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VHF Converter

—easy to build, yet state of the art

Editor's Note: This state-of-the-art VHF converter design is reprinted from the British publication *Radio and Electronics World.* A complete parts kit is available from RadioKit, Box 411, Greenville NH 03048. The special TOKO coils are available from Ambit International, 200 North Service Road, Brentwood, Essex CM14 4SG, England.

Despite the plethora of ready-made equipment for the 2-meter (144-148 MHz) amateur communication band, most radio enthusiasts like to try to salve their consciences as participants in the once exclusively "practical" art of amateur radio by making at least one or two items of equipment that can justifiably be described as "home grown."

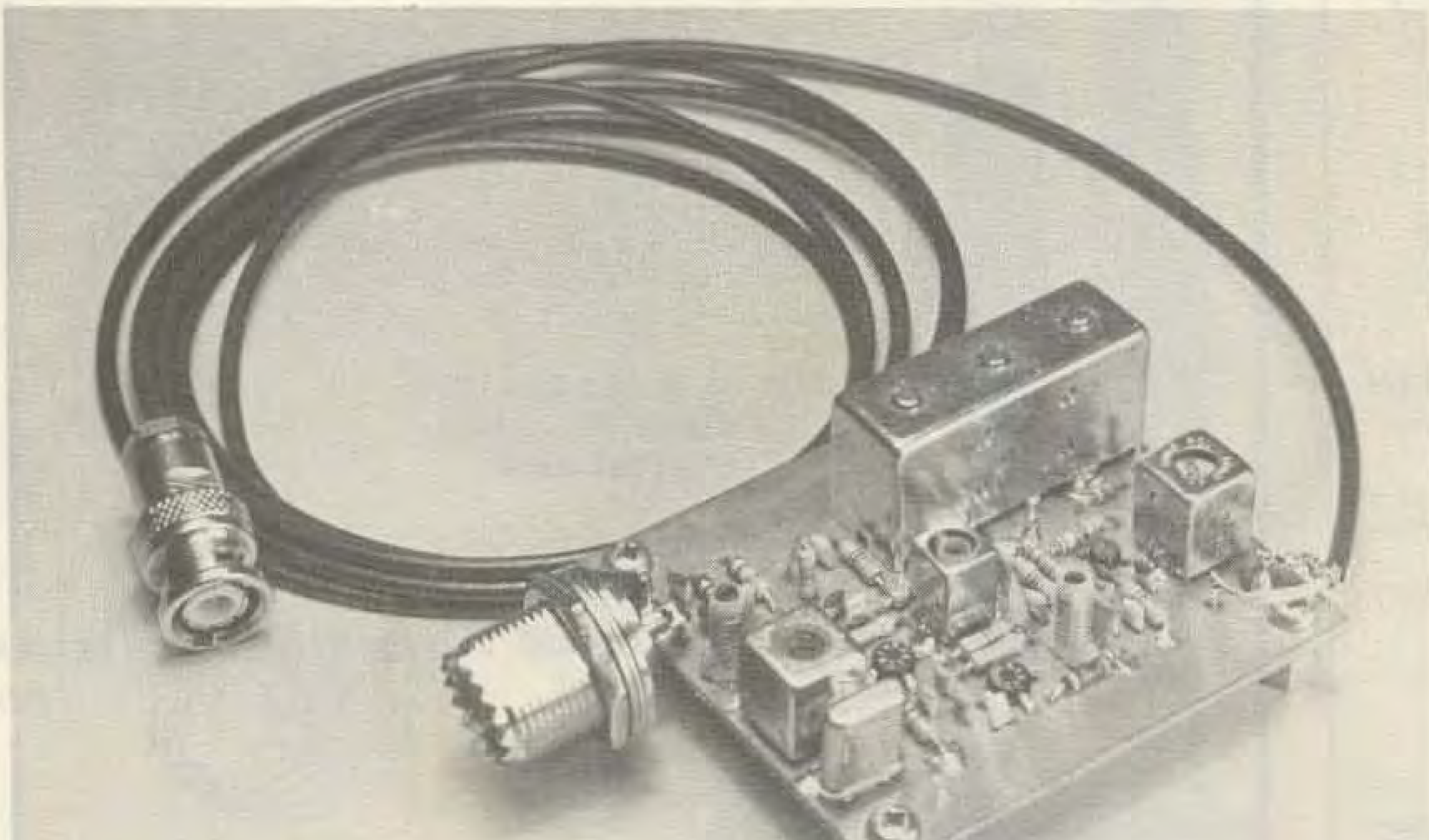

Photo A. The finished unit with cable.

Most of the commercial transceivers for the VHF bands are primarily FM systems for simply "nattering," and some of the hobby's traditionalists might suggest that the use of 2m NBFM bears more than a passing resemblance to the principles behind CB radio—but that's an entirely more contentious subject. . .

The exclusive use of NBFM tends to overlook the more interesting aspects of CW and SSB communications (Morse code and single sideband to the uninitiated). But since most enthusiasts have an HF communications receiver (or two) at their disposal, it is an easy enough task to

Specifications	
Noise figure	less than 2 dB
Gain	28 dB nominal
3-dB bandwidth	144-146 MHz
I-f output	28-30 MHz
1-dB compression	+ 5-dB output
Saturated output	+ 7 dBm
Supply voltage	8-16 V
Supply current	15 mA nominal
In-out impedance	50 Ohms
Size	70 × 60 × 20 mm

Photo B. An exploded view of the 2-pole version of the helical filter.

make a thoroughly professional converter for 144-146 MHz, with an i-f output to be tuned on the 28-30-MHz section of the HF receiver. The radio enthusiast may thus fulfill the repressed constructional instinct, as well as be able to have a serious look at the CW and SSB aspects of the 2-meter band before launching into a few hundred dollars worth of oriental temptation.

The converter is basically a linear device within the expected range of input signal levels, so any mode (AM, FM and SSB) can be converted to the required HF output. Some HF receivers are available with NBFM demodulators, but to do the job properly, the correct bandwidth i-f filter needs to be used with a purpose-made NBFM i-f system. In the absence of this facility, slope detection of NBFM is better than nothing. (Slope detection relies on the i-f filter passband edge to translate the frequency modulation information into an amplitude variation for detection as simple AM.)

Judging by the numbers of "nearly new" SSB transceivers advertised for sale, it is no doubt better to investigate your long-term interest in this aspect of communication without first contributing to the wrong side of the balance of payments. This converter provides reception of repeaters, NBFM simplex, and demanding long-range communications using CW or SSB.

The 2-Meter Converter

This converter was originally designed to complement the RX80 receiver described in the British magazine *Radio Communication*, although it will obviously operate with such receivers as the FRG-7, R1000, DX160, etc. It has been designed with the latest state-of-the-art components, notably the NEC 3SK88 MOSFET which has been chosen for its repeatably low noise figure and low cost. The TOKO CBT series helical filter provides an outstanding bandpass and stopband response, but most significantly of all from the point of view of those of you wishing to duplicate this converter, it is supplied prealigned and requires virtually no trimming to optimize alignment.

Although a VHF converter usually requires considerable expertise and recourse to a selection of signal generators and other analytical equipment, the converter can be built by anyone with kit building experience and a multimeter.

Circuit Description

Fig. 1 shows the complete circuit diagram. C1, C2, and L1 provide the optimum noise match between the 50-Ohm antenna input and the rf amplifier—this is a carefully derived selection of values, and not simply a haphazard choice from the junk box. Gate 2 of Q1 is biased at 5 V (externally derived—i.e., from the main receiver or tuneable i-f—negative-going agc may be applied at this point by those with adequate confidence and experience). The source of the rf amplifier, Q1, is then taken directly to ground to ensure minimum impedance.

The drain of Q1 is taken to the supply through R3, which provides the correct terminating impedance to the helical resonator, L2,

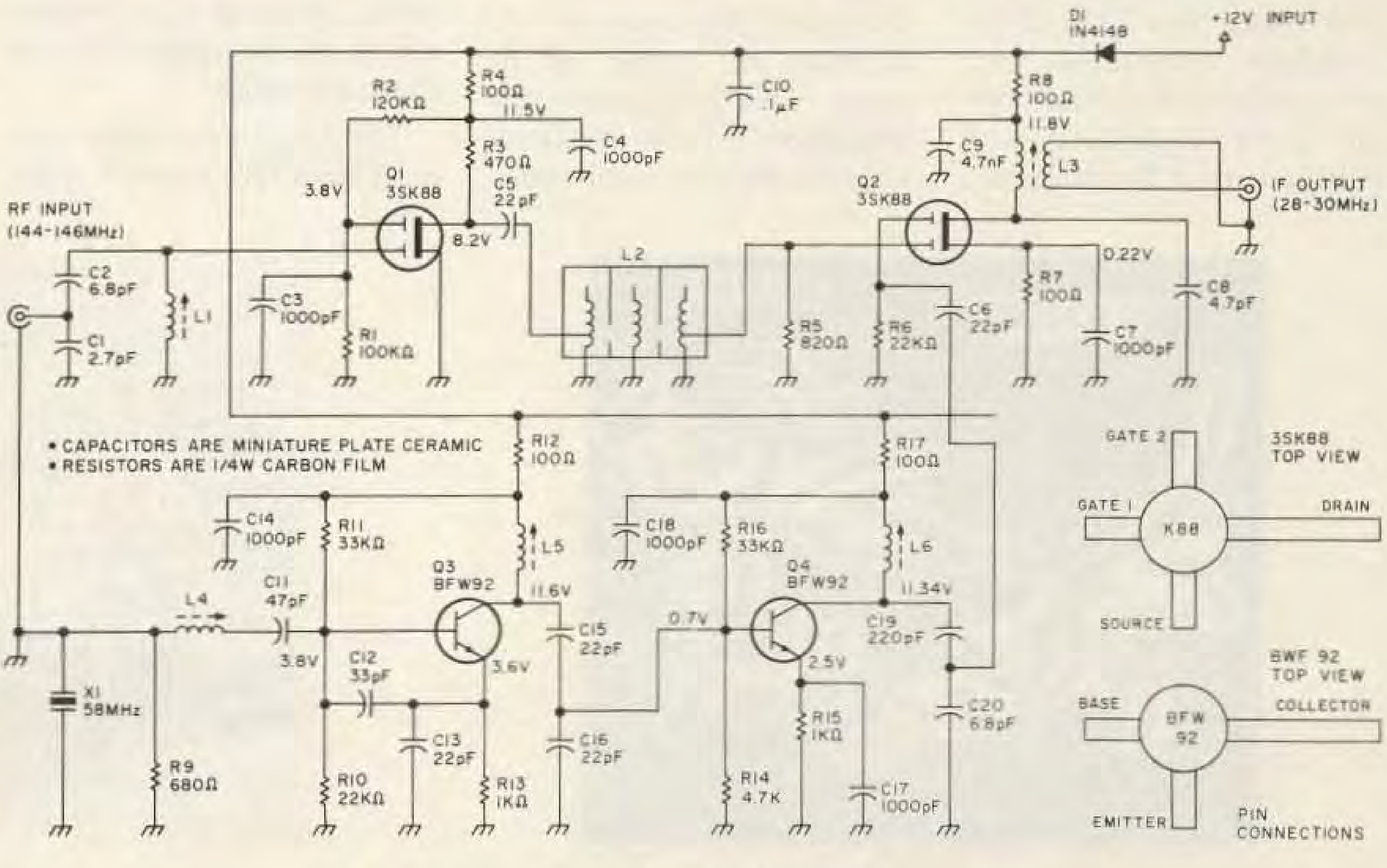

Fig. 1. Circuit diagram.

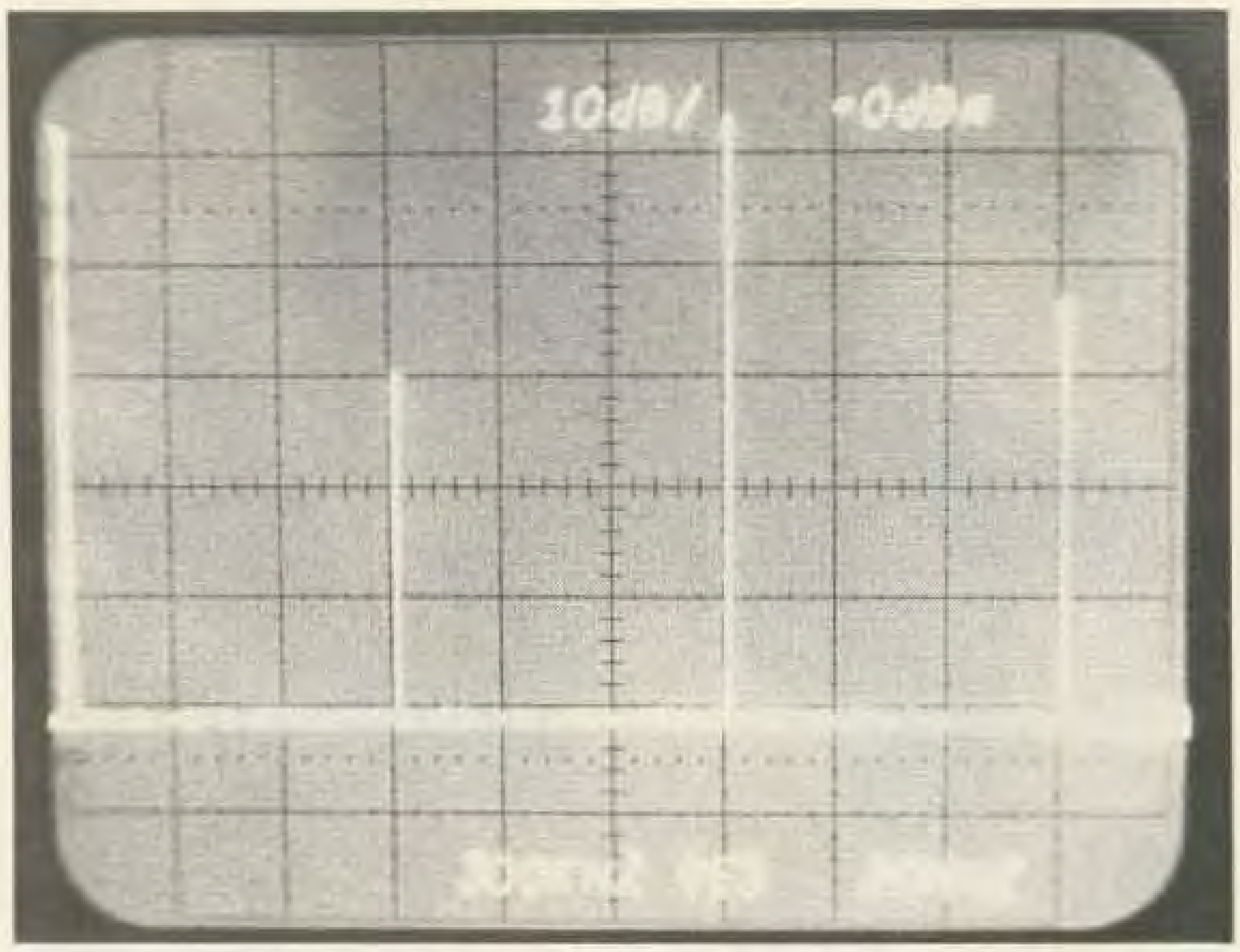

Photo C. The spectrum of the LO multiplier output (10 dB per vertical division, 20 MHz per horizontal division).

which has an input and output impedance of approximately 450 Ohms. The output of L2 is connected straight to the gate of the mixer, Q2, R5 providing the necessary extra load in parallel with gate 1 of Q2 for a correct 450-Ohm matching load.

The appearance in the market of low-cost helical filter blocks (Photo B) will probably change the approach to VHF designs, since yet another circuit variable has now been substituted by a building block that takes out most of the problems for the less-experienced designer and user. More than 75% of the problems associated with VHF radio designs are simply those associated with getting lost in the MHz as a result of the uncertainties of DIY coil designs.

Helical filters will not salvage designs that fall into the all-too-familiar abyss of "dry" joints and a shortage of basic experience in handling components and a soldering iron—but these filters will help allay the fears of the more experienced audio constructor whose neat rf projects have always been relegated to the "pending" tray, since the problems of alignment associated with the green fingers of the rf engineer sometimes seem insurmountable.

Unlike the rf amplifier, the mixer does not use any dc bias on either of its gates. This is because the amplitude of the local oscillator injection voltage is designed to be sufficient to switch Q2 *directly* at 116 MHz, thereby improving the intermodulation performance of the converter. This technique is used in some professional receivers and is similar in concept to the esoteric Schottky diode double balanced mixer—except, of course, that this system is single ended. It is possibly the first time that this approach has been used in an enthusiast's constructional feature. Unless you know better . . .

At the drain of Q2, the wanted mixer product (28-30 MHz) is selected in the tuned circuit formed by L3 and C8 and matched at the secondary to 50 Ohms to feed the main receiver. It is this output network that mainly constitutes the 3-dB bandwidth of the converter. This means that the gain is approximately 25 dB at 144 MHz, 28 dB at 145 MHz, and 25 dB at 146 MHz. This reduction of gain is of no consequence as the design has plenty in hand at all times.

It should be noted that the ultimate sensitivity of any receiving system is defined by its noise figure and *not* its gain. This means that the sensitivity will be the same over at least 144-146 MHz, although the S-meter might read slightly less at the band edges.

The oscillator chain uses a 38.667-MHz crystal rather than the more usual 116-MHz type. Transistor Q3 serves the function of both oscillator and frequency doubler. L4 tunes out the capacitive reactance presented to the third overtone crystal and allows fine adjustment of its operating frequency. L5, C15, and C16 select the third harmonic from the oscillator at 116 MHz and match it into Q4 where it is amplified to an adequate level to switch the mixer, Q2. The capacitive divider, C19 and C20, provide the necessary level and impedance adjustment to feed the oscillator injection of approximately 2 mW to gate 2 of Q2.

On a general point about decoupling, note the way in which tuned circuits are decoupled with capacitance and inductance. Taking the example of L3 (R8/C9), R8 is apparently superfluous.

This presumes that there is zero ac impedance to the rf ground on the positive supply rail which—for reasons of the effects of lead inductance and the unpredictability of stray coupling at VHF—is certainly not always the case. Thus the low-pass filter formed by the RC combination provides a far more positive and reliable method for keeping the rf off the supply line. The danger of creating a positive feedback loop somewhere in the physical (as opposed to the-

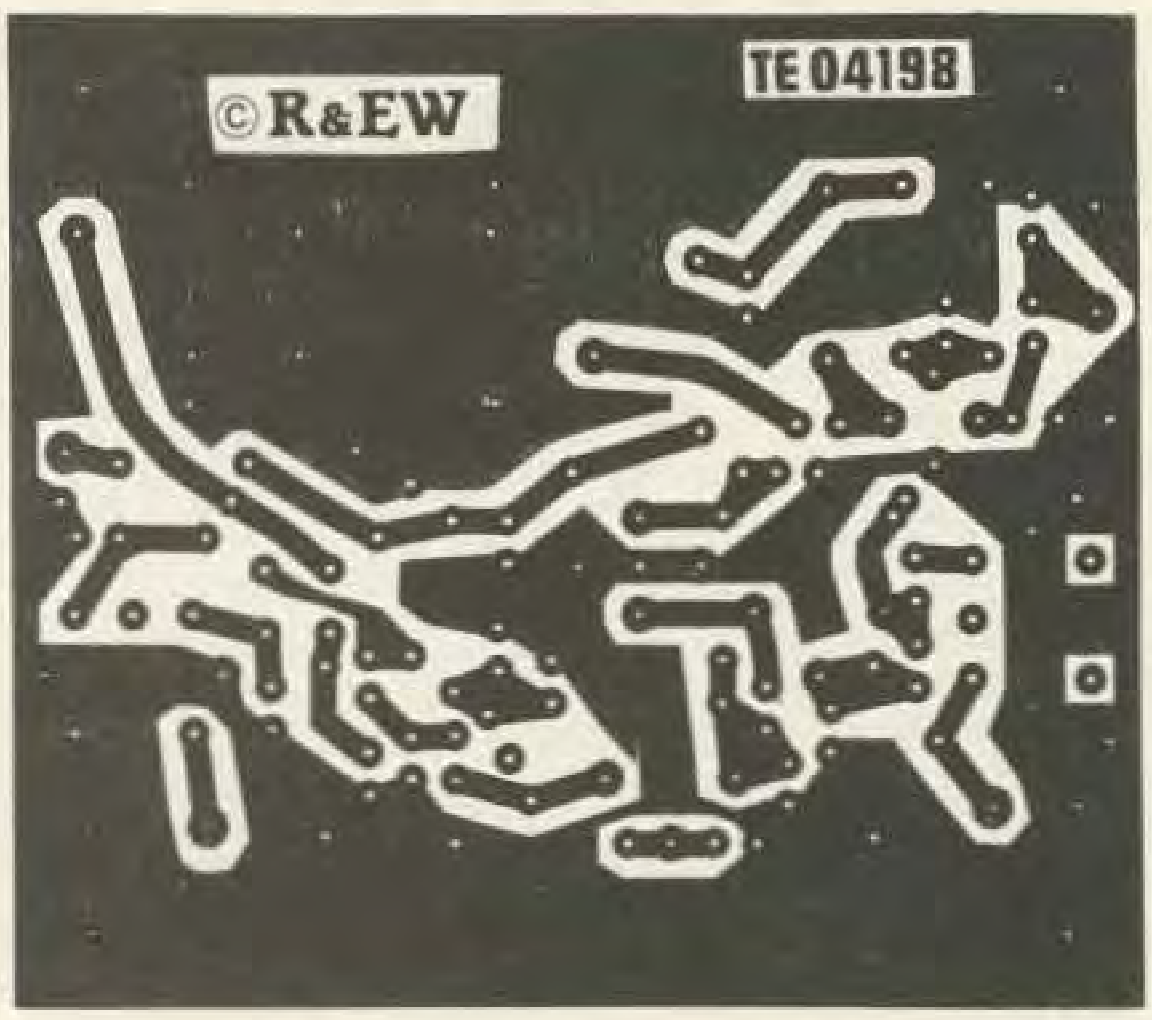

Fig. 2. PC board layout.

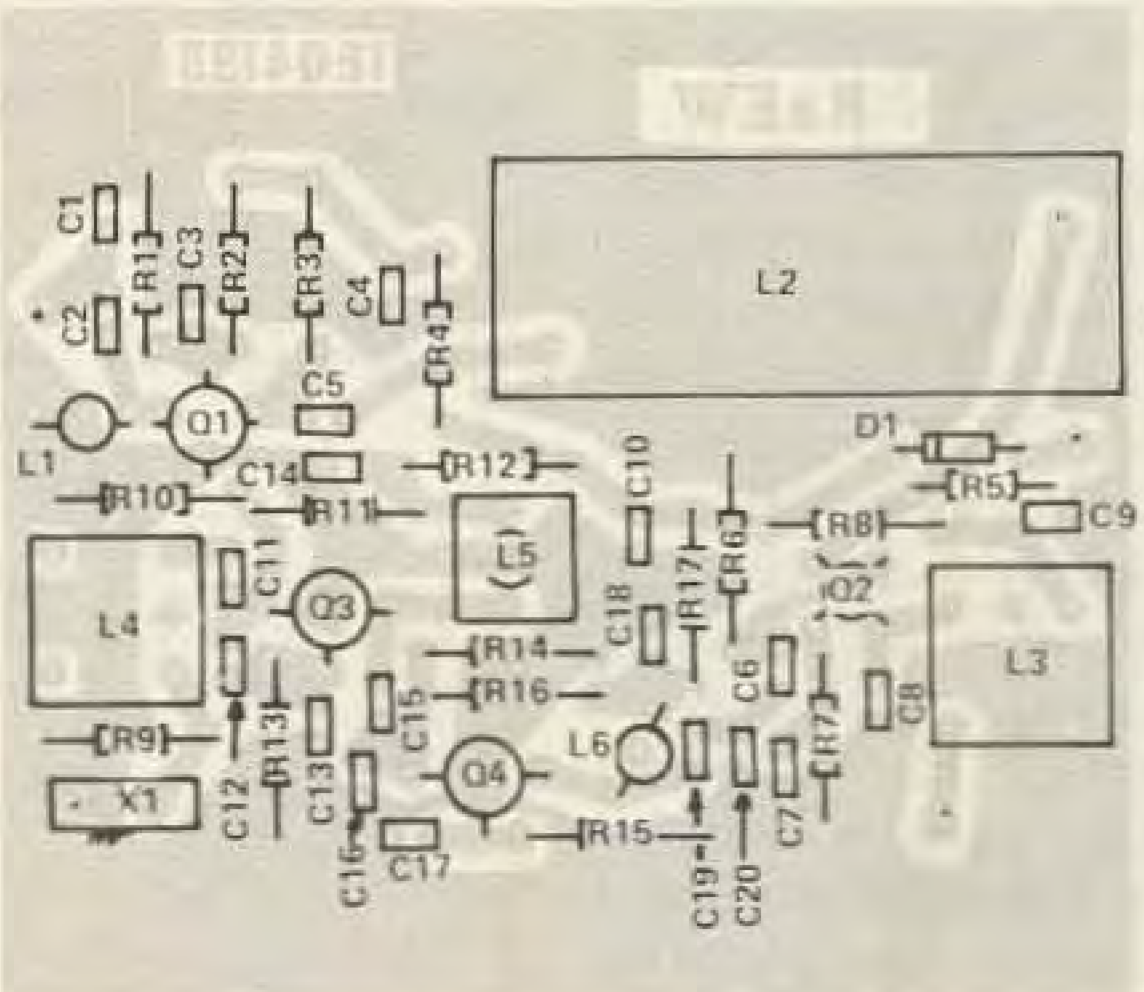

Fig. 3. Parts placement.

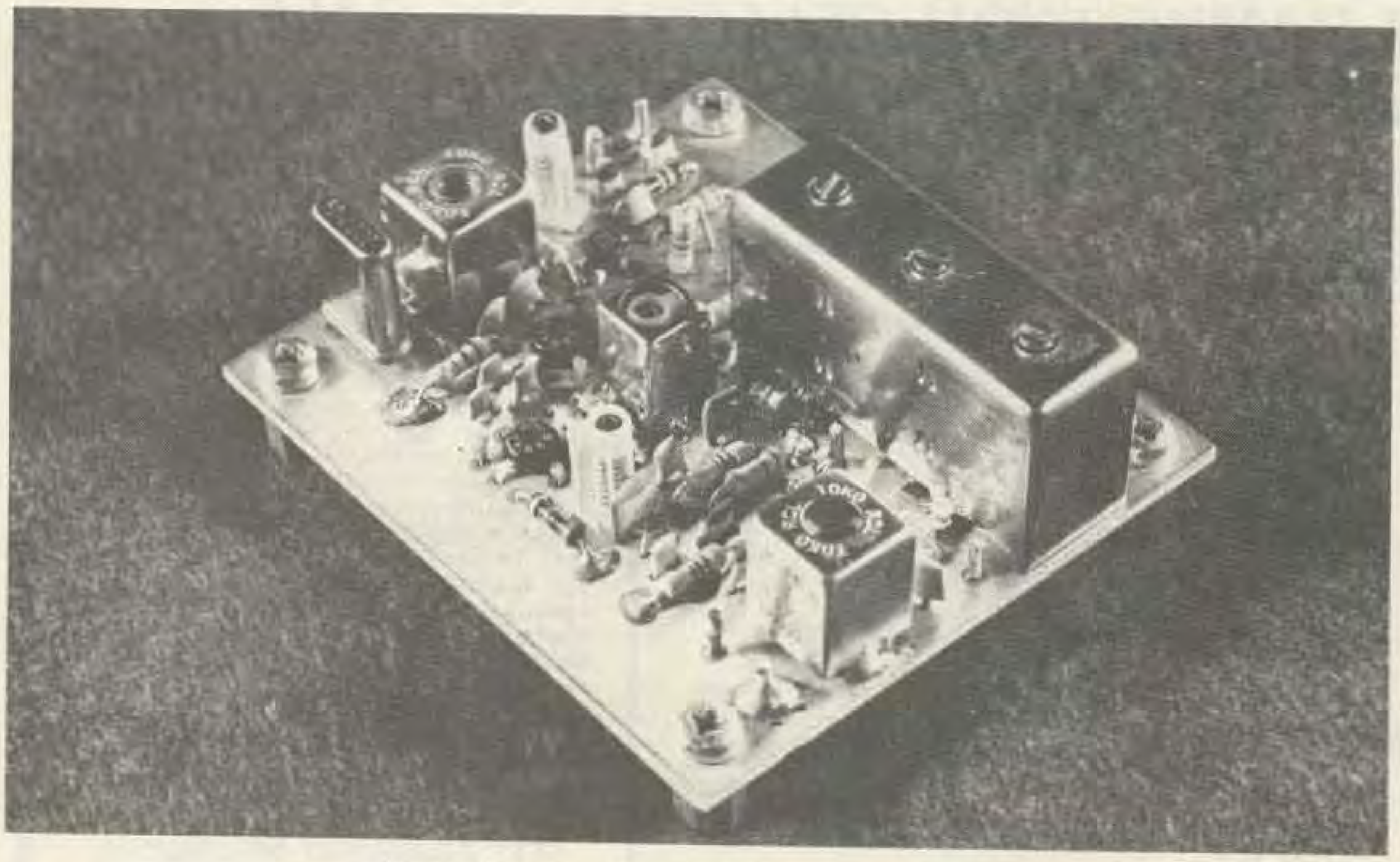

Photo D. The completed converter PCB.

oretical) circuit layout is thereby greatly reduced.

D1 provides reverse polarity protection, which most readers with practical experience will have discovered is essential when connecting things up in a hurry. Strangely enough, this simple and effective precaution is omitted from many designs. Perhaps more components get sold that way.

Construction And Alignment

Using the PCB and components placement guide (Figs. 2 and 3), assemble the converter. Do not forget to solder the earthy legs of R1, R5, R6, R7, R9, R13, R14, and R15—and also the can legs of L2, L3, L4, and L5. There are no critical or easily-damaged components, although due to their size it is advisable to leave the coils and helical filters until last.

After construction is completed, remove any solder splashes, check for dry joints, and remove the flux residue. Connect to a 12-V regulated power supply and check that the current consumption is about 10 mA without the crystal fitted.

Preset coils L1, L5, and L6 so that their cores are flush with the top of their formers. At this stage, do not touch L2, L3, and L4.

Connect a voltmeter between Q3 emitter and ground; the voltage should be approximately 3.2 V. Plug in the crystal, and the voltage should rise to about 3.5 V; slightly adjust L4 for maximum reading. Transfer the meter to Q4 emitter, and adjust L5 for maximum reading—which will be about 3.5 V. If the crystal is removed, the voltage will fall to approximately 0.48 V. Transfer the meter to the source of Q2 and adjust L6 for maximum reading. This will be about 0.15 V to 0.3 V, depending on the IDSS of Q2; there will be less than 0.1 V present with the crystal removed.

Connect a 50-Ohm aerial to the 2-meter input and a suitable receiver to the output via a 50-Ohm coax lead. Don't bother to tuck it all away neatly into a case/box just yet, since there is a reasonable chance that you will need to do some work on the unit to get everything working perfectly.

Tune to a weak signal around 145 MHz (the output will tune to 29 MHz) and adjust L3 for maximum output using the receiver's own S-meter. Adjust L1 for maximum signal-to-noise by ear, and do *not* use the S-meter if optimum results are required. Maximum gain does *not* coincide with minimum noise figure.

Unless you have the necessary equipment to sweep the 2-meter band with a spectrum analyzer and signal generator, do not adjust L2. There is little point anyway, as the helical resonator has been very accurately set up during the course of its manufacture and test, and no improvement could be effected on the samples tested. This is not unexpected, as TOKO offers an unparalleled repeatability in their ranges of high quality rf and i-f coils. Experience has shown them to be suitable for most demanding applications, and, indeed, there are hardly any high-quality receivers that do not use some.

The bandpass characteristic over 144-146 MHz shows a perfect textbook response (Photo C). The helical filters were originally designed for use by manufacturers of Oriental "black boxes." If you take the lid off some Kenwood and Standard equipment, you probably will find one of these devices lurking near the receiver front end.

The remaining adjustment is to put the converter onto the correct frequency, but this is not important unless the receiver itself has an accurate frequency readout. If it has, then tune to a known frequency such as a beacon signal or a repeater and adjust L4 so that output frequency corresponds to the known input signal. For example, a repeater on R6 (145.75 MHz) reads 29.75 MHz on the main receiver display.

This completes the alignment, and it is gratifying to be able to comment that no problems have occurred with stability in any examples tested so far—doubtless due to the carefully designed double-sided printed circuit board.

Conclusions

Once you are confident that all is well, fit the completed PCB into an appropriate container and fit

Parts List

(Capacitors are miniature plate ceramic.)
C1—2.7 pF
C2, C20—6.8 pF
C3, C4, C7, C14, C17, C18—1000 pF
C5, C6, C13, C15, C16—22 pF
C8—4.7 pF
C9—4700 pF
C10—.1µF
C11—47 pF
C12—33 pF
C19—220 pF
(Resistors are ¼ w carbon film.)
R1—100k Ω
R2—120k Ω
R3—470 Ω
R4, R7, R8, R12, R17—100 Ω
R5—820 Ω
R6, R10—22k Ω
R9—680 Ω
R11, R16—33k Ω
R13, R15—1k Ω
R14—4.7k Ω
(All coils are TOKO brand.)
L1, LS, L6—MC108, 7.5 turns
L2—272MT—1006A
L3—154FN6439
L4—KXNK3766
Q1, Q2—3SK88
Q3, Q4—BFW92 or 2N918 (Watch pinout)
X1—38.667 MHz HC18U crystal
D1—1N4148
Misc: 7 mm Coil Can, printed circuit board.

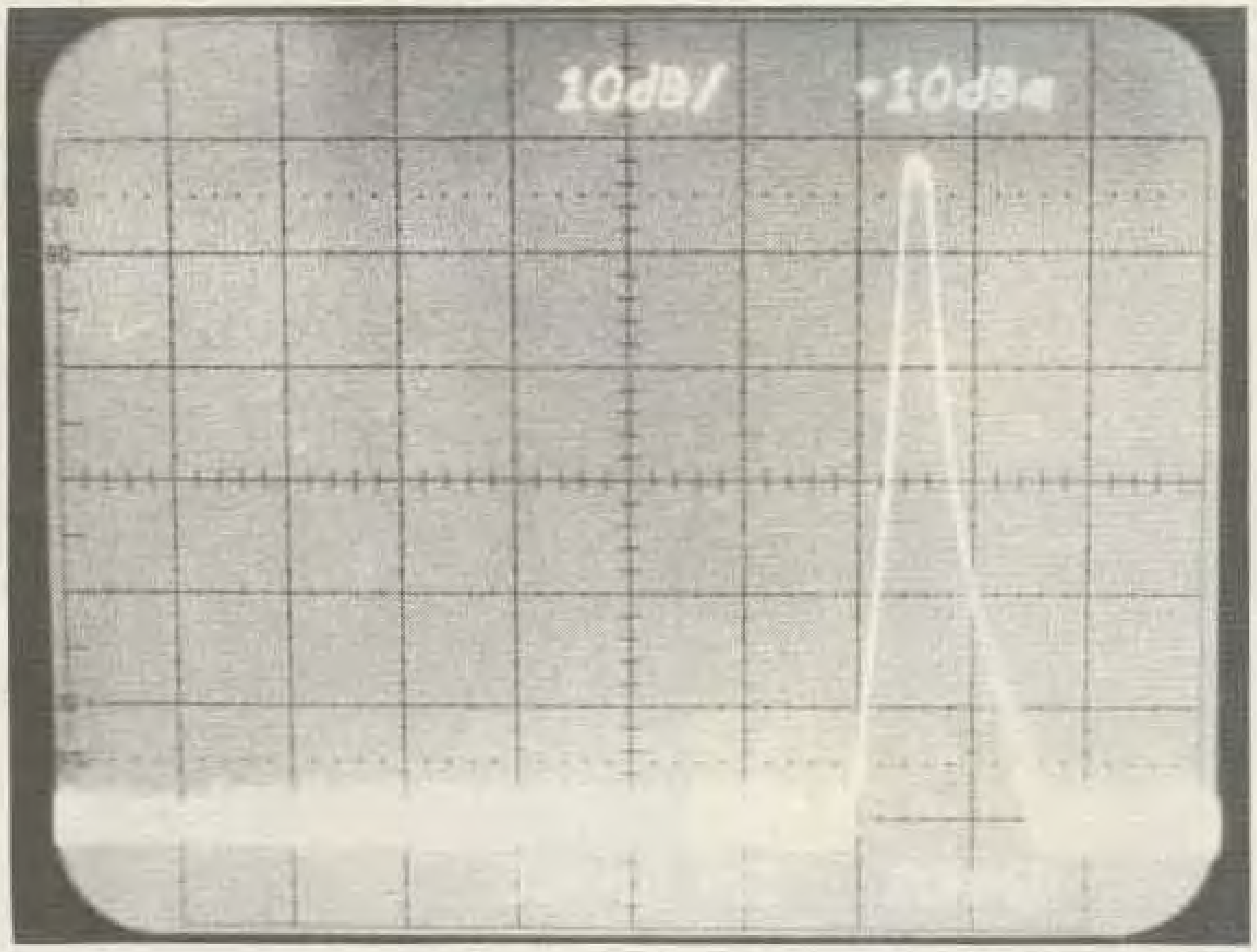

Photo E. Bandpass at mixer input (10 dB per vertical division, 10 MHz per horizontal division).

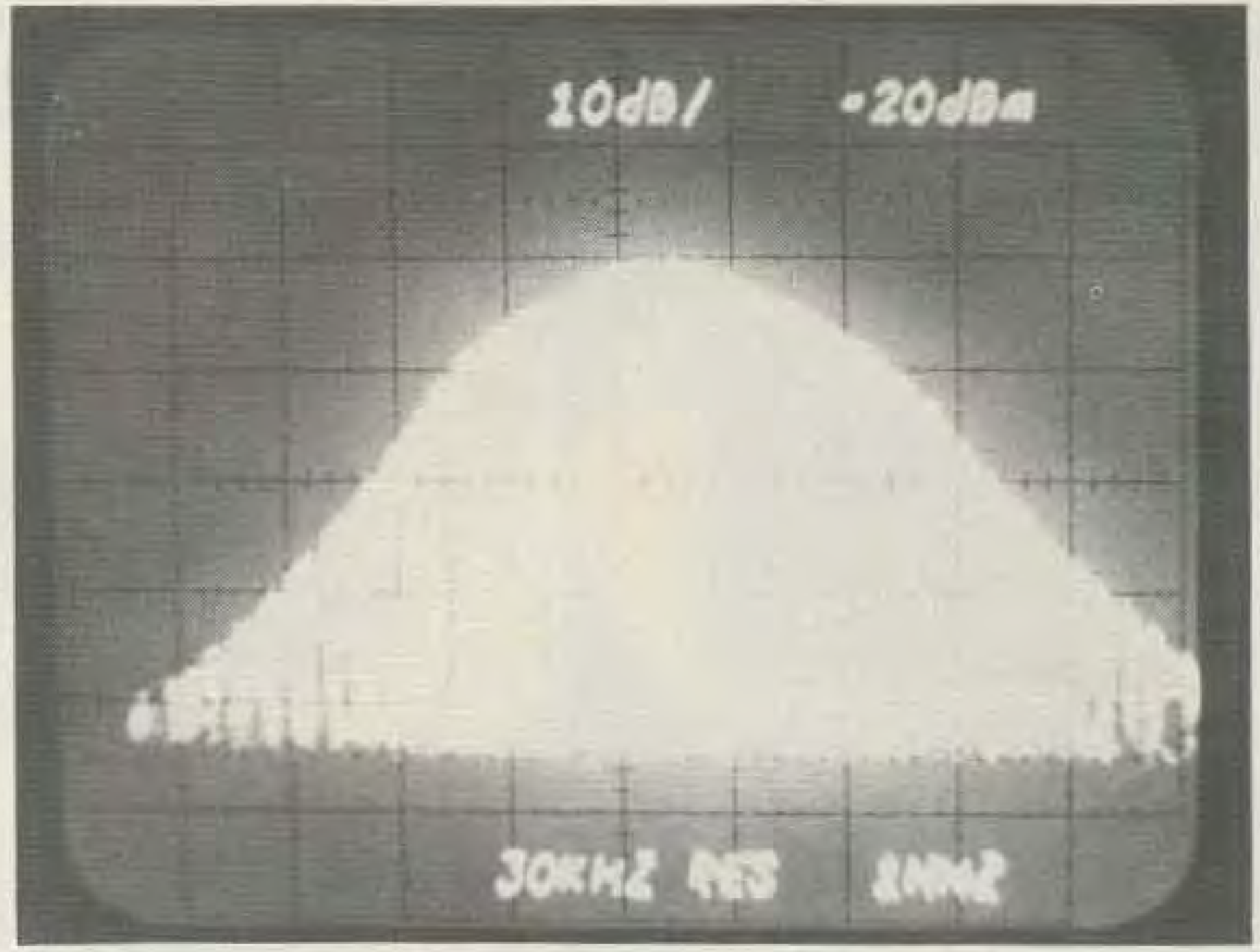

Photo F. The converter bandpass (2 dB per vertical division, 1 MHz per horizontal division).

some form of rf connector such as PL259 or BNC. If you do not already possess a standard of your own, then the BNC system is probably the best choice. Fitting a BNC connector to a cable is not the easiest task for the uninitiated, but it is worth persevering and acquiring the necessary skills, since the BNC system is probably the best general-purpose rf connector available.

The spectrum analyzer photographs were taken using Tektronix and Hewlett Packard test equipment. Because the input and output frequencies are not the same, it was not possible to use the conventional technique of sweeping a tracking generator with the spectrum analyzer. Instead, a Hewlett Packard 8640B signal generator was swept by hand over 130-160 MHz while the spectrum analyzer was tuned to a center frequency of 29 MHz. The resulting display was stored in the analyzer and photographed with a Polaroid camera. The results speak for themselves and, best of all, are entirely repeatable. ■