunn-diode cavity Q.
3. Select appropriate Gunn diodes. Diodes from the same slice will exhibit different noise spectra, possibly because of varying quality of the epitaxial material across the slice. The differences may be as high as 10 dB or more.
4. Use pure dc (no ripple) voltage in the Gunn-diode bias supply.

There's little the Gunnplexer user can do about items 2 and 3 above, but it's easy to set the Gunn bias supply at the frequency turnover point to minimize fm noise and to provide zero ripple dc power to the Gunn diode.

The fm noise/carrier two sidebands ratio falls off at about 10-dB per octave from 100-1000 Hz out from the carrier, and about 6-dB per octave thereafter. The region from 100 Hz away from the carrier is of special interest to the narrowband Gunnplexer operator who wishes to use either 170- or 850-Hz FSK for CW or RTTY, or 3-4 kHz deviation for NBFM voice.

Two- or 3-kHz from the Gunn oscillator carrier, the fm noise is atrocious. One kHz from the carrier, the fm noise makes any communications impossible. Now, let's virtually eliminate this noise and get on with truly narrowband 10-GHz communications systems.

The Crystalmatic Phase-Lock System

The reason for the foregoing comments is that the *Crystalmatic* phase-lock system not only provides controlled frequency stability, but also virtually eliminates the fm spectral noise generated by the Gunn oscillator for a few hundred Hz or so from the carrier. Thus, very narrowband fm voice and FSK either CW or RTTY) are practical modes of 10-GHz Gunnplexer communications.

The mechanism that the *Crystalmatic* system uses to accomplish this very significant reduction in fm spectral noise is not fully understood at this time, as the crystal-controlled 10-GHz rf source is not injected into the Gunnplexer at the Gunn-diode oscillator frequency. Rather it is injected on the low-frequency side of the Gunn oscillator carrier at the first i-f difference frequency, which is nearly 100 MHz lower than that of the Gunn oscillator. That is, assuming a Gunn-oscillator output frequency of 10.250 GHz and first i-f of 98 MHz, a *Crystalmatic* injection frequency of 10.152 GHz would result.

Crystalmatic System Noise-Reduction Phenomenon

There is no obvious way that the Gunn diode can operate in the "locked-oscillator" mode 98 MHz from the harmonic injection frequency. Yet this is what appears to occur. The spectral noise disappears, giving a T8-T9 note when the *Crystalmatic* system is turned on.

For example, if part of the Gunn oscillator output is fed to the Gunnplexer mixer and compared with the 10-GHz harmonic of a crystal oscillator; and if fm/pm components are detected; and if the resulting error voltage is amplified and fed back to the Gunnplexer varactor, we'd have a simple AFC loop locking the Gunn-oscillator output to the crystal oscillator.

The Gunn oscillator frequency and stability would be no better nor worse than the crystal 10-GHz harmonic (assuming drift-free converters and a receiver exactly on frequency). The Gunn oscillator, though frequency stabilized, would have the same fm spectral noise. The perplexing paradox is that the *Crystalmatic* system apparently presents us with a free bonus: virtually all the Gunn diode fm spectral noise from a few hundred Hz from the carrier disappears *whenever the Crystalmatic system is turned on.*

As this phenomenon hasn't been previously reported in the literature I have named it the "Chautauqua Effect," for the area where I first observed it during the fall and winter of 1977.

Circuit Description

Figure 12-1 is a simplified block diagram of the *Crystalmatic* phase-lock system. Although the first i-f is 98 MHz, it could just as well have been 111 MHz, 29 MHz, or whatever frequency best meets your requirements.

The *Crystalmatic* phase-lock system illustrated in *Figure 12-1* is similar to that of a classic phase-locked loop except for the method on injecting the crystal's 10.152-GHz harmonic and the method used to modulate the Gunnplexer with very narrowband frequency-shift-keyed RTTY or CW. *Figure 12-2* shows a classic phase-locked loop (PLL) from the ARRL 1976 edition of the *Radio Amateur's Handbook*, page 143, Figure 6-10. In this classic phase-locked loop the voltage-controlled oscillator phase is compared with that of the crystal oscillator in the phase detector. The resulting error voltage is amplified by the dc amplifier, filtered, then fed back to the voltage-controlled oscillator. The error voltage changes the frequency (in the proper direction) until lock is achieved. The filter bandwidth determines the frequency range over which the PLL will stay in lock. It's really a simple servo loop, much like the basic proportional temperature control loop covered in *Chapter 5* and automatic frequency control loops covered in *Chapter 8.*

What To Expect

Let's briefly review what we're trying to accomplish:

1. Absolute frequency control of the Gunnplexer 10-GHz signal, so that Gunnplexer output always equals the 19-MHz crystal 528th harmonic plus the i-f.
2. Frequency stability of the Gunnplexer 10-GHz output signal is always equal to that of the crystal 528th harmonic.

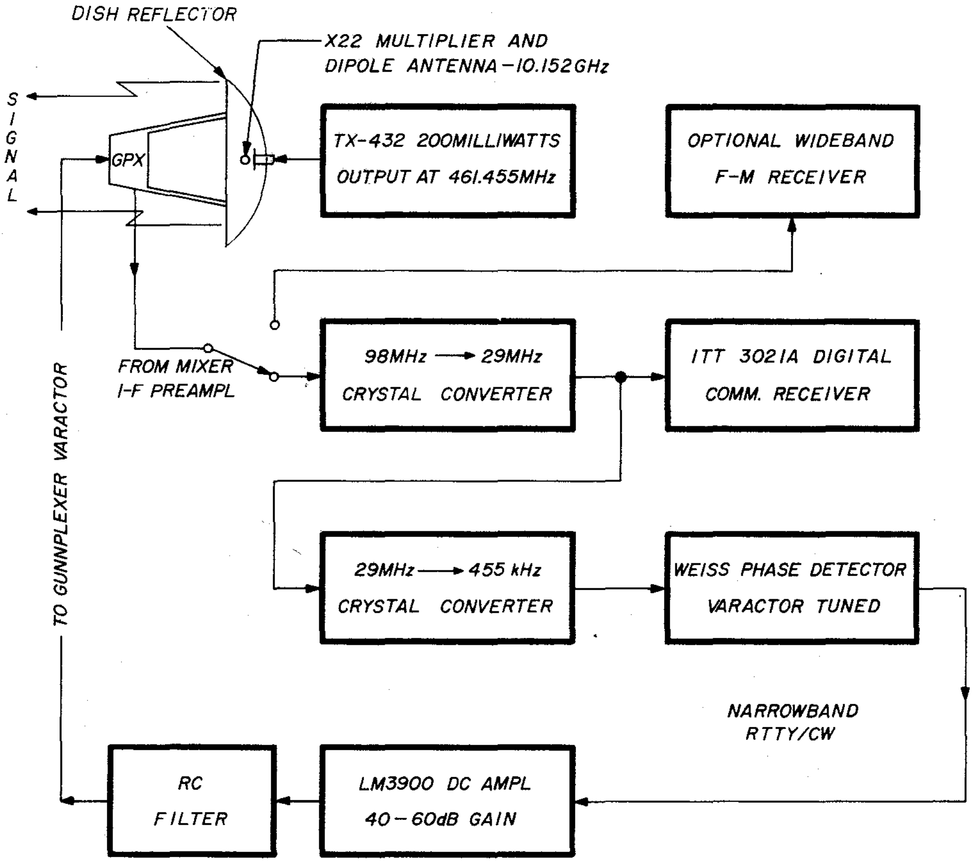


Figure 12-1.

Simplified block diagram of *Crystalmatic* phase lock system. Circuit is similar to that of a phase-locked loop except for the method of injecting the crystal-oscillator 10.152-GHz harmonic and for modulating the Gunnplexer with very narrowband FSK or CW.

3. Reduction, suppression and near elimination of the Gunn oscillator fm spectral noise to allow very narrowband modulation systems to be used at 10 GHz.

Items 1, 2, and 3 are all good; i.e., knowing exactly what frequency we're on, staying there, and using very narrowband

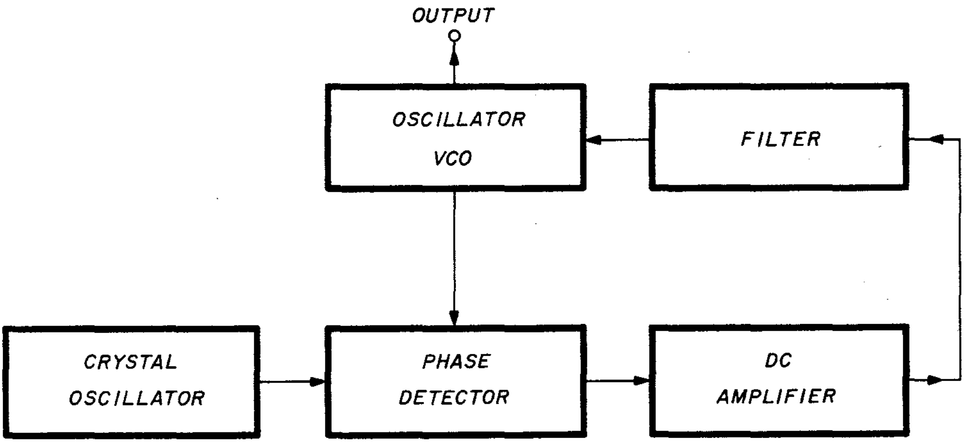


Figure 12-2.
Block diagram of a phase-locked loop (from The *Radio Amateur's Handbook*, 1976 edition, American Radio Relay League, Newington, Connecticut).

modulation to make the most of our milliwatt-level Gunnplexer signal.

The *Crystalmatic* system also provides one more free bonus that's equally as important as items 1 and 2 and allows use of item 3. This operating bonus is that two Gunnplexer stations with *Crystalmatic* may operate the *Crystalmatic* system simultaneously for most efficiency; whereas with the AFC systems covered in *Chapter 8* only one station could have the AFC on at a time to avoid having each AFC chase the other up and down the 10-GHz band. Whether you operate simplex or duplex, this is a significant operating advantage and requires only two crystals for simplex and a single crystal for duplex operation.

Referring to *Figure 12-1*, note that this layout uses a 98-MHz first i-f, (it could have been 111 MHz or any other frequency you wish), thus allowing you to switch from wideband fm with a tunable 88-108-MHz fm receiver (hopefully with Gunnplexer AFC amplifier), over to a narrowband, digitally tuned communications receiver with the *Crystalmatic* phase lock system. You have many other frequency-plan options; i.e., you could go directly from the Gunnplexer mixer-i-f preamp output directly to a 29-MHz receiver and/or converter, skipping over the crystal-controlled 98-MHz converter. *Chapters 13* and *14* cover two options using a 29/30-MHz i-f.

Some of the new monolithic low-noise, very wideband gain blocks, would solve the i-f preamp bandwidth problem, with electronic retuning of the Gunnplexer through its varactor. Two of the Gunnplexers will easily tune 80 to 100 MHz using varactor tuning voltages to 30 Vdc with no problems whatsoever. Volume II treats this subject in much more detail.

The crystal converters-subsystems, in conjunction with the *Crystalmatic* system, use inexpensive kits manufactured by Hamtronics-Rochester and VHF Engineering:

98 MHz-29 MHz	C110 (special 98-MHz crystal) (Hamtronics)
29/30 MHz-10.7 MHz	RF28 (VHF Engineering)
10.7 MHz-455 kHz	IF10B (Hamtronics-Hilton, New York)

Crystalmatic Frequency Multiplier and Antenna Assembly

The *Crystalmatic* phase-lock system is the natural evolution of *Chapter 10*'s crystal-controlled weak-signal source. *Figure 12-3* shows the final evolution of the crystal-controlled frequency multiplier and antenna assembly mounted in the center of a Mirro Corporation T-3580 *Snocoaster* 25-inch (64-cm) diameter aluminum dish, which is described in *Chapter 11*. This multiplier-antenna was soldered as a single assembly including the BNC male plug, reflector, and diode-multiplier. The BNC square chassis-mount connector was bolted into a ⅜-inch (9.5 mm) diameter hole, which was drilled exactly into the center of the parabolic reflector. (*Figures 12-4 and 12-5.*)

Early Experiments

Many different multiplier-antenna combinations were built and tested at the close-in range of 13 inches (33 cm) between the multiplier-antenna combination and the face of the Gunnplexer horn on the parabolic dish. Having worked the horn antenna-multiplier combination (*Figure 12-3*) up to 1 mile (1.6 meters) on NBFM, it wasn't too surprising when either a) the rather strong

10-GHz signal, or b) a reflection from the horn partially blew out the Gunnplexer mixer diode. The next configuration tried was a 7-element Yagi antenna scaled down to 10 GHz (the world's smallest Yagi antenna). It is shown in *Figure 12-6.*

This Yagi configuration also puts out a bodacious signal. For some reason, the partially blown Gunnplexer mixer diode gave up the ghost completely. It seems that the E matching networks (top and bottom views in *Figure 12-7*) produce a much stronger twenty-second harmonic at 10 GHz than either theory or previous experience would have indicated.

One possible explanation for this perplexing "it works too well" syndrome would be that the TX-432 output contains considerably more harmonic energy in the Gigahertz range than expected. After a moment's consideration, one can understand the possibility that the TX-432 final output stage could be tuned as a

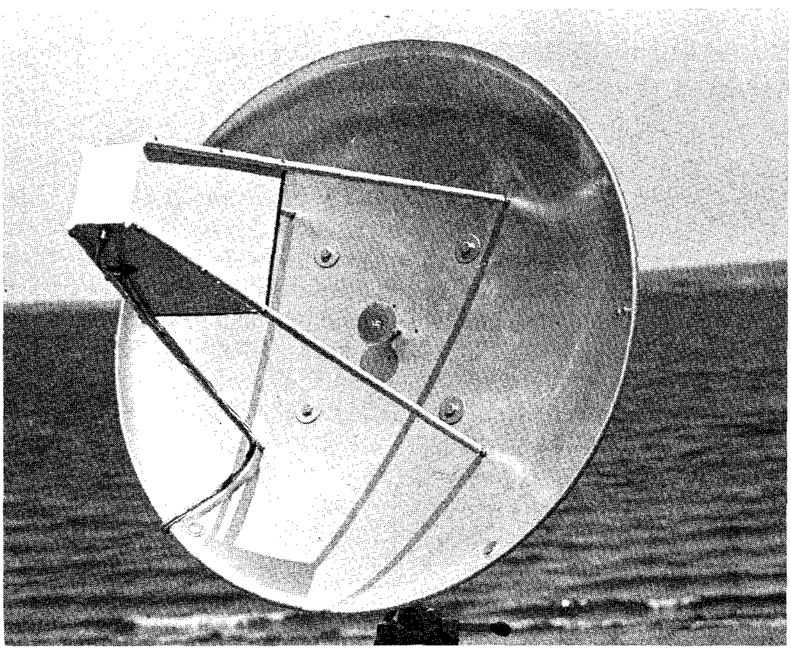


Figure 12-3. Final Version-Crystalmatic Multiplier/Antenna

Final version of the crystal-controlled frequency multiplier and antenna assembly. Dish is a *Snocoaster* toy sled (an aluminum near-parabolic device that works well as a 10-GHz reflector). Reflector construction is described in *Chapter 11*.

frequency doubler to 932 MHz with fair efficiency, as it indeed is running Class C. This would mean that the multiplier-antenna system performed a X11 multiplication, which is not all that difficult. After many years of scrounging around for every microwatt of 10-GHz signal I could find it was a real pleasure, for the first time, to have too much signal.

Simplified Multiplier-Antenna Assembly

The solution to the "too-much 10 GHz signal" problem was to greatly simplify the final version of the multiplier-antenna assembly, as shown in *Figure 12-8.* The E matching network was eliminated entirely, leaving only a male BNC connector, a 1-⅞-inch (26.4-mm) diameter brass reflector, and the 1N21D diode-dipole antenna, which was sort-of "matched" with a 1-inch (25.5-

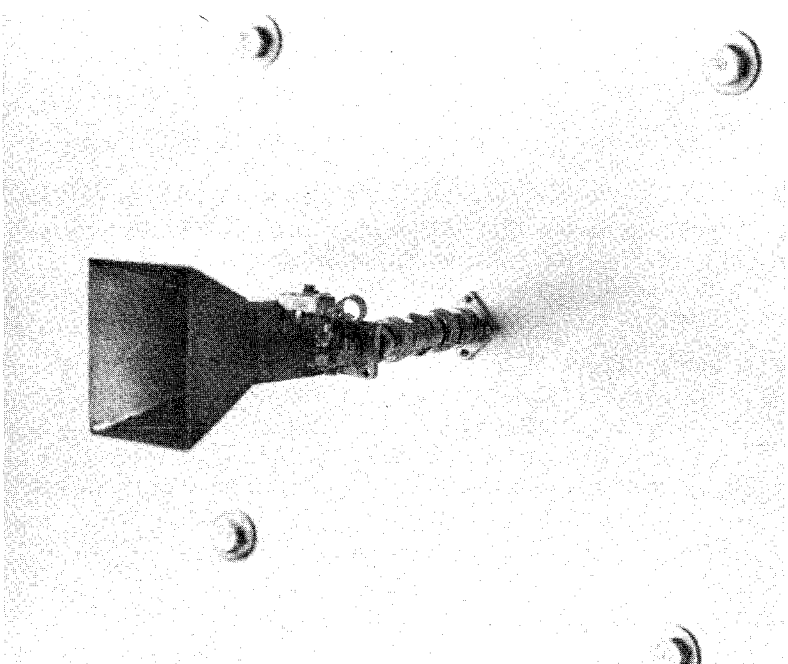


Figure 12-4. Female BNC Chassis Mount Connector In Center of Dish A
Detail of the female BNC chassis-mount connector in the center of the dish.

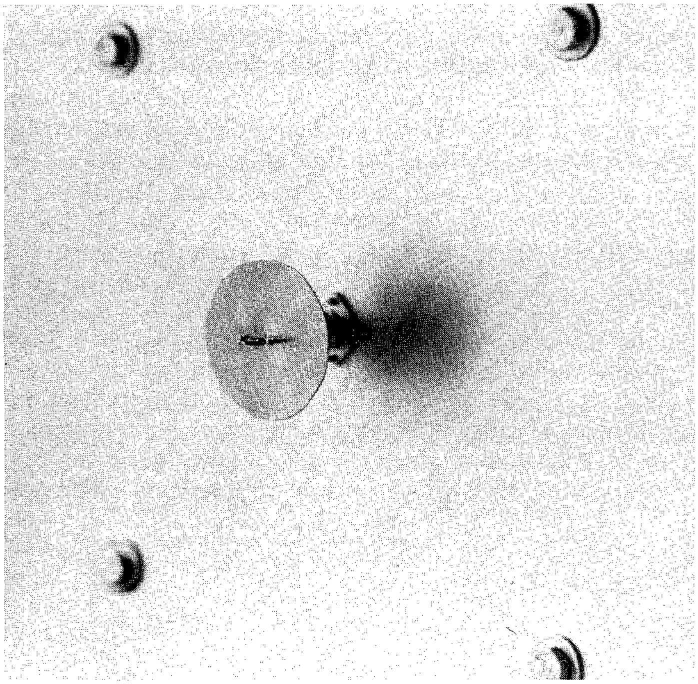


Figure 12-5. Female BNC Chassis Mount Connector In Center of Dish B
Another view of the female BNC chassis-mount connector mounted in the center of the 25-inch (64-cm) diameter aluminum reflector.

mm) length of insulated no. 26 (0.4 mm) hookup wire from an extension of the BNC connector center pin. This configuration also provided a too-strong 10-GHz signal, so power output from the TX-432 was reduced to the 100-200 milliwatt level with a 5-ohm dropping resistor between the +12 Vdc supply and final amplifier.

Crystalmatic Multiplier-Antenna Assembly

Details for building the *Crystalmatic* multiplier antenna arrangement are shown in *Figure 12-8.* Step-by-step instructions are as follows:

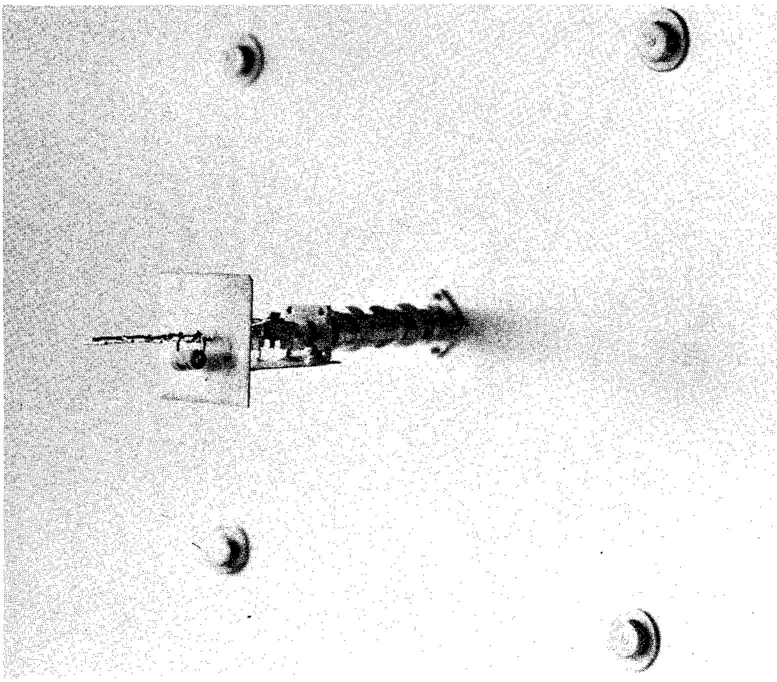


Figure 12-6. 7 Element 10 GHz Yagi Multiplier/Antenna

Seven element, 10-GHz Yagi antenna used in early experiments to illuminate the 25-inch (64-cm) diameter dish made from a *Snocoaster* toy sled. This antenna was used with the E matching networks shown in *Figure 12-7.* A surprising phenomenon occurred, which produced a much stronger twenty-second harmonic at 10 GHz than expected.

1. Scribe a 1-⅞ inch (26.4 mm) diameter circle on 0.016-inch (0.4-mm) sheet brass. Cut out with scissors.
2. Drill two 1⁄16-inch (1.5-mm) diameter holes 9⁄32 inch (7 mm) on each side of center for the 1N21D leads.
3. Unscrew coax end of BNC male connector. File coax end to bare metal and tin.
4. Drill ⅛-inch (3-mm) diameter hole through BNC connector about ¼ inch (6.5 mm) from end, as shown in the side view of *Figure 12-8.*
5. Solder ½-inch (12.5-mm) length of no. 16 (1.3 mm) bus bar wire to BNC center pin.

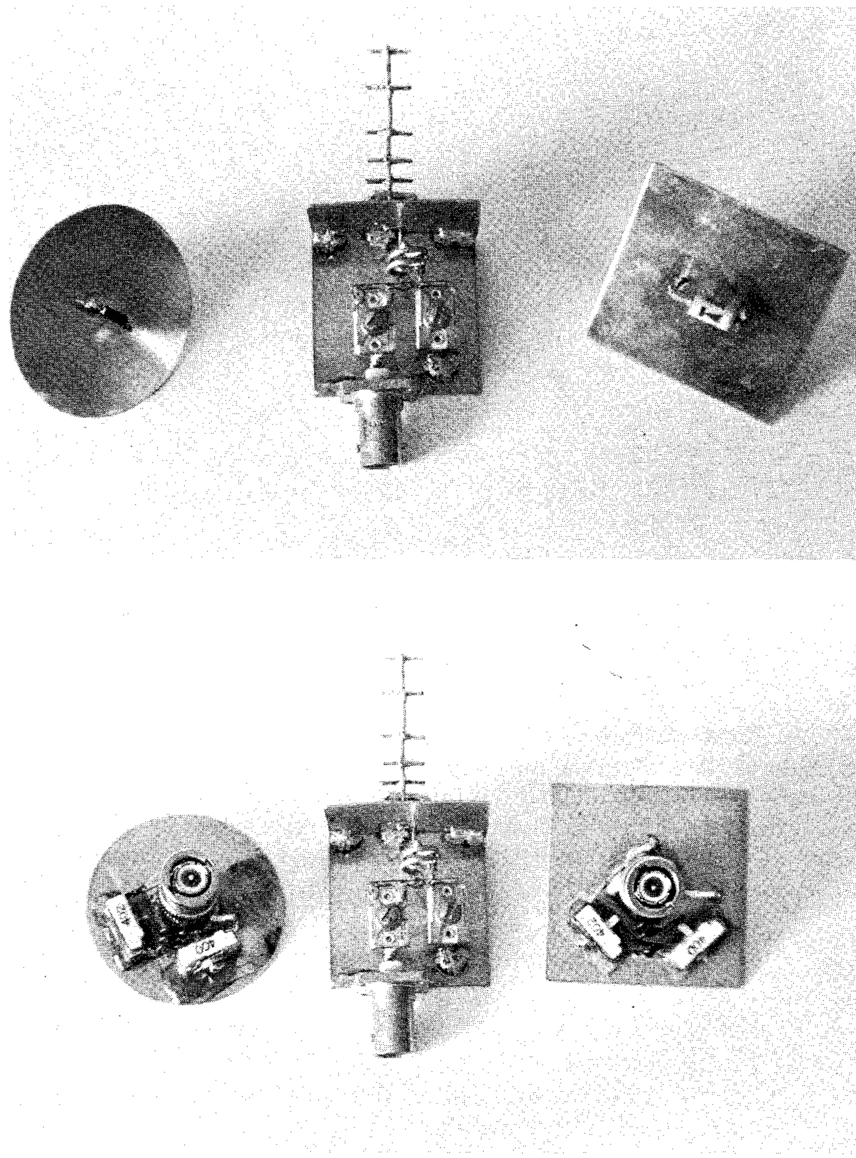


Figure 12-7. Top View-Experimental Multipliers/Antennas — Bottom View-Experimental Multipliers/Antennas

Top and bottom views of the experimental antenna and multiplier configuration used in early tests.

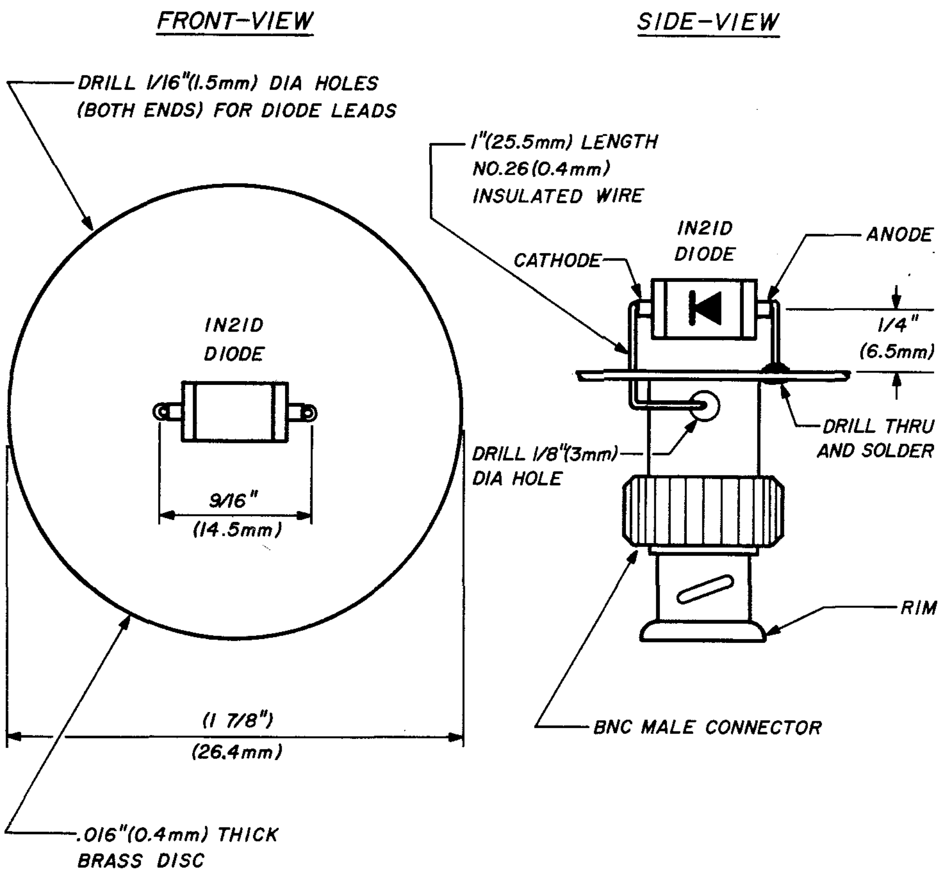


Figure 12-8.

Construction of a simplified version of the multiplier-antenna assembly, which eliminates the E matching network. This is the final version of the *Crystalmatic* system.

6. Insert center pin and wire lead into BNC about 1/16 inch (1.5 mm) short of rim.
7. Solder 1-inch (25.5-mm) length of no. 26 (0.4 mm) teflon insulated wire to top of the BNC center pin wire extension. Bring this insulated wire out the ⅛-inch (3-mm) hole in side of the BNC connector.
8. Fill center of BNC from coax end with 5-minute epoxy to about 1/16 inch (1.5 mm) short of top.

9. Center 0.016-inch (0.4-mm) thick brass disc on coax end of BNC connector and solder with the diode holes 90 degrees to the ⅛-inch (3-mm) diameter hole on the side of the BNC connector.
10. Cut and file each end of the 1N21D diode so that total length, end-to-end, is ½ inch (12.5 mm) with diode holder in center.
11. Quickly solder the 1N21D anode (arrow side) to a ⅜-inch (9.5-mm) length of no. 16 (1.3 mm) bus bar wire. Push the wire through one of the 1/16-inch (1.5-mm) diameter holes in brass reflector. Solder both sides of reflector to this wire so that the 1N21D center is spaced ¼ inch (6.5 mm) away from the reflector. (See *Figure 12-8.*)
12. Run the no. 26 (0.4 mm) teflon insulated wire around the side of the BNC connector 90 degrees, at least ⅛ inch (3 mm) away from the side of the connector, and then up through the 1/16-inch (1.5-mm) diameter unused hole in the reflector to the 1N21D cathode. Solder quickly. With the wires soldered on each end of the 1N21D diode it should measure 9/16 inch (14.5 mm) end-to-end.

TX-432 Tuning with Crystalmatic Multiplier-Antenna Assembly

Adjusting the TX-432 for the optimum 10-GHz injection level by the *Crystalmatic* multiplier-antenna assembly is straight-forward and quite easy. Adjust C26 and C27 on the TX-432 for maximum signal at 10 GHz, as indicated by your Gunnplexer tunable i-f receiver S meter after installing a 5-10-ohm, ½-watt dropping resistor between RFC3 and the +12 Vdc line on the TX-432 PC board. A 10-dB-over-S9 signal is desired, which is rather sensitive to the length of RG-58/U coax between the TX-432 and the multiplier-antenna assembly. For any distance over 50 feet (15 meters) RG-8/U is recommended. RG-58/U at 461 MHz is about as efficient as a wet clothes line.

The 10-dB-over-S9 10-GHz injection signal level is a compromise, in that too much 10-GHz signal will desensitize the Gunnplexer mixer and may introduce cross-modulation products. Too little 10-GHz injection signal will cause the *Crystalmatic* system to lose lock when deviation exceeds 4-5 kHz. (Additional injection level tuneup data are covered in *Chapter 14*.)

Modulating the Crystalmatic System

There are a number of ways to modulate the *Crystalmatic* system while still maintaining lock between the Gunnplexer output and the TX-432 crystal 528th harmonic + i-f. Unfortunately, the simplest way to do it is the most difficult; i.e., use the TX-432 microphone input with either voice or tone modulation and adjust the TX-432 deviation potentiometer for the 10-GHz deviation desired, remembering that the RC filter bandwidth (*Figure 12-1*) on the output of the LM-3900 dc amplifier sets the maximum frequency excursion to about 4-5 kHz. The reason for the simplest way being the most difficult is understood when you realize only a few Hertz deviation at 19 MHz equals 4-5 kHz deviation when multiplied by 528. This method will work on NBFM voice but is very sensitive, difficult to adjust, and doesn't like to stay put once it's set.

This method won't work satisfactorily for frequency-shift keying of either 850-kHz shift RTTY or 2-kHz-shift CW. Trying to set an approximately 1.5-Hz shift at 19 MHz to yield an 850-Hz shift at 10 GHz is virtually impossible without an atomic frequency standard or Bureau-of-Standards equipment. *Figure 12-9* illustrates a novel solution to this problem that's relatively easy to build and very easy to adjust.

Crystalmatic Modulator — How It Works

T1 is the 455-kHz Weiss discriminator (phase detector) transformer used in the Hamtronics R40 i-f/audio kit. The newest version is the Hamtronics IF10B, which is almost identical. Since both ends of transformer T1 are above ground in the Weiss configuration, the +12 Vdc supply for this modulation system must also be above PC-board ground. This is quite simply accomplished by using a full-wave bridge rectifier of cheapy germanium or silicon diodes to isolate both + and -. The modulator is fed from the +12 Vdc main power supply, which includes a 10-μF filter capacitor across the bridge output.

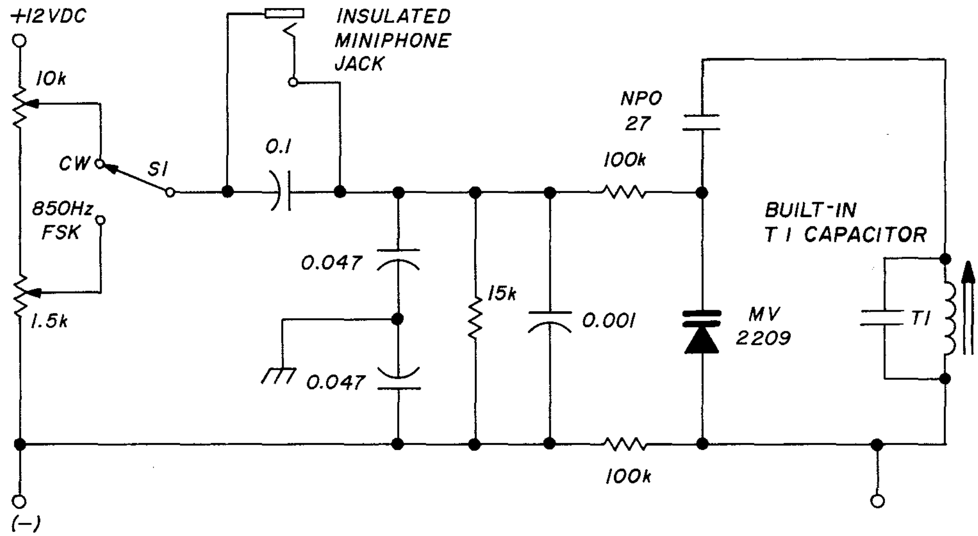


Figure 12-9. T1 455-KHz Weiss Discriminator Transformer Used in the Hamtronics R40 i-f/Audio Kit

Crystalmatic modulation system. Circuit will operate on CW with 2000-Hz shift, on RTTY with 850-Hz shift, and on very narrowband fm radiotelephone with about 3-kHz deviation (see text).

Although the circuit in *Figure 12-9* shows switch S1 with two positions, CW (2000-Hz shift) and 850-Hz shift for RTTY, it will operate just as well on very narrow-band fm phone (approximately 3-kHz deviation) by plugging the 8-ohm output from a small amplifier into the mini phone jack (also above ground), and adjusting the 10k pot and audio amp gain for 3-kHz NBFM deviation on voice.

Operation of the circuit is simple. Assume a normally open key or keying relay is plugged into the mini phone jack and frequency shifts of 850 Hz for RTTY and 2000 Hz for CW are desired. With the LM3900 dc amplifier level control adjusted to capture the 10-GHz crystal harmonic and switch S1 in the 850-Hz position, the 1.5k pot is adjusted for exactly 850-Hz shift on your Gunnplexer tunable i-f communications receiver, from key up to key down. The same procedure is followed with S1 in the CW position, adjusting the 10k pot for exactly 2000-Hz shift on your tunable i-f receiver.

The MV2209 varactor diode in series with the 27-pF NPO ceramic disc capacitor retunes T1 for the frequency shift desired. The Weiss discriminator (phase detector) generates a dc error voltage when retuned that's, a) amplified by the LM3900 dc amplifier (*Figure 12-1*), b) filtered by an RC filter, and c) applied to the Gunnplexer varactor, which produces the 10-GHz shift desired. That's all there is to it.

This circuit is easy to adjust and holds the set frequency shift day in and day out without further adjustment. Assuming you've built the proportional temperature control circuit (PTC) for the TX-432 crystal described in *Chapter 5*, the frequency repeatability and frequency stability of your 10-GHz signal will be as good as many signals on 20 meters.

Parts Source

Hamtronics, Inc, 65 Moul Road Hilton, New York 14468	C110 converter IF10B i-f/audio	\$34.95 \$49.95
G & G Electronics Co. 45-47 Warren Street New York, New York 10007	1N21D diode about	\$ 3.00

13

Level II Communications Systems - Part 1

A first approach to narrowband frequency modulation using an electronically tuned Gunnplexer 10-GHz converter. Comparison between AFC and *Crystalmatic* phase-lock system. Design, theory, and construction of a 98-MHz - 29/30-MHz crystal-controlled converter using available kits. Emphasis is on problems associated with narrowband fm voice modulation and getting the system on frequency.

The Level-II communications systems differ from Level I because they use narrowband frequency modulation. All Level-I systems were of the wideband variety with plus and minus 75-kHz frequency deviation. The Level-II systems are divided into two chapters to allow you to choose between two approaches to Gunnplexer narrowband fm operation. The first approach, covered in this chapter, uses straightforward narrowband fm techniques little different from 2-meter fm except for the electronically tuned Gunnplexer 10-GHz converter. The AFC circuit is similar to that used for Level-I wideband fm operation except for considerably higher dc gain to achieve a much tighter servo loop that will accommodate weak signals close to the noise level. Frequency calibration is through the weak-signal source presented in Chapter 10.

The second approach, covered in Chapter 14, uses the *Crystalmatic* phase-lock system summarized in Chapter 12. It's an evolutionary rather than a revolutionary approach to locking the Gunn oscillator to a low-frequency crystal's 528th harmonic in that it uses virtually all the same components and subsystems built in this Chapter's Level-II AFC approach. Nothing is wasted nor duplicated.

This second approach uses a tuneable communications receiver with an input frequency of 29.0 MHz for slope detecting the narrowband fm signal, whether it be voice or FSK with CW or RTTY modulation. The components and subsystems built in this chapter for the narrow-band fm with AFC to the Gunn oscillator are used to phase lock the Gunn diode 10-GHz signal to the low-frequency crystal oscillator's 528th harmonic, as outlined in Chapter 12. The similarities between the two systems are so close that it will surely occur to some readers to ask, "Why not build the two systems so that you can easily switch from AFC Gunn oscillator control to *Crystalmatic* control for narrowband fm operation?" Why not indeed! That is exactly what we'll do in the next chapter. Let's compare the characteristics of the two operating approaches:

	AFC	*Crystalmatic*
absolute 10-GHz frequency control		X
crystal-control stability		X
track other 10-GHz station's drift	X	
duplex AFC *Crystalmatic* frequency control		X
separate receiver required		X
use low-cost kits to assemble	X	X
+12-volt dc operation	X	X
fits into two minicabinets	X	X
use either 29- or 30-MHz i-f	X	
crystal oscillator and multiplier required		X

850 Hz FSK for RTTY or CW	X
Gunn-diode spectral noise quieting	X

There's no point in arguing the pros and cons of the AFC approach versus the *Crystalmatic* approach, because we'll have the "best of all possible worlds" by building both systems using the same components and changing a few plugs and switches to change from one mode to the other.

The text, block diagrams, and schematics in both this chapter and the next show a 98-MHz - 29-MHz converter. This may be ignored by those who are interested only in 29 or 30 MHz i-f operation. I used the 98-MHz - 29-MHz converter two years ago because it was the simplest and easiest approach to getting started on the 10-GHz band and probably still is today, using standard fm-broadcast receivers for the tunable i-f, as covered in the first three sections of Chapter 9.

I-f Bandwidth

The optimum i-f wideband duplex fm depends on whom you plan to work on 10 GHz. If all the local 10-GHz stations are working simplex on the base (transmitting) frequency of 10.250 GHz, it doesn't matter what i-f you choose, although it's easier to electrically retune the Gunnplexer 30 MHz than 98 MHz, or what have you, for wideband fm simplex operation. If all the local 10-GHz stations are working duplex on 10.250 and 10.280 GHz, you've little choice but to build a 30-MHz i-f wideband fm receiver. The last section of Chapter 9 covers two 30-MHz i-f wideband fm receivers using the EXAR 215 and RCA CA3089E IC chips. Both are inexpensive and simple to build.

AFC and Crystalmatic Systems

Figures 13-1 and *13-2* are simplified block diagrams of both Level-II communications systems. A glance at *Figures 13-1* and *13-2* shows considerably more similarities than differences between the two systems. The Level-II AFC system uses the level control of the AFC amplifier to electrically tune the Gunnplexer varactor plus or minus approximately 2 MHz to yield an i-f of 29 or 30 MHz, as desired. The Level-II *Crystalmatic* system uses a separate communications receiver to tune 1 MHz above and below the 29-MHz i-f.

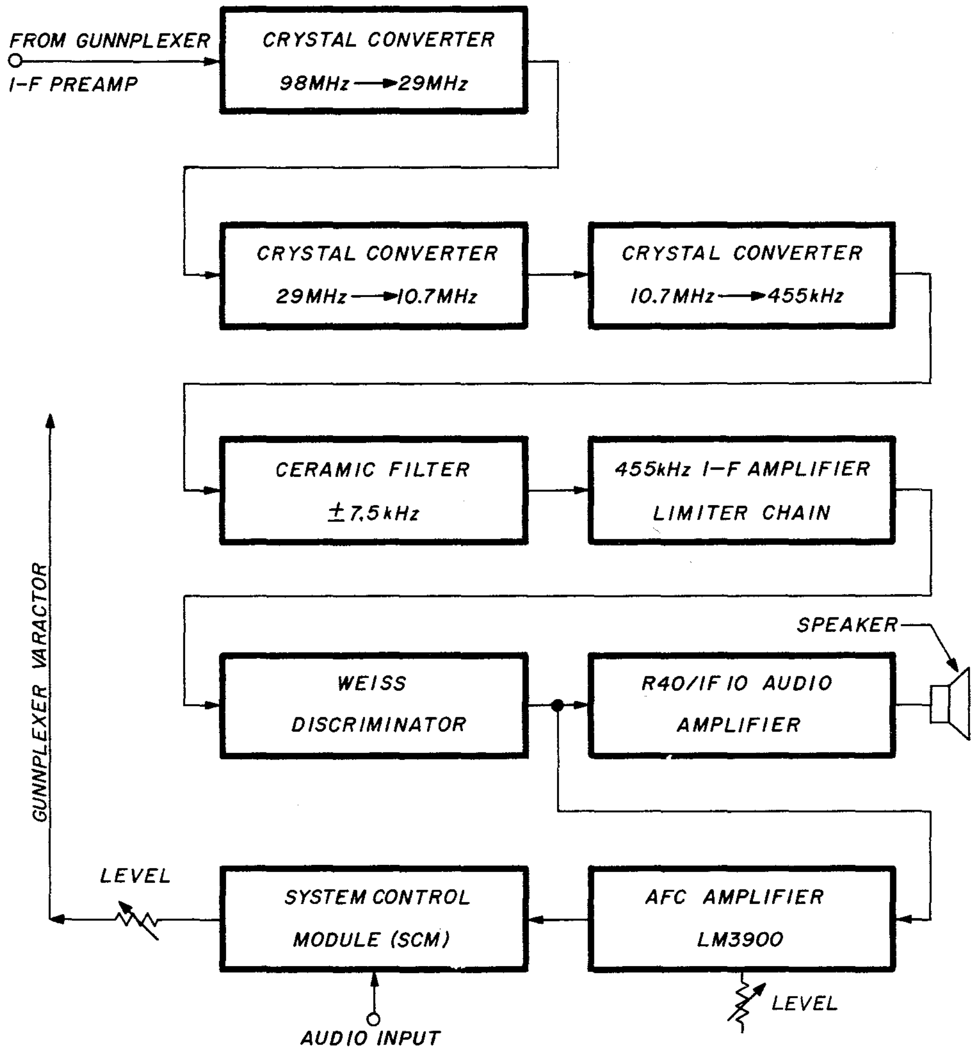


Figure 13-1.

Level-II communications system with automatic frequency control. The AFC amplifier level control is used to electrically tune the Gunnplexer varactor approximately ±2 MHz to yield a 29- or 30-MHz i-f, as desired.

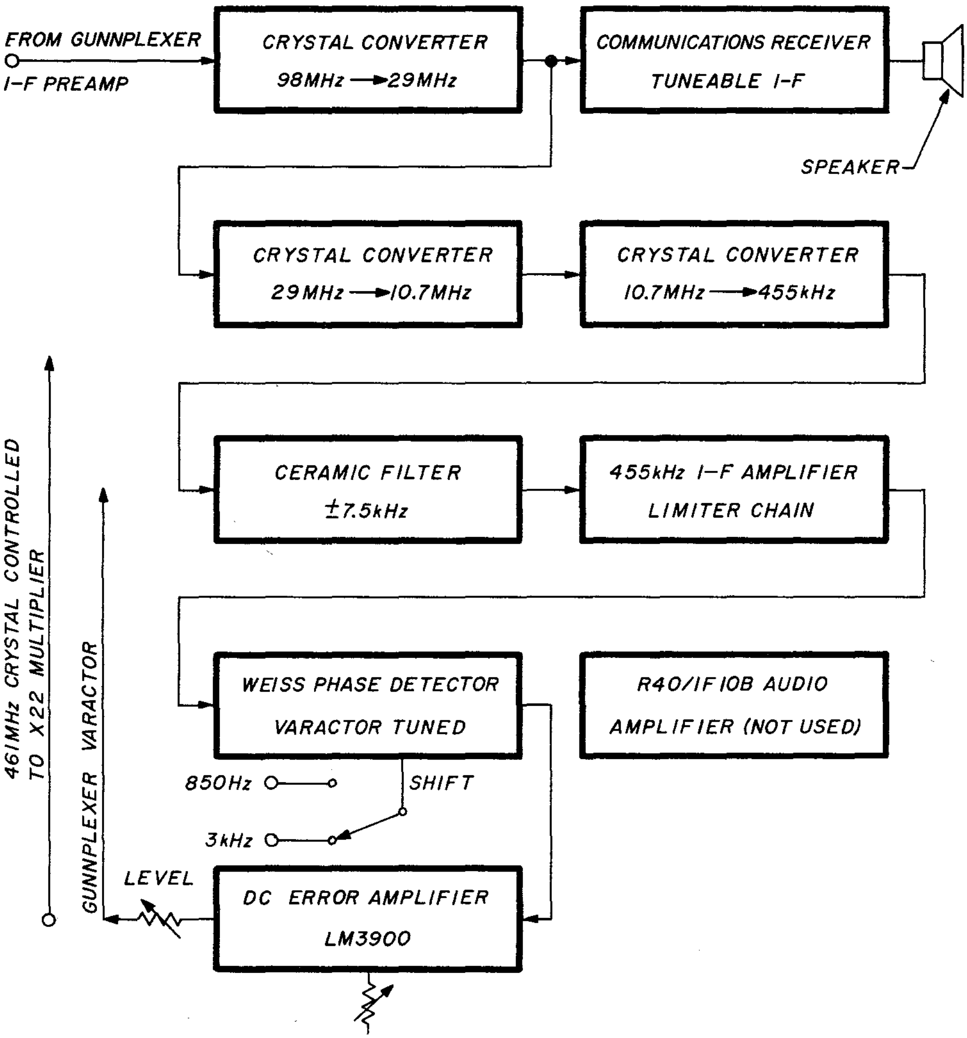


Figure 13-2.

Level-II communications system with Crystalmatic feature, which uses a separate communications receiver to tune 1 MHz above and below the 29-MHz i-f.

The only difference between the Weiss fm discriminator in the AFC system and the Weiss phase detector in the *Crystalmatic* system is the small parallel capacitance across the transformer shown in

Figure 12-9 that affects frequency-shift keying for RTTY or CW and sets the carrier frequency for narrowband voice modulation.

Both Weiss circuits are intentionally misaligned +500 millivolts to provide offset biasing for both LM3900 amplifiers. The audio distortion isn't noticeable on narrowband fm voice and has no effect on either 850 Hz or 3-kHz FSK when using the *Crystalmatic* system.

AFC Amplifiers

The LM3900 dc/AFC amplifiers are identical for both systems, with voltages gains varying between 40 and 60 dB, depending on the level-control setting. As both are inverting amplifiers, they are designed to lock on to signals below the Gunnplexer output; i.e., 29 MHz, 30MHz, 98 MHz, or whatever i-f you choose to use for either system. If you wish to reverse i-f sense, both above and below your Gunnplexer output frequency, by all means use DJ700's in the dual-sense AFC circuit given in *Figure 8-4* (Chapter 8) of the LM3900 dc/AFC amplifier.

Remember, that when using the *Crystalmatic* system in *Figure 13-2,* you may work Gunnplexer stations either above or below your Gunnplexer output frequency, as the *Crystalmatic's* crystal harmonic is always injected (in our version) on the low side of the Gunnplexer output. The probability of having the *Crystalmatic* injection frequency fall exactly on or within the audible beat range of the station being worked is so infinitely small at 10 GHz that it may be ignored. I'd enjoy hearing from the first person who experiences this one-in-ten-trillion probability.

Some Advice for Those Wishing to Use a 29/30-MHz i-f

If you're an optimist and a VHF/UHF buff who wishes to use a 29/30-MHz i-f for your narrowband fm Gunnplexer operation, skip this section and take one step forward to the next section. But note the following before you do so.

Despite your broad VHF/UHF experience and all the similarities of the 10-GHz band to the other VHF/UHF Amateur bands, we are dealing with an Amateur band wider than the *entire* *spectrum* from 160 meters through ¾ meters. That's a whole bunch of Hertz and a pretty big frequency forest in which to lose yourself!

Unless you're fortunate enough to have a 10-GHz digital frequency counter (most of us don't), I suggest you build the crystal-controlled, weak-signal source to help you locate *exactly* where you are in the 10-GHz band. Without it you're just guessing where you are. The 10-GHz Amateur band is more than three times wider than TV's vast VHF wasteland. You'll find the Australian desert an easier place to find yourself when lost than trying to find a Gunnplexer carrier using narrowband fm somewhere between 10.000 GHz and 10.500 GHz.

If you have a digital frequency counter and prescaler that goes to 500 MHz, here's another means of relatively accurate frequency calibration for the 10-GHz frequency band.

1. Use a harmonic from your grid-dip oscillator if it will tune the 400 - 500-MHz range. Located it a foot or so from the mouth of the Gunnplexer horn antenna.
2. Simultaneously couple enough rf energy from the grid-dip oscillator into the digital-frequency counter prescaler with a one turn link to give a reading.

As long as you stay in the upper half of the 400-MHz - 500-MHz range, you should have no difficulty finding the grid-dip oscillator 22nd harmonic in the 10-GHz band. Most Gunnplexers will easily receive grid-dip oscillator harmonics from the 200-MHz - 400-MHz range, but if you use them you'll never be sure *exactly* which harmonic you're receiving on the Gunnplexer. The 22nd harmonic from your grid-dip oscillator is about the minimum harmonic upon which you can rely with any confidence.

98-MHz - 29/30-MHz Crystal-Controlled Converter

There are many excellent two-meter converter designs that may be easily modified for 98 MHz - 29/30 MHz converter applications. My favorite is the Hamtronics C25-150, which has been superseded by their similar model C110, selling for $34.95. The C110 is designed to cover any 4 MHz of the aircraft navigation-communication band from 108 MHz - 136 MHz, with an i-f output of 26 MHz - 30 MHz. Modifying it to convert a 98-MHz Gunnplexer i-f to 29 or 30 MHz center frequency requires little more than ordering the proper series-resonant third overtone crystal in an HC25/U holder.

The C25-150 VHF converter schematic, illustrated in *Figure 13-3*, is a straightforward design that may be assembled and tested in only a few hours. I've found no sneaky or tricky problems with this kit after building two of these converters. The printed circuit board measures 2-½ by 4-½ inches (64 by 114 mm) and fits into the Poly Paks black vinyl cabinet shown in *Figure 13-4*. Although somewhat difficult to see, the front panel consists of only an on-off switch on the right side and a red LED on-off light in a Cliplite(tm) panel-mount holder on the left side.

Circuit Description

Referring to *Figure 13-3*, note that an N-channel FET cascode rf amplifier using 2N5486s is used, which is almost identical to the J8 Gunnplexer i-f preamplifier covered in Chapter 6 except for the double-tuned input and output stages, which simplifies tuning for wide bandpass response. The number of turns for each coil at the frequencies noted are shown on the schematic. The mixer also uses an N-channel 2N5486 transistor with oscillator injection of 69 MHz for 29-MHz output and 68 MHz for 30-MHz output.

Switching Options

If you wish the option of switching between 29 and 30 MHz crystal-controlled converter output, the simple way to do this is to add a spdt mini-toggle switch, S2, where the on-off LED is located on the front panel. Connect one end of the 34.5-MHz crystal, X1, (29-MHz i-f) and the 34.0-MHz crystal, X2 (30-MHz i-f) to the junction of R3 and L8. Connect the other end of each crystal to each side of S2, as shown in *Figure 13-3*.

The center terminal of S2 is soldered to the PC-board ground with a ½ inch (13-mm) no. 16 (1.3-mm) length of hookup wire.

With the crystals only 500 kHz apart on their third overtone, a single adjustment of L8 will suffice for both crystals. A small "gimmick" capacitor, 2 - 6 turns of twisted no. 26 (0.3 mm) insulated hookup wire soldered across each crystal, will allow you to trim each crystal exactly on frequency if you have a frequency

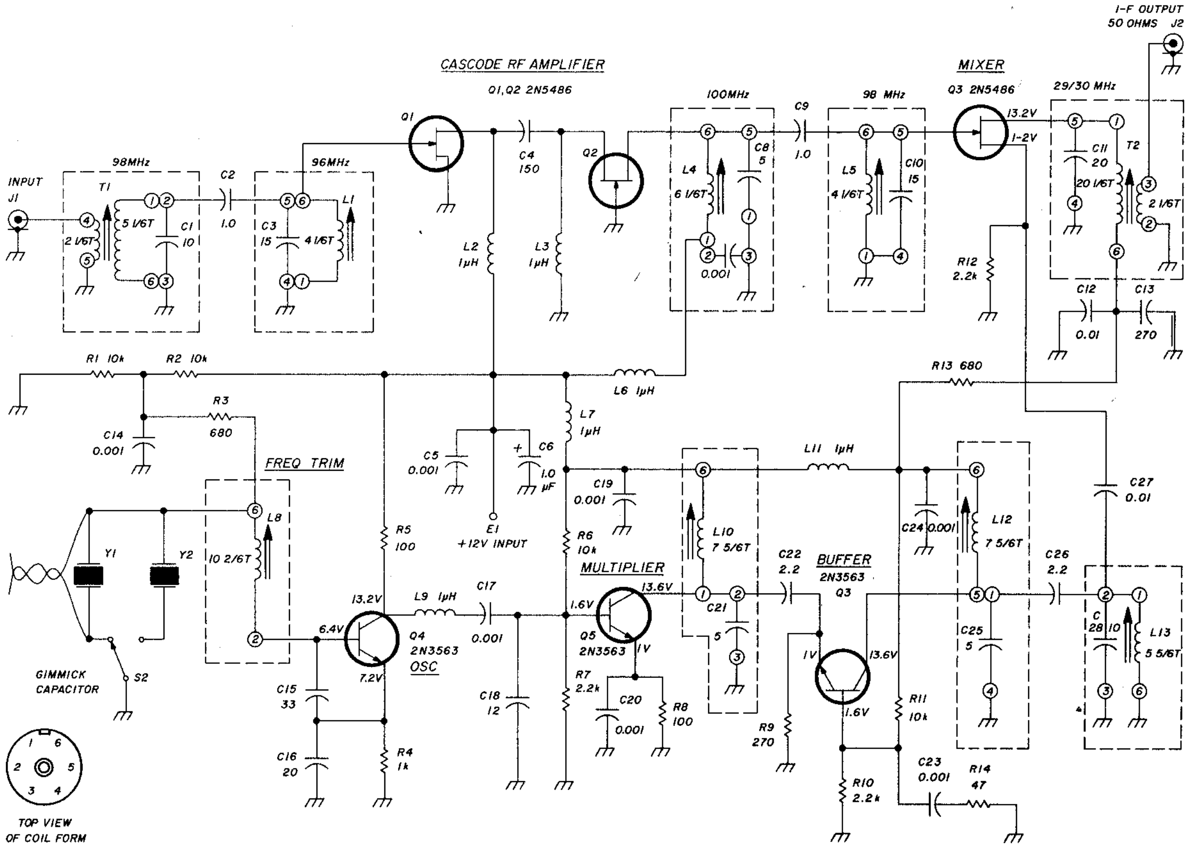


Figure 13-3.

Schematic of the Hamtronics C25-150 VHF converter, which may be easily modified for 98 MHz - 29/30-MHz. Modifications and switching options are described in the text.

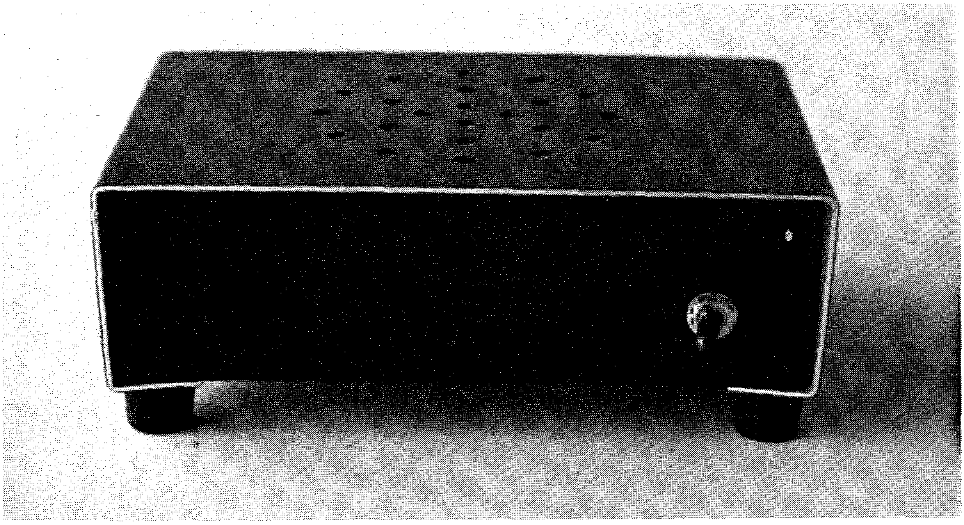


Figure 13-4. C25-150 Converter In Poly Paks Cabinet - Front View - Photo. Front view of the Hamtronics C25-150 VHF converter enclosed in a Poly Paks cabinet.

counter available. If not, don't be concerned, as the 0.002-per cent tolerance crystals will be close enough to the specified frequency for all but the most exacting work.

Tune Up

Try this assembly technique to speed up construction. It's easiest to grid-dip each coil/capacitor combination (except L8) to the approximate desired frequency with each coil tuning slug half-way in, before soldering the coil to the PC board, as changing the number of turns on any of the coils after they're soldered to the PC board is a tedious job at best. This converter is easily tuned up using a communications receiver S meter and your grid-dip meter as the signal source. Tune-up directions in the kit's instructions are very clear.

Assembly

Figure 13-5 is a top view of the C25-150 crystal-controlled converter mounted in a Poly Paks black-vinyl-covered cabinet. The crystal is just behind the ON-OFF LED mounted on the left-hand side of the shielded-coil can that covers L8. If you install the mini toggle i-f output switch and the two crystals, this is where they go. Move the ON-OFF LED and its Cliplite front panel holder to the center of the panel.

The converter is mounted to the cabinet with four each ⅜-inch (9.5 mm) long 6-32 (M 3/5) threaded aluminum standoffs on each corner with $^{3}/_{16}$ inch (20.5-mm) long 6-32 (M 3/5) bolts. The dropping resistor for the LED is ½ watt at 3300 ohms,

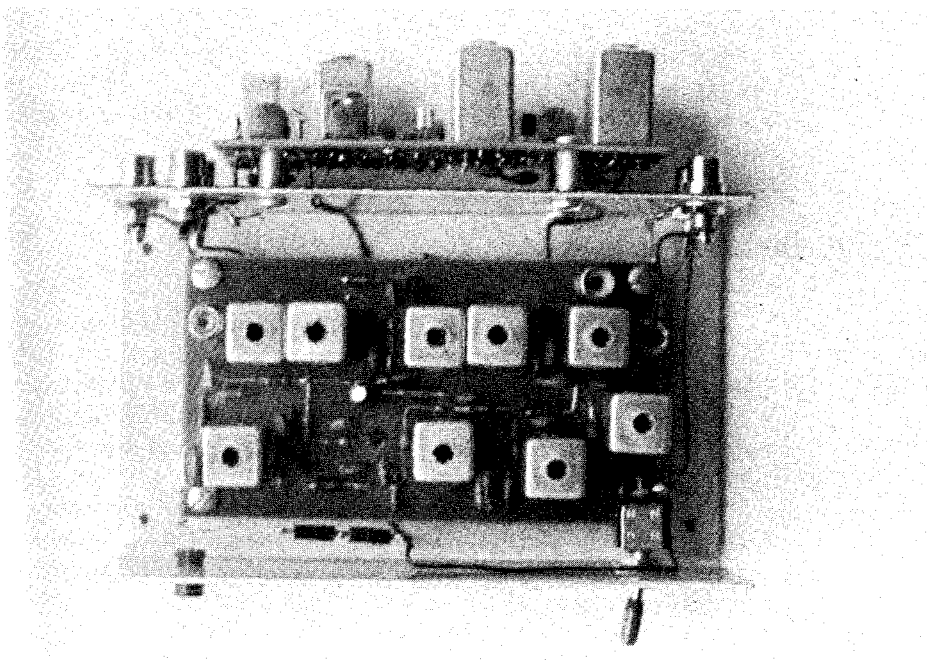


Figure 13-5. C25-150 Converter In Cabinet - Top View (Photo)
Top view of the Hamtronics C25-150 VHF converter in cabinet. The crystal is just behind the ON-OFF LED mounted on the left-hand side of the shielded-coil can that covers L8. Also included is a mini toggle i-f output switch and two crystals.

connected to the +12 Vdc supply. The top of *Figure 13-5* shows the VHF Engineering RF28 crystal-controlled converter, which will be used as a 29/30 MHz - 10.7-MHz converter.

29/30 MHz - 10.7 MHz Crystal-Controlled Converter

This crystal-controlled converter is much the same as that described in Chapter 9, "Gunnplexer 30-MHz wideband fm receiver." The major difference is the double-tuned input stage, which we will now use, as we have system gain to spare. Also, as in the last section, we have the option of switch-selectable 29-MHz or 30-MHz input center frequency to yield the 10.7-MHz i-f output.

For those who choose not to build the 30-MHz i-f wideband fm receiver described in Chapter 9, I shall briefly reiterate the high points of the RF28 converter and the changes made to accommodate the switch-selectable 29- or 30-MHz input.

Circuit Description

Figure 13-6 shows Q1, a 2N5486 N-channel JFET transistor, as the rf amplifier in low-noise, grounded-gate configuration. (In this Chapter we'll use both tuned circuits, as we have system gain to spare, whereas in Chapter 9 we needed every dB of i-f gain we could find for the very simple CA3048 integrated circuit wideband combination i-f/discriminator circuit.)

The mixer, Q3, is a 3N204 dual-gate MOSFET transistor. The dual gates allow oscillator injection on one gate and signal input on the other gate, which gives much greater dynamic range; that is, excellent overload protection from strong local signals with superior immunity to cross modulation. The device should be handled only by the case to avoid damage from static discharge. The crystal oscillator, Q2, uses a 2N2222 NPN transistor with third overtone crystals at:

i-f input (MHz)	crystal frequency (MHz) (.002% tolerance)
30	40.7
29	39.7

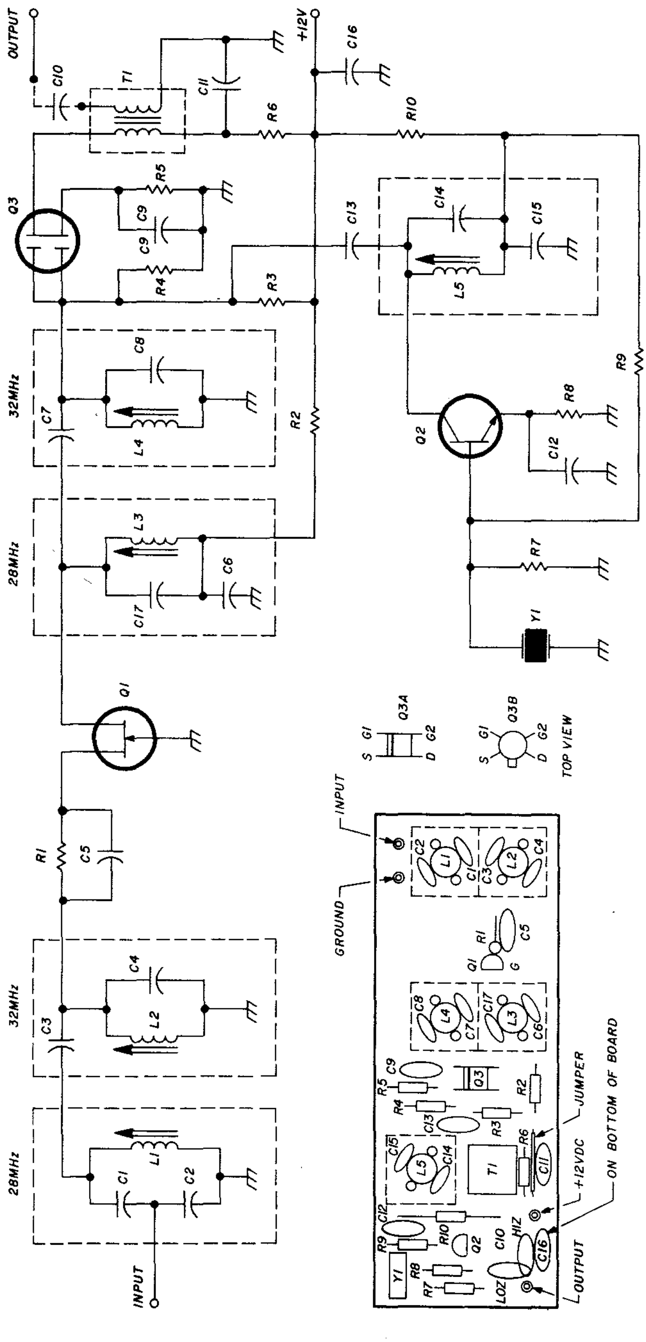


Figure 13-6.
The RF28 29/30-MHz converter by VHF Engineering. Some minor changes are required to accommodate the switch-selectable 29- or 30-MHz input.

The crystal oscillator circuit is the old reliable tuned-plate, tuned-grid (TPTG) with a transistor. It's completely foolproof, easy starting, and will work with most anything except a broken crystal. If you plan to switch back and forth between 29 MHz - 30 MHz inputs frequently, install a spdt mini-toggle switch similar to the arrangement shown in *Figure 13-3* for easy frequency switching.

Assembly

Figure 13-7 shows the RF28 crystal-controlled converter mounted on the rear of the Poly Paks black vinyl cabinet. If you plan to operate your Gunnplexer only with first i-fs of 29 or 30 MHz, by all means install this converter inside the cabinet with the crystal toward the cabinet front to allow crystal switching if desired. I mounted this converter on the rear of the cabinet because I ran out of space and didn't want to use another cabinet.

If you plan to use a single Gunnplexer with dual i-fs or dual Gunnplexers with separate i-fs of 98 or 29/30 MHz, you should add a normally closed mini phone jack above the right-middle connector on the rear panel for 29/30-MHz input. There's plenty of room for it. As most HC25/U crystal sockets don't have a tight fit, it's a good idea to tape the HC25/U crystal into its socket with masking or Scotch tape to keep it from falling out of the socket. During 1978 Field Day I spent two hours looking for the RF28 crystal (I finally found it). Hence the "tape-the-crystal" advice. During '79 & '80 Field Day, no problem.

Tune Up

Tune up and alignment of the RF28 crystal-controlled converter is simple, straightforward, and can be done quite quickly:

1. With +12 Vdc power on and the cover removed from L5, adjust L5 for maximum output on your grid-dip oscillator in the wave-meter/diode detector mode. Turn the adjusting slug about one-half turn out past maximum output and replace the coil cover. Solder the coil cover mounting lugs to the PC board.

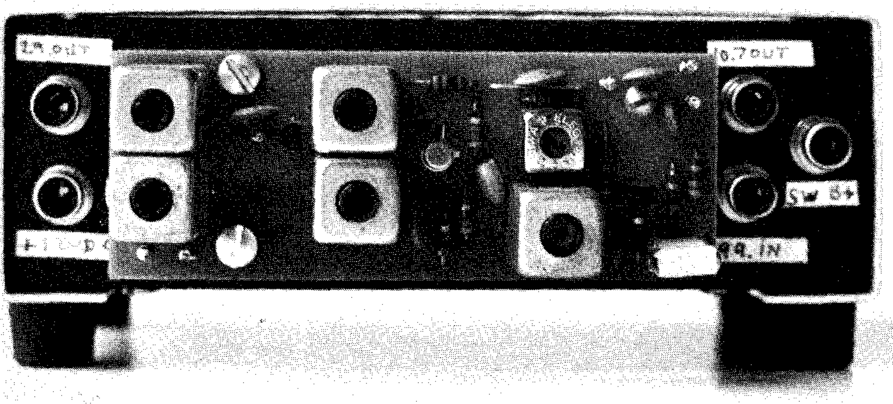
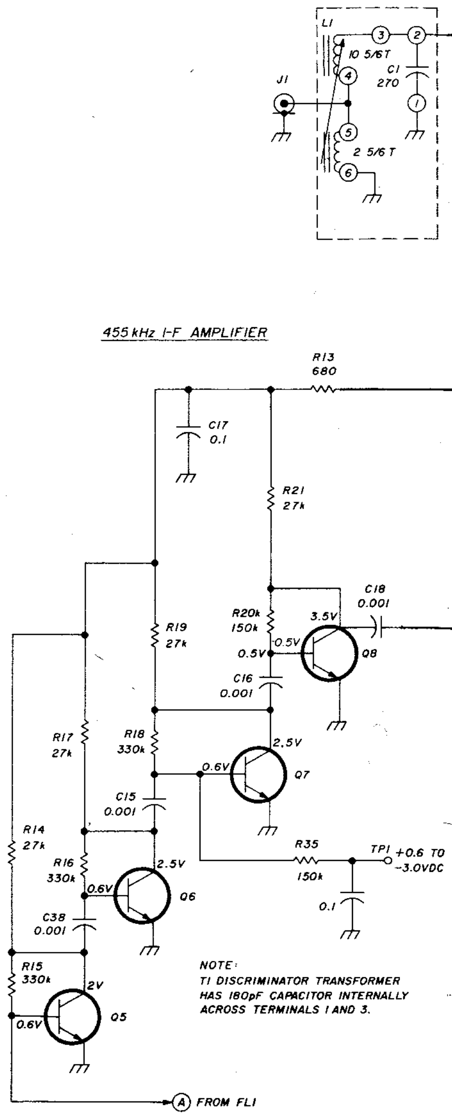


Figure 13-7. 98 MHz & 29/30 MHz Converters Cabinet - Rear View (Photo).

Rear view of the 98-MHz and 29/30-MHz crystal-controlled RF28 converter mounted on the rear of a Poly Paks cabinet. Connectors are: left top, 29-MHz output to communications receiver. Left bottom, +12 Vdc power-supply input. Right top, 10.7 MHz rf output. Right center, switched +12 Vdc to the 455-kHz i-f, detector, and audio. Right bottom, 98-MHz input.

2. If you don't have one, make a vtvm rf probe from the *ARRL Handbook* and connect it to the junction of R3 and R4 on the PC board. Adjust L5 for maximum output. If you are using the switch-selected two-crystal option, follow this procedure using the 39.7-MHz crystal and not the 40.7 MHz crystal. This procedure ensures easy starting of both crystals, as the lower-frequency crystal will not always start if done *vice-versa*.
3. If you wish super frequency accuracy for the *Crystalmatic* system described in the next chapter, now is the time to connect a digital frequency counter to the junction of R3 and R4 (through a 22-k isolating resistor) on the PC board. Using homebrew gimmick capacitors across each crystal (see *Figure 13-3*), trim each gimmick until each crystal output is exactly on frequency.


L1
10 5/6T
2 5/6 T
J1
C1
270
455 kHz I-F AMPLIFIER
R13
680
C17
0.1
R21
27k
C18
0.001
R20k
150k
3.5V
0.5V
0.5V
Q8
R19
27k
C16
0.001
R17
27k
R18
330k
2.5V
0.6V
Q7
C15
0.001
R14
27k
R16
330k
2.5V
0.6V
Q6
R35
150k
TP1 +0.6 TO -3.0VDC
0.1
C38
0.001
R15
330k
2V
0.6V
Q5
NOTE:
T1 DISCRIMINATOR TRANSFORMER HAS 180pF CAPACITOR INTERNALLY ACROSS TERMINALS 1 AND 3.
FROM FL1

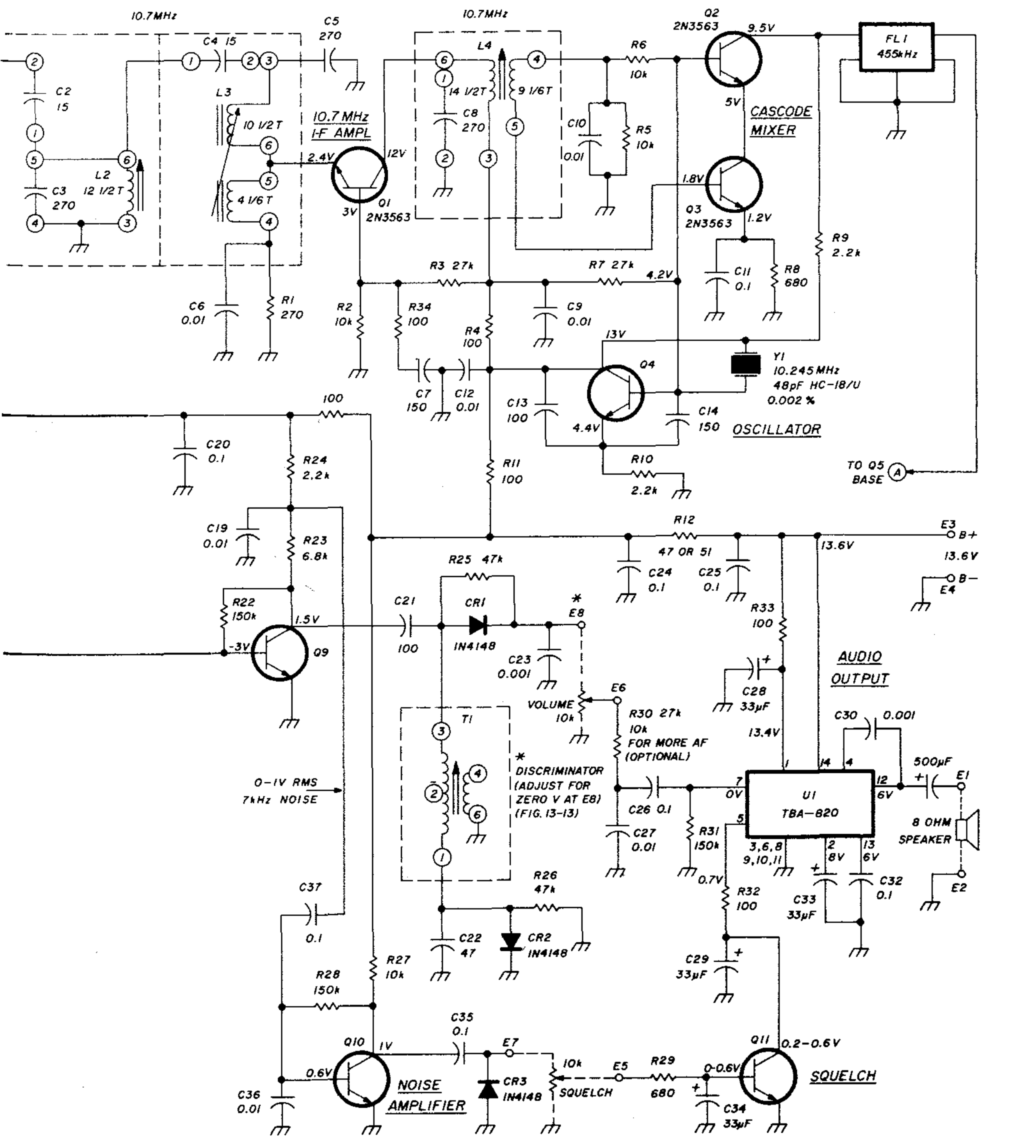


Figure 13-8.

Schematic of Hamtronics second-generation i-f/audio kit, the model R40. This kit is being replaced by the model 1F10B kit, which is very similar. The only critical items are the ceramic filter and Weiss discriminator which will be identical to those in the R40.

4. With the coil removed from L1 through L4, adjust each coil to the frequency shown in *Figure 13-6* with a grid-dip oscillator.
5. Use a receiver that will tune to 10.7 MHz and its S meter to measure output from the RF28. Inject a 30-MHz signal into the converter input with your grid-dip oscillator (or signal generator). Adjust T1 for maximum output and L1 through L4 for maximum quieting at the frequencies shown in *Figure 13-6.* Some tweaking for L1-L4 should give nearly flat response from 28 - 32 MHz. If you're lucky enough to have a sweep generator and oscilloscope, use them. The 3-dB-down points should be at about 28 and 32 MHz. If this is difficult to obtain with less than 3-dB ripple in the passband, narrow the bandpass 3-dB-down points to 28.5 and 31.5 MHz.
6. If you don't have a communications receiver that will tune 10.7 MHz, you can use an ordinary standard broadcast fm receiver for alignment. Connect the RF28 output to the fm receiver 10.7-MHz i-f and align as in Step 5.

Hamtronics R40 i-f Audio Kit

The Hamtronics (Hilton, New York) R40 i-f/audio kit is being replaced (summer/fall 1979) with their model IF10B kit, which is very similar. The plus and minus 7.5 kHz ceramic filter and Weiss discriminator will be identical to the R40. Fortunately, these are the only critical items.

Circuit Description

Figure 13-8 is a schematic of Hamtronic's second-generation i-f/audio kit, the model R40. Hamtronics' earlier model used an IC chip i-f amplifier/limiter, but the R40's five transistor i-f/limiter chain provides improved operation. Let's briefly run through the R40 circuit.

The first transistor, Q1, a 10.7-MHz rf amplifier is in a low-noise, grounded-base configuration with a three-pole LC filter ahead of it. The mixer, transistors Q2 and Q3, is a unique cascode circuit with 455-kHz output to FL1, a highly selective

455-kHz ceramic filter (plus - minus 7.5-kHz bandwidth) that provides better than 70 dB rejection of adjacent channels (if used on 2 meters), and 40-dB image rejection.

The 455-kHz i-f amplifier and limiter chain, transistors Q5 - Q9, are simplicity itself. The Weiss discriminator transformer, T1, has an internal 180-pF capacitor across the primary winding, pins 1 and 3 (not shown on the schematic). T1 secondary is not used in the Weiss discriminator configuration.

Capacitor C22, a 47-pF ceramic disc, balances the discriminator to ground. Discriminator output drives U1, an IC 2-watt audio amplifier, which incorporates low-pass filtering and de-emphasis (C27) to minimize the characteristic hiss on weak signals.

The squelch circuit consists of noise-amplifier transistor Q10 and squelch-control transistor Q11. The a-m noise in the plus and minus 7.5 kHz bandpass i-f is detected and the squelch activated at the level set by the 10k squelch pot. Squelch-circuit time constants are set to keep flutter from inadvertently activating the squelch control, much like a standard repeater squelch tail, which holds the squelch open a fraction of a second to determine whether the signal has gone off the air or only momentarily faded.

Assembly

All transistors in the kit are 2N3563 +100 MHz NPN types; all diodes are 1N4148s, so it's difficult to make an assembly error. Assembly time is a few hours at most if you take it slow and easy. Polarities of the diodes and electrolytics are well marked on the kit PC board assembly drawing. The notched end of U1, the 2-watt audio amplifier IC, faces the closest outer edge of the PC board. Make sure that the pins of FL1, the ceramic filter, easily slide in and out of the holes drilled for it on the PC board. If not, very carefully bend them straight with needle-nose pliers, trying not to put any pressure on FL1 as ceramics will not bend very gracefully.

The R40 PC board is mounted to the Poly Paks cabinet with three ⅜-inch (9.5-mm) long 6-32 (m $^3/_5$) threaded aluminum standoffs. Two of the bolts go to the holes next to L1 and C11. Drill a $^5/_{32}$-inch (4-mm) diameter hole half-way between Q10 and the edge of the PC board and install the third bolt and spacer.

Before installing the R40 with its spacers in the Poly Paks cabinet, make the following brief tests:

1. Temporarily install the 10k volume control, 10k squelch control, and attach the leads from an 8-ohm speaker to holes E1 and E2 on the PC board.
2. Using an ohmmeter, check the resistance of E3 to ground (the +12 Vdc input). Anything less than 60 ohms or so indicates a problem.
3. Double check the following: transistors in backwards? A diode in backwards? An electrolytic in backwards? Coil-can cover internal short? Hair-line solder trace short? Murphy's ghost is always beside you trying to make it happen if it's possible to do so.

Avoiding Transistor Burnout

With Murphy in mind, now might be a good time to solder a 1-amp silicon diode in series with E3 to prevent blowing out the transistors by inadvertently reversing power-supply polarity. The Poly Paks grab bags of 100 each silicon 1 amp diodes for $2.00 are super low-cost insurance if you don't mind checking peak inverse voltage yourself. About 80 per cent of the grab bag are usually good, and a dozen or so diodes have PIVs of 200 Vdc or better. All you need here is one diode with at least 20 Vdc PIV to prevent future disaster. With only a few hundred millivolts forward voltage drop, the effect of the diode won't be noticed.

Alignment

There are probably as many ways to align the R40 as there are imaginative R40 builders. The easiest method is to follow the instructions and use a signal generator. The following method uses the grid-dip oscillator. If done carefully, it will work just as well for those without a signal generator.

1. With C2 and C4 opened at one end, adjust L1, L2, and L3 to resonance at 10.7 MHz as measured with the grid-dip meter. Reconnect C2 and C4 and solder the coil covers in place.

2. Allow the grid-dip meter to warm up until stabilized. Adjust its output to exactly 10.7 MHz as measured on your communications receiver. If your receiver doesn't cover 10.7 MHz, use a standard fm broadcast receiver. Placing the grid-dip oscillator close to the fm receiver i-f strip should allow you to tune it to exactly 10.7 MHz, which will be the point of maximum quieting.
3. With a clip lead on the R40 input, bring the grid-dip oscillator close enough to this clip lead until you hear a signal on the R40 speaker with volume advanced and squelch fully retarded.
4. Using a VTVM or VOM, connected to point E8 on the PC board (top of the 10k volume control), adjust T1 for zero volts dc output. Double check to make sure that the grid-dip oscillator is still on 10.7 MHz.
5. Move the VTVM/VOM to test point 1, the 150k resistor from Q7 base and set it for negative voltage reading on the 1.5 or 3 Vdc scale. Q7 base input is the last point in the i-f amplifier/limiter chain before limiting occurs. Any signal amplitude measurement after this point would be misleading at best.
6. Adjust L1, L2, and L3 for maximum negative voltage reading while moving the grid-dip oscillator further and further away from the clip-lead antenna. Continue adjusting L1, L2, and L3 until no further increase in the negative voltage reading is obtained, as all three of the 10.7-MHz tuned circuits interact.
7. Readjust T1 for +500 millivolts output at point E8 with the grid-dip oscillator turned off. The +500 millivolts provides offset bias for the AFC amplifier.

LM3900 AFC Amplifier

Figure 13-12, discussed later in this chapter, illustrates the location of the AFC amplifier perf board with respect to the R40 when installed in the Poly Paks cabinet. The AFC amplifier assembly is on the left-hand side.

The LM3900 AFC amplifier for the Level-II communication system is constructed on a piece of perf board measuring 2-¾ inch by 1-⅛ inches (70 by 29 mm). A 2-inch (57-mm) length of no. 16

(1.3 mm) bus bar wire tied to each end of the perf board is soldered to the bottom foil of the R40 for rigid mounting. Two wire legs, made of no. 16 (1.3 mm) bus bar ⅜-inch (9.5 mm) long hold the perf board off the Poly Paks cabinet floor. *Figure 13-9* illustrates the AFC amplifier component layout on the perf board.

This AFC amplifier (*Figure 13-10*) is similar to the LM3900 inverting AFC amplifier covered in Chapter 8 except for the Audio choke, T2, which carries the Weiss discriminator dc error voltage to the AFC amplifier. T2 is a Radio Shack 273-1380 miniature audio transformer ($.99 each) with a 1000-ohm primary and 8-ohm secondary. Only the 1000-ohm primary winding is used in this audio-choke configuration. T2 may be replaced with a ¼-watt 20k resistor if desired with only a modest reduction in AFC amplifier gain.

When using T2, a more accurate AFC amplifier dc gain calculation may be made, because the input and output impedances of the LM3900 are more closely mateched (though still far

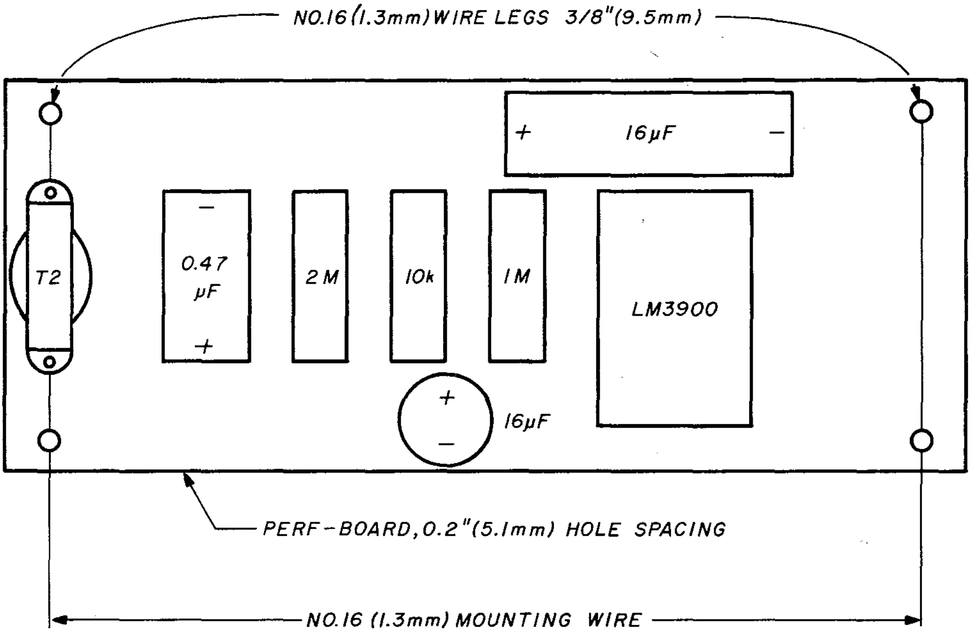


Figure 13-9.
Perf board layout for the LM3900 AFC amplifier.

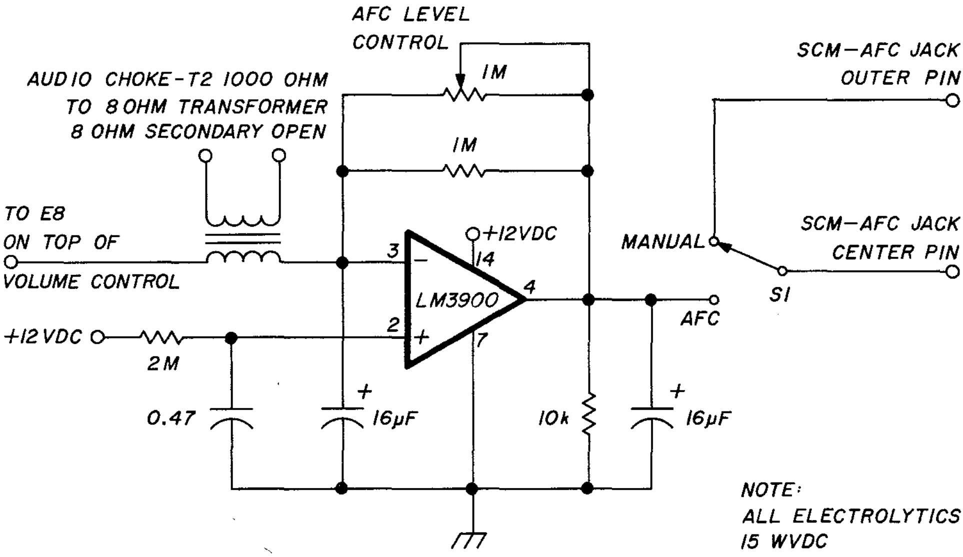


Figure 13-10.
Schematic of the Level-II AFC amplifier using the LM3900 IC. This amplifier is similar to the LM3900 inverting AFC amplifier discussed in Chapter 8 except for the audio choke, T2, which carries the Weiss discriminator dc error voltage to the AFC amplifier.

from ideal). Voltage gain of the LM3900 AFC amplifier equals feedback resistance between pins 3 and 4 divided by the input resistance (we will guesstimate 5k.)

Assume that the feedback resistance of the 1-meg resistor in parallel with the 1-meg potentiometer is 470k. In round numbers, this yields an amplification factor of 100. *Gain (dB) = 20 log 100 = 40 dB voltage gain.* Actually, the 1-meg pot is typically set at a level to capture and lock another Gunnplexer signal with a total feedback resistance of about 200k, which yields a voltage gain of 40, or approximately 22 dB.

Putting it All Together

Figure 13-11 is a front view of the Level-II communication system 10.7-MHz converter, 455 kHz i-f, audio, AFC circuits mounted in the Poly Paks box. The controls shown in *Figure 13-11* are, left to right, AFC LEVEL, AFC ON-OFF, SQUELCH, LED ON-OFF, and VOLUME. Mount the R40/AFC circuit board with the ceramic filter and 10.7 MHz coils to the rear of the cabinet, as shown in *Figure 13-12*. For the time being, ignore the small perf board on top of the R40 printed circuit board on the right as it will not be used until later (described in the next chapter).

The +12 Vdc switch on the front of the 98/30-MHz converter black box controls the +12 Vdc to this black box through the RCA phono jack marked SWB+ With the R40/AFC circuit boards mounted in their black box, and all controls and connectors installed, now is a good time to recheck the AFC amplifier offset bias at point E8 on the R40 printed circuit board (*Figure 13-13*) in case all the drilling and mounting disturbed the earlier setting of T1. Readjust T1 discriminator transformer (*Figure 13-8*) for exactly +500 millivolts dc at point E8 with no signal present.

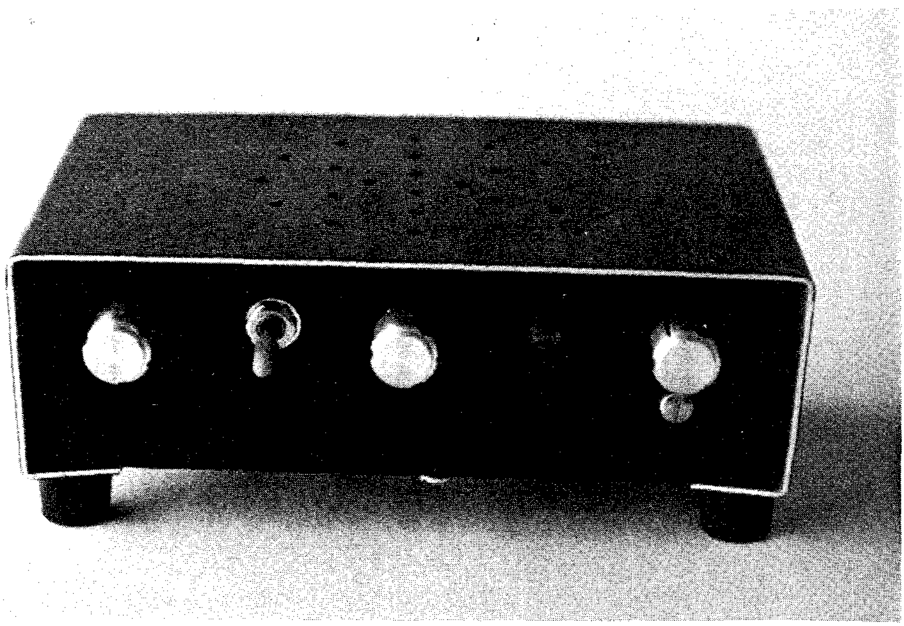


Figure 13-11.

Front view of the Level-II communications system 10.7-MHz converter, 455-kHz i-f, audio, and AFC circuit mounted in the Poly Paks enclosure. From left, the controls are AFC LEVEL, AFC ON-OFF, SQUELCH, LED ON-OFF, and VOLUME.

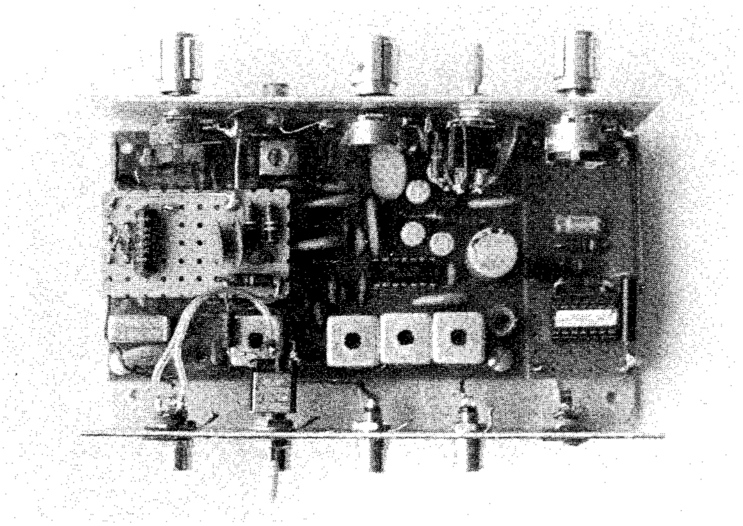


Figure 13-12. Level II Communications System: 10.7 MHz Converter/455 kHz i-f/ Audio/AFC (Top View)

Top view of the Level-II communications system 10.7-MHz converter, 455-KHz i-f, audio, and AFC stages. The R40/AFC board is mounted with the ceramic filter and 10.7-MHz coils to the cabinet rear.

This setting should be about 1 - 2 turns out (counter clockwise) for T1 tuning slug on top of the transformer.

Level-II System with AFC—Tune Up and Operation

Without a crystal-controlled weak-signal source or a $7000-plus microwave digital frequency counter, accurate tune up and adjustment of a narrowband fm i-f system with a Gunnplexer head-end is extremely difficult or well-nigh impossible. I say "difficult" because I was never able to do it, and "well-nigh impossible" instead of "impossible" because someone will undoubtedly find a way to do it that was overlooked.

Having a nearby friend with a Gunnplexer aligned using a digital microwave frequency counter doesn't count in this contest, as we're aiming Volume I of the Gunnplexer Cookbook at the microwave enthusiast who's all alone, way out in the boondocks.

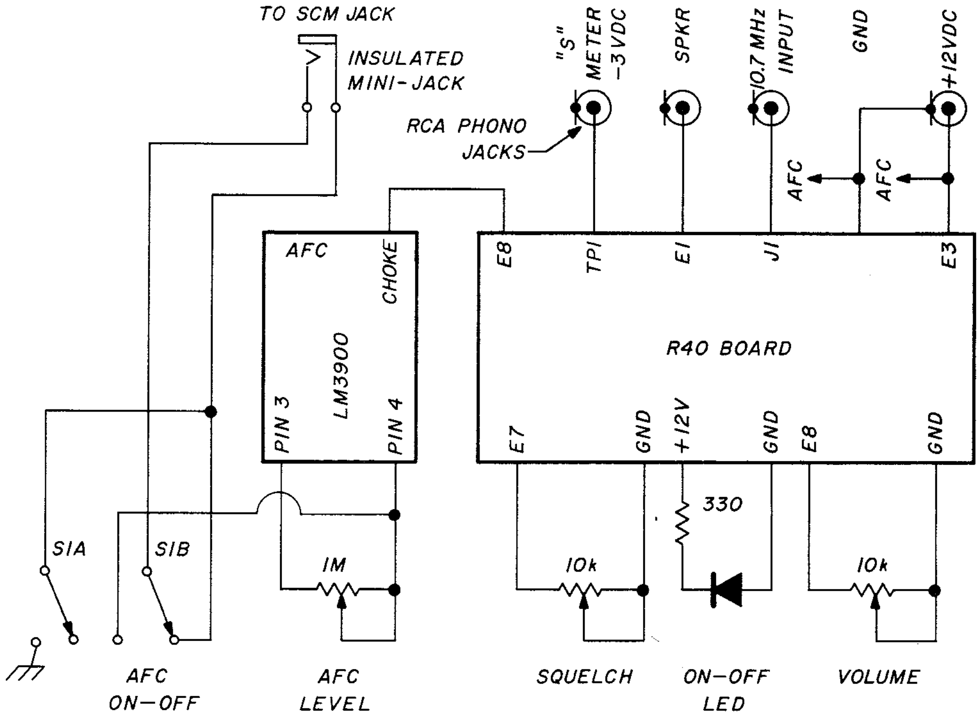


Figure 13-13.
Interconnections between the LM3900 AFC board and the R40 board.

So we'll use the crystal-controlled weak signal source covered in Chapter 10.

Using the Weak-Signal Source

For illustration only, we'll use the weak-signal source with output on 10.152 GHz to yield a first i-f of 98 MHz with a 10.250 GHz Gunnplexer because:

1. We already have a crystal for × *528* = *10.152-GHz* output; i.e., 19.227,273 MHz (Chapter 10).
2. Using a wideband fm receiver that will tune from 88 - 108 MHz, it is a thousand times easier to adjust the

Gunnplexer tuning slug (on the bottom of the Gunn diode/varactor cavity) for exactly 10.250-GHz output at plus 4.000 Vdc to the varactor).

If you have the crystals and a 29- or 30-MHz wideband fm receiver, the weak signal source could just as well be:

10.220 GHz or 10.280 GHz = 30 MHz first i-f
10.221 GHz or 10.279 GHz = 29 MHz first i-f

I assume that the crystal oscillators in the 98-MHz and 29/30-MHz crystal converters have been put *right on* frequency by either listening to a station of known *exact* frequency or by borrowing an accurate digital frequency counter. With the weak-signal source on, warmed up, and in the same room as the Gunnplexer and your Level-II system, let's try to find the weak signal. System alignment is in two steps: first find the signal if possible on your narrowband fm receiver; and second, set the Gunnplexer varactor diode for exactly 10.250 GHz at +4.000 Vdc.

Step 1—Finding the Signal

With the AFC switch in the OFF position, volume up, and squelch fully retarded, slowly adjust the system control module (SCM) coarse-tuning control over the range of 2.5 Vdc - 4.0 Vdc. With a bit of luck you should hear full quieting from the R40 speaker when you pass through the weak-signal source signal. Use the SCM FINE tuning control to center the signal in the passband. If you can't find the signal, try slowly tuning the SCM fine tuning control in 100-millivolt segments, from 2.0 to 6.0 Vdc, to the Gunnplexer varactor. This is time consuming but is one way to find the weak signal in that big gigahertz haystack. When you find it, write down the *varactor voltage.*

Frequency Readout

At about this stage of the game you're probably wondering why a tuning scale, dial, or some form of readout isn't included to make tuning a bit easier. The answer: the Gunnplexer voltage-tuned varactor needs only a *voltmeter* for obtaining frequency readout.

We have a number of choices for converting varactor to frequency readout:

1. VTVM/VOM voltage measurement and lookup table.
2. Digital voltmeter and lookup table.
3. Analog-to-digital converter with direct frequency readout.

I had a small battery-powered digital voltmeter that reads out to 1 millivolt on the 20-Vdc scale, so I chose method 2 initially. In Volume II of the Gunnplexer Cookbook, an analog-to-digital converter with direct frequency readout is included.

For those who wish to start right off with an analog-to-digital converter for frequency readout, reference 1 is recommended reading. This article will surely give you some ideas and get you started.

Figure 2-6 in Chapter 2 illustrates the excellent linearity of Gunnplexer varactor voltage versus Gunnplexer frequency output over the range 3.0 - 8.0 Vdc. I also found near perfect varactor voltage versus output frequency over the range 14.0 - 27.0 Vdc. The slope in *Figure 2-6,* Chapter 2, is 6-MHz/volt over the 3 - 8 Vdc range. In my measurements, between 14 - 27 Vdc, the slope had tapered off to 3-MHz/volt.

Undoubtedly every Gunnplexer diode, varactor, and cavity combination will have somewhat different frequency output curves versus varactor voltage. But after testing three different Gunnplexers, all at 10.250 GHz at a nominal 4.0 Vdc to the varactor, I found that approximately 7 MHz/volt is the average slope in the 3.0 - 5.0 varactor-voltage range.

Step 2—Adjusting the Varactor Diode

As mentioned earlier, mechanically adjusting the tuning slug in the Gunn diode cavity is complex. It's easy to get lost in the multi-gigahertz forest without a microwave digital frequency counter. Nevertheless, let's try it using a wideband fm receiver. It takes a special touch to do it accurately.

1. The goal is to have Gunnplexer output *exactly* at 10.250 GHZ with varactor voltage *exactly* at 4.000 Vdc. Varactor voltage is proportional to Gunnplexer frequency output. Frequency is a direct function of varactor voltage.

2. Assume that the varactor voltage you wrote down when you found the crystal-controlled weak signal source was *3.500 Vdc = 10.250 GHz* Gunnplexer output. To obtain 10.250 GHz output at 4.000 Vdc, the frequency must be decreased.
3. Remember, our crystal-controlled weak-signal source is lower than our Gunnplexer output frequency. At a slope of 7 kHz/millivolt, we'll lower the Gunnplexer output frequency somewhere in the vicinity of 3.5 MHz *(500 millivolts × 7 kHz/ Vdc = 3500 kHz = 3.5 MHz).*
4. Before adjusting anything, temporarily connect a wideband fm standard broadcast receiver to the Gunnplexer output and tune in the crystal-controlled weak-signal source. It should be at 98.0 MHz on the dial. Readjust varactor bias from 3.500 Vdc to 4.000 Vdc and tune up to around 101.5 Mhz, where you should find the weak-signal source.
5. Use a small screwdriver and ever so gently screw in (clockwise) the ceramic tuning slug on the bottom side of the Gunn cavity housing just forward of the Gunn and varactor diodes. Try about 1/16th of a turn then try to find the weak-signal source on the fm receiver. Any frequency above 98 MHz requires the tuning slug to be turned in and any frequency below 98 MHz requires the slug to be turned out. Keep up this exercise until the weak-signal is *exactly* on 98.0 MHz. That is all there is to it.

Making a Lookup Table

The only thing left to do is to make a varactor-voltage-versus-frequency lookup table. You can do it by subtracting 7 kHz from 10.250 GHz for every millivolt that varactor bias is reduced from 4.000 Vdc, and adding 7 kHz for every millivolt varactor bias is increased above 4.000 Vdc.

Table 13-1 is a printout of varactor voltage (first column) versus Gunnplexer output frequency (second column) for varactor voltages of 3.700 - 4.299 Vdc. This table covers more than ±2 MHz from the 10.250-GHz center frequency. Gunnplexer frequency output is in MHz above 10.200 GHz.

Computer Program

After *Table 13-1*, I include the absurdly simple BASIC program that will run in most any microcomputer to calculate varactor voltage versus frequency for almost any slope desired, from 3.7 - 4.3 Vdc varactor input:

BASIC Program

```
 3  CLS
 4  :
 5  REM VARACTOR E VS. GPX FREQUENCY OUTPUT
    TRS-80 PROGRAM
 6  :
 7  REM FOR CENTER FREQUENCY 10.250 GHZ –
    VARACTOR E=4.0 VDC
 8  :
 9  REM AUTHOR:  W4UCH/2 – APRIL 1978 – FOR
    GPX COOKBOOK
10  :
11  INPUT"KHZ/.001 VOLT";KH:KH=INT(KH)
15  :
20  E=3.699
30  :
35  F=50.0:LF=301*KH/1000
36  :
41  KK=KH/1000:K=INT(KK*1000+.5)/1000
42  :
43  LF=(F-LF)
44  :
45  D=E+.001:DD=INT(D*1000+.5)/1000:PRINTDD,:E=DD
46  :
47  LG=LF+K:LL=INT(LG*1000+.999)/1000:PRINTLL:LF=LG
48  :
50  A=A+1:IFA=15THENINPUTJ:A=0
55  :
60  IFD=> 4.299THENSTOP
61  :
65  GOTO45
```

Table 13-1.

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
3.7	47.901	3.734	48.139
3.701	47.908	3.735	48.146
3.702	47.915	3.736	48.153
3.703	47.922	3.737	48.16
3.704	47.929	3.738	48.167
3.705	47.936	3.739	48.174
3.706	47.943	3.74	48.181
3.707	47.95	3.741	48.188
3.708	47.957	3.742	48.195
3.709	47.964	3.743	48.202
3.71	47.971	3.744	48.209
3.711	47.978	3.745	48.216
3.712	47.985	3.746	48.223
3.713	47.992	3.747	48.23
3.714	47.999	3.748	48.237
3.715	48.006	3.749	48.244
3.716	48.013	3.75	48.251
3.717	48.02	3.751	48.258
3.718	48.027	3.752	48.265
3.719	48.034	3.753	48.272
3.72	48.041	3.754	48.279
3.721	48.048	3.755	48.286
3.722	48.055	3.756	48.293
3.723	48.062	3.757	48.3
3.724	48.069	3.758	48.307
3.725	48.076	3.759	48.314
3.726	48.083	3.76	48.321
3.727	48.09	3.761	48.328
3.728	48.097	3.762	48.335
3.729	48.104	3.763	48.342
3.73	48.111	3.764	48.349
3.731	48.118	3.765	48.356
3.732	48.125	3.766	48.363
3.733	48.132	3.767	48.37

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
3.768	48.377	3.804	48.629
3.769	48.384	3.805	48.636
3.77	48.391	3.806	48.643
3.771	48.398	3.807	48.65
3.772	48.405	3.808	48.657
3.773	48.412	3.809	48.664
3.774	48.419	3.81	48.671
3.775	48.426	3.811	48.678
3.776	48.433	3.812	48.685
3.777	48.44	3.813	48.692
3.778	48.447	3.814	48.699
3.779	48.454	3.815	48.705
3.78	48.461	3.816	48.712
3.781	48.468	3.817	48.719
3.782	48.475	3.818	48.726
3.783	48.482	3.819	48.733
3.784	48.489	3.82	48.74
3.785	48.496	3.821	48.747
3.786	48.503	3.822	48.754
3.787	48.51	3.823	48.761
3.788	48.517	3.824	48.768
3.789	48.524	3.825	48.775
3.79	48.531	3.826	48.782
3.791	48.538	3.827	48.789
3.792	48.545	3.828	48.796
3.793	48.552	3.829	48.803
3.794	48.559	3.83	48.81
3.795	48.566	3.831	48.817
3.796	48.573	3.832	48.824
3.797	48.58	3.833	48.831
3.798	48.587	3.834	48.838
3.799	48.594	3.835	48.845
3.8	48.601	3.836	48.852
3.801	48.608	3.837	48.859
3.802	48.615	3.838	48.866
3.803	48.622	3.839	48.873

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
3.84	48.88	3.876	49.132
3.841	48.887	3.877	49.139
3.842	48.894	3.878	49.146
3.843	48.901	3.879	49.153
3.844	48.908	3.88	49.16
3.845	48.915	3.881	49.167
3.846	48.922	3.882	49.174
3.847	48.929	3.883	49.181
3.848	48.936	3.884	49.188
3.849	48.943	3.885	49.195
3.85	48.95	3.886	49.202
3.851	48.957	3.887	49.209
3.852	48.964	3.888	49.216
3.853	48.971	3.889	49.223
3.854	48.978	3.89	49.23
3.855	48.985	3.891	49.237
3.856	48.992	3.892	49.244
3.857	48.999	3.893	49.251
3.858	49.006	3.894	49.258
3.859	49.013	3.895	49.265
3.86	49.02	3.896	49.272
3.861	49.027	3.897	49.279
3.862	49.034	3.898	49.286
3.863	49.041	3.899	49.293
3.864	49.048	3.9	49.3
3.865	49.055	3.901	49.307
3.866	49.062	3.902	49.314
3.867	49.069	3.903	49.321
3.868	49.076	3.904	49.328
3.869	49.083	3.905	49.335
3.87	49.09	3.906	49.342
3.871	49.097	3.907	49.349
3.872	49.104	3.908	49.356
3.873	49.111	3.909	49.363
3.874	49.118	3.91	49.37
3.875	49.125	3.911	49.377

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
3.912	49.384	3.948	49.636
3.913	49.391	3.949	49.643
3.914	49.398	3.95	49.65
3.915	49.405	3.951	49.657
3.916	49.412	3.952	49.664
3.917	49.419	3.953	49.671
3.918	49.426	3.954	49.678
3.919	49.433	3.955	49.685
3.92	49.44	3.956	49.692
3.921	49.447	3.957	49.699
3.922	49.454	3.958	49.706
3.923	49.461	3.959	49.713
3.924	49.468	3.96	49.72
3.925	49.475	3.961	49.727
3.926	49.482	3.962	49.734
3.927	49.489	3.963	49.741
3.928	49.496	3.964	49.748
3.929	49.503	3.965	49.755
3.93	49.51	3.966	49.762
3.931	49.517	3.967	49.769
3.932	49.524	3.968	49.776
3.933	49.531	3.969	49.783
3.934	49.538	3.97	49.79
3.935	49.545	3.971	49.797
3.936	49.552	3.972	49.804
3.937	49.559	3.973	49.811
3.938	49.566	3.974	49.818
3.939	49.573	3.975	49.825
3.94	49.58	3.976	49.832
3.941	49.587	3.977	49.839
3.942	49.594	3.978	49.846
3.943	49.601	3.979	49.853
3.944	49.608	3.98	49.86
3.945	49.615	3.981	49.867
3.946	49.622	3.982	49.874
3.947	49.629	3.983	49.881

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
3.984	49.888	4.02	50.14
3.985	49.895	4.021	50.147
3.986	49.902	4.022	50.154
3.987	49.909	4.023	50.161
3.988	49.916	4.024	50.168
3.989	49.923	4.025	50.175
3.99	49.93	4.026	50.1a2
3.991	49.937	4.027	50.189
3.992	49.944	4.028	50.196
3.993	49.951	4.029	50.203
3.994	49.958	4.03	50.21
3.995	49.965	4.031	50.217
3.996	49.972	4.032	50.224
3.997	49.979	4.033	50.231
3.998	49.986	4.034	50.238
3.999	49.993	4.035	50.245
4	50	4.036	50.252
4.001	50.007	4.037	50.259
4.002	50.014	4.038	50.266
4.003	50.021	4.039	50.273
4.004	50.028	4.04	50.28
4.005	50.035	4.041	50.287
4.006	50.042	4.042	50.294
4.007	50.049	4.043	50.301
4.008	50.056	4.044	50.308
4.009	50.063	4.045	50.315
4.01	50.07	4.046	50.322
4.011	50.077	4.047	50.329
4.012	50.084	4.048	50.336
4.013	50.091	4.049	50.343
4.014	50.098	4.05	50.35
4.015	50.105	4.051	50.357
4.016	50.112	4.052	50.364
4.017	50.119	4.053	50.371
4.018	50.126	4.054	50.378
4.019	50.133	4.055	50.385

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
4.056	50.392	4.092	50.644
4.057	50.399	4.093	50.651
4.058	50.406	4.094	50.658
4.059	50.413	4.095	50.665
4.06	50.42	4.096	50.672
4.061	50.427	4.097	50.679
4.062	50.434	4.098	50.686
4.063	50.441	4.099	50.693
4.064	50.448	4.1	50.7
4.065	50.455	4.101	50.707
4.066	50.462	4.102	50.714
4.067	50.469	4.103	50.721
4.068	50.476	4.104	50.728
4.069	50.483	4.105	50.735
4.07	50.49	4.106	50.742
4.071	50.497	4.107	50.749
4.072	50.504	4.108	50.756
4.073	50.511	4.109	50.763
4.074	50.518	4.11	50.77
4.075	50.525	4.111	50.777
4.076	50.532	4.112	50.784
4.077	50.539	4.113	50.791
4.078	50.546	4.114	50.798
4.079	50.553	4.115	50.805
4.08	50.56	4.116	50.812
4.081	50.567	4.117	50.819
4.082	50.574	4.118	50.826
4.083	50.581	4.119	50.833
4.084	50.588	4.12	50.84
4.085	50.595	4.121	50.847
4.086	50.602	4.122	50.854
4.087	50.609	4.123	50.861
4.088	50.616	4.124	50.868
4.089	50.623	4.125	50.875
4.09	50.63	4.126	50.882
4.091	50.637	4.127	50.889

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
4.128	50.896	4.164	51.148
4.129	50.903	4.165	51.155
4.13	50.91	4.166	51.162
4.131	50.917	4.167	51.169
4.132	50.924	4.168	51.176
4.133	50.931	4.169	51.183
4.134	50.938	4.17	51.19
4.135	50.945	4.171	51.197
4.136	50.952	4.172	51.204
4.137	50.959	4.173	51.211
4.138	50.966	4.174	51.218
4.139	50.973	4.175	51.225
4.14	50.98	4.176	51.232
4.141	50.987	4.177	51.239
4.142	50.994	4.178	51.246
4.143	51.001	4.179	51.253
4.144	51.008	4.18	51.26
4.145	51.015	4.181	51.267
4.146	51.022	4.182	51.274
4.147	51.029	4.183	51.281
4.148	51.036	4.184	51.288
4.149	51.043	4.185	51.295
4.15	51.05	4.186	51.302
4.151	51.057	4.187	51.309
4.152	51.064	4.188	51.316
4.153	51.071	4.189	51.323
4.154	51.078	4.19	51.33
4.155	51.085	4.191	51.337
4.156	51.092	4.192	51.344
4.157	51.099	4.193	51.351
4.158	51.106	4.194	51.358
4.159	51.113	4.195	51.365
4.16	51.12	4.196	51.372
4.161	51.127	4.197	51.379
4.162	51.134	4.198	51.386
4.163	51.141	4.199	51.393

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
4.2	51.4	4.236	51.652
4.201	51.407	4.237	51.659
4.202	51.414	4.238	51.666
4.203	51.421	4.239	51.673
4.204	51.428	4.24	51.68
4.205	51.435	4.241	51.687
4.206	51.442	4.242	51.694
4.207	51.449	4.243	51.701
4.208	51.456	4.244	51.708
4.209	51.463	4.245	51.715
4.21	51.47	4.246	51.722
4.211	51.477	4.247	51.729
4.212	51.484	4.248	51.736
4.213	51.491	4.249	51.743
4.214	51.498	4.25	51.75
4.215	51.505	4.251	51.757
4.216	51.512	4.252	51.764
4.217	51.519	4.253	51.771
4.218	51.526	4.254	51.778
4.219	51.533	4.255	51.785
4.22	51.54	4.256	51.792
4.221	51.547	4.257	51.799
4.222	51.554	4.258	51.806
4.223	51.561	4.259	51.813
4.224	51.568	4.26	51.82
4.225	51.575	4.261	51.827
4.226	51.582	4.262	51.834
4.227	51.589	4.263	51.841
4.228	51.596	4.264	51.848
4.229	51.603	4.265	51.855
4.23	51.61	4.266	51.862
4.231	51.617	4.267	51.869
4.232	51.624	4.268	51.876
4.233	51.631	4.269	51.883
4.234	51.638	4.27	51.89
4.235	51.645	4.271	51.897

Table 13-1. (Continued)

varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)	varactor voltage (volts)	Gunnplexer frequency above 10.2 GHz (MHz)
4.272	51.904	4.286	52.002
4.273	51.911	4.287	52.009
4.274	51.918	4.288	52.016
4.275	51.925	4.289	52.023
4.276	51.932	4.29	52.03
4.277	51.939	4.291	52.037
4.278	51.946	4.292	52.044
4.279	51.953	4.293	52.051
4.28	51.96	4.294	52.058
4.281	51.967	4.295	52.065
4.282	51.974	4.296	52.072
4.283	51.981	4.297	52.079
4.284	51.988	4.298	52.086
4.285	51.995	4.299	52.093

This program is absurdly simple but it saves a lot of work. If you wish to measure your Gunnplexer's varactor-voltage-versus-frequency output and calculate the slope in kHz per millivolt, the program will print out the frequency versus varactor voltage, all center on *4.000 Vdc varactor voltage = 10.250 GHz.*

Conclusion

The Level-II communications system with AFC and plus - minus 7.5-kHz ceramic filter is about as narrowband a receiving system as a standard Gunn diode's spectral noise will allow. On weak signals, the noise is noticeable but not objectionable.

For those who wish to operate only 30-Mhz Gunnplexer i-fs, the combination of this narrowband system with either of the wideband fm detectors presented in the last section of Chapter 9 is obvious. All have 10.7-MHz input and could share a common

29/30 MHz converter and the R40 audio amplifier with a single dpdt switch for selecting either wide or narrowband operation. If the RCA CA3089 wideband fm circuit is used, it's easy to add AFC through its pin 7 (AFC amplifier) to a single LM3900 op amp to feed the Gunnplexer varactor. For those wishing to operate 29/30 MHz simplex, it's a simple matter to switch varactor voltage up 3 - 4 Vdc to swing Gunnplexer output from 10.250 GHz to either 10.279 or 10.280 GHz.

For those wishing truly narrowband (850 - 3000 Hz) FSK with crystal-controlled Gunn-diode operation, the next chapter is devoted entirely to this subject, using the Crystalmatic phase-lock system. With only minor modifications it's compatible with the narrowband fm-AFC system.

Reference

1. Doug Grant, K1DG, "Digital Readout for the Ham-3 Rotator, *ham radio*, January, 1979, pages 56-56.

14

Level II Communications Systems - Part 2

Description of a truly narrowband 10-GHz system. How to reduce bandwidth and improve signal-to-noise ratio. Using the TRS-80 computer. Tips on how to make the best of your endeavours using readily available hardware. Operating suggestions. A program for the TRS-80 computer that allows Morse code transmission and reception.

There's an old saying: "When all else fails, try Morse code." Much wisdom is in this simple statement, which really means "Reducing bandwidth increases signal-(carrier)-to-noise ratio." The method used to modulate the rf carrier is not important—only bandwidth counts when signal-to-noise ratio is measured. The type of modulation may be continuous wave (CW), frequency-shift keying (FSK), pulse-code modulation (PCM), a-m or fm.

Now might be a good time to re-read Chapter 2, whose graphs illustrate that, every time bandwidth is reduced by one-half, signal-to-noise ratio is improved by 3 dB; *i.e.*, halve the bandwidth and double the signal-to-noise ratio.

Bandwidth and S/N Improvement

Let's compare signal-to-noise ratio improvement when we go from 200-kHz-bandwidth wideband fm to 1-kHz bandwidth frequency-shift keying using Morse, Baudot, or ASCII code:

Bandwidth (kHz)	Gain (dB)
200	
100	3
50	3
25	3
12.5	3
6.25	3
3.12	3
1.56	3
1.00	2
	23

Now, 23dB represents a power ratio improvement of 200 to 1 which, in the local vernacular, is "quite a bunch." Suddenly our 40 milliwatts of 10-GHz Gunnplexer output looks like an 8-watt signal at the receiving end of the communications link "if a 1-kHz i-f bandwidth" is used at the receiver instead of a 200-kHz bandwidth. Unfortunately, you don't get something for nothing, even at 10 GHz. What we've given up for this 23-dB improvement in signal-to-noise ratio at the receiving end is *considerably reduced information transfer rate.* Depending on our communications requirements, this may or may not be good, as the case may be.

Bandwidth Tradeoffs

If our objective is maximum range in a VHF contest (or a record-setting attempt), and the stations we're trying to work know (for instance) that we're using frequency-shift keying of 850 Hz with Morse code (sent by hand or computer) at 15 words per minute, then all is well. But we use very-narrow-band fm voice, then we must a) open up the i-f bandwidth at the receiving end of the link to at least 3kHz and give away 5 dB, or b) expand the time domain approximately by 3 by transmitting out 3-kHz voice fm signal at one-third normal speed to stay within the 1-kHz i-f bandwidth. This is the old "tape recorder speed trick" and is the same principle used by slow-scan video systems to reduce bandwidth. All we're doing is trading time for reduced i-f bandwidth and improved signal-to-noise ratio.

Chapter 12 provided an introduction to the *Crystalmatic* system concept and also covered the construction of the X22 crystal-controlled frequency multiplier/antenna that's driven by the VHF Engineering TX-432, which provided the weak-signal-source drive in Chapter 10. A brief review of what the *Crystalmatic* system accomplishes is now in order:

1. Absolute output-frequency control of the Gunnplexer 10-GHz signal.
2. Frequency stability of the *Gunnplexer signal* = *X528* of the 19-MHz crystal in the TX-432 transmitter.
3. Near elimination of the Gunn oscillator close-in fm spectral noise.

It's obvious that, for any variety of Gunnplexer operation using i-f bandwidths of 3 kHz or less, all requirements of 1, 2, and 3 above must be met for successful and repeatable operation.

Figure 14-1 illustrates the second version of the Level-II Communications System with the *Crystalmatic* phase-lock system that I constructed. The only significant differences between this version and that of the version in *Figure 12-2* are:

1. The P8 preamplifier built into the Gunnplexer enclosure is tuned to 28-32 MHz instead of 95-101 MHZ to allow the choice of a 29- or 30-MHz centered first i-f. Most important it eliminates commercial fm broadcast station stray pickup and feedthrough, which is a tremendously difficult problem to overcome in metropolitan areas.
2. Modification of the earlier version to allow convenient switching between Level II with AFC (Chapter 13) and the Level II with *Crystalmatic* which is a decided improvement for the average Gunnplexer operator who wishes to operate on both modes with a single system.
3. Addition of a Hamtronics (Hilton, New York) P9 i-f preamplifier (entirely optional) ahead of both the communications receiver and the RF28 crystal converter to:
   (*a*). Compensate for line loss on long coax runs between the remotely mounted Gunnplexer/preamp/enclosure and communications receiver/RF28 converter.

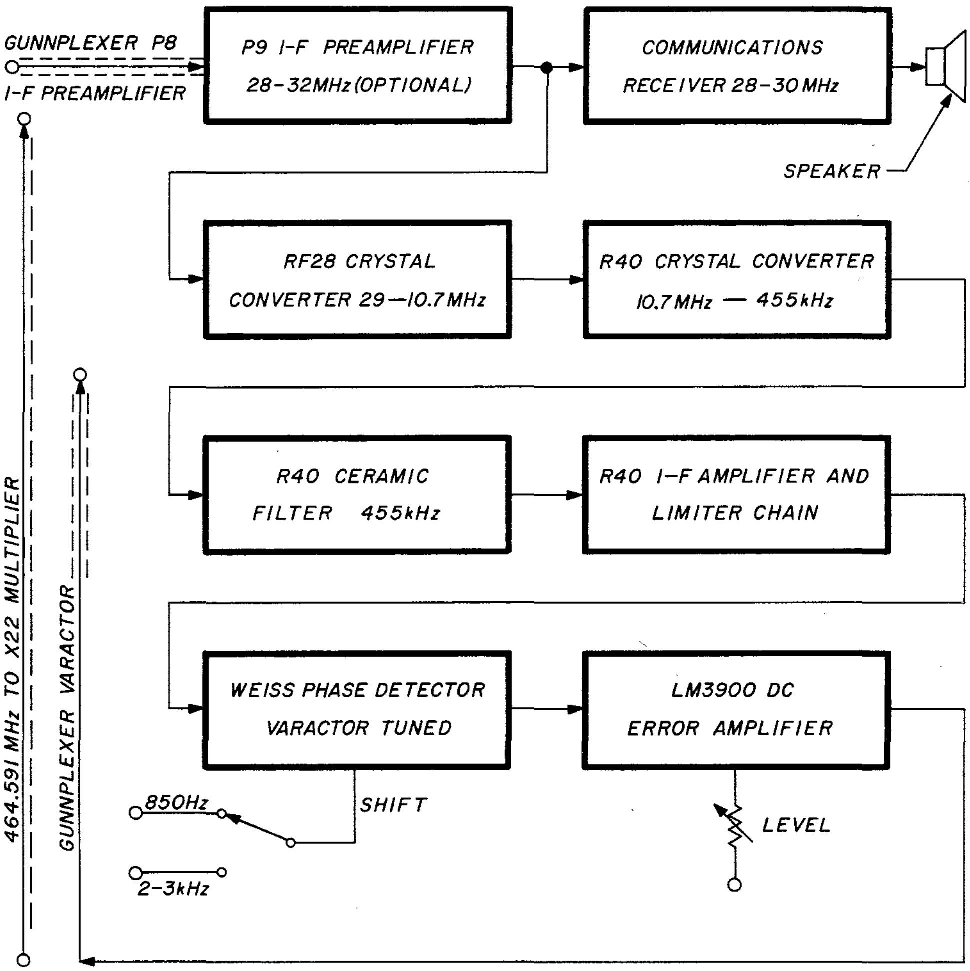


Figure 14-1.

Block diagram of the Level-II communications system with *Crystalmatic* feature. This version features a) elimination of commercial fm-broadcast interference, b) convenient switching between Level II with AFC and Level II with Crystalmatic, and c) addition of an i-f amplifier ahead of receiver and converter – all designed to enhance communications in the 10-GHz Amateur band.

(*b*). Compensate for the -3dB power split to simultaneously drive the communications receiver and RF28 crystal converter.

(*c*). Provide additional front-end rf gain for older-model communications receivers, whose performance on 10 meters (28-30 MHz) is somewhat lacking.

4. Changing the TX-432 crystal to 19.357995 MHz provides TX-432 output on 464.591 MHz and, with the multiplier/antenna, furnishes X22 output on *10.221 GHz = 29 MHz* i-f when using a Gunnplexer with output on 10.250 GHz.

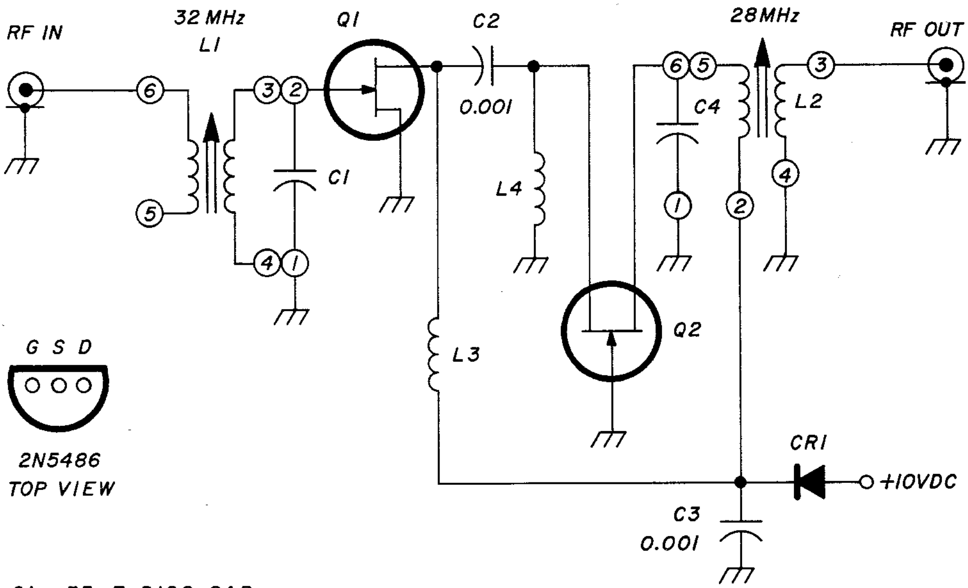
Hamtronics P8 Gunnplexer i-f Preamplifier—Construction and Alignment

This new Gunnplexer i-f preamplifier, mounted on the Gunnplexer module assembly in the weatherproof enclosure, is the same model P8 cascode FET preamp described in Chapter 6 except it covers 28-32 MHz rather than 95-101 MHz. Additionally, the ratios of L1, C1 and L2, C4 have been increased to improve bandwidth, as the 2N5486 FETS provide more than adequate gain at these low frequencies.

Circuit description. Figure 14-2 illustrates this simple circuit and the new recommended component values for optimum 28-32-MHz frequency coverage. CR1 is most any type of germanium or silicon diode to protect Q1 and Q2 against supply polarity reversal. Use an inexpensive 500 mA - 1 ampere silicon diode here. It will protect both the preamplifier and the Gunn diode in the Gunnplexer module, as both use the same +10 Vdc power-supply line.

Alignment. Using your grip-dip oscillator, adjust L1, C1 initially to 32 MHz and L2, C4 to 28 MHz. With the wideband fm receiver described in the last section of Chapter 9 used as a signal-level moitor, and with 10 Vdc to the preamplifier, readjust L1 and L2 for a response as flat as possible from 28 - 32 MHz (use a ¼ watt, 200-ohm resistor across the rf input). This 200-ohm resistor is a very close match to the Gunnplexer mixer-diode output impedance presented to the preamplifier input.

With the wide bandwidth of 28-32 MHz, there should be no tendency for the preamplifier to oscillate or exhibit any tendency toward regeneration; *i.e.*, to produce excessive noise. If you have a problem, try soldering a 1000-ohm, 1/4-watt loading resistor across C4. This resistor will not significantly reduce gain and will improve bandpass response slightly over the 28-32 MHz range.



C1 33pF DISC CAP
C4 20pF DISC CAP
CR1 ANY 500mA 20PIV DIODE
L1 4 1/6 TURNS LINK TERMINALS 5 AND 6
13 5/6 TURNS TERMINALS 3 AND 4
L2 5 5/6 TURNS LINK TERMINALS 3 AND 4
20 3/6 TURNS TERMINALS 2 AND 5
L3, L4 15μH CHOKE
Q1, Q2 2N5486 FET

Figure 14-2.

Schematic diagram of the Gunnplexer i-f preamplifier using the Hamtronics P8 cascode FET circuit, which covers 28-32 MHz. (See chapter 6).

The Hamtronics P8 preamplifier will produce over 20 dB gain with a noise figure less than 2 dB at these frequencies.

At $10.95 for the model P8-kit version and $21.95 for the wired and tested version (model P16), this little cascode amplifier, which fits easily with the Gunnplexer assembly into the weatherproof Gunnplexer housing, is truly a bargain.

For those who want the ultimate noise figure using this simple cascode circuit, and who are willing do a bit of cut and try, substitute a pair of Silconix J310 JFET transistors for Q1 and Q2.

The J310 transistors are selected, very low-noise J308s. With proper matching they will yield a preamplifier noise figure of about 1.0 dB over the 28 - 30 MHz range.

Hamtronics P9 Preamplifier Kit— Construction and Test

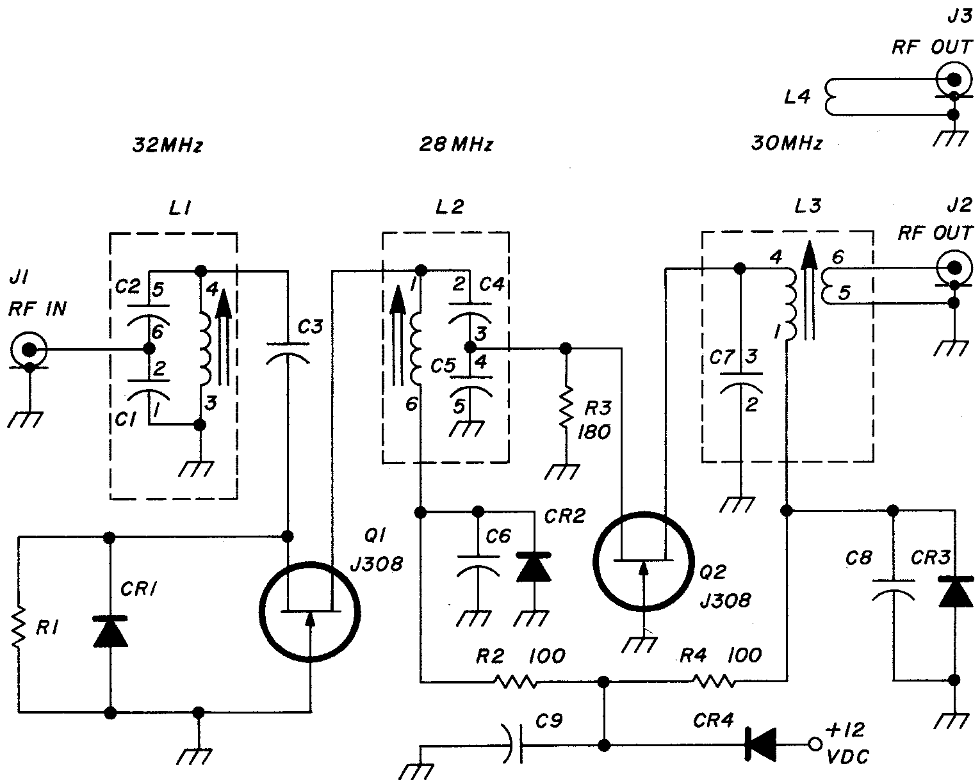
This optional grounded-gate preamplifier will improve most older-generation communication receivers that lack adequate gain and noise figure over the 28 - 30 MHz range. It will also compensate for a) the coax-line loss between the Gunnplexer housing/assembly and Level II receiver, and b) the -3/ dB power-split loss incurred when simultaneously driving the RF28 converter and communications receiver.

If you have any doubts as to whether it will be needed or not, build one anyhow. Try it, and if it helps, keep it. Otherwise, it will be used in the next chapter as a video i-f amplifier in the 40 - 50 MHz (45-MHz center frequency) range. It most certainly will not be wasted, as we use one to four of the P9 amplifiers, depending on the distance you wish to cover with your Gunnplexer television and/or computer system. *Figure 14-3* shows the circuit.

The Hamtronics model P9 preamplifier kit (model P14 assembled) sells for $12.95 and $24.95 respectively. It uses the Siliconix UHF super junction-field-effect transistors. (JFET) type J308 in cascaded grounded-gate configuration. In the 28 - 32-MHz range it delivers more than 25 dB gain with a 1.5 dB or better noise figure.

Again, for those who insist on the ultimate, J310 selected low-noise figure JFETS may be directly substituted for the J308s supplied with the kit. They'll deliver a noise figure very close to 1.0 dB in the 28 - 32-MHz range in this circuit, which doesn't accomplish a thing here because system noise figure is pretty much set by the Gunnplexer mixer and built-in Gunnplexer i-f preamplifier.

Circuit description. The P9 cascaded grounded-gate configuration is the JFET counterpart of the old cascaded triode grounded-grid amplifiers of over 20 years ago. These amplifiers used the Western Electric gold-plated 417A triodes, which cost $20 each and up. Although they had the "best noise-figure in town" for their time, they didn't compare



C1 100pF
C2 33pF
C3 12pF
C4 20pF
C5 100pF
C6,C8,C9 0.001
CR4 MOST ANY SILICON
DIODE = >15 VDC P.I.V.
CR1-3 1N4148

L1 12 1/6 TURNS TERMINALS 3 AND 4
L2 18 1/6 TURNS TERMINALS 1 AND 6
L3 PRIMARY 18 1/2 TURNS
TERMINALS 4 AND 1
SECONDARY 2 1/6 TURNS
TERMINALS 5 AND 6
L4 2 1/2 TURNS NO. 26(0.3mm)
INSULATED ON TOP OF L3 TO
GROUND AND J3

Figure 14-3.
Hamtronics P9 preamplifier schematic. This kit covers 28-32 MHz.

with today's JFETS in the less-than-$1.00 each price class. My goodness! How times have changed for the better.

Note that each JFET input and output stage is protected by 1N4148 diodes in *Figure 14-3.* These devices protect the rather sensitive JFETS from voltage transients, which would otherwise destroy their extremely thin (micron range) junctions. CR4 is included to protect the J308s from accidentially reversed B+ polarity. CR4 may be most any old junk-box germanium (or silicon) diode, as the total current drawn by the P9 preamplifier is less than 20 mA.

Tune up. It's impossible to grid dip L1 and L2 on frequency without disconnecting C3 to L1 and R3/Q2 to the junction of C4 and C5. A good starting point is to grid dip L1, L2 and L3 to the frequencies shown in *Figure 14-3* then reconnect everything.

L4 is nothing more than a short 3 ½ inch (90mm) length of no. 26 (0.3mm) insulated hookup wire wrapped 2-½ turns over L3. Use a 1/16 inch (1.5mm) diameter drill, drill two holes through the pc board between the coil can cover mounting lug holes and L3 base to allow L4 to exit. Also drill a 5/32 inch (4mm) hole next to J2 and install a threaded RCA phone jack for J3. The closest L4 wire goes to the J3 center connector, and the other L4 wire goes to the pc board ground next to J3. Make sure that the L3 metal can coil cover clearrs the two insulated wires from L4 when installed.

Final tune up of the P9 preamplifier may be done using the wideband 28-32 MHz fm receiver described in the last section of Chapter 9, using the grid-dip oscillator as a signal source. Considering the three tuned circuits in the P9 preamplifier and the recommended LC ratios for each one, you should have little difficulty adjusting the preamplifier for the 4-MHz bandpass with 3 dB or less ripple. If you plan to use the Level II Communications System only with *Crystalmatic*, set the 3-dB down points at 28 and 30 MHz using a communications receiver S meter for signal level indication and adjust L1, L2 and L3 for proper bandpass. Use either your grid-dip oscillator or signals on the 10-meter band for sources.

So far, I've constructed four of the P9 amplifier kits with no tune up, or self oscillation, or regeneration problems. Each has worked as advertised or better.

Idealized 1979 All-Mode Gunnplexer System

Figure 14-4 is a block diagram of what I believe is the ultimate (*circa* 1979) all-mode (legal) Gunnplexer operating system. Surely many readers will be able to improve on it (and many undoubtedly will), but at least it's a beginning. It's design is based on the following assumptions:

1. 10.250 GHz will become the national and international standard 10-GHz Amateur band calling frequency for any type or variety of modulation during 1980-1985.

2. Radio Amateurs worldwide will standardize on the following i-fs for both simplex and duplex operation:

(*a*). Wideband fm, 30 MHz.

(*b*). Narrowband fm, 30 MHz.

(*c*). Very narrowband fm, 29 MHz (3 kHz or less deviation using voice, Morse, Baudot, or ASCII code).

(*d*). Wideband fast-scan television, 45 MHz center i-f.

Note: Pulse modulation is not presently allowed in the U.S. on the 10-GHz amateur band, but "presently" doesn't necessarily mean forever.

3. The first AMSAT satellite with a modified 10-GHz Gunnplexer will be launched *circa* 1985-1987.

4. Amateur-built 10-GHz fm/CW radars will operate only on frequencies above 10.4 GHz by "gentleman's agreement."

While we're making prognostications, we might as well include one more: Microwave Associate, Inc., will introduce the 24.5-GHz Gunnplexer transceiver module during 1982-1984.

The preceding assumptions are only calculated guesses at best, in early 1979. It will be interesting to observe how very conservative they were in the next few years (hopefully).

Figure 14-4 illustrates the idealized all mode Gunnplexer system that could be assembled during 1979 (am and ssb are intentionally omitted for the time being). The concept follows the earlier assumptions that 10.250 GHz will become the national and international standard calling frequency for all modes of Amateur 10-GHz communications, at least for the next 5 or 6 years. It includes most all modes of Amateur communications that are practical (today) using a Gunnplexer. It intentionally excludes Amateur-built-and-operated fm/CW radars, as one appears in Volume II of the Gunnplexer Cookbook for those who need a radar altimeter to "auto-land" their airplane or hot-air balloon.

All components for the *Figure 14-4* system are available today at modest prices except for the low-noise Gunnplexer i-f preamplifier gain block that covers the 28-50 MHz range.

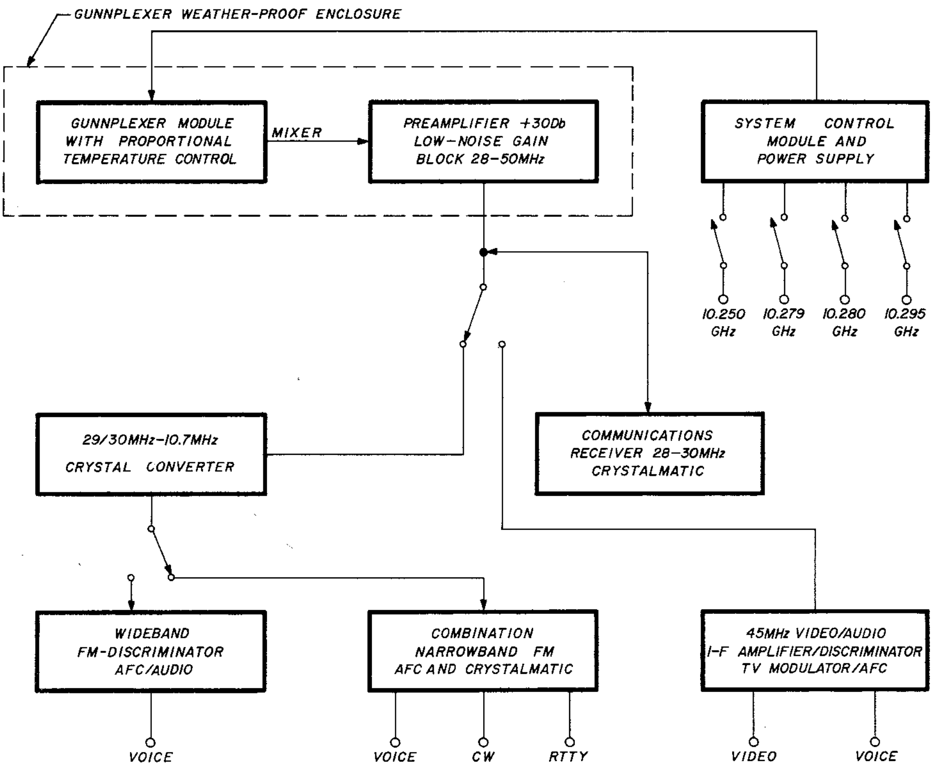


Figure 14-4.

Block diagram of the "ultimate" all-mode Gunnplexer system. Most all modes of Amateur communications are included, using Gunnplexer technology.

About the only modestly priced gain-blocks available today in the $100 price-class are far too noisy for our use. Typical noise figures are 10 - 11 dB, with the few available low-noise circuits far too expensive. I expect that +30-dB gain blocks with 2 dB or better noise figures will be available during 1981-1982 in the under-$50 price class.

The reason for presenting *Figure 14-4* is to impress on the reader how very close we are to completing this ultimate 1979 all-mode Gunnplexer system. With the exception of the low-noise wideband gain block, we'll have completed it all by the end of Chapter 15.

Level-II Switching For The Crystalmatic System

Only a modest amount of switching is necessary for the Level-II communications system to change from 30 MHz i-f AFC operation to 29 MHz i-f *Crystalmatic* operation. *Figure 14-5* illustrates the minimum requirements.

Let's examine each item in *Figure 14-5.*

1. *TX-432 power.* If you use the HC25/U crystal proportional-temperature control (PTC) unit for the TX-432 crystal (covered in Chapter 5), remember that at least 5 - 10 minutes are needed for the crystal temperature to stabilize. If you plan to switch frequently between Level II AFC and *Crystalmatic,* leave the PTC, crystal oscillator, and first multiplier stage ON continually when operating, and switch the + 12 Vdc ON and OFF *only* to the following TX-432 stages.

2. *TX-432 crystal frequency.* If you plan to use the *Crystalmatic* system on 10.250 GHz for the duplex operation only with a 29-MHz i-f, you don't have a crystal-switching problem, because a single 19.357955-MHz crystal (X528) will put the Gunnplexer output exactly on 10.250 GHz. An obvious freebie is to use this same crystal for spotting or calibrating 10.279 GHz (*10.250 GHz + 29 MHz = 10.279 GHz*) when using the Level-II system with AFC that may be tuned plus or minus 2 MHz from its 30-MHz center frequency.

To operate 10.250-GHz simplex with a 29-MHz i-f for *Crystalmatic* and 30 MHz i-f in the AFC mode would require the following crystals for the TX-432:

29-MHz i-f Crystalmatic. Transmit: 10.250 GHz, 19.357955-MHz crystal for lock. Receive: 10.229 GHz, 19.412879-MHz crystal for lock.

30-MHz i-f with AFC. Transmit: 10.250 GHz, 19.356061-MHz crystal for spotting. Receive: 10.280 GHz, 19.412879-MHz crystal for spotting.

The VHF Engineering model CD2 10-channel transmit crystal deck, with switches and trimmer capacitors, at $15.50 each, is an excellent buy if you wish to operate simplex with your *Crystalmatic* or want to spot your exact frequency with the Level-II AFC mode system. There's plenty of room for extra crystals to spot 10.295 GHZ for 45-MHz center i-f for fast-scan TV or computer

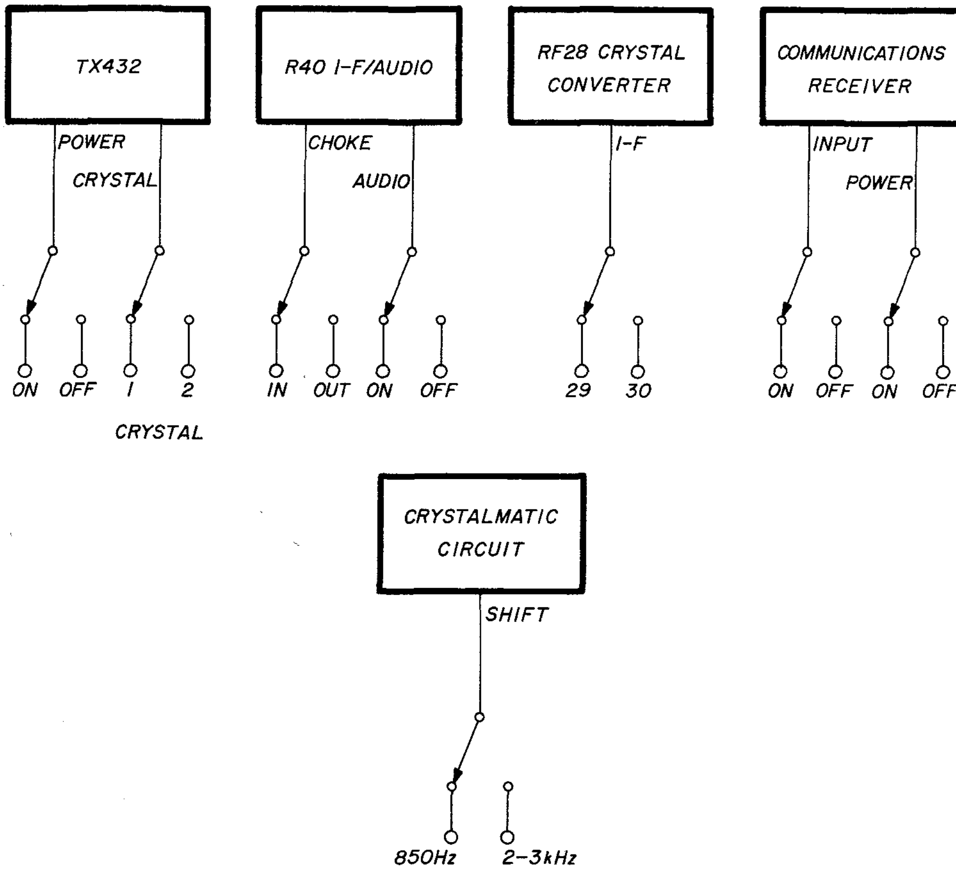


Figure 14-5.
Scheme for switching from AFC to Crystalmatic control.

video/audio signals (Chapter 15), or for those who want everything: spotting crystals for 10.250 GHZ plus i-fs of 98 MHz, 111 MHz, 113 MHz, or what have you.

3. *R40 audio choke.* T2 in *Figure 13-10* should be shorted with a switch when using the *Crystalmatic* system for optimun CW or RTTY keying. T2 distorts (as it should), the rise and fall times of the desired square wave. We could eliminate the

16-μF electrolytic capacitor at input terminal 3 of the LM3900 AFC/error amplifier, but it also reduces ac hum pickup, so should be left in place or if desired, reduced in value.

4. *R40 audio ON-OFF.* Referring to *Figure 13-8,* note that the Weiss discriminator output at point E8 is placed across the 10k volume control, which also provides a dc ground return. When operating as a phase detector in the *Crystalmatic* mode, we want "all" the dc error voltage fed to the LM3900 dc-error amplifier. Thus the 10k R40 volume control on-off switch is used to open its ground return when in the full counterclockwise position.

The reasons for opening the volume-control ground return are:

(*a*). In the *Crystalmatic* mode we have no use for the R40 audio amplifier. The communications receiver tunes the desired signal as well as the crystal's X528 harmonic at 29 MHz.

(*b*). *Crystalmatic* operates at its highest efficiency (especially for spectral noise reduction) when the total phase detector error signal goes to the LM3900 dc error amplifier.

(*c*). Listening to the TX-432 crystal X528 harmonic on two receivers (both the R40 and your communications receiver) is no fun at all and serves no useful purpose.

5. *RF28 Crystal Converter 29/30 MHz - 10.7 MHz.* As previously mentioned, you may use either a switch to change crystal frequencies for *Crystalmatic* or AFC modes or simply plug in another crystal for the mode desired. I chose the latter method.

6. *Communications Receiver Input and Power Switching.* There's no point in losing a 3-dB signal to a communications receiver when operating in the Level-II AFC mode because the receiver is not being used. You have two choices: unplug the receiver input from the P9 preamplifier or install a switch to disconnect its input.

The probability of copying a signal in the AFC mode on the communications receiver is obviously 50:50, as it tunes one-half the 28-32 MHz (28-30 MHz) range that's electronically tuned by the R40. If you're operating simplex (transmit on 10.250 GHz and receive on 30 MHz) you can offset your Gunnplexer frequency to receive the other station's 10.250 GHz signal on both the R40 and communications receiver simultaneously.

One possible application would be by a net-control station looking for late comers and newcomers during net check in, who were slightly off the net frequency.

Although somewhat surprising, my communications receiver did a fair-to-good job of slope detecting narrowband fm signals with frequency deviation up to 15 kHz while in the 8-kHz bandwidth am mode. But for all practical purposes, the communications receiver might just as well be disconnected and turned off when operating in the AFC mode.

7. *Crystalmatic Frequency - Shift Keying Selection. Figure 12-9* illustrates the concept of how to generate either 850 Hz frequency-shift keying (FSK) or 2 - 3kHz FSK. Whether the code is Morse, Baudot, or ASCII (when legalized) is of no consequence and solely up to you. You can generate Morse code with a frequency shift of 850 Hz just as easily as Baudot or ASCII with a frequency shift of 2 - 3 kHz. Convention and accepted practice would indicate that *vice-versa* is more appropriate in most cases.

"Convention" means that stations on the other end of the 10-GHz communications link would find it easier to tune their RTTY demodulator for standard 850-Hz-wide FSK.

Many communications receivers may be tuned so that the Morse key-down beat-frequency-oscillator beat note is in the receiver i-f passband and the key-up beat is well outside the passband, which would allow conventional Morse-code reception. If you have a 1-or 2-kHz i-f bandwidth selection switch on your receiver, by all means use the narrowset Improving Communications reliability bandwidth possible to pick up those freebie dBs.

Now is the time that a "light" will come on in the eyes of Gunnplexer buffs who realize that, when using frequency-shift keying for Morse-code transmission, there are actually two channels of information being transmitted, key up and key down, on two different frequencies. These fellows, will ask themselves, "Why not use both channels for improved communication-link reliability?" Why not, indeed! If selective fading (not caused by D, E, or F layers) occurs on 10 GHz, would not this redundant-information channel improve communications link reliability? The answer is: maybe yes and maybe no, depending on the fading mechanism. The old adage "when in doubt, try it," seems to apply to this question.

An interesting experiment that could be used to find the answer to this question through empirical means is as follows. Using two communications receivers with a single *Crystalmatic* system, tune the first to the key-up frequency and the second to the key-down frequency, of a distant Gunnplexer signal that's being keyed automatically with a Morse-code message of most any variety. It could simply be "CQ CQ CQ DE W4UCH/2 ," or any message you wish.

The experiment would be most meaningful if the distant automatically keyed Gunnplexer signal was only about one S unit above the noise level during bright, sunny-day conditions. The communications receiver, tuned to the key-up frequency, would have its audio output rectified and driving a TTL inverter that turns an audio oscillator on and off, which feeds a two-channel stereo tape recorder on channel 1.

The second communications receiver audio output (audio tone when key down) could be mixed with the audio output from the keyed audio oscillator and fed to the stereo recorder channel 2.

A very long-playing tape is inserted into the recorder. The recorder is set to its slowest speed so tapes will have to be changed only once a day.

Turn everything on and pray for a rainy day. A good first-class thunderstorm with moderate-to-heavy rain would be super! When the sun reappears, play back the tape and listen. Was the dual-signal channel signal more reliable than that of the single channel?

This may seem a difficult way to do it (and it is). But most individuals have a remarkable stereo hearing sense, which after a few minutes practice, allow them to discern even brief signal dropouts on channel 1. What improvement in 10-GHz-path reliability did the dual channels offer?

Use Your TRS-80 Computer, Sit Back, and Watch

Rather than listen to hours of recorded tapes of the Gunnplexer automatic keyer sending CQ, why not set up your TRS-80 microcomputer to count bits of data INPut to port 0 from the single channel 1 receiver, and bits of data INPut to port 2 from the combined two channels of both receivers?

Write a brief program so that the computer continually compares the presence of signals on both port 0 and port 1. (It's a great bean-counting machine with a clock at nearly 2 MHz and never tires or gets bored with such mundane tasks as this.) When the signal inputs to ports 0 and 1 differ, have it print out date, time, and bit difference per minute. If you have a Heathkit electronic weather station with suitable A-D converters, the TRS-80 could print out weather conditions as well as date and time whenever received bits differ. See reference 1 for an excellent article on low cost A-D converters. It will give you the fundamentals to modify your Heathkit weather station.

What did your author find out from this 1-*versus* 2-channel 10-GHz frequency-diversity experiment? Volume II of the Gunnplexer Cookbook will have the answer.

Crystalmatic Modulation System and Above-Ground Power Supply

Figure 14-6 illustrates the final version of the *Crystalmatic* modulation system and its above-ground power supply.

Bridge rectifier CR1-CR4 (*Figure 14-6*) increases the dc modulating voltage to the MV2209 varicap (varactor) above ground, so that the Weiss phase detector remains in balance with respect to dc ground. CR1-CR4 may be most any variety from the junk box. They deliver only 800 microamps. (I used some mini-silicon switching diodes from Poly Paks, 200 for $2.00.)

The pots used to adjust frequency shift, shown in *Figure 12-9* were replaced by fixed resistors in the schematic of *Figure 14-6*, the final version. It was found that the LM3900 level control "lock" range adjustment, on the X528 crystal-controlled injection signal, allowed ±50 percent frequency shift adjustment on either the 850-Hz or 3-kHz positions of switch S1. Either frequency shift, 850 Hz or 3 kHz, may be heard in your communications receiver.

If the receiver has digital frequency readout, it's a simple matter to adjust the LM3900 dc error amplifier level control for the exact frequency shift desired. If your receiver doesn't have digital frequency readout, you can purchase an inexpensive digital frequency counter and measure the frequency shift at the output of the R40 mixer.

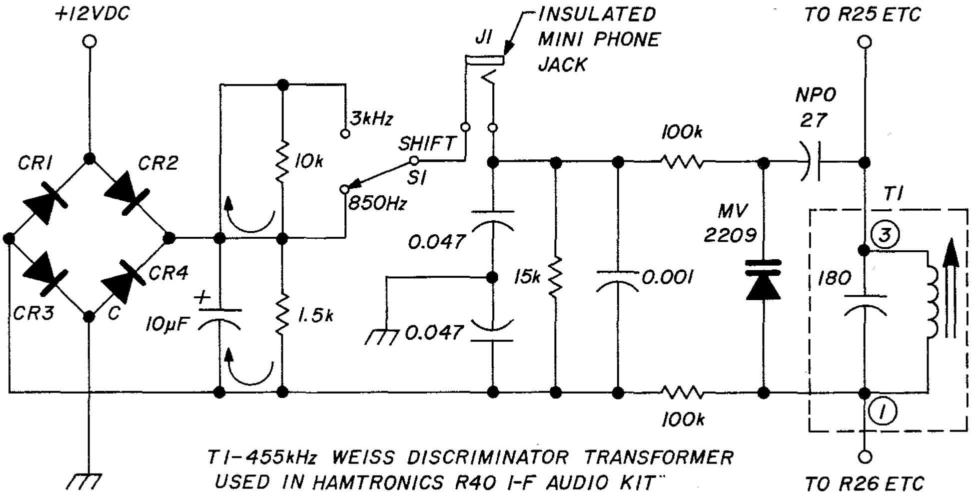


Figure 14-6.

Schematic diagram of the final version of the Crystalmatic modulation system and its above-ground power supply.

The 0.1-μF disc capacitor across the insulated mini phone jack terminals shown in *Figure 12-9* was removed in the final version to enhance both computer-generated high-speed CW and RTTY with Baud rates greater than 100 words per minute. The 16-μF electrolytic capacitor across the LM3900 input terminal 3 (*Figure 13-10*) may be changed to a 1-μF (or higher) tantalum if you plan to use high-speed computer-generated Morse, Baudot, or ASCII. At ordinary Morse keying speeds in the range of 5-25 words per minute, the note is clean, click and chirp free, and quite pleasant to copy. For the real high-speed brass pounders it may sound a bit soft, but with my "club fist" it suits me just fine. No matter. Feel free to adjust the value of the LM3900 terinal-3 capacitor to suit your taste as you monitor it on your *Crystalmatic* system communications receiver. Don't decrease its value below 1 μF or you'll encounter problems with the AFC mode. As with so many other things in life, it's a compromise.

The NPO 27-pF disc cap in series with the MV2209 varicap (varactor) (*Figure 14-6*) might just as well be a mica cap if you have one and can fit it into the narrow space available. *Figure 14-6* shows the 180-pF cap that's installed internally in transformer T1. *Figure 12-9* didn't show this internal capacitor.

The MV2209 varicap (varactor) is quite hard to fine through mail-order outlets. They're available for $1 - $2 each from VHF Engineering (VHF Engineering Division of Brownian, 320 Water Street, Binghamton, New York 13901.) and are exactly the same as used in the TX-432 to phase modulate the 18-19 MHz crystal oscillator output. The MV2209 varicap silicon diode has a capacitance swing of about 70 pF over the range of +0.1 Vdc-+12 Vdc back bias.

The NPO 27-pF disc cap and the MV2209 varicap (varactor) across T1 terminals 1 and 3 will detune T1 from 455 kHz slightly. Turn the T1 tuning slug about one turn counterclockwise so that the voltage at R40's point E8 is +0.5 Vdc with no signal present.

Crystalmatic System—Construction and Installation

Figure 14-7 illustrates layout and parts placement for the *Crystalmatic* modification to the Level-II AFC communications system. The 1-by 2-inch (25.4 by 51mm) perfboard is mounted on ⅝ inch (16mm) long no. 16 (1.3mm) busbar wire standoffs soldered to 1/32 inch (1mm) holes drilled into the right edge of the R40 pc board.

Figure 13-12, a top-view photo of the Level-II R40 board with *Crystalmatic* installed, illustrates the small perf-board position with respect to the rest of the cabinet. A 1-inch (25.5mm) length of no. 16 (1.3mm) busbar wire supports the left side of the perf board and is soldered to the top lug (ground) of the R40 10k volume control to support this side of the perf board.

Crystalmatic Modification Check List

1. TX-432 power modification installed?
2. TX-432 crystal switch installed (if desired)?
3. R40/AFC amplifier T2 choke shorting switch installed on rear of cabinet above VAR mini phone jack?
4. Open the lead from R40 PC board point E8 to the 10k volume control ON-OFF switch, then to the volume control bottom terminal.

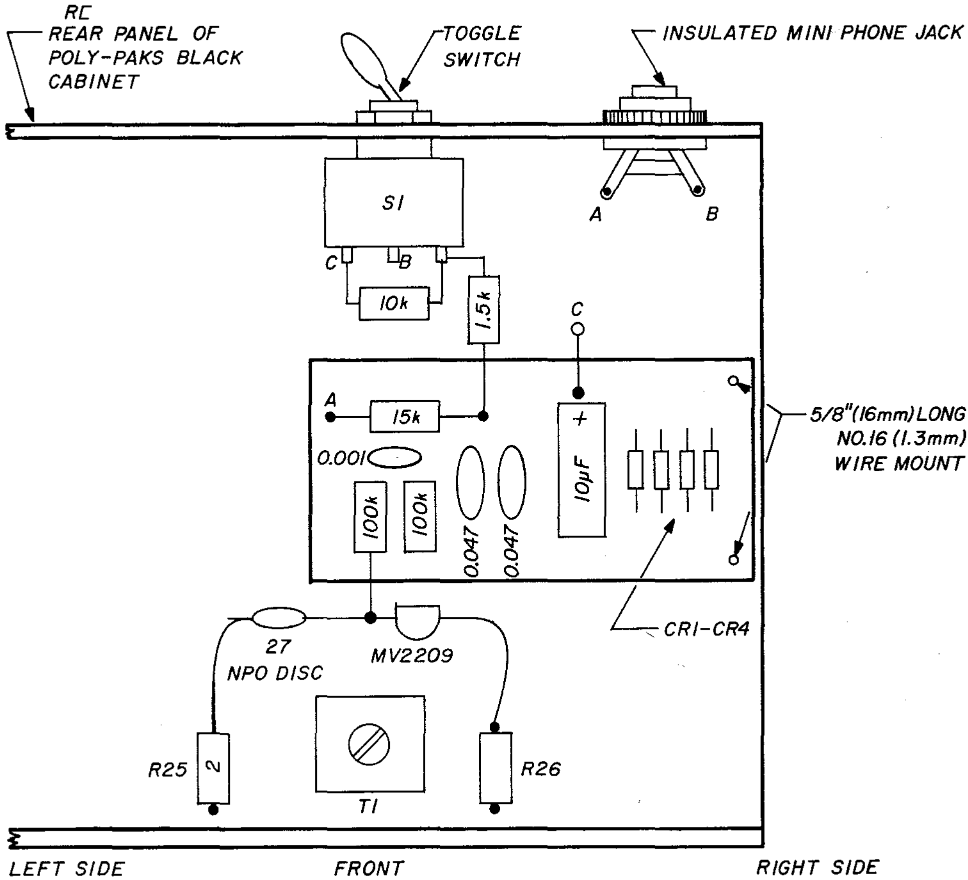


Figure 14-7.

Layout and parts placement of the Crystalmatic modification to the Level-II AFC communications system.

5. RF28 crystal switch installed, (if desired)? Correct crystal installed for 29 MHz - 10.7 MHz? Recommended crystal is a HC25/U third-overtone crystal at 39.7 MHz, so that the image (*39.7 + 10.7 MHz*) falls into the 6-meter band rather than just above the 40-meter band (*18.3 - 10.7 MHz*) if a 18.3-MHz fundamental-frequency crystal is used.
6. *Crystalmatic* modifications illustrated in *Figure 14-6* and *14-7* completed and double checked?

7. Rear panel of the R40/ *Crystalmatic* cabinet should look like that of *Figure 14-8*, plus T2 choke shorting switch above VAR jack.
8. Does R40 pc board point E8 have +0.5 Vdc on it with everything turned on and no signal present? If not, readjust T1 tuning slug as appropriate.

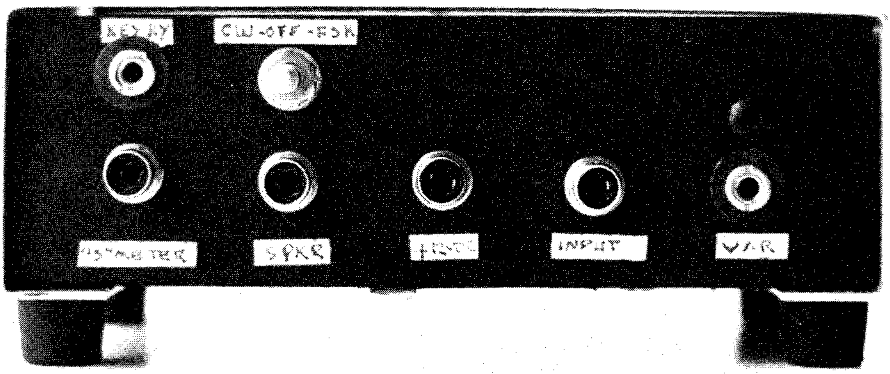


Figure 14-8.
Rear view of the Crystalmatic cabinet showing connectors and switches.

Figure 14-8 was taken before the T2 choke shorting switch was installed above the VAR mini phone jack. Items, top left to right, are:

- Keyer connection for normally open Morse keying relay or normally open RTTY (mark or space) relay; insulated mini phone jack.
- Frequency-shift-keying select switch. CW 3 kHz, FSK and RTTY 850 Hz FSK, or as desired. Bottom, left to right:
- S meter connection (RCA phono jack).
- Speaker connection (RCA phone jack).

- +12 Vdc power input (RCA phono jack). From 98 and 29/30 MHz converter cabinet rear phono jack marked Sw B+.
- 10.7 MHz input from RF28 converter (RCA phone jack).
- VAR output (insulated mini phone jack). Actually, this mini-phone jack connects to the system control module AFC jack when using the combination Level-II AFC and *Crystalmatic* systems together.

Crystalmatic Tune Up and Alignment

Plug everything in and allow both the Gunnplexer and TX-432 crystal proportional temperature control units to stabilize. Remember, you can monitor Gunnplexer proportional temperature control current through the jack on the rear of the system control module as well as on the Gunn-diode real-time temperature meter.

Finding 10.250 GHz. If you've completed the Gunnplexer tuning-*versus*-varactor voltage alignment presented in Chapter 13, you'll know exactly what Gunnplexer varactor voltage equals 10. 250-GHz output; *i.e.*, you carefully (very carefully) adjusted the bottom tuning slug in the Gunnplexer Gunn diode so that 4.000 Vdc equals 10.250 GHZ output. Even though we've changed from a 30 MHz i-f to a 29-MHz centered i-f, obviously 4.000 Vdc to the Gunnplexer varactor still represents 10.250-GHz output.

With the AFC ON-OFF switch (now it should be called the "phase lock error amplifier ON-OFF switch") in the ON position and all other AFC-*versus*-*Crystalmatic* switches in the *Crystalmatic* position, tune the communications receiver to exactly 29.000 MHz. Slowly adjust the AFC-level control (phase-lock error-amplifier-level control) for 4.000 Vdc (plus or minus a few millivolts) output to the Gunnplexer varactor diode. With luck you should hear a distinct "plop" sound. The TX-432 crystal X528 10.221 GHz harmonic is locked. (Depending on all the crystal tolerances in the system, the signal may be up or down a few kHz from exactly 29.000 MHz.)

If you didn't readjust the Gunnplexer Gunn cavity tuning slug as outlined in Chapter 13, you'll probably achieve lock at a Gunnplexer varactor voltage in the +3.2—+3.7 Vdc range, due to the 120F (48C) level set for the Gunnplexer Gunn cavity by the proportional temperature control system. Remember, the Gunnplexer was adjusted at the factory for 10.250 GHz output with +4.00 Vdc varactor voltage at room temperature, not at 120F (48C).

Final steps. Follow these steps for final proof testing.

1. Turn the AFC/phase lock ON-OFF switch to the OFF position.

2. Adjust the system control module coarse and fine varactor-voltage level controls to the same varactor voltage as obtained in the *Crystalmatic* lock mode.

3. Tune in the Gunnplexer 10.250-GHz signal on the communications receiver. It will probably be within plus or minus a few hundred kHz of 29.0 MHz.

4. Set your communications receiver i-f bandwidth to the 2-kHz position with the beat frequency oscillator ON in the CW mode. The TX-432 crystal X528 10.221-GHz harmonic should sound terrible. (Terrible is about a T1 note.)

5. Switch your communications receiver i-f bandwidth to the 1-kHz position. The TX-432 crystal harmonic should not be readable in the midst of the overwhelming spectral noise.

6. Repeat steps 4 and 5 except with the phase lock ON-OFF switch in the ON position. In both tests, the CW note should now be a clean T8 to T9.

The T8-T9 signal is exactly the same quality signal another Gunnplexer station with *Crystalmatic* will hear when tuning your signal, and *vice-versa.* One question frequently asked is, "When a *Crystalmatic* station works a non-*Crystalmatic* station, what do each station's signals sound like?" Answer: both stations will hear signals with 50-per cent spectral noise reduction. Operation with 2 or 3 kHz i-f bandwidth is possible, but 1 kHz is still far too noisy for useful communications.

Summing up. That's all there is to it. You've now mastered truly narrowband 10-GHz microwave techniques equal to or better than virtually all microwave commercial communication systems in use throughout the world today. Proportional temperature-controlled crystal-frequency stability at 10 GHz isn't significantly more difficult than crystal control on the 432-MHz or 1296-MHz Amateur bands!

Crystalmatic System Operating Techniques

Calling "CQ, CQ, CQ" blindly with a manual Morse-code key (no schedule or contest) on the 10-GHZ Amateur band isn't quite as productive as running after rabbits and barking at the moon. You'll probably get an answer from the moon much sooner than you will on 10 GHz. This quaint homily illustrates two points:

1. As of today (1979), the 10-GHz Amateur band is a sleeping-giant wasteland with a population that makes the Sahara Desert look like a heavily populated metropolitan area. As always, there are a few exceptions: namely the Frankfurt area in Germany and the Boston area in New England. The point here is that a manual Morse-code key will probably wear your fist down to the elbow before you make your fist contact. This point applies to 10-GHz RTTY as well.
2. Without a schedule of some sort, or during a VHF contest in either the greater Boston or Frankfurt areas, you'll be wasting your time calling CQ with either Morse code or Baudot/ASCII on RTTY. The key word here is *schedule.* Without a prearranged schedule, running rabbits will be considerably more productive.

Make schedules for contacts. Solutions to these problems are self evident. One, an automatic keyer, or better yet, computer-generated Morse and/or RTTY; and two, make a schedule with a friend or fellow Gunnplexer buff. Most all Amateur Radio VHF clubs participate in the VHF contests held every January, June, and September and would welcome new members who bring a 10-GHz operating capability with its extra bonus points.

Keying systems. There are many solutions to the automatic-keying problem for both Morse and RTTY. These range from simple electronic keyers such as the HAL Devices model 1550 with its diode matrix memory to sophisticated machine-language programs that will transmit and receive both Morse and RTTY at most any speed using a TRS-80 microcomputer.

By the end of 1979, over 200,000 TRS-80s will have been manufactured and delivered by the some 7000 Radio Shack stores. My guess is that Radio Amateurs will have purchased some 20,000 TRS-80s by the end of 1979, so I'll include the following computer data for these farsighted individuals.

Computer Program

The best software/hardware program and system that will handle Morse and RTTY at most any speed imaginable is one written by Dr. Ron Lodewyck, N6EE. It is

- Macrotronics M-80 CW and RTTY Ham Interface for the TRS-80.
- Price $99. Order from Macrotronics, Inc., Box M, Hughson, California 95326.

The program is written in machine language for Level-II TRS-80s with 16k (or more) memory and is by far the leader in its field. The price includes a small PC board kit, easily assembled in a few hours. (An additional audio frequency-shift keyer is required for RTTY transmit mode.)

My favorite Morse-code transmit-and-receive software program for the Level-II TRS-80 microcomputer, 4k or 16k (and up) memory versions is written in BASIC (so that most everyone may understand it and modify it to suit their own wishes). It is

- TRS-80 Morse Code System—Transmit & Receive, Version 2.1, 16k memory.
- Price: $19, 16-k memory. Order from Richcraft Engineering, Ltd., Drawer 1065, Chautauqua, New York 14722.

Features. This unique program requires no external devices (although a $2.99 keying relay is recommended). It uses the TRS-80 cassette motor-control ON-OFF relay for keying Morse output and the cassette output line for Morse input (1 volt p-p) from your communication receiver speaker terminals.

The software program allows you to select 20 prepared messages using your call sign, name, and location, such as: "CQ, QTH, QRZ, QRM, QRX, QRT, CQSS, QSY, QSY+, QSY-, QRN, QRQ, QRS plus random five-letter group code practice, speed test (PARIS PARIS PARIS)—all at any speed between 5-35 words per minute for the 16-k memory version.

The receive mode is called by pressing the CLEAR key at any time and is self-adjusting for any speed up to about 20 words per minute. The receive-mode speed adjustment is automatically made during the first 3-6 letters received and is constantly updated should the transmitting station speed vary.

The 16-k (and up) memory version of the Richcraft program includes an automatic logbook with 100 automatically sequenced entries. Each entry may contain up to 255 letters and spaces. This logbook is automatically recorded on cassette for a permanent record at the end of each operating day.

The author and copyright owner of this unique program (Bob Richardson, W4UCH/2), has allowed the Gunnplexer Cookbook publisher to reproduce the "transmit" part of the abbreviated 4-k memory (version 2.0) of the *TRS-80 Morse-Code System* (*Table 14-1*). The reason is to encourage Gunnplexer operators to use very narrowband FSK with Morse code to enhance both DX and band occupancy of this vast 10-GHz wasteland (if we don't use it, we may lose it).

The program is written in level II BASIC, which was developed by Microsoft, who wrote the advanced BASIC for many other microcomputers, including KIM, Apple, and Commodore's PET, to name a few. This Morse-code program will run in all of them with only a single modification to line 502; *i.e.*, the OUT(port) must be the port that controls the cassette motor control relay ON-OFF function.

A word to TRS-80 users. The cassette motor control relay, K1 in the keyboard assembly, is very fragile at best. For best long life keying applications, it should drive a Radio Shack 275-004 relay ($2.99 each) with +5Vdc across it as a keying relay. It only draws a few milliamps and is fast enough to reach 25 words per minute plus. Another option is to drive a single TTL load, such as a 7407, which drives a very high-speed keying reed relay (good up to 35 plus words per minute) from integrated circuit Z-59 directly from the keyboard.

TRS-80 Morse System Program Summary

This BASIC Morse-code program is as simple and straightforward as can be written. It asks the user whether alphanumerics or Morse code is wanted on the video display. Enter A or M. It then asks "CODE SPEED?" Use the following table for approximate words per minute desired. (This table is used to save memory space only in the 4K-memory version.)

enter	wpm	enter	wpm
10	25	40	9
20	20	45	8
25	15	50	7
30	12	60	6
35	10	70	5

The entire Morse-code character set is reduced to simple 1- to 6-digit numbers in five lines; *i.e.*, lines 200 through 220 using the IF-THEN-ELSE function for character selection and assigning a number equal to: *dot* = *1* and *dash* = *2*, which would have the letter *A* = *12*, *B* = *2111*, *C* = *2121*. Keyboard input is automatic using the *INKEY$* function. Press a key, and the Morse character is generated automatically. If a key is pressed that has no Morse-code equivalent, such as $ or #, nothing is transmitted.

The heart of the program is in lines 500, 501, 502, and 503. Line 500 determines whether alphanumerics or Morse code are to be shown on the video display (you selected one or the other during initialization). Lines 501 and 502 break each number down into individual dots and dashes using the MID string function and sets the timing depending on the SPEED input at the beginning of the program. Following international standards, each dash is always three times longer than a dot. Each dash and dot is always spaced one dot interval. Each Morse character is always spaced one dash interval, and each word (in prepared messages) is always spaced seven dot intervals (see line 1210).

Line 502 actuates the cassette motor control relay for the calculated time interval and prints out the keyed alphanumeric or Morse equivalent on the video display. Line 503 tells the program where to go after each Morse character is generated; *i.e.*:

(*a*) Back to the keyboard.

(*b*) Back to a prepared message until finished.

(*c*) Back to random number generator in line 1313 if Morse-code practice was called in the subcommand mode.

If UP-ARROW on the keyboard is pressed, line 1000 displays the Q signal-message-subcommands available for the 4K memory version. The 16K memory version has many more.

Q signal-message-subcommands

CQ	QTH
QRZ	QRM
QSB	QSY
QRQ	QRS
TEST	CODE

In this subcommand mode, only the abbreviation is ENTERed. By typing CQ and then ENTER, the message in line 1020 is automatically generated. If TEST is ENTERed, the word PARIS is generated at the selected code speed. By timing the number of times PARIS is transmitted in 15 seconds and multiplying by 4, you have accurately measured your code speed using the international standard.

If CODE is ENTERed on the keyboard, the Z-80 microprocessor random-number generator will randomly generate a number between 1 and 26. The program translates this number to the ASCII (American Standard Code for Information Interchange) equivalent of the letters A to Z, which is then transmitted at whatever code speed you selected, a letter at a time, in standard 5-letter code groups.

You may escape whatever function is currently operating and immediately return to keyboard input in the TRANSMIT mode by pressing BREAK, then @, then ENTER . This is done by intentionally generating an error, which the ON ERROR GOTO function, senses and immediately returns control to line 99.

The 16K memory and up (Version 2.1 of the TRS-80 Morse-Code system) offers many more operating features including:

- Twenty or more messages. It's possible to have a complete QSO by touching only one or two keys. If the station on the other end is computer equipped, the two computers may converse at length without human assistance.
- CODE 1: Code practice - alphabet only.
- CODE 2: Code practice - alphabet and numbers.
- CODE 3: Code practice - alphabet, numbers, and punctuation.
- Automatic logbook: 100 pages with automatic cassette recording optional. A super program for contests.
- Transmit speed selection to over 40 words per minute.
- Instruction summary part of main program (six pages).
- Direct code speed input (25 *ENTER = 25 words per minute).*

For Gunnplexer operation you should modify the program so that the prepared CQ DE (your call) automatically repeats itself until you press the BREAK key. By adding the following program modification it will do so without interfering with any of the program functions or other subcommands:

```
1203 IF X$="CQ"AND L=LEN(D$)THEND$="  CQ CQ CQ
DE W4UCH/2 ":
Z=0: E=-1: GOTO 1200
```

The two blank spaces before CQ CQ CQ and the one blank space after W4UCH/2 are necessary for correct program timing.

The computer also can operate the transmit/receive switch, tune the band for a station, answering your CQ, and carry out a "near human" QSO (in many ways better than some ops on 40 and 20 meters), all by itself.

Table 14-1

```
10    REM TRS-80 MORSE CODE SYSTEM TRANSMIT &
      RECEIVE PROGRAM (C)

15    :

20    REM          SPECIAL VERSION 2.01 TRANSMIT
      ONLY FOR:

25    :

30    REM          THE GUNNPLEXER COOKBOOK - A
      MICROWAVE PRIMER

35    :

40    REM          COPYRIGHT 1978 BY RICHCRAFT
      ENGINEERING LTD.

45    :

55    DEFINTA-Z:CLS:INPUT"ALPHANUMERICS OR
      MORSE ON VIDEO DISPLAY (A/M)";AA$:CLS:INPUT
      "CODE SPEED";S:CLS:DIMA$(100)
      :ONERRORGOTO97

97    RESUME 99

99    PRINT"TRANSMIT MODE"

100   Z=100:M$=""
```

Table 14-1 (Continued)

```
101   A$=INKEY$:IFA$=“”THEN101

102   IFA$=“  ”ANDLEN(D$)<1THENPRINT“  ”;
      :GOTO100

200   IFA$=“E”THENM$=“1”ELSEIFA$=“T”THENM$=“2”
      ELSEIFA$=“I”THENM$=“11”ELSEIFA$=“A”THENM$=
      “12”ELSEIFA$=“N”THENM$=“21”ELSEIFA$=“M”
      THENM$=“22”ELSEIFA$=“S”THENM$=“111”
      ELSEIFA$=“U”THENM$=“112”ELSEIFA$=“R”
      THENM$=“121”ELSEIFA$=“W”THENM$=“122”
      ELSEIFA$=“D”THENM$=“211”

205   IFA$=“K”THENM$=“212”ELSEIFA$=“G”THENM$=
      “221”ELSEIFA$=“O”THENM$=“222”ELSEIFA$=“H”
      THENM$=“1111”ELSEIFA$=“V”THENM$=“1112”
      ELSEIFA$=“F”THENM$=“1121”ELSEIFA$=“L”
      THENM$=“1211”ELSEIFA$=“P”THENM$=“1221”
      ELSEIFA$=“J”THENM$=“1222”

210   IFA$=“B”THENM$=“2111”ELSEIFA$=“X”THENM$=
      “2112”ELSEIFA$=“C”THENM$=“2121”ELSEIFA$=
      “Y”THENM$=“2122”ELSEIFA$=“Z”THENM$=“2211”
      ELSEIFA$=“Q”THENM$=“2212”ELSEIFA$=“5”
      THENM$=“11111”ELSEIFA$=“4”THENMS=“11112”
      ELSEIFA$=“3”THENM$=“11122”

215   IFA$=“2”THENM$=“11222”ELSEIFA$=“1”THENM$=
      “12222”ELSEIFA$=“6”THENM$=“21111”ELSEIFA$=
      “-”THENM$=“21112”ELSEIFA$=“/”THENM$=“2112
      1”ELSEIFA$=“7”THENM$=“22111”ELSEIFA$=“8”
      THENM$=“22211”ELSEIFA$=“9”THENM$=“22221”

220   IFA$=“0”THENM$=“22222”ELSEIFA$=“?”THENM$=
      “112211”ELSEIFA$=“.”THENM$=“121212”ELSEIFA$
      =“,”THENM$=“221122” ELSEIFA$=CHR$(91)GOTO1000

225   IFA$=“”ORM$=“”GOTO100

500   IFAA$=“A”THENZ$=A$ELSEZ$=M$+“ ”
```

Table 14-1 (Continued)

```
501   FORK=1TOLEN(M$):C$=MID$(M$,K,1):IFC$="2"
      THENC=S*3ELSEC=S

502   OUT255,4:FORA=1TOC:NEXT:OUT255,0:FORA=
      1TOS:NEXT:NEXTK:PRINTZ$;:FORA=1TOC:NEXT

503   IFZ=0THENNEXTLANDGOTO1200ELSEIFZ=100GOTO
      100ELSEIFZ=1313GOTO1313

1000  CLS:PRINT@74," Q SIGNAL - MESSAGE - SUBCOM-
      MANDS ":PRINT

1001  PRINT," -CQ","- QTH":PRINT:PRINT,"- QRZ","- QRM"
      :PRINT:PRINT,"- QSB","- QSY":PRINT:PRINT,"-
      QRQ","-QRS":PRINT:PRINT,"-73","-QRX ": PRINT:
      PRINT, "-TEST","- CODE":PRINT:PRINT"";,:INPUT"
      SIGNAL/MESSAGE    ";X$:Z=0:E=-1:CLS

1020  IFX$="CQ"THEND$="CQ CQ CQ DE W4UCH/2 K "

1025  IFX$="QTH"THEND$="QTH IS BOX 1065,
      CHAUTAUQUA LAKE, N.Y. 14722 "

1030  IFX$="QRZ"THEND$="QRZ QRZ QRZ DE
      W4UCH/2 K "

1035  IFX$="QRM"THEND$="QRM QRM PSE TRY AGN.
      DE W4UCH/2 K "

1040  IFX$="QSB"THEND$="QSB QSB PSE REPEAT.  DE
      W4UCH/2 K "

1045  IFX$="QSY"THEND$=QRM TERRIBLE.  WHERE
      MOVE? DE W4UCH/2 K "

1050  IFX$="73"THEND$="73 73 CU SOON I HOPE.  DE
      W4UCH/2 K "

1055  IFX$="QRQ"THEND$="QRQ QRQ.  SHALL I SPEED
      UP ? DE W4UCH/2 K "
```

Table 14-1 (Continued)

```
1060  IFX$="QRS"THEND$="QRS QRS. PSE SLO DOWN A
      BIT.  DE W4UCH/2 K "

1064  IFX$="CODE"THENZ=1313:GOTO1313

1070  IFX$="TEST"THEND$="PARIS PARIS PARIS PARIS
      PARIS PARIS PARIS PARIS PARIS PARIS "

1075  IFX$="QRX"THEND$="QRX QRX THE PHONE.  DE
      W4UCH/2 "

1200  FORL=1TOLEN(D$) :A$=MID$(D$,L,1)

1205  IFL=LEN(D$)THEND$="" :GOTO100

1210  IFA$=" "THENPRINT" "; :FORA=1TO7*S:NEXT
      GOTO503

1220  GOTO200

1313  D=RND(26)+64

1320  A$=CHR$(D) :E=E+1 : IFE > 4GOTO1330ELSEGOTO
      200

1330  FORF=1TO7*S :NEXT:PRINT" "; :E=0 : GOTO200
```

Reference

1. Doug Grant, K1DG, "Digital Readout for the Ham-3 Rotator," *ham radio*, January, 1979, pages 56-59.

15

Television and Computer Video Data Links

Introduction to wideband video operation. Design of a 10-GHz video system. Hardware using off-the-shelf modules. A unique distortion-free video discrimator. Video displays versus TV receivers. Construction and checkout of a homemade Gunnplexer video system.

After the emphasis in Chapters 12, 13, and 14 on narrowband Gunnplexer operation, I'll now present material describing a wide bandwidth (10 MHz) video Gunnplexer system. You won't set any DX records spreading your 15 - 40 milliwatt 10-GHz signal over 10 MHz, but you will indeed derive a great deal of pleasure from live TV transmission and reception, relaying ordinary baseband TV signals, or tying two TRS-80 microcomputers together through a Gunnplexer video data link.

The Gunnplexer transceiver, on a stand-alone basis, has the widest bandwidth capability of any commercially manufactured Amateur Radio device in the world today (1979), over 100 MHz varactor tuning and nearly 1,000 MHz through mechanical tuning. It's possible, though completely impractical, to place all VHF television chanels, on a single Gunnplexer transmitter using appropriate modulation techniques. The problem, of course, is power density when you consider a nominal 20 milliwatts of output spread over 72- to 120-MHz bandwidth. Assuming 120-MHz bandwidth and a 20-milliwatt signal, the power density averages out 166 microwatts per MHz. So, for Volume I of the Gunnplexer Cookbook, let's concentrate on transmitting or receiving a single video channel at one time.

The first amateur Gunnplexer video pioneer was Bob Cooper, W5CKT, editor-in-chief of CATJ. Immediately after the introduction of the Microwave Associate's Gunnplexer system in early 1977, Bob published the first article on an Amateur Gunnplexer video system in the July, 1977 issue of CATJ. Bob then developed the Mini-Wave Gunnplexer video and audio system which was published in a three-part series in *Popular Electronics* during 1978 and the July and August, 1978 issues of CATJ. The Mini-Wave system was manufactured in kit form, and hundreds are now in use throughout the world. The Gunnplexer Cookbook television and computer video data links use an entirely different approach than the Mini-Wave system, but nevertheless Bob Cooper is the father of amateur Gunnplexer television systems. While on the subject of Gunnplexer history, the following letter from the late Jim Fisk, W1HR, editor-in-chief of *ham radio* magazine outlines the development and naming of the Gunnplexer, which should be of interest to all 10 GHz enthusiasts.

June 10, 1979

"Dear Bob:

Since you bring it up in the last page of your letter, I should also like to comment on the parentage of the Gunnplexer. As you probably know, I have been an advocate of Amateur microwave communications for more than 20 years, and have encouraged increased Amateur use of this very important part of the spectrum, first as editor of 73 in 1966-67, and later as editor/co-founder of *ham radio.*

In the mid 1970s I became increasingly unhappy with progress on the microwave scene, because American hams for the most part were ignoring Gunn diodes et al and going their solitary way with 2K25 Polaplexers and other vacuum-tube hardware (I doubt that one Amateur in ten even had a solid-state 30-MHz i-f strip). I had been following the developments in England with great interest, and had several long discussions with Dane Evans on the subject of Gunn-diode oscillators. The British, of course, had low-cost Gunn diodes on the surplus market — we did not.

"I continued to push the Americans toward solid-state microwave — and to strongly criticize American dependence on vacuum tubes — both in print and personally at the East and West Coast vhf/uhf conferences. Then in August, 1976, G4BRS and GM3OXX broke the 10-GHz DX record. Their achievement was reported in *HR REPORT* (and November *ham radio Presstop*) with the editorial comment that," 'Despite the much larger U.S. Amateur population, the U.K. and other European countries seem to be much more active on 3 cm and the other Amateur microwave bands.' I had, with the help of G4BRS and GM3OXX, finally struck a responsive chord.

In late November (1976) I was invited to have dinner with Dana Atchley, W1CF, and other members of the Microwave Associates staff to discuss what they could do to improve microwave activity among U.S. Amateurs. I first suggested that culled Gunn diodes be made available to experimenters at low cost through existing surplus channels; Dana obviously wanted to do more. I then suggested a Gunn-diode-based oscillator with a built-in varactor for frequency modulation, perhaps with a magic-tee mixer with silicon diodes so the same Gunn oscillator could serve as the local oscillator. One of the others suggested Schottky diodes, and I believe it was Will Collier, K1JSC, who first thought of the ferrite circulator. Thus, the concept of a commercial 10-GHz Gunn-diode transceiver was born, and I was the father. Within a few weeks, Dr. Ron Posner had a working model — in the evolution of things, I guess that makes him father and me grandfather. Or perhaps I am the great-grandfather, Dana Atchley is grandfather, and Dr. Ron Posner is father. Regardless, I am proud to be part of the geneology.

"In January, 1977, Tom McMullen, W1SL and I had one of the first pair of Gunnplexer transceivers on the air. Later that month, when I was writing my editorial for the March 1977 issue of *ham radio*, which announced the availability of commercial Gunn-diode transceivers, I coined the term Gunnplexer. Microwave Associates liked it so much that Dana Atchley asked if I would mind if they used it for their trademark. Obviously, I was delighted.

Best regards,
s/Jim
James R. Fisk, W1HR

editor-in-chief
(HAM RADIO MAGAZINE)"

Bandwidth Tradeoffs

You will recall from Chapter 2 that at 10 GHz the path loss is 116.8 dB for the first mile (1.6 km) (in free space) and increases 6 dB every time you double the distance. *Figure 2-3* illustrates the carrier-to-noise ratio to be expected for free-space ranges when using a 200-kHz i-f bandwidth, 15 milliwatt Gunnplexer transmitter, 12-dB noise figure receiver (typical Gunnplexer with low noise i-f preamplifier), and a receiver equivalent noise input (ENI) of -109 dBm. By increasing the i-f bandwidth from 200 kHz to 10 MHz you decrease the carrier-to-noise ratio by approximately 17 dB (3 dB every time you double bandwidth). For the moment, assume the use of a 10-MHz bandwidth for a fm/fm, video/audio signal with the Gunnplexer. *Figure 2-3C* shows that if you use two 24-inch (61 cm) diameter parabolic reflector antennas at each end of a 10-mile (16 km) Gunnplexer video data link circuit, the resulting fade margin will be:

a. A 48-dB carrier-to-noise ratio with 200-kHz bandwidth equals 48 - 17 (for 10-MHz bandwidth) equals 31-dB C/N ratio.
b. Useful fm threshold requires 10-dB C/N ratio.
c. A 31 dB - 10 dB equals 21-dB fade margin in free space.

A 21-dB fade margin is about 1/2 of what Bell Telephone uses for its telephone/data microwave links and for good reason too:

rainfall/precipitation attenuation. In the southwestern U.S. desert climate, 21 dB is probably all right, most of the time. In the Atlantic states, states on the Gulf of Mexico, the Washington-state rain forest, and states near the Great Lakes where occasional heavy precipitation is not uncommon. The Gunnplexer operator who wishes a more conservative fade margin has little choice but to use a larger antenna or reduce data link circuit range. I chose the latter option by setting up a 5.5 mile test range, which was the distance to a local radio club's hill-top site across Lake Chautauqua. For good measure, I used four separate i-f stages with approximately 20 dB gain each rather than the original three stages.

Looking back some 50 odd years ago to Major Armstrong's pioneering fm development work, he proved both theoretically and empirically that as fm deviation is increased (up to a certain limit), the signal-to-noise ratio at the receiver is improved (assuming good limiting).

The optimum fm deviation at 10 GHz to achieve the best signal-to-noise ratio for a marginal rf power level would be on the order of 60 plus MHz, which would require an i-f of the same bandwidth to capture all the available rf energy. For example, Westar and RCA Satcom I and II, geostationary TV relay satellites, with outputs on 3.7 - 4.2 GHz, use fm deviations of 30+ MHz for optimum signal-to-noise ratio at the receiving end of their systems.

Building a Gunnplexer-driven receiver with an i-f bandwidth of 60 MHz and with a good phase-distortion-free discriminator, both with relatively flat response curves over the passband, is not a difficult job in a properly equipped laboratory. As the majority of the readers of this Gunnplexer Cookbook don't have a completely equipped laboratory at their disposal, a much more easily constructed and aligned 10-MHz-wide system is presented. This system will require the following:

a. A video source signal (TV camera, TV set, TV recorder, or microcomputer video output.
b. Video signal level of 0.5 volt, peak-to-peak.
c. Grid-dip meter.
d. VTVM or multimeter.
e. Another TV set for visual readout and alignment.
f. Communications receiver to calibrate the audio subcarrier.

It will be a rather elementary 10-GHz video/audio, fm/fm minimum system, but it will work and do so quite well to ranges beyond 5 miles (8 km).

10-GHz Video-System

As in all the other Gunnplexer Cookbook projects, readily available low-cost kits have been used where possible to simplify parts acquisition. There is nothing more frustrating when building a project from a magazine article or book to find half way through the assembly that the author specified a part or number of parts that may only be ordered from the manufacturer in minimum quantities of $50, $100, or what have you. with NO optional part substitutions available. You'll find that the Gunnplexer Cookbook does not have any of these hidden hookers buried in small print at the end of a chapter.

The choice of i-f is left to the builder. I have built 10-MHz-wide video i-fs centered on both 45 MHz and 113 Mhz with no interfering signal feed-through problems of any type. One must remember, though, that at my location the nearest fm broadcast station is over 20 miles away. For a Gunnplexer-system builder living in a metropolitan area it would probably be a wise choice to use 45 MHz to avoid the potential problems from fm broadcast stations. *Fig. 15-1* is a block diagram of the Gunnplexer Cookbook 10-GHz video system. Although the 45-MHz i-f is shown, merely extrapolate the numbers to any 10-MHz-wide i-f of your choice, as the P9 i-f amplifier stages and the broadband Wheatstone bridge discriminator will undoubtedly work nearly as well at any frequency up through 230 MHz.

Purists who like audio with their video have many choices:

a. Video on 10 GHz with audio on any Amateur band direct or through a repeater. This can be a considerable aid during initial tune up and alignment.
b. Composite video/audio on the 10-GHz signal using an ordinary TV receiver as shown in *Figure 15-1.* A 4.5-MHz fm subcarrier generator is shown.
c. Should you choose a microcomputer video readout (as in the TRS-80) that does not have audio circuitry you have two more choices to make:

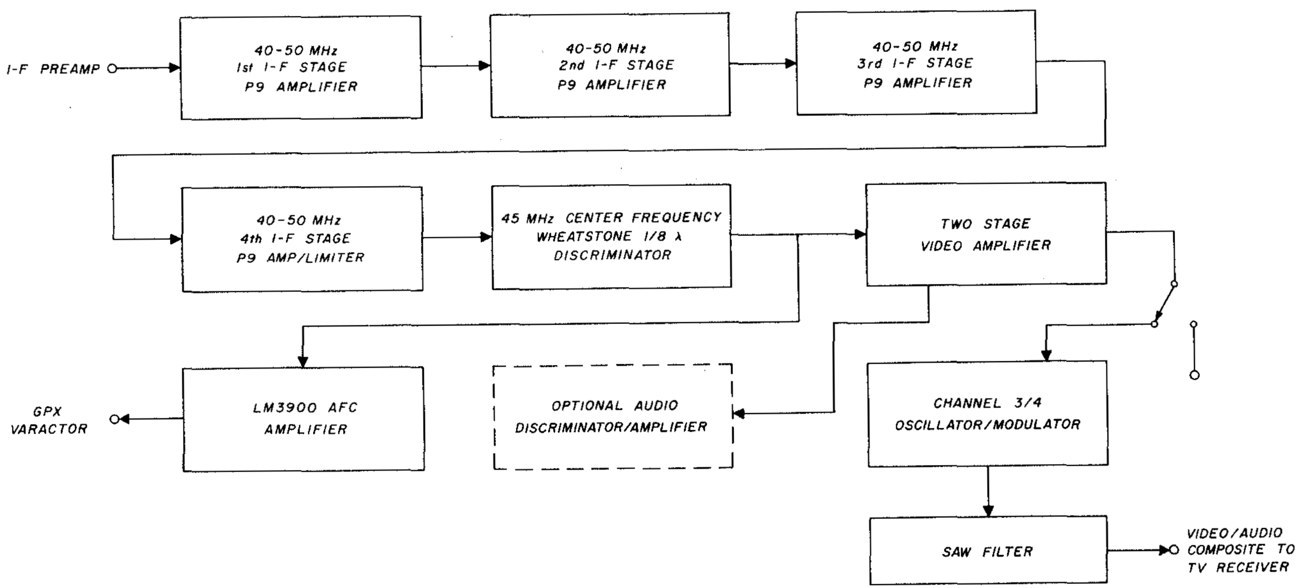


Figure 15-1.
10 GHz video receiver - block diagram

1. Use a TV receiver in parallel with the computer, but with the audio demodulated by the TV set.
2. Build a 4.5-MHz i-f amplifier, discriminator, and audio amplifier driven by the two-stage video amplifier shown in *Figure 15-1*. Bob Cooper has described a simple and easy-to-build unit on page 40, July, 1978 issue of the Community Antenna Television Association (CATA) Journal. You can probably borrow a copy from your local cable TV operator.

Let's run through the 10-GHz video system illustrated in *Figure 15-1*, although it's largely self explanatory. This circuit has been built and tested at two different i-f frequencies, 113 and 45 MHz. There was no measurable or noticeable difference in performance between the two i-fs. It took slightly longer to align the 45-MHz i-f amplifiers than the 113-MHz units, but that was the only difference between the two.

The i-f preamplifier built into the Gunnplexer weatherproof housing, may be either the Microwave Associates low-noise unit (highly recommended and easy to realign to a 40 - 50 MHz bandpass) or the Hamtronics P8 cascode FET unit. If ranges beyond 2 or 3 miles (3.2 or 4.8 km) are planned, by all means use the Microwave Associates preamp, as every extra dB of noise figure really helps.

The i-f amplifier chain consists of cascaded Hamtronics model P9 amplifiers using low-noise grounded-gate Siliconix J308 junction field-effect transistors (JFET) for each stage. Use only as many i-f stages as necessary for the range desired. One stage is enough for very short range (1 km). Four to five stages are recommended for 5 - 10 miles (8-16 km).

The discriminator is a novel Wheatstone bridge with $\lambda/8$ pieces of RG-174/U mini-coax for the bottom legs of the bridge. The Wheatstone bridge discriminator linearity is excellent with very low phase distortion. Most important it needs no tuning once the proper lengths of coax are installed. A two-stage RC-coupled video amplifier drives either a video display (as in the TRS-80) or a low-channel TV oscillator/modulator for direct, standard TV-receiver readout. An optional Plessey surface-acoustic-wave (SAW) filter reduces the channel 3 or 4 TV video/audio signal lower sideband by 22 dB, thus presenting a vestigial sideband signal virtually identical to that of a standard TV broadcast station's NTSB signal.

Microwave Associates i-f Preamplifier

If you built the Microwave Associates 30-MHz i-f preamplifier illustrated in *Figure 6-1,* the modifications required to retune it to the 40 - 50 MHz range with a 45-MHz center frequency may be done in a few minutes.

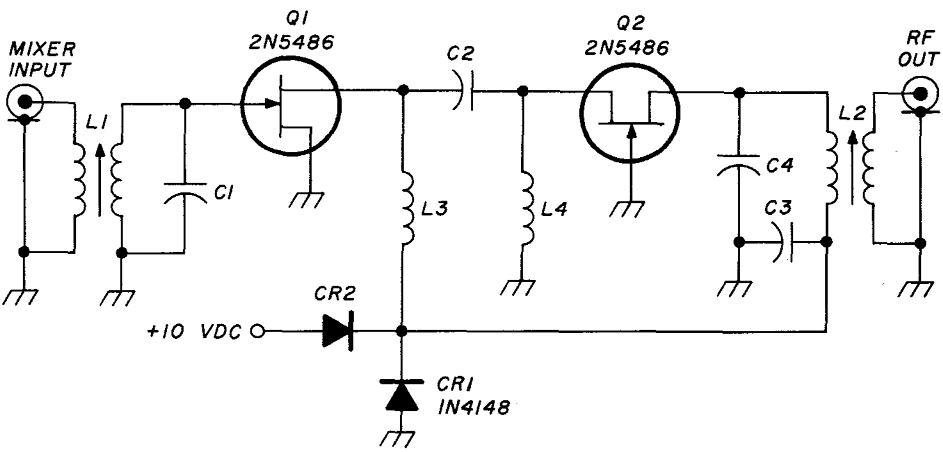
a. Change L1 to 0.5 μH; 5 turns Airdux 610T or 11 turns no. 28 (0.3 mm) enameled copper wire wound on a Micrometals T-25-6 ferrite toroid.
b. Change L2 to 0.77 μH; 8 turns Airdux 610T or 17 turns no. 28 (0.3 mm) enameled copper wire wound on Micrometal T-25-6 ferrite toroid.
c. C1, C2, and C3 may be adjusted later for best weak-signal picture quality, or the 3-dB-down points should be set at 40 and 50 MHz if you have a sweep generator and an oscilloscope.

Hamtronics P8 i-f Preamp

The Hamtronics P8 i-f preamplifier mounted on the Gunnplexer module in the Gunnplexer weatherproof enclosure was modified as shown in *Figure 15-2* to get a flat bandpass over the 40-50 or 108-118 MHz ranges. Values for both i-f ranges are given in the diagram.

The LC ratios for L1 and L2 have been increased considerably over the original Hamtronics design to increase the bandwidth at the 3-dB-down points to 10 MHz at a modest 2 - 3 dB sacrifice in amplifier gain. Of the Preamplifier gain is now measured at 17 dB. The gimmix capacitor in the 113-MHz center frequency i-f version are made from number 26 (0.4 mm) insulated hookup wire twisted tightly together, about ½ (12.5 mm) inch long. Start with the gimmix capacitors about 1 inch (25.4 mm) long and trim to the followng frequencies.

coil-capacitor combination	45-MHz center i-f trim to:	113-MHz center i-f trim to:
L1, C1	42 MHz	110 MHz
L2, C4	48 MHz	116 MHz



PART REFERENCE	45 MHz CENTER I-F	113 MHz CENTER I-F
C1	10pF	GIMMIX (SEE TEXT)
C2, C3	0.001μF	220pF
C4	5pF	GIMMIX (SEE TEXT)
CR2 - ANY PROTECTIVE DIODE	(20mA DIODE)	SAME
L1 LINK	3-1/6t	1-5/6t
L1 SECONDARY	13-5/6t	5-5/6t
L2 PRIMARY	20-3/6t	8-3/6t
L2 LINK	5-5/6t	2-5/6t
L3, L4	15μH	1μH

Figure 15-2.
P8 I-F preamplifier 45 MHz and 113 MHz center frequency

If you have a sweep/marker generator and oscilloscope, use them and set the 3-dB-down points at 40 and 50 MHz or 108 and 118 MHz as appropriate.

Video i-f Amplifiers

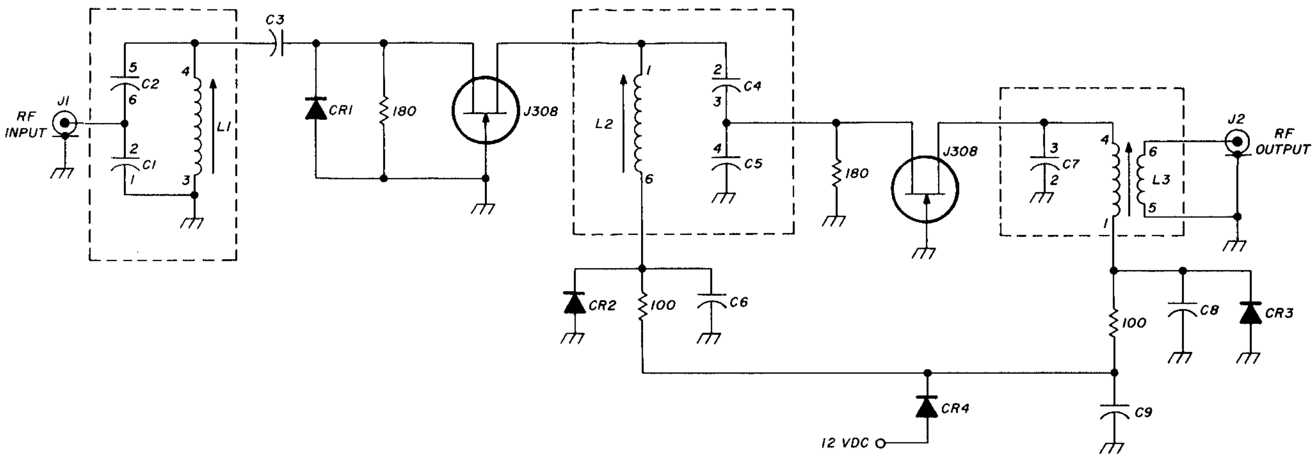
There are many approaches to video i-f amplifier design and construction. Virtually all modern solid-state designs used today require a sweep/marker generator and oscilloscope for alignment regardless of bandwidth or frequency. Many Radio Amateurs and electronics students don't have this test equipment, so I designed and built a complete video i-f amplifier system that could be aligned using only a standard TV receiver for readout. Alignment is not as accurate as that obtained with the proper test equipment, but it passes the final test because it works. Highlights of this approach include:

1. Relatively simple tuning, no test equipment required other than a standard TV receiver.
2. Low-cost kits are available, the Hamtronics model P9 is used as i-f amplifier at $12.95 each per stage.
3. Approximately 20 dB gain per stage. (Use only as many stages as required for the distance you wish to cover.)
4. Very low-noise cascaded JFET transistors used, with option to substitute the super low-noise J310 if desired.
5. Allows choice of i-f, either 45 or 113 MHz (or most any frequency) with 10-MHz bandwidth capability.
6. Layout yields excellent interstage isolation and decoupling with no regeneration problems when using up to five stages.
7. Very forgiving to slight tuning errors due to wide bandwidth.
8. Each stage may be constructed in less than an hour and tuned in just a few minutes.
9. Assembly is virtually mistake-proof with excellent instructions and a parts layout drawing furnished with the kit. It takes real effort to put the wrong parts in the wrong place.
10. Gain-bandwidth product divided by availability/cost is probably the best available today. Undoubtedly a number of Gunnplexer enthusiasts will discover a source of surplus 45-MHz i-f strips.

Figure 15-3 shows a single stage of the Hamtronics model P9 amplifier with modified component values for 10-MHz bandwidth at both 45 and 113 MHz center i-fs.

The following is the initial tuning scheme if no sweep/marker generator and oscilloscope is available:

coil capacitor combination	**45 MHz center i-f** trim to:	**113 MHz center i-f** trim to:
L1/C1, C2	47 MHz	115 MHz
L2/C4, C5	42 MHz	110 MHz
L3/C7	50 MHz	118 MHz



PART REFERENCE	45 MHz CENTER I-F	113 MHz CENTER I-F
C1	33	20
C2	15	10
C3	5	3.9
C4	10	5
C5	50	20
C6, C8, C9	0.001	0.001
C7	10	5
L1 3 AND 4 turns	10-1/6t	4-1/6t
L2 1 AND 6 turns	15-1/6t	5-5/6t
L3 1 AND 4 turns	14-1/2t	5-1/2t
L3 5 AND 6 turns	2-1/6t	1-1/6t
CR1, CR2, CR3	1N4148	1N4148
CR4 (ANY SILICON PROTECTIVE DIODE)		

Figure 15-3.
Hamtronics P9 video I-F amplifier stage-schematic

The combinations above should be tuned *before* installing them on the PC board (be sure each combination has an rf ground). After installation, L1 should resonate at 45 or 113 MHz, L2 at 40 or 108 MHz, and L3 at 50 and 118 MHz. (These settings are approximate and are adjusted later for best picture quality.)

This may sound like a broken record, but *use a sweep/marker generator and oscilloscope for alignment* if you have access to one. Conversely, do as I did, and align the entire system using the eyeball TV receiver trick. Then later use the proper test equipment to see how close you came to optimum. In most procedures there's a right way and a wrong way to accomplish a given task. The eyeball TV receiver trick is neither right or wrong, but a middle-of-the-road approach if you can't obtain the proper equipment.

All i-f amplifier stages are identical except for the last one feeding the Wheatstone bridge video discriminator. In this last stage, CR1 across the input is replaced with two silicon switching diodes. In their own simple but effective way, these two diodes serve as approximately 0.5-volt clippers/limiters on the input to this last i-f stage. All the resulting hash generated by their clipping/limiting action is filtered by the two following tuned circuits. With any weak input signals below the 0.5-volt peak-to-peak level, the diodes are invisible.

Figure 15-4 is a top view of the first three stages of the i-f amplifier mounted in the Poly Paks black box. The box front is at the top of the photo with an on-off LED connected through a 1.2-k resistor to the 12 Vdc line. The RCA phono jacks at the bottom of the photo are i-f output, 12 Vdc input, and i-f input, left to right. These three i-f stages are mounted on a 3 by 4 by ⅝-inch (76 by 102 by 16 mm) piece of scrap PC board with 1 ⅝ by 3-inch (41 mm) pieces of tin can shielding between stages, as shown in *Figure 15-5.*

All internal rf wiring uses RG-174/U mini-coax with the outer vinyl jacket removed and soldered to ground every inch (25.4 mm) or so between *all* outputs and inputs. This coax passes through ⅛-inch (3 mm) diameter holes drilled through the vertical shields where the outer jacket is soldered. With about 60 dB gain in this black box, good isolation and shielding of all leads is a must if you are to avoid regeneration (positive feedback) with its resulting bandwidth/bandpass distortion which is definitely unacceptable for good picture quality.

The ⅛-inch (3-mm) diameter mounting holes are first drilled on each end of the PC board. The 100-pF feed-through capacitor holes and coax holes are then drilled in the shields. Now, solder the shields in place (both sides). The 15-μH decoupling rf chokes between each i-f stage in the 12-Vdc line in *Figure 15-8* are for the 45-MHz centered i-f. Should you choose to use the 113-MHz centered i-f, use the 1-μH rf chokes. Both are available from Hamtronics as separate items if you don't wish to roll your own.

If you have a sweep/marker generator and oscilloscope, assemble the first three i-f stages on their mounting base and install this assembly in the Poly Paks black box as illustrated in *Figure 15-4*. Now, align the three stages so that the 1 to 2 dB-down points are at 40 and 50 MHz. Total gain should be about 60 dB. If you substituted J310 transistors for the J308s, you may pick up a little more gain, since these are selected transistors, and some J310s have been found to have slightly more gain than the J308s.

If you don't have access to a sweep/marker generator and oscilloscope, install each i-f stage on the PC board mounting base, but *do not* install them in the box and *do not* install the output

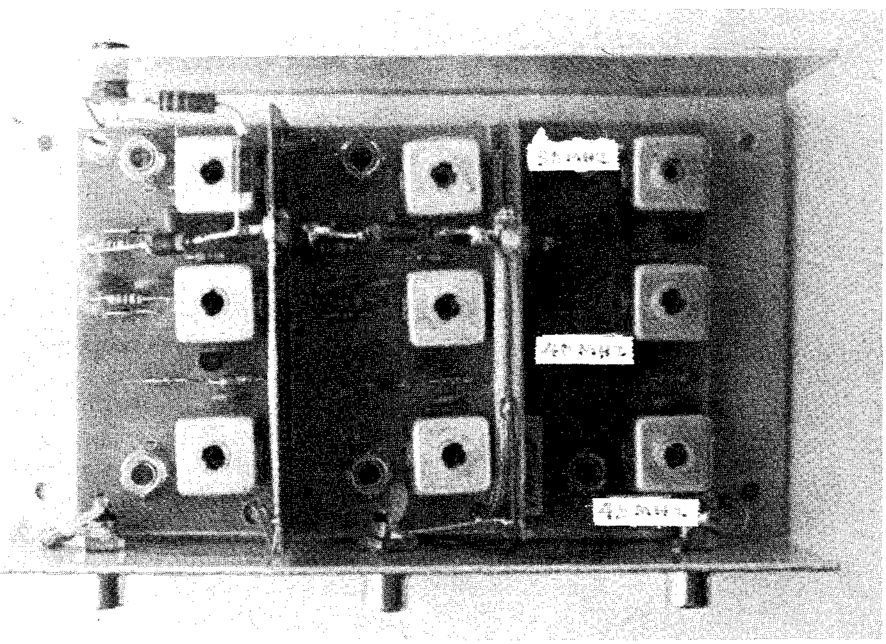


Figure 15-4.
Three stage IF amplifier in poly paks box - top view

output and lower, i-f input. The AFC insulated mini-phone jack is on the upper far left, and the two RCA phono jacks on the lower far left are 12-Vdc input to this box and 12-Vdc output to the three-stage i-f amplifier.

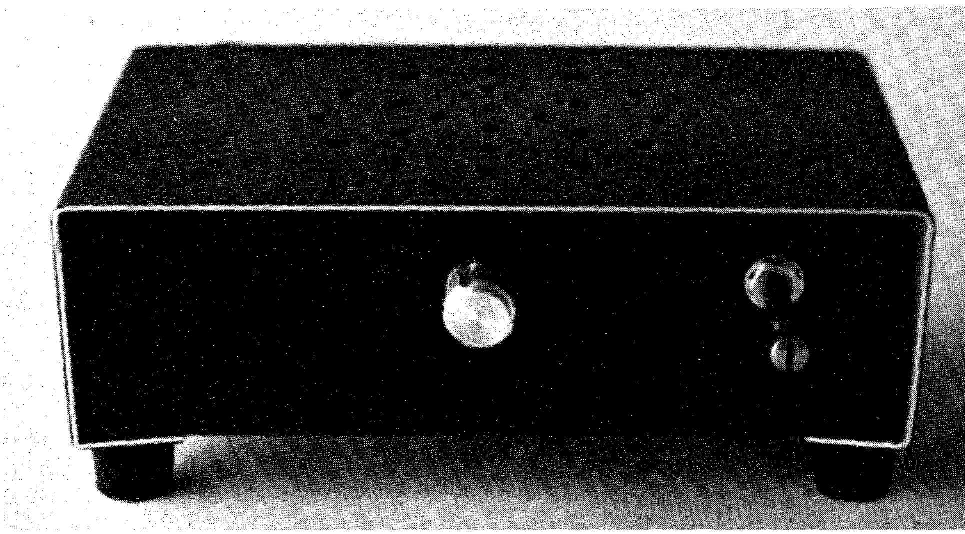


Figure 15-6.
Last stage video IF/discriminator/etc. - front view

Wheatstone Bridge Video Discriminator

The development of commercial fm stereo transmission, with the requirement that the fm receiver discriminator introduce a minimum of phase distortion, led to the development of the Wheatstone bridge discriminator, which is capable of nearly phase-distortion-free output over a very wide bandwidth. Applying this unique discriminator design to an i-f strip allows studio-quality video to be displayed when using the Gunnplexer television and computer data links. The schematic of the Wheatstone bridge video discriminator and two-stage video amplifier is illustrated in *Fig. 15-9.* The 220-pF discaps at the center of the bridge arms are for a 45-MHz center i-f. At 113 MHz use 100-pF discaps. The two voltage doubler rectifiers provide a better impedance match, with more output, than the single rectifiers

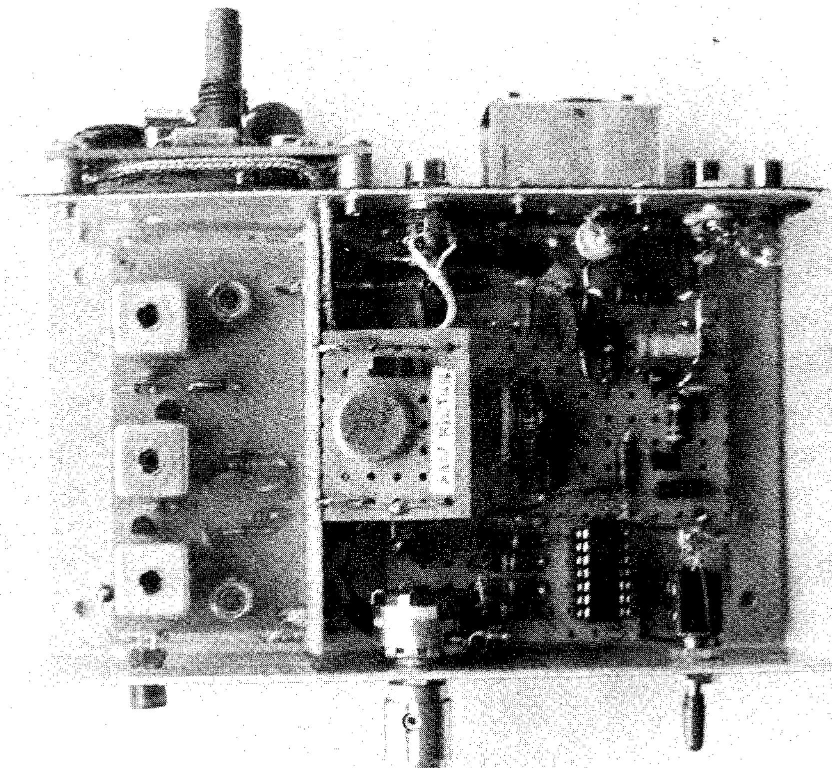


Figure 15-7.
Last stage video IF/discriminator/etc. - top view

would provide in *Figure 15-9*. Ordinary Poly Pak point-contact germanium diodes were used for CR1 through CR4. These diodes should be matched, using an ohmmeter, for equal forward resistance (and at least 1-megohm reverse resistance) to ensure good bridge balance: equal output from each side of the bridge. If you have a selection of Hewlett-Packard HP2835 Schottky diodes, by all means match four of them and give them a try as you may obtain even greater efficiency.

The $\frac{1}{8}^{th}$ λ arms of the bridge, L1 and L2 are made from two short lengths of RG-174/U minicoax rolled into a 2½ by 1¼-inch (64 by 32-mm) oval and installed on the PC board base plate with tape (see *Figure 15-14*).

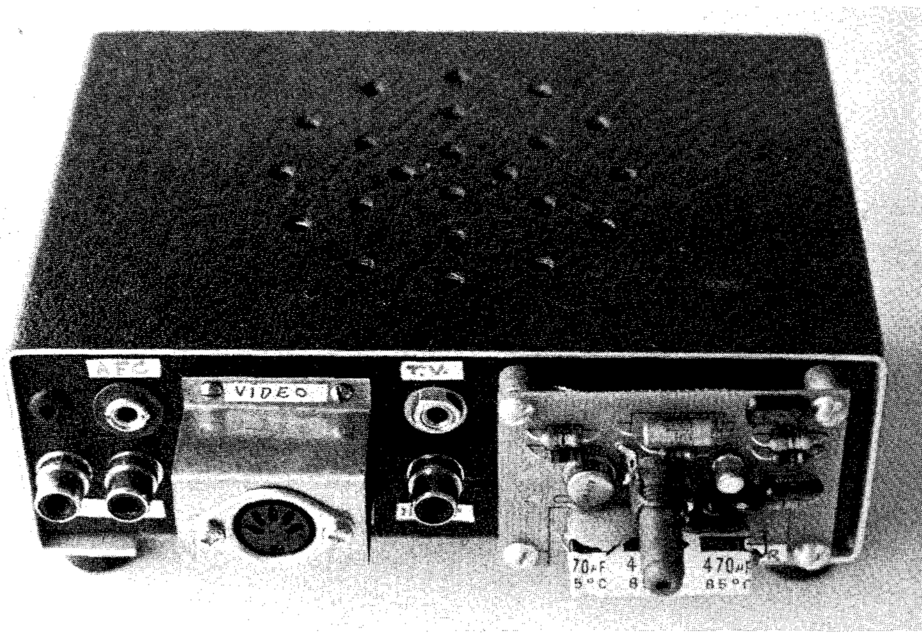


Figure 15-8.
Last stage video IF/discriminator, etc. - rear view

L1 and L2 dimensions — ⅛th λ Wavelength RG-174/U
45 MHz center i-f 21.65 inches (55 cm)
113 MHz center i-f 8.62 inches (22 cm)

If you've any doubt about the velocity factor of the minicoax you're using, by all means grid dip a ¼ wavelength section of it with one end open and a small ¼-inch (6 mm) loop at the other end. It goes without saying that, when an electrical ¼ wavelength is exactly on 45 or 113 MHz, its total length will be exactly two ⅛th wavelengths. When satisfied that you are on the desired frequency, cut the coax exactly in half.

Note in *Figure 15-9* that only the inner conductor of each piece of coax is connected to each side of the bridge center. At the bottom of the bridge junction to ground, one piece of coax (L2) has both the inner and outer conductor connected to ground, while the other piece of coax (L1) has *only* the outer conductor connected to ground. Even though the outer conductors of both L1 and L2 are grounded at the bottom of the bridge, I at first had grave doubts about bridge balance when coiling L1

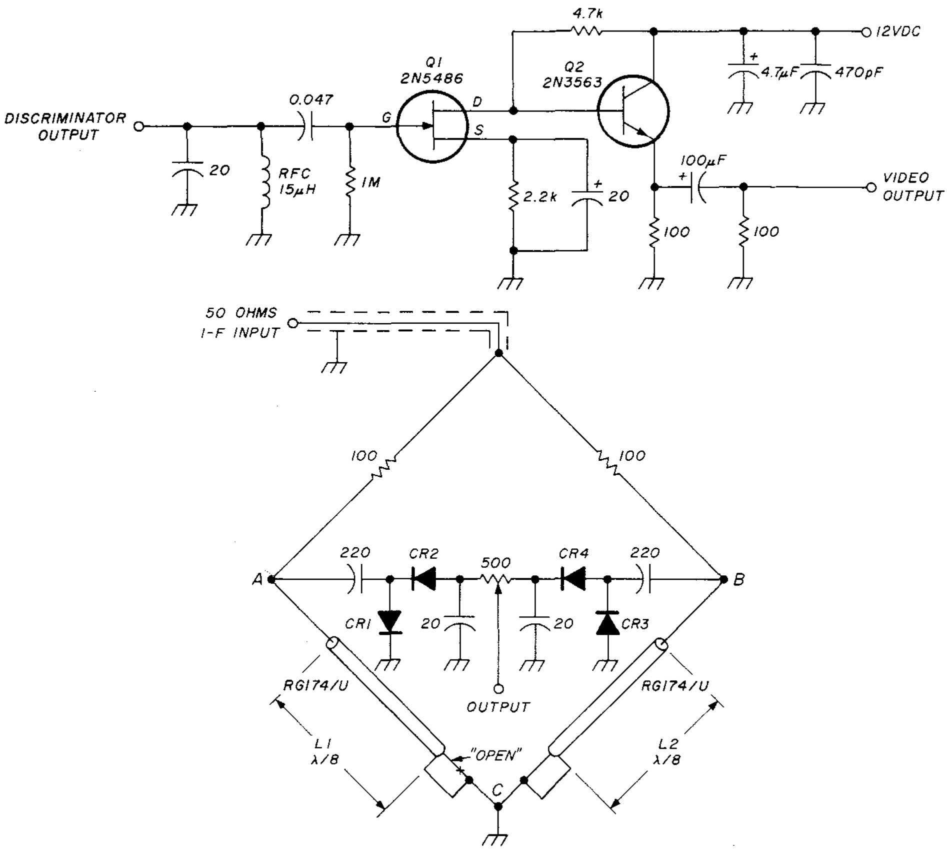


Figure 15-9
Wheatstone bridge video discriminator and video amplifier-schematic

and L2 and taping them to the PC-board base. These doubts were ill-founded, as bridge balance occurred well within the adjustment range of the 500-ohm pot at the bridge center.

The two-stage video amplifier shown in *Figure 15-9* is a simple two stage RC-coupled amplifier using a low-cost 2N5486 FET in the first stage and a 2N5363 in grounded-collector configuration in the second stage. At video frequencies, the load seen by the 2N5363 is approximately 50 ohms (the two 100-ohm resistors in parallel separated by the 100-μF dc blocking capacitor). It works very well into either a 50- or 72-ohm coax line driving a video display directly or a low-channel TV oscillator/modulator, if an ordinary TV receiver is to be used.

Video Displays vs TV Receivers

Picture definitions and resolution of any type of cathode ray tube readout is roughly proportional to the bandwidth of the driving signal. As examples:

1. The TRS-80 model 1 microcomputer video output has a 6-MHz bandwidth and can present 16 lines of 64 characters per line on the 12-inch (30 cm) video display in both upper and lower case letters (you add a 2102 chip for lower case).
2. Using the TRS-80 video output to modulate a channel 3 or 4 TV oscillator/modulator, then reproducing the signal on a standard TV receiver, leaves a great deal to be desired regarding character definition and resolution, even on 19-inch (48 cm) and 25-inch (64 cm) TV screens.

The problem is one of video bandwidth. The TRS-80 alphanumerics on the standard TV receiver are blurred and very difficult to make out, unless the special CHR$(23) function is used, which forms double-sized alphanumerics. The TV receiver video bandwidth of about 3.5 - 4.5 MHz will not provide the small character definition necessary for a high-quality, easy-to read display that TRS-80 6-MHz bandwidth can produce.

On the other hand, the standard TV receiver with its rf and i-f stages provides additional gain that, with a weak Gunnplexer video signal, will never be seen when using the broadband TRS-80 video display. I recommend using the standard TV receiver and the CHR$(23) function for long paths (over 2 miles or 3.2 km), so that the computer data can be easily read.

Video AFC Amplifier

The video AFC amplifier shown in *Figure 15-10* is the LM3900 Norton operational amplifier in its usual inverting configuration. If you use the proportional temperature control (PTC) system covered in Chapter 5, the video AFC amplifier is not required when the other Gunnplexer station also has PTC. The reason it is included here is that quite often you will probably be working Gunnplexer stations without PTC, and its quite irritating at best (especially with audio subcarrier) to have to retune constantly the other station's drifting signal on windy or gusty days when the Gunnplexer module temperature wanders.

Under ideal conditions (no wind or temperature variations), the Gunnplexer video system and audio subcarrier also, will remain on frequency for hours without PTC, but unfortunately ideal conditions are the exception rather than the rule. There's no reason why you can't use the Crystalmatic crystal-controlled weak-signal source to lock your video AFC if you wish. With a 10-MHz i-f bandwidth, you certainly will not be able to notice any reduction in Gunn diode fm spectral noise, but you will have crystal-controlled frequency stability and know right where you are at all times.

Rf Oscillator-Modulator for TV Channels 2-6

One of the nice-to-have features of the Gunnplexer Cookbook television and computer data link system is the option of using either a video display (as in TRS-80) or a standard TV receiver

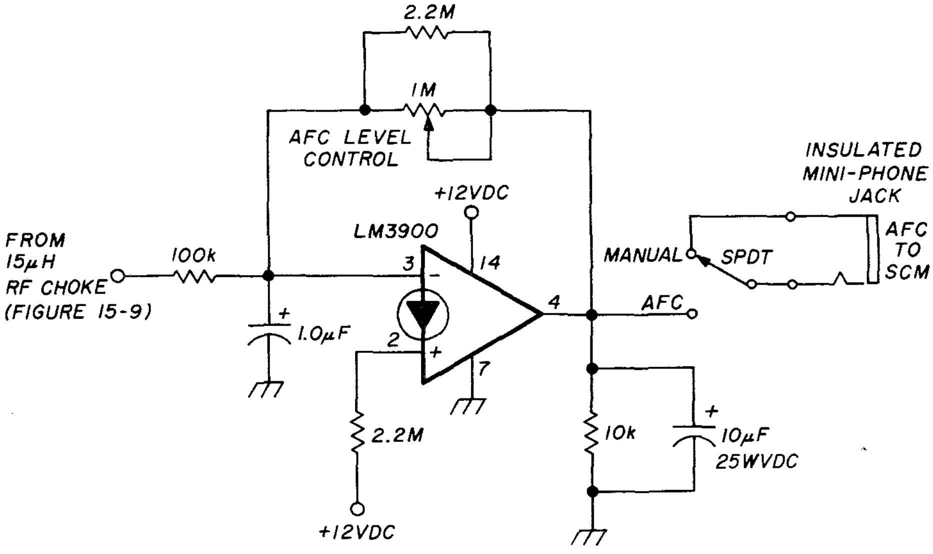


Figure 15-10.
Inverting video AFC amplifier-schematic

for readout. There are many circuits that provide the TV function, from the ultra-stable crystal-controlled units to simple modulated oscillators with varying degrees of stability. My favorite circuit is a modulated 2N2222 NPN transistor oscillator that is sold in kit form, part 107, by Electronic Systems, P.O. Box 212, Burlingame, California 94010, for about $13.50 each plus postage. The kit includes all parts, a drilled PC board, and an

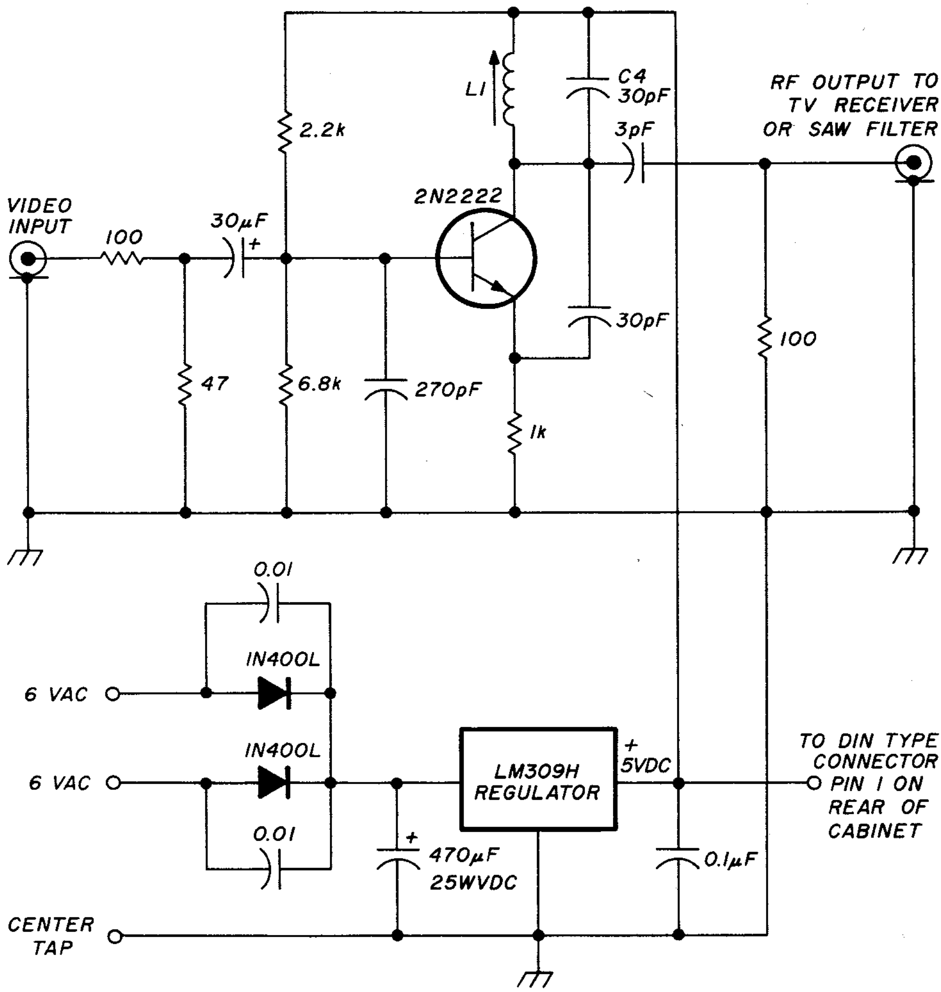


Figure 15-11.
Electronic systems - RF modulator channels 2 to 6

LM309H 5-volt dc regulator. The schematic is shown in *Figure 15-11.*

The stability of this little unit is outstandingly good, largely due to a) running it at only 5 Vdc, and b) the dipped mica capacitors furnished with the kit. I constructed one two years ago for running my TRS-80 microcomputer, with large CHR$(23) double-sized alphanumerics, to a standard TV receiver. It has never required adjustment since it was constructed.

The values shown for L1 and C4 in *Figure 15-11* are for nominal output on TV channels 2 or 3, but by substituting a 20-pF mica capacitor and adjusting the size of L1, channels 4, 5, or 6 are easily tuned. I used a ¼-inch (6.4-mm) diameter phenolic (paper) slug-tuned coil for L1 (see *Figure 15-8*) with 3 ½ turns of number 26 (0.4 mm) insulated hookup wire, and I can tune TV channels 2, 3, or 4 with the ferrite tuning slug.

As you already have 12 Vdc in the discriminator black box, the LM309H 5-Vdc regulator is not absolutely necessary, but it is a convenience, nevertheless, as you will also need 5 Vdc for the TRS-80 video display opto-coupler; so that it might as well be left in and put to good use. Besides, it's an exotic voltage dropping resistor in this application.

The bottom ½ inch (12.5 mm) of the rf oscillator-modulator PC board is sawed off so it will fit onto the rear of the Poly Paks box, shown in *Figure 15-8.* Good engineering practice would be to put it in a well-shielded box of its own, so your neighbors wouldn't be able to enjoy your channel 3 or 4 machinations regardless of whether they wished to or not. As I have no neighbors nearby and ran out of black-box space with which to shield it, I took the lazy route and mounted it on the rear of the discriminator cabinet in the open.

The 1N4001 rectifiers and 0.01 *microfarad* or μF discaps shown in *Figure 15-11* are not used. The 12 Vdc input is fed to the junction of the plus side of the 470-μF electrolytic cap and the input side of the LM309H 5-volt regulator. The PC board is mounted on the box rear with ¼-inch (12.5-mm) spacers and 6-32 by ½ inch (M3.5 by 12.5 mm) long bolts in each corner.

Surface Acoustic Wave Filter

The output of the rf oscillator-modulator is an ordinary amplitude-modulated signal containing the carrier and upper and lower sidebands. When received on a standard TV receiver, it will appear as a normal picture on the desired channel. In the U.S., all TV channels are 6-MHz wide (in the U.K. they are 8-MHz wide), and a vestigial sideband signal is transmitted by all U.S. commercial TV stations (in accordance with the National Television Standards Board agreement, and adoption by the FCC some 27 years ago).

Vestigial sideband is nothing more than an ordinary amplitude-modulated signal with (in the case of commercial U.S. transmission) the lower sideband considerably attenuated to allow closer TV channel spacing. A standard U.S. video TV signal without vestigial sideband processing would occupy 9.5-MHz bandwidth, including the fm audio subcarrier, rather than 6.0-MHz bandwidth. The means of generating the vestigial sideband signal are little different from those following standard Amateur radio practice using either phase quadrature or filtering techniques, then reinjecting the carrier. *Figure 15-12* shows a typical vestigial U.S. signal.

Were you building your TV modulator system to commercial standards and had to obtain FCC type approval of the system before entering the marketplace, it would have to meet the following criteria:

1. Lower sideband greater than 20 dB down from carrier.
2. Radiation through TV antenna greater than 60 dB down from carrier (carrier measured at 10dBm).

Neither of these requirements is difficult to meet if you simply disconnect the TV antenna from the TV set, using a switch with

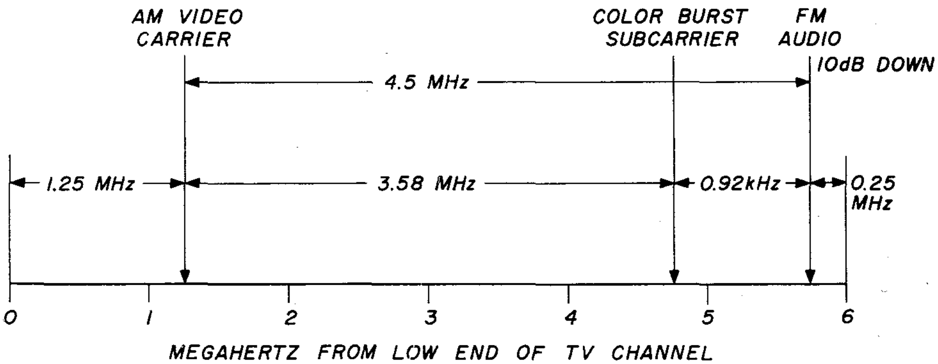


Figure 15-12.
Location of video, color & sound carriers on std. U.S. tv channel

good isolation, and simultaneously use a SAW filter on the TV modulator output to attenuate the lower sideband by 20 dB or more. Sound difficult, time consuming, and expensive? Actually, it's easy, takes only a few minutes to assemble, and will only cost about $1.95.

This little SAW filter is the Plessey SW300 vestigial sideband filter available from Poly Paks, 92CU3975, at $1.95 each. It was originally developed and mass produced for use with TV game circuits. It functions on both TV channels 3 and 4 with separate 75-ohm inputs for each channel and has a combined 75-ohm output on a single pin. *Figure 15-13* illustrates a typical hookup to the TV modulator, TV receiver, and TV antenna.

A dpdt mini-toggle switch grounds the TV antenna or SAW filter output as appropriate. If you wish, forget about the switch and diconnect the TV antenna when using the TV modulator, unless you wish to share your Gunnplexer program with your former friends and neighbors. Shorting the SW300 output to ground or TV antenna to ground (good nearby rf chassis grounds of ½ inch, 12.5 mm, or less) appears to be the most efficient way to eliminate unwanted radiation. A 4:1 balun should be used at the TV receiver antenna terminals and another balun at S1B center terminal if you're using 300-ohm feed line from your TV antenna.

The 300-ohm, ¼-watt resistors on the input of SW300 are effectively in parallel with the TV modulator 100-ohm output resistor about 2 inches (50 mm) away, and yield an exact 75-ohm match to the SAW filter input. They may probably be omitted if desired.

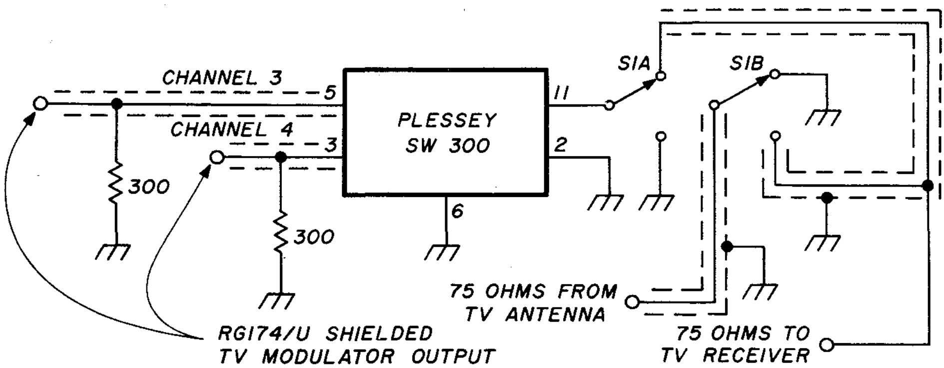


Figure 15-13.
Plessey SW300 vestigial sideband filter hookup

Complete Gunnplexer Video System

Figure 15-14 shows the layout of the second Gunnplexer video system Poly Paks box base plate, shield, and bottom two coax legs of the Wheatstone video discriminator bridge. The base plate is a piece of double-sided, 1/16-inch (1.6-mm) thick PC board measuring 4¾ by 3⅛ inches (12 by 8 cm). It may be most any type of board or even a scrap piece of thin brass, copper, or tin can sheet that will take solder easily. The same is true for the vertical shield material.

Inductors L1 and L2 shown in *Figure 15-14* are the RG-174/U bottom legs of the Wheatstone video discriminator bridge. Each piece of coax (whether cut for a 45-MHz or 113-MHz center i-f) is wound into an oval shape about 1¼ by 2½ inches (32 by 6.4 mm) using Scotch tape to hold it together and more Scotch tape to hold it down to the base. The only important point is to make sure that each end of L1 and each end of L2 (points A, B, and C in *Figure 15-9* are positioned as shown to ensure good bridge

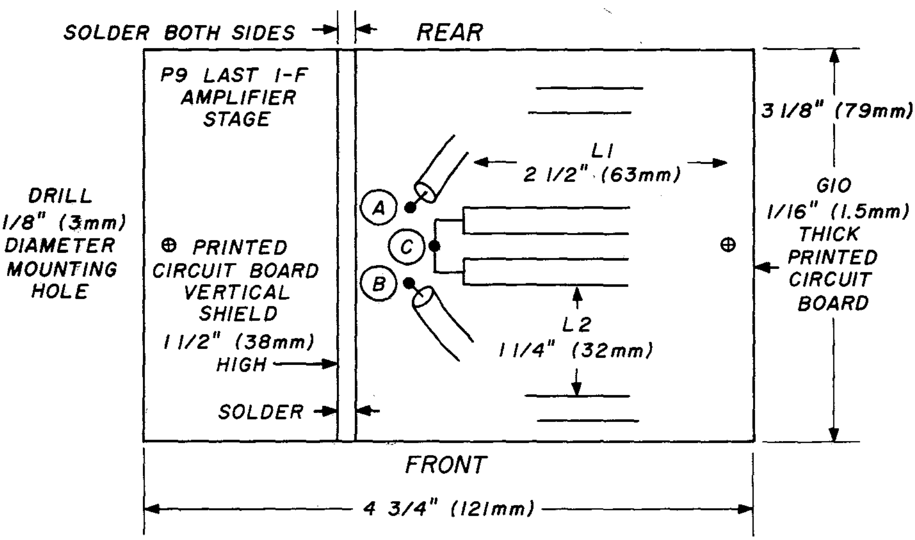


Figure 15-14.
Base plate/shield/L1 & L2 legs of bridge - layout

balance. They are bent 90 degrees upwards, ½-inch high (12.5 mm), and will be connected later to the perf board.

Component layout for the Wheatstone Bridge disciminator, video amplifier, and AFC amplifier is not very critical when using the 45-MHz center i-f, but does require careful placement if you choose to use the 113-MHz center i-f. No matter which center i-f you use, the layout illustrated in *Figure 15-15* has been constructed for both i-fs and works very well. The forward-most 2.2-megohm resistor connects to the AFC level control 1-megohm pot in the front-panel center. The LED on-off light is mounted in a Cliplite™ holder on the front panel left side and is connected to the P9 preamplifier 12-Vdc line through a 1200-ohm dropping resistor.

The rear panel of the discriminator/video/AFC box is an extremely busy place, so both words and pictures are used to describe it. Refer to *Figure 15-8.* The insulated mini-phone jack marked AFC above the two 12-Vdc phono jacks is for the line from the system control module AFC jack. The inner conductor goes to the Gunnplexer varactor, and the outer conductor is from the SCM coarse- and fine-tuning controls. This AFC jack on the rear panel is connected to the AFC on-off switch with the varactor line to the switch center terminal, SCM varactor tuning is connected to the top switch terminal, and the video AFC amplifier output to the bottom terminal. The U bracket for the TRS-80 video display DIN-type connector (marked video) is wired as illustrated in *Figure 15-16.*

Referring to *Figure 15-15,* note that the 100-μF dc blocking capacitor on the output side of Q2 feeds both the TRS-80 video display connector and the TV modulator. If you plan to use the TRS-80 video display by itself, a spst switch should be installed to open this line to the TV modulator so that the video signal is not split 50/50 between the two. There's room for a mini-toggle switch on the rear panel next to the AFC jack.

The video i-f input RCA phono jack is mounted directly beneath the TV output mini-phone jack as shown in *Figure 15-8.* A short 2- to 3-inch (50- to 76-mm) length of RG-174/U mini-coax should be run between this jack and the last-stage i-f amplifier input. Drill a ⅛-inch (3-mm) diameter hole through the rear vertical shielding soldered to the baseplate and pass the coax through. Be sure to solder the outer coax braid to the vertical shielding.

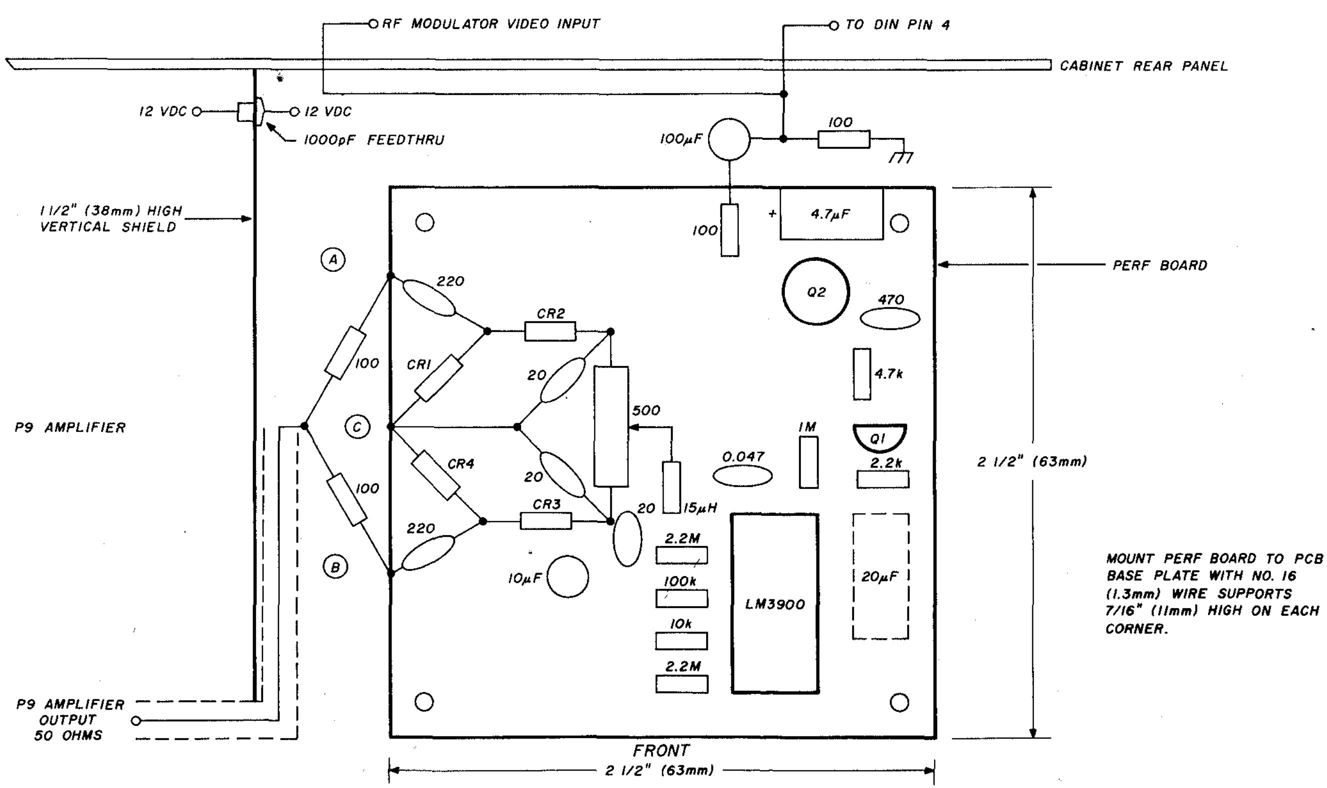


Figure 15-15.
Discriminator/video amplifier/afc amplifier - parts layout

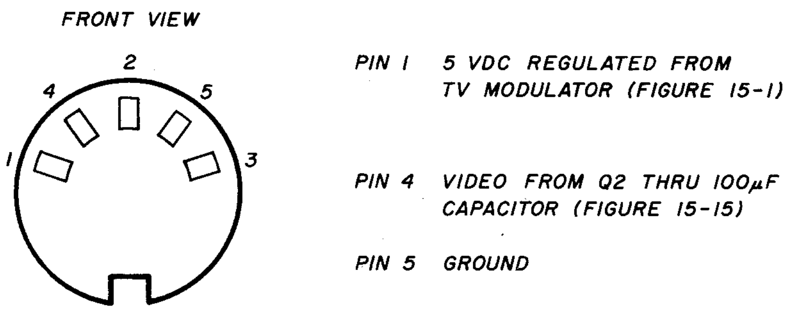


Figure 15-16.
Din type connector to TRS-80 video display

Modifications for Transmitting Gunnplexer Video

The reason for placing this section so far back in the Chapter is that there is so very little to do to modify the Gunnplexer system to transmit video. Referring to the Chapter 4 Mark II system-control module schematic, you'll note that the microphone/video level control is a 1000-ohm pot. You should parallel this pot's two outer terminals with 100-ohm, ¼- or ½-watt resistor to achieve a closer match to the 75-ohm video source. Some TV cameras will work fine without this modification, but some video recorders have been used that will not work at all without it. To be on the safe side, install this 100-ohm resistor so that your system control module microphone/video input will work with any type of video source capable of ¼-volt peak-to-peak or more output.

The Gunnplexer Cookbook is not a book full of video/audio source recipes, as it's supposed to be a microwave primer. Some of the more common video sources are:

1. An ordinary TV receiver video output signal.
2. A cable TV composite baseband signal (video and audio).
3. A TV camera video output.
4. A TV tape recorder video output.
5. A TRS-80 microcomputer video output.

Amateurs and electronics students who have access to a composite baseband signal (as in cable TV) must do nothing more than feed this signal into the system control module mike/video input jack and they are on the air with a complete TV channel video and audio when the Gunnplexer receiving end of the circuit is using the TV oscillator/modulator illustrated in *Figure 15-11.*

If you don't have a composite baseband video/audio signal handy, why not create your own? The following circuit may be built in a few hours for a few dollars. My favorite circuit to generate a 4.5-MHz fm audio subcarrier uses only one integrated circuit, an LM380 audio amplifier, and three transistors. It may be built on a small 2-inch by 4-inch (50- by 102-mm) piece of perfboard. This perfboard assembly may be mounted piggyback on top of the existing perfboard in the system control module box. If you're willing to forego use of the SCM's LM555 tone oscillator and key jack, no extra controls or jacks need be added. Conversely, this circuit may be mounted in its own box if desired.

Most all TV receiver (and fm receiver) audio circuits include a certain amount of de-emphasis to compensate for the broadcast stations pre-emphasis audio shaping networks. Although this may sound ridiculous, it's not. Actually, the signal-to-noise ratio of an audio fm system is improved by reducing the level of the low audio frequencies at the transmitter, which results in a transmitted signal with more constant energy distribution.

At the receiving end, the detected audio signal is then de-emphasized (audio lows enhanced) to restore normal-sounding high-fidelity audio. Don't worry about putting your hi-fi voice subcarrier on the video signal now, and let the 27K ohm resistor and 0.01-μF capacitor in the LM380 mike input line provide the pre-emphasis audio shaping. This network will make you sound natural when using a good-quality, high-impedance microphone. *Figure 15-17* is a schematic of the 4.5-MHz fm audio subcarrier system that will complement your video signal.

Parts layout of the audio subcarrier system is of little importance, as it will work in most any configuration imaginable. The MPF-109 is an N-channel field-effect transistor Hartley oscillator working at 4.5 MHz. Most any N-channel FET will work in this circuit. All things considered, it's surprisingly stable. With the 500-ohm fine tune potentiometer in its center position, adjust the ARCO 402 trimmer capacitor for 4.5-MHz output using a communications receiver for calibration. The fine tune potentiometer was formerly the F2 MCW level control on the system control module, and the key input jack on the SCM is now used as the microphone jack. With composite video and audio on 10 GHz, you don't really need another signal to identify yourself.

Q1 in *Figure 15-17* is a unique 4.5-MHz oscillator in that the ARCO 402 coarse tuning trimmer capacitor sets the fm subcarrier

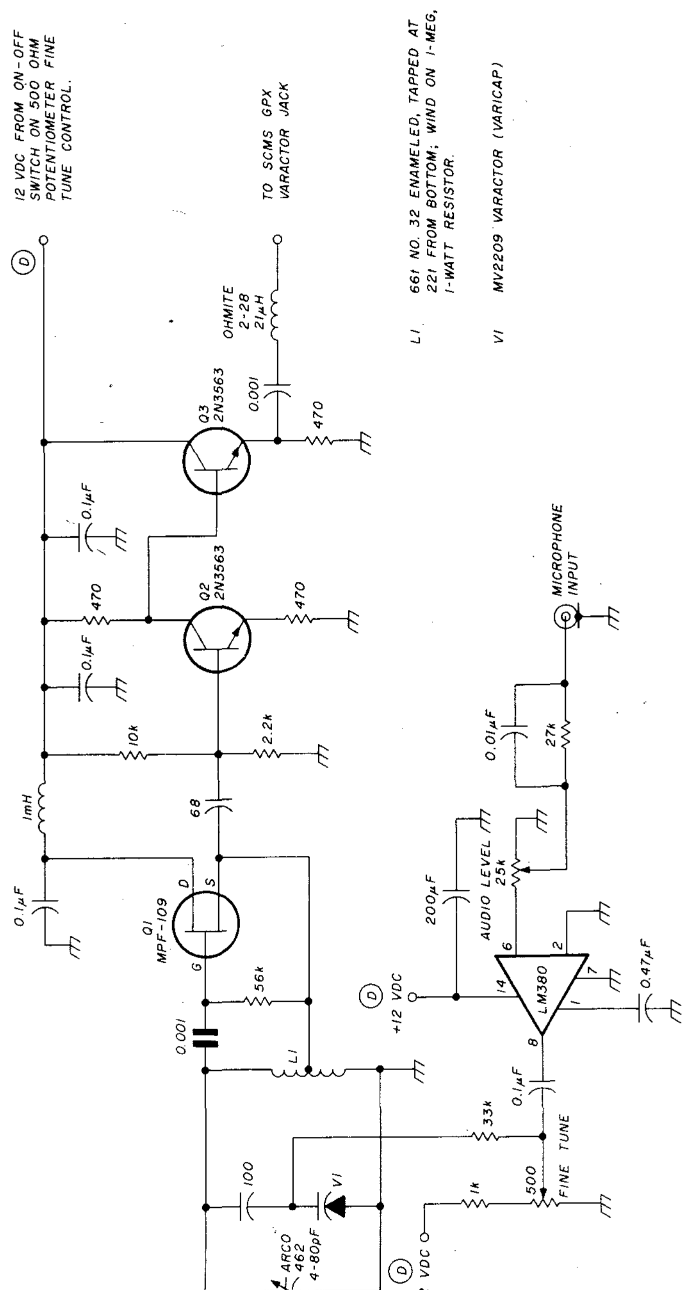


Figure 15-17.
4.5 MHz fm audio subcarrier system-schematic

oscillator at about 4.5 MHz; while V1, a Motorola MV2209 varactor (varicap), is used to fine-tune the oscillator exact frequency as well as frequency modulate it with deviation determined by the amplitude of the driving audio signal. Q2 is an RC coupled buffer-amplifier driving Q3 in an emitter-follower configuration. Q3 rf output could be series tuned, using another ARCO 462 trimmer capacitor in place of the 0.001-μF disc cap, but was found unnecessary.

Another alternative is to change Q3 emitter resistor to a 500-ohm carbon trim pot, which might make it easier to adjust the audio fm subcarrier exactly 10 dB down from the video carrier. I found empirically that a 0.001 μF discap feeding the Z28 rf choke to the system control module varactor jack set the subcarrier 10 dB down very neatly, after adjusting the LM380 audio level control for proper deviation. Undoubtedly, a clipper/limiter as shown in the TX-432 schematic (Chapter 10) would also improve readability under marginal conditions. However, it was intentionally left out for simplicity. Tuneup and adjustment of the 4.5-MHz fm subcarrier system is described after video-system alignment.

Sweeper-Marker Tune Up

This section covers alignment with special test equipment and the following section covers alignment using only a TV receiver.

Using sweep-marker generators and an oscilloscope with detector-demodulator probe, with a 50-ohm load on the four-stage P9 i-f amplifier output, align the stages for a scope pattern as shown in *Figure 15-18.* It's desirable for the passband variation to be adjusted to about plus or minus 1 dB, but don't spend a great deal of time tweaking all twelve tuning slugs trying to obtain it, because plus or minus 2-3 dB will work about as well. Another important objective is to strive for approximately 20-dB gain per stage or about 68-80 dB for the total i-f system. A variation of 3-dB gain per stage is acceptable, but any less than 17-dB gain per stage indicates a problem; take the coil covers off and check resonant frequency with a grid-dip meter.

If you're using a 113-MHz center i-f, the upper and lower markers should obviously be set at 118 and 108 MHz. The sweep-marker signal input should be continually reduced so that the input to the last i-f amplifier stage is always less than 0.5 volt

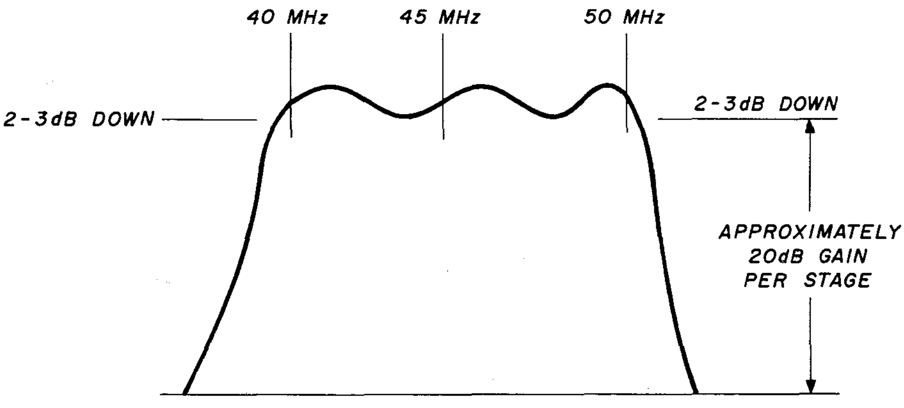


Figure 15-18.
P9 IF amplifier bandpass-oscilloscope pattern

peak-to-peak to avoid clipping or limiting by the back-to-back diodes. Now, hook up the Wheatstone discriminator bridge and two-stage video amplifier shown in *Figure 15-9*, leaving the sweep-marker generator in place on the first i-f stage input.
Move the oscilloscope detector to the output side of the 100-μF electrolytic cap connected to Q2 emitter, video output, shown in *Figure 15-9*. If all is well, the oscilloscope pattern should look like that shown in *Figure 15-19*.

The exact center-point frequency is determined by how well you matched the point-contact germanium diodes used in the Wheatstone bridge discriminator and how close to the desired center i-f you cut the $\lambda/8$ wavelength sections of RG-174/U mini-coax for the two bottom legs of the bridge. The bridge 500-ohm balance potentiometer will compensate for diode imbalance, within limits. The center i-f need only be within plus or minus 1 MHz of that desired for an excellent quality picture. The extremely wide bandwidth (with little phase distortion) of the Wheatstone bridge discriminator is one of the major contributors to the excellent picture.

Alignment Without Special Test Equipment

This was one of the most challenging and fun projects accomplished while preparing material for the Gunnplexer Cookbook. It was challenging because a number of self appointed television

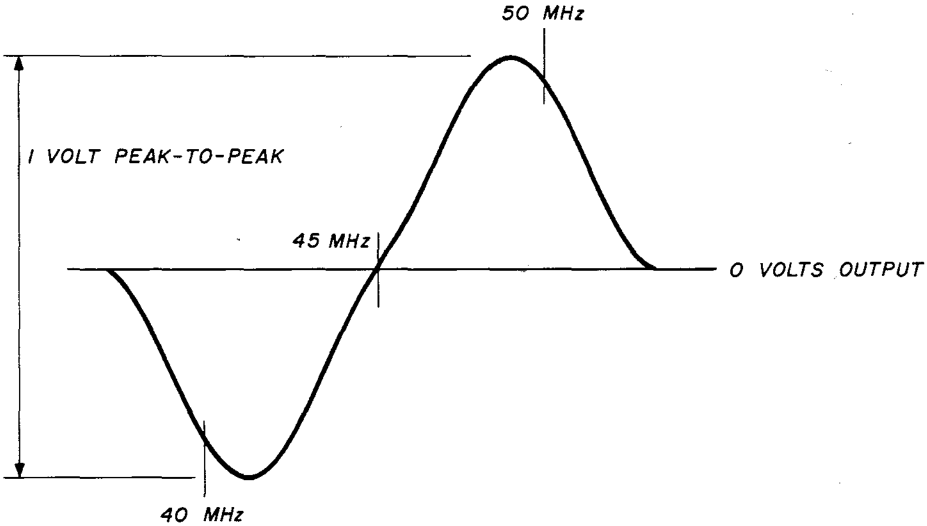


Figure 15-19.
Discriminator/video amplifier output-scope pattern

experts said it couldn't be done, and because it turned out not to be all that difficult.

The following tune-up and alignment procedure worked the first time. The video i-f center frequency of 45 MHz is used in describing this method, but it applies as well to any i-f of your choice.

Adjust the frequencies accordingly. Two Gunnplexers are required using this method. Gunnplexer number 1 is set at 10.250-GHz output using a TV camera as a video source (any video source may be used) with a 0.5 - 1.5 volts peak-to-peak video signal. Gunnplexer number 2, with the output on 10.295 GHz (for a 45-MHz center i-f), is used as the receiver, with an i-f preamplifier covering 40 - 50 MHz. If a P8 i-f preamplifier is used, add 4.7K ohm resistors across the input and output coils to increase bandwidth (they are removed later). Grid dip the input to 42 MHz and the output to 48 MHz. Connect standard TV receiver to the rf modulator output on Gunnplexer number 2 video receiver system. The TV receiver picture is the sole indicator of system tuning. Perform the following steps in the order presented.

1. Place Gunnplexer number 1 and Gunnplexer number 2 about 10 - 15 feet (3-4.5 meters) apart, facing each other.
2. Adjust the system control module microphone-video level control pot on Gunnplexer number 1 to midrange (with a 100-ohm resistor in parallel with the 500-ohm potentiometer).
3. With the TV receiver fine-tuning control set at midrange, adjust L1 on the rf modulator *Figure 15-11* so that the TV receiver noise, sparklies, whites out completely on the channel of your choice. Channel 3 is used in this example, but any channel from 2 - 6 may be used.
4. Temporarily install the first P9 video i-f stage in the discriminator box and hook up. Connect Gunnplexer number 2 to its system-control module, and connect the system control module to the discriminator box.
5. Turn everything on and allow the Gunnplexer to warm-up and stabilize. With the AFC switch on the discriminator box in the off position, adjust Gunnplexer number 2 system-control module coarse and fine varactor tuning control for maximum video signal on the TV receiver. At least some vestige of a video signal should be coming through with only 10-15-feet (3-4.5-meter) Gunnplexer spacing.
6. Adjust the microphone/video-level control on Gunnplexer number 1 system control module for best black and white picture graduation. Also adjust the TV camera lens opening for best definition of whatever is coming through. Repeat this step until no further improvement is noted.
7. Adjust the 500-ohm balance pot on the video discriminator output for best picture quality.
8. Adjust L1, L2, and L3 on the P9 i-f amplifier for best picture quality. There will be considerable interaction between adjustments, so keep repeating until no further improvement is noted. You should have a good quality picture by now. Turn Gunnplexer number 2 antenna slightly away from a direct shot at Gunnplexer number 1 until only a weak signal is received.
9. Repeat steps 6, 7, and 8 until no further improvement is noted. Patience and perseverance will pay off later. This is not the time to be in a hurry.
10. Substitute the second P9 video i-f amplifier stage in the discriminator box, and repeat steps 8 and 9.

11. When completed, substitute the third and fourth P9 video i-f stages in the discriminator box, and repeat steps 8 and 9.
12. Permanently install P9 video i-f stages 1, 2, and 3 in their own box and stage 4 in the discriminator box.
13. Move Gunnplexer number 1, its system-control module, and power supply a few hundred feet ($\approx$90 meters) away and point Gunnplexer number 1 antenna, so that only a weak signal is received. If possible, bounce the signal off a nearby building so that Gunnplexer number 2 is receiving only the reflection. Repeat steps 5 – 8, carefully tweaking all i-f amplifier tuning slugs for best picture.
14. Remove the 4.7K ohm resistors across Gunnplexer number 2 i-f pre-amp input and output coils. Adjust the preamplifier coils, L1 and L2, for best picture.

This procedure is certainly a time-consuming and lengthy method of video tuning and alignment, but it passes the final examination because it works. After alignment, my first try, using video on a 2.0-mile (3.2 km) path across Chautauqua Lake was an outstanding success. *Figures 15-20* and *15-21* are photos of the first try across the lake. *Figure 15-22* is a photo of the Unimetrics TV camera used in all the Gunnplexer video tests. Equivalent TV cameras can be purchased today for about $150.

Alignment of the Gunnplexer video system using only a video source, a Gunnplexer transmitter, and Gunnplexer video system receiver with a standard TV set may indeed be a challenge and fun the first time. However, it's not the type of thing most sane individuals would care to repeat, as it's time consuming and requires infinite patience with the myriad variables involved. Subsequent alignment of the same system with standard TV repair shop varieties of sweep-marker generators and an oscilloscope showed that total video i-f gain could be improved an additional 20 dB over that obtained using the eyeball TV receiver method. Therefore, if you can beg or borrow the proper test equipment, or have your friendly local TV repair shop align the video system, by all means do so, because it's certainly the way to go. *Figure 15-23* illustrates the realigned Gunnplexer video system operating over a 5.5-mile (8.8-km) path. Even over the longer path, 5.5 miles (8.8 km) versus 2 miles (3.2 km), the contrast was improved, and the small amount of noise that can be seen in *Figures 15-20* and *15-21* was eliminated after realignment.

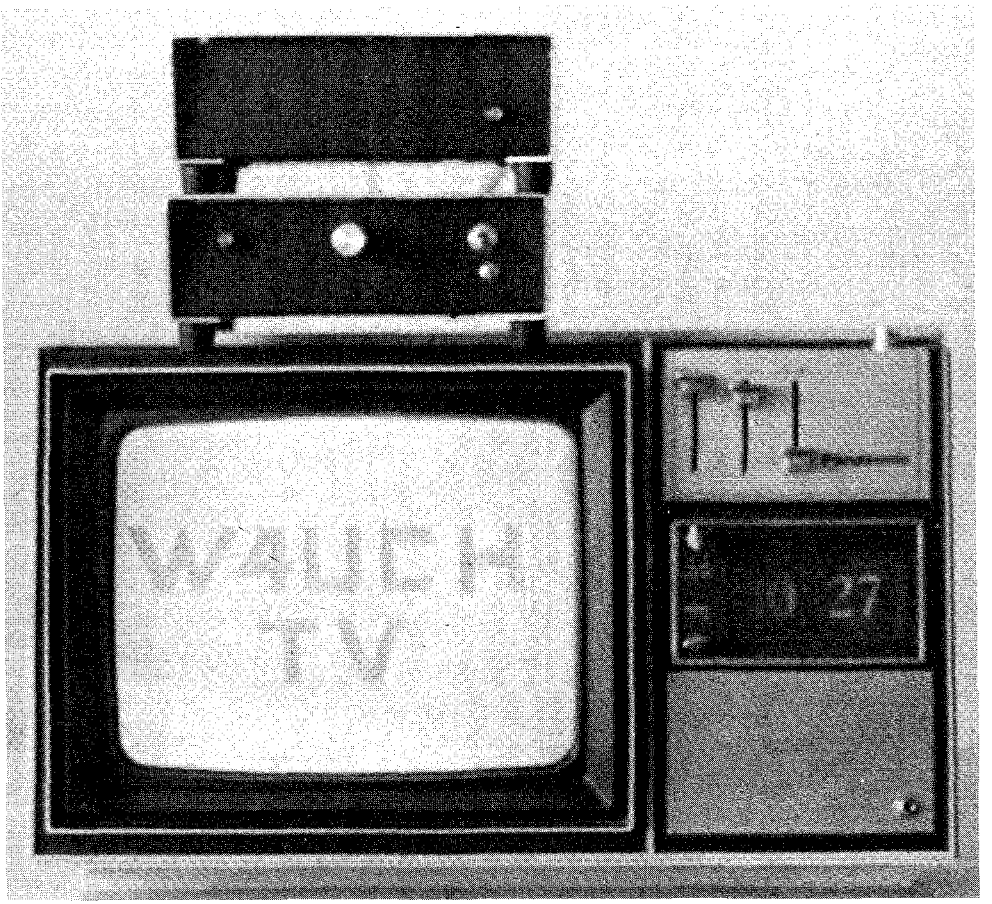


Figure 15-20.
First W4UCH Gunnplexer video test 2.0 mile path-call letters

Audio Sub-Carrier System Alignment:

Figure 15-24 is a photo of the 4.5-MHz fm audio subcarrier system mounted piggy-back atop the system-control module perfboard in the same Poly Paks box. The MPF-109 oscillator is on the left, the LM380 audio amplifier on the right, and the two 2N3563 transistors in the center.

Figure 15-21.
First W4UCH Gunnplexer video test 2.0 mile path-author

With the Gunnplexer video system tuneup and alignment completed and behind you, aligning the 4.5-MHz audio subcarrier system will seem like child's play. It can be done in only a few minutes, again using a standard TV receiver for adjustment:

1. Referring to *Figure 15-17*, the schematic of the 4.5-MHz fm audio subcarrier system, make sure that the ARCO 462 trimmer capacitor is adjusted for exactly 4.5-MHz oscillator output with the 500-ohm fine tune pot at midrange. Use a communications receiver or digital frequency counter for calibration.

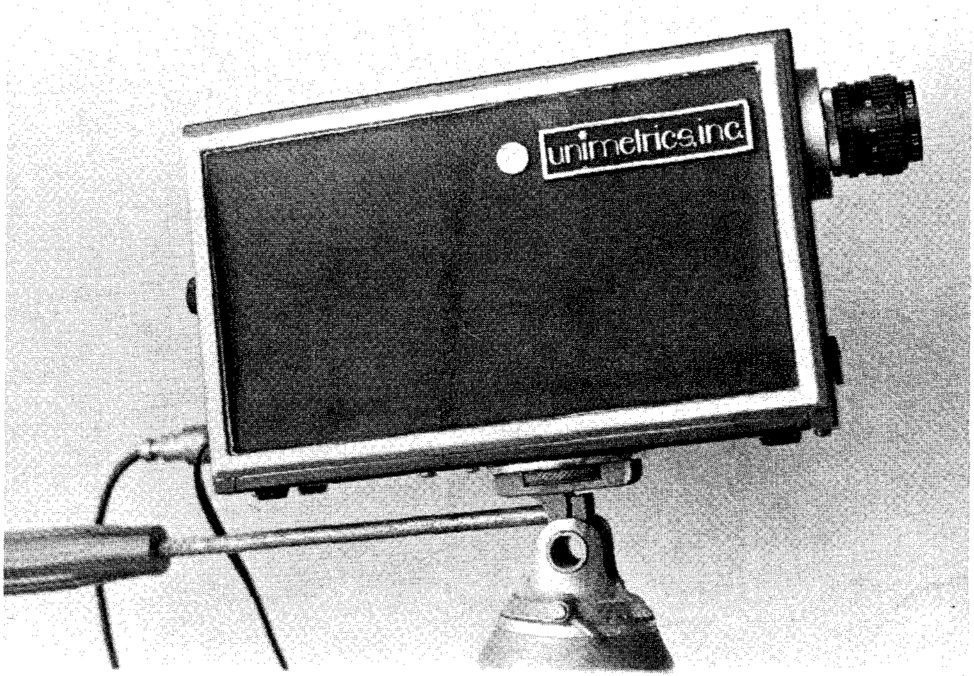


Figure 15-22.
Unimetrics television camera model XL-1

2. Turn on the Gunnplexer video system and adjust for good quality picture with the outer end of the Z28 rf choke attached to the Gunnplexer varactor jack on the system control module.
3. Adjust the 500-ohm fine tune pot for maximum quieting of the TV receiver audio output.
4. Using a normal voice level while speaking into the microphone, advance the LM380 volume control (25 input pot) until sound bars are seen on the TV screen.
5. Back off the 25k LM380 volume control just a bit more than it takes to completely eliminate the sounds bars on the TV screen (while talking). That's all there is to it. You've now completed the full course.

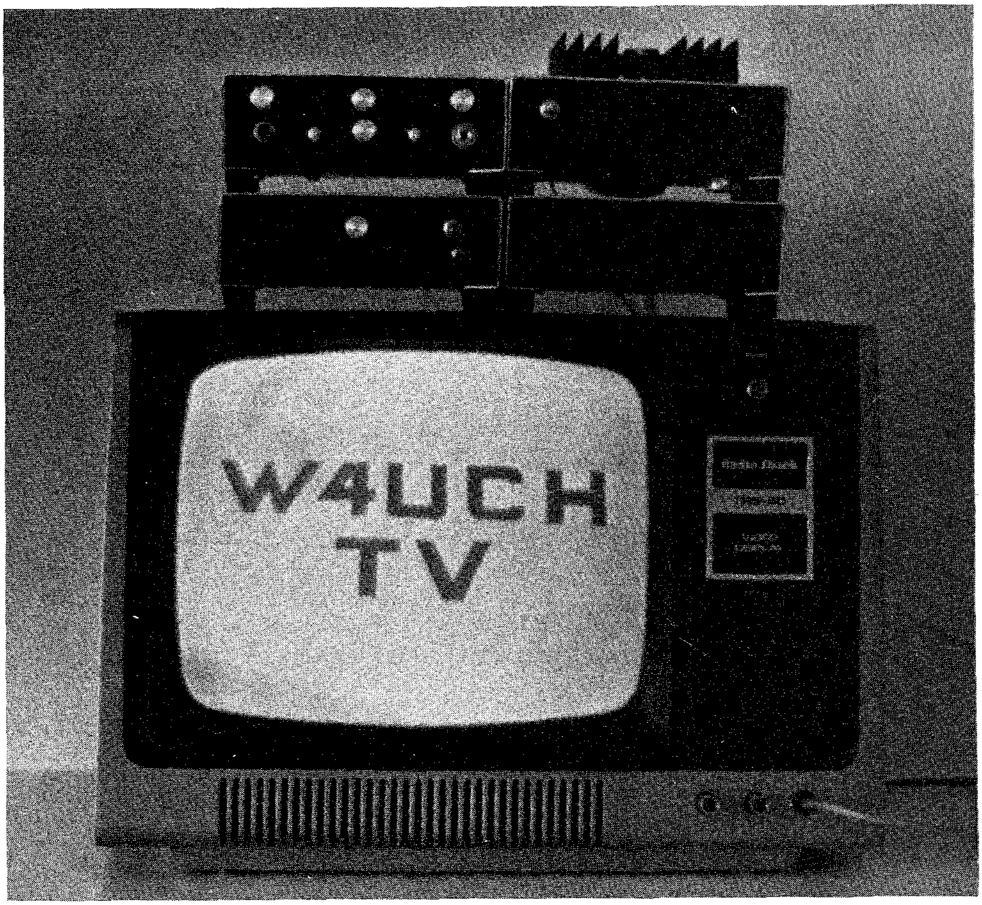


Figure 15-23.
Realigned Gunnplexer video receiver system 5.5 mile path

Summary

Gunnplexer video systems are well worth the effort, whether it be for ordinary sight and sound Amateur television, relaying composite baseband TV programs, or for tying two TRS-80 microcomputer programmers together over a 5.5-mile (8.8 km) computer data link (Figure 15-25). An extra i-f stage helps with the TRS-80 video display.

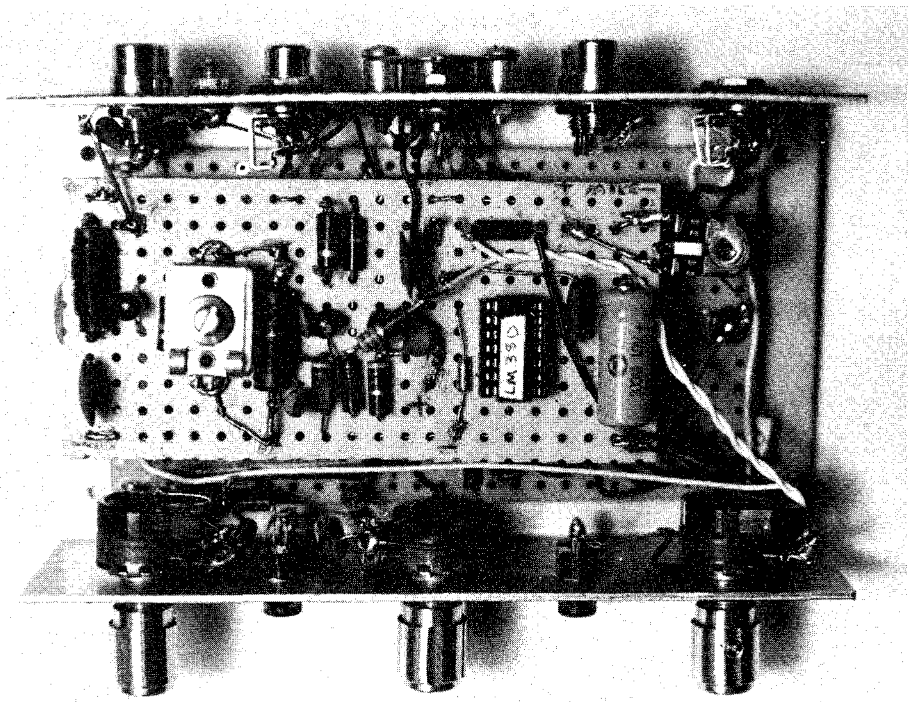


Figure 15-24.
4.5 MHz FM Audio Sub-Carrier System

My Gunnplexer video system has never been used on a path longer than 5.5 miles (8.8 km). There's no reason whatsoever that, with a larger parabolic reflector and the excellent Microwave Associates-designed preamplifier, ranges well beyond 10 miles (16 km) couldn't be worked under normal dry conditions.

One word of caution again on the subject of precipitation signal attenuation at 10 GHz. For path lengths greater than 2 miles (3.2 km), rain or snow (freezing rain is worst) attenuation can make your 15 - 40 milliwatt Gunnplexer signal disappear.

One "amaze your friends" program that's always a crowd pleaser at Gunnplexer demonstrations is to run the TRS-80 Morse-code program presented at the end of Chapter 14 with alphanumerics readout on video, then have the TRS-80 cassette control relay (the keying relay in this software program) key an

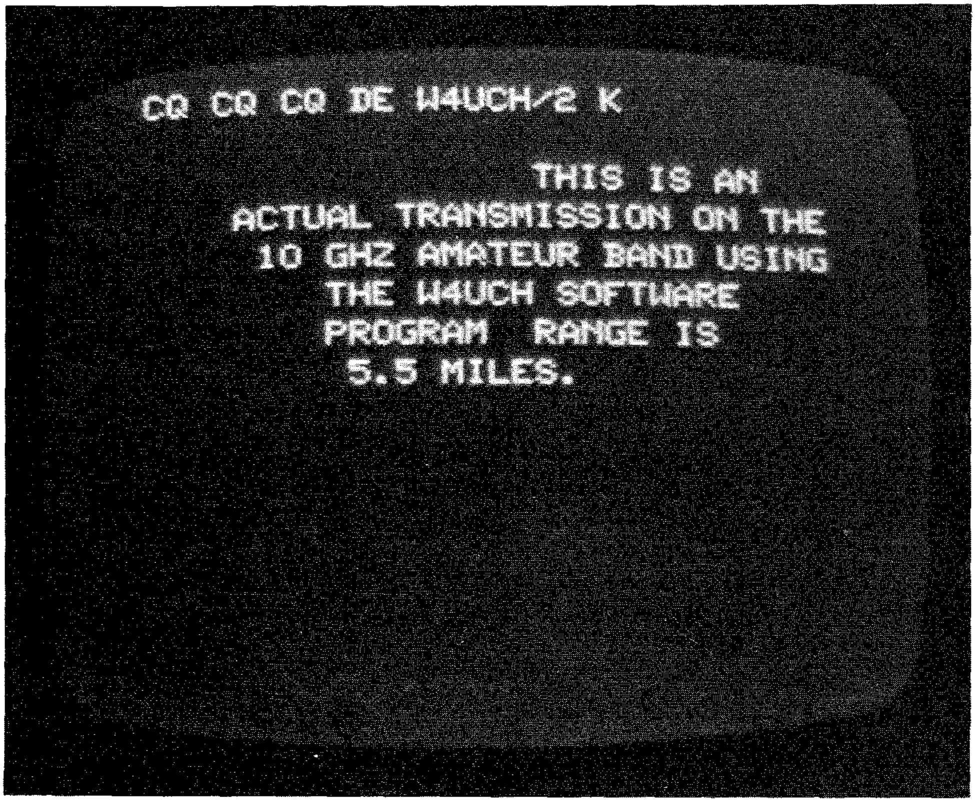


Figure 15-25.
Gunnplexer 10 GHz video system signal from TRS-80 microcomputer as displayed on a Sanyo 19 inch tv receiver - 5.5 mile path

audio oscillator with Morse code on the fm audio subcarrier. The whole bit is received across the auditorium or demonstration room by your Gunnplexer video system using a standard TV receiver for both video and audio reproduction. Although quite simple to accomplish, it leaves an impression that those in attendance will never forget. It's good showmanship to prepare a canned message of three or four lines appropriate to the occasion and insert them into the program (like CQ or what have you) before the demonstration.

16

Epilogue

On April 3, 1979, thanks to the princes of serendip and a lot of hard work, I discovered that Gunnplexer fm/fm video and audio signals could be demodulated by an ordinary television receiver with no fm to a-m external processing. This system was demonstrated to almost 20,000 Amateurs, who attended the 1979 convention in Dayton, Ohio. However, I still found it hard to believe, so I didn't tell how the Gunnplexer video and audio signals were demodulated. Bob Cooper, W5GKT, was the only person told of this discovery.

Super shock? You bet. Television signals of every variety, from scanning discs to shadow boxes, have been around since 1929. And the discovery that an fm video signal could be detected by an a-m TV receiver with a picture quality as good or better than a-m video was incredible.

The use of frequency modulation to transmit video signals is as old as television itself, but the use of a standard NTSB a-m video television receiver to demodulate fm video has not ever been described in the literature (after a thorough literature search) in the past 50 years. This discovery led me to the following action and to answer some pertinent questions.

1. Make a notarized patent disclosure at once.
2. Complete a literature search and start a patent search.
3. Double check the discovery. Was it only slope detection on a single grossly misaligned TV receiver?
4. Check the process on the following TV receivers: RCA, Admiral, Philco, Zenith, Sanyo, and Panasonic.

5. Was the fm video signal being slope detected by the Gunnplexer i-f preamplifier? No, it was not. It worked perfectly (better than studio quality picture) when the Gunnplexer mixer output was connected directly to the TV receiver without any i-f preamplifier installed.
6. Was the fm video signal being slope detected by the TV receiver rf or mixer stages, and the resulting a-m signal being amplified by the TV's i-f amplifier? No, it was not. It worked perfectly (better than studio quality picture) when the Gunnplexer i-f output was fed *directly* to the TV reviewer i-f input, fully bypassing the rf and mixer stages.
7. Does the Gunnplexer i-f mixer somehow convert the received fm video signal to a largely a-m video signal? Highly unlikely, since the fm video system presented in Chapter 15 works so efficiently. If I had a Panadaptor (old-time word for spectrum analyzer), I would look at it and see.
8. Does the transmitted Gunnplexer video signal have a large a-m component as well as fm? No, it does not. The a-m components beyond a few hundred hertz from the carrier are supposed to be greater than 100 dB down.
9. How do six different standard TV receiver i-f amplifiers, with supposedly flat (plus or minus 1 dB) passbands, manage to slope detect the fm video signal and produce picture quality equal to or better than studio quality a-m video? We obviously know how the 4.5-MHz audio subcarrier is detected, as it is supposed to be fm. Answer—I do not have the slightest idea of the mechanism that accomplishes this miraculous conversion, unless the supposedly flat 4.5-MHz i-f passband of all six TV receivers tested is *not* so flat after all. When Volume I of the Gunnplexer Cookbook is finished, I will certainly find out and include the answer in Volume II.

Rationalization

What does all this mean? It means that an inexpensive Gunnplexer transmitter, modulated with a composite baseband (video and audio) signal, or a separate fm audio subcarrier plus video, can transmit a complete TV channel for 2 to 5.5 miles (3.2

to 8.8 km) to the receiving end of the circuit where a Gunnplexer receiver, broadband low-noise i-f preamplifier, and *only* a standard TV receiver is required. Both ends of the circuit would, of course, use parabolic reflector antennas.

The receiving Gunnplexer could be fix-tuned at 10.000 GHz. With a proportional temperature control system, it will stay on frequency year-round. Only the TV receiver channel selector is tuned to the desired i-f. Each transmitting Gunnplexer frequency will equal 10.000 GHz plus standard channel video frequency:

Channel 2 = 10.000 GHz + 51.25 MHz = 10.051 GHz
Channel 4 = 10.000 GHz + 67.25 MHz = 10.067 GHz
Channel 6 = 10.000 GHz + 83.25 MHz = 10.083 GHz
Channel 7 = 10.000 GHz + 175.25 MHz = 10.175 GHz
Channel 9 = 10.000 GHz + 187.25 MHz = 10.187 GHz
Channel 11 = 10.000 GHz + 199.25 MHz = 10.199 GHz
Channel 13 = 10.000 GHz + 211.25 MHz = 10.211 GHz.

I certainly am not suggesting or recommending that the 10-GHz Amateur band be used for commercial TV relay service. The frequencies shown are only examples. If the public demands low-cost Gunnplexer TV relay service, be assured that the FCC will find the frequencies necessary to accommodate them.

Note that in the previous frequency plan only every other channel is used. This is not necessary, but provides a guard channel when transmitted video deviation is set at 9.0 MHz which, at this early development stage, appears to be optimum.

Initial "Richardson Effect" Gunnplexer Video/Audio Tests

With the advent of our discovery, I have modestly named it the "Richardson effect." Note in *fig. 16-1* that each assembly consists only of a Gunnplexer, no i-f preamplifier, and only a system control module (the SCM on the left incorporated the 4.5-MHz fm audio subcarrier in the same box). The system on the right was used as the receiver and fed the Gunnplexer mixer output directly to two 19-inch (48 cm) Sanyo TV receivers with both video and audio output.

Maximum range of the Richardson-effect transmitter and receiver video/audio system without 25-inch (63.5-cm) diameter reflectors and without a wideband low noise i-f preamplifier on the receiver is approximately ¼ mile (0.4 km).

During May 1979, two Gunnplexer transmitters were set up in front of my ham shack on the following frequencies:

Number 1 Gunnplexer = 10.250 GHz + channel 2 = 10.305 GHz

Number 2 Gunnplexer = 10.250 GHz + channel 4 = 10.317 GHz

Gunnplexer Number 1 was driven by a TV camera with microphone audio subcarrier. Gunnplexer Number 2 was driven by TRS-80 video with Morse code subcarrier. Both Gunnplexer transmitters used 25-inch (63.5-cm) diameter Snowsled parabolic reflector antennas.

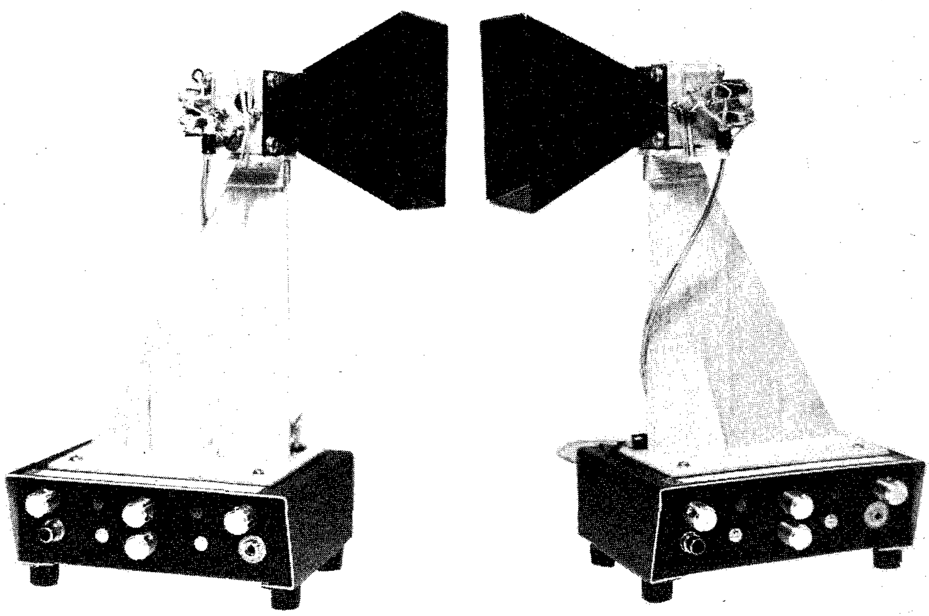


Figure 16-1.

First "Richardson Effect" Gunnplexer video/audio system demonstrated initially at the Dayton Hamvention 4/27/79

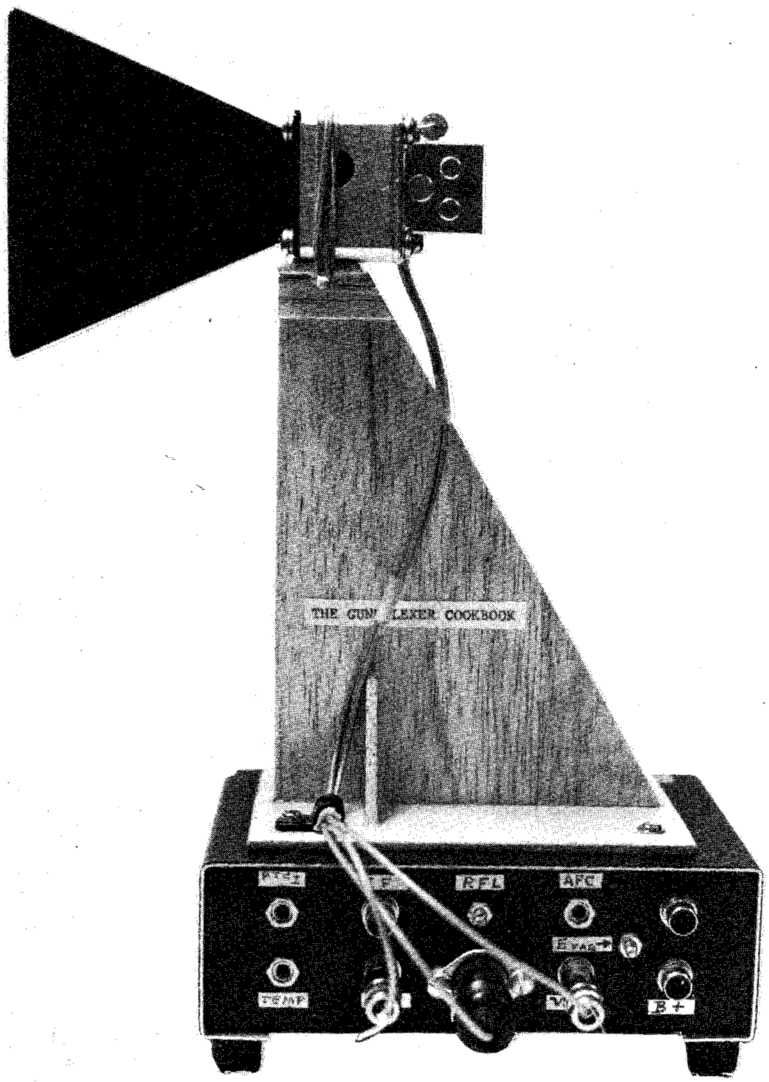


Figure 16-2.
Oblique view "Richardson Effect" video Gunnplexer transmitter

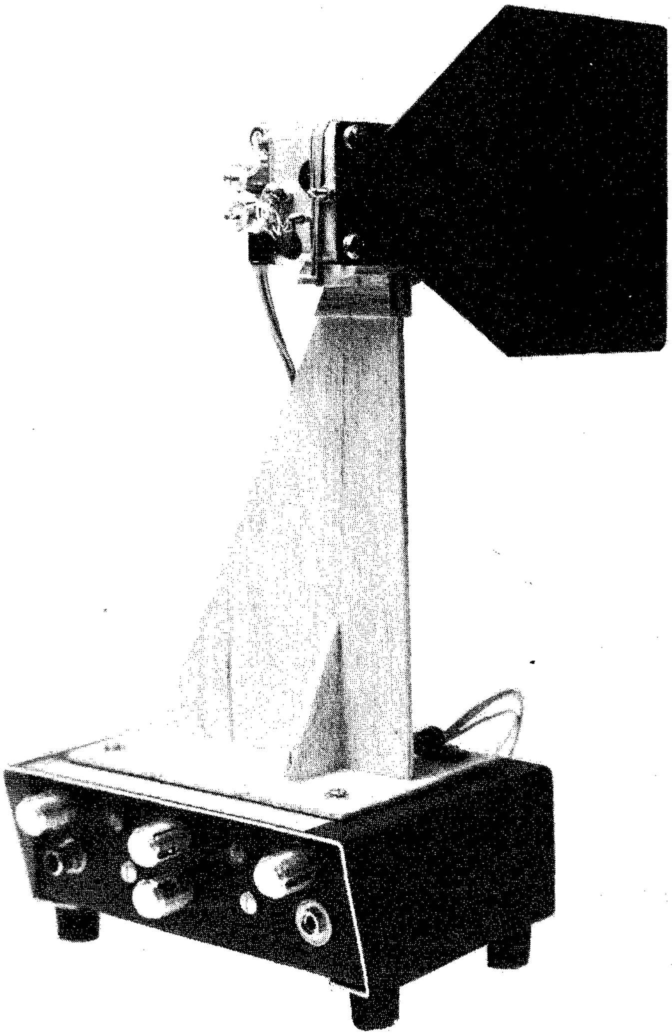


Figure 16-3.
Rear view "Richardson Effect" video Gunnplexer transmitter

The receiving site was located 2 miles (3.2 km) across Chautauqua Lake. A Gunnplexer receiver operated on 10.250 GHz with a 25-inch (63.5-cm) diameter Snowsled antenna. A Winegard model AC-9130 24-dB-gain wideband TV preamp was used as the Gunnplexer i-f preamp, which fed a Sanyo model 91T49 19 inch (48 cm) TV receiver directly through a balun.

The highly predictable results of this test were

1. Video quality was excellent on both channels.
2. Audio quality was excellent on both channels.

What Does All This Portend?

A best estimate at this discovery stage is that the Richardson effect fm/fm Gunnplexer television distribution system may have considerable impact on the cable TV industry. By impact, I mean a positive effect in that areas where cable TV is not economically feasible may now be served by existing and/or new cable/microwave TV distribution firms due to the tremendously reduced startup capital investment.

There are two obvious applications of the Richardson effect fm/fm low-cost Gunnplexer television distribution system:

1. Point-to-point relay of up to 20-plus TV channels (number of channels is limited only by frequency band being used), with local cable distribution in small communities.
2. Point-to-home, hotel, or apartment-building relay of up to seven channels of television programming (ABC, NBC, CBS, PBS, independent, Showtime, and Home Box Office), in which each home, hotel, or apartment building need only have a single roof-top-mounted Gunnplexer receiver.

Amateur Applications of the Richardson Effect System

What can be done in the Amateur radio area with a $100 Gunnplexer, a $6 to $7 Snowsled antenna, a low-cost TV preamp, and a standard TV receiver that can receive up to seven channels of video and audio? Picture (no pun intended) the local college campus Amateur radio station adding a video/audio channel without the high cost of cable. A few Gunnplexers on the roof and the campus is covered. Is this truly Amateur or commercial? If a licensed Amateur operates the station, he need only have a FCC Technician-Class license. It might be considered Amateur by the powers that be. Picture also an Amateur radio computer club meeting with all members on 10-GHz video/audio working through the club station's omnidirectional 10-GHz repeater. It would be a real free for all but interesting to watch.

Figs. 16-4 and *16-5* illustrate the absurd simplicity of the Richardson effect fm/fm television system using a standard a-m television receiver. Our tests and results were verified and duplicated by James Keeth, AF9A in Indianapolis, Indiana during the winter of 1979/80, ... and in color too. Jim's January, 1980 letter follows:

"Dear Bob:

I tried the Richardson effect system using an fm modulator module from an RCA broadcast video tape machine and heterodyned the signal to the color TV i-f. You are right. It works very well and the color is good also. The color TV i-f makes a very good slope detector for fm signals of about 2-MHz bandwidth. The i-f bandpass is the typical haystack shape to achieve linear phase response. The slopes on each side are quite linear, and either side will work equally well, depending on the direction of the fm modulation. If you are one the *wrong* side, the video will be negative.

Thanks for discovering the Richardson effect. It will sure make it easier to build microwave TV links. 73,

Jim Keeth, AF9A
Indianapolis, Indiana 46260

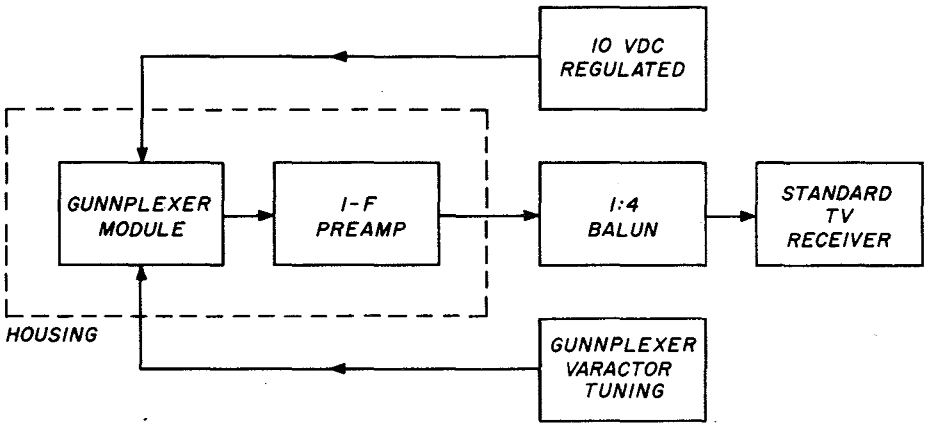


Figure 16-4. Block Diagram FM/FM TV Receiver System

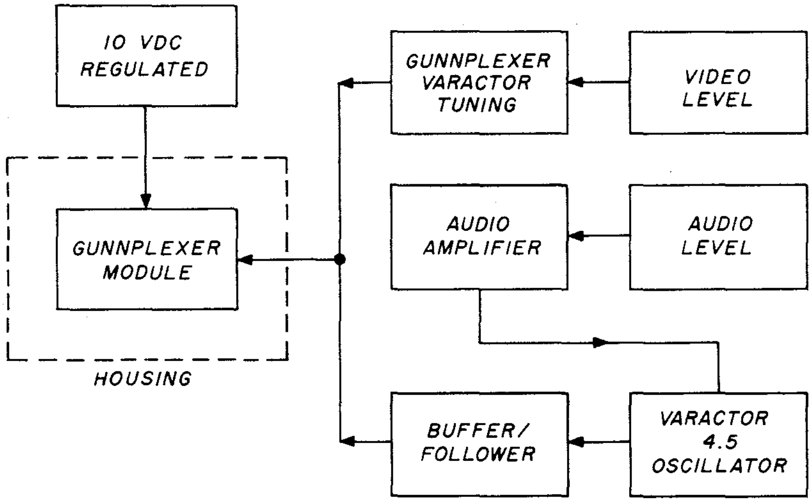


Figure 16-5. Block Diagram FM/FM TV Transmitter System

10-GHz TV Plan for 7 Channels

The following table illustrates a possible frequency plan for Richardson effect 10-GHz Gunnplexer fm/fm television that gives seven channels and would not interfere with any known existing Amateur services.

transmit gpx (GHz)	receive gpx (GHz)	i-f output (MHz)	tv channel No.
10.180	10.235	55	2
10.168	10.235	67	4
10.152	10.235	83	6
10.060	10.235	175	7
10.048	10.235	187	9
10.036	10.235	199	11
10.024	10.235	211	13

Only the TV receiver channel selector is tuned for the desired signal. Plus, we have an extra 6-MHz guard band between each channel to eliminate any spill over interference if any of the transmit Gunnplexers are unintentionally mistuned. The system will work without the 6-MHz guard bands, but requires proportional temperature control and accurate transmit Gunnplexer tuning to avoid interference.

The frequency of 10.235 GHz for the receiving Gunnplexers was selected for two reasons.

1. It is 15 MHz below the standard Amateur calling frequency of 10.250 GHz on this band and should be well out of anyone's way.
2. If Amateur Gunnplexer TV relay systems proliferate, 10.235 GHz offers a convenient marker/beacon frequency almost dead center in the Amateur band.

The unmodulated 10-milliwatt signals would serve admirably well for checking propogation conditions if one were fortunate enough to be in their path. Also, these signals with their limited 5-degree beamwidth (if a 25-inch (63.5-cm) Snosled dish is used) should cause no interference whatsoever to any other users of the 10 GHz spectrum. Actually, no one will even know they are there, as our 10-GHz Amateur band is shared with radar pulse systems in the multi-kilowatt peak-pulse-power range.

Conclusion

It is truly impossible to try and foretell what Amateur applications of the Richardson effect fm/fm 10-GHz television system will come to pass and especially when. The first 10-GHz Amateur TV data link using this concept may very well be put into service by Keith Ballinger and a dedicated group of Canadian microwave amateurs in the Ottawa/Montreal area. They have pioneered PACKET communications and certainly have the ability to install a 10-GHz video/audio television/computer data link using the Richardson effect concept anytime they choose to do so. Let's hope that someday is indeed tomorrow, no matter where the system is installed.

Except for the Richardson-effect system, I completed all development work in this book during 1977/78 and it was written in early 1979. Good luck and good DX.

Robert M. Richardson, W4UCH/2, February 1981
Chautauqua Lake, New York

ADDENDUM:

For those who wish to dig deeper into the companion "art" of microcomputing (Gunnplexers and microcomputers shared near parallel time frame development periods), the Editor recommends Robert M. Richardson's 3 new books/tutorials that present a NEW approach to assembly language programming for the TRS-80 (tm) microcomputer. This NEW approach will save the average computer buff 1 to 2 years study in mastering the fascinating subject of assembly language programming.

These books are:

Vol. 1 "Disassembled Handbook for TRS-80"-$ 10 ppd. 67 pages
Vol. 2 "Disassembled Handbook for TRS-80"-$ 15 ppd. 175 pages
Vol. 3 "Disassembled Handbook for TRS-80"-$ 18 ppd. 237 pages

They are available from: Richcraft Engineering Ltd., Drawer 1065, # *1* Wahmeda Industrial Park, Chautauqua, NY 14722.

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