ABOVE & BEYOND

VHF and Above Operation

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Filters for Amateur Use

Last month I briefly discussed 10 GHz Gunn oscillators and the components used with WBFM systems. This month I would like to get into another subject altogether: different RF filters and coaxial and waveguide systems. I have accumulated questions from readers on this topic for quite a while. These questions vary from problems on very low frequencies (60 kHz) to very high up into the microwave spectrum.

I usually orient each of my columns to some of the topics brought up in letters I receive from our readers. I feel that this is the best way to present material of interest. I appreciate your feedback on these and similar topics. Most specific questions invoke a more general discussion of applications and materials that can benefit our amateur endeavors. Sharing the information has always been paramount to me.

Transmission Paths

Let's start off with a simple premise. "Why don't we move some of our radio-based systems to a closed coaxial or waveguide environment? In that way we would reduce quite a bit of interference and congestion on much of our frequency spectrum." I think this question has been asked in various ways ever since spark ran king. Why don't we use coax or waveguide to contain communications paths instead of using atmospheric-type transmission paths?

Before we get far afield, let me say that we don't use coaxial cable or waveguide for systems covering great distances because the cable losses become too large to pass signals as the distance gets greater and greater. Loss in the atmosphere is great also but nowhere near the loss encountered in coaxial systems. Antennas perform better in transmitting and receiving energy at very great distances.

Filters also entèr into a major aspect of our lives: They help to separate the multitude of signals and help prevent overload in some of the very simple systems. Additionally, filters can be used to prevent out-of-band image product signals from reaching the antenna when mixing low frequency IFs for 144 MHz or 432 MHz. Of course, we want the desired frequency signal to pass and the filter does just that.

The trend for advancement in communications has brought along a corresponding reduction in bandwidth and improvement in signal-to-noise ratios due mainly to filters. There are other advanced wide-based systems employing spread spectrum and frequency hopping; I am not going to get into them here. Before we get on to several different filter types and discuss them, let's see how they help to solve part of the problem.

First, filters to me are the doorways of modern transceivers. By comparison, early receivers were wide open, consisting of only a detector, and would receive everything. It's just like a simple crystal detector or "potato" receiver—you receive everything that is strong in your area (a potato receiver is very similar to a crystal detector). The same analogy for low frequency is true for both our VHF/UHF and microwave bands.

For example, when you take an HT to a favorite overlook or mountaintop, why does your HT seem dead? Is your HT OK or is the band dead? Well, the band is not dead and your HT is OK. What is going on is that the same problem a simple crystal receiver experiences is happening to your HT, but in a slightly different manner. The HT is being desensitized by operating near a high power transmitter. Your HT's front end is shutting down due to the high power RF that is being thrust upon it. The cure for the HT is a low-pass filter that will pass 148 MHz with low loss and provide high loss at 150 MHz and higher. This will minimize the effect on your HT and allow normal operation to be restored, as attenuation is given the higher frequency RF as presented to your first stage amp in the receiver. The same would be true for other UHF frequency bands.

On microwave the problems are the same. Filters can be used to minimize out-of-band influence and aid operation. With basic systems operating wideband FM (WBFM), the addition of filters would not be of much use but would be rather cumbersome to the basic systems. The basic systems provide enjoyment and easy contacts. While they could be modified, I feel that a point is reached where refinements do not give apportioned results for the effort put forth. When you have reached this point, as I did some time ago, the necessary switch to a reduced bandwidth and mode of transmission would yield higher efficiency of operation—for starters, reducing bandwidth improved operation several orders of magnitude. Changing from FM to single sideband with less than 3 kHz bandwidth also made improvements. Filters again play an important part in the series of improvements in circuit performance and operating practices.

Types of Filters

This month I will describe a few new types of filters and discuss some of the methods and materials used to construct them. The first filter is one that was designed by Chip Angle and presented quite a few years ago for 1296 MHz. Basically, it's a copper pipe 3" in diameter and 2-1/2" long. See Figure 1 for details. The filter is constructed with a 7/8" copper section fixed to the top lid of the cavity. Two coupling links are soldered to this 7/8" pipe section, directly to the center pipe section 0.600" up from ground. These coupling links are 180 degrees apart from each other and connected to their respective input/output coaxial connector, type "N" in this case. The bottom of the cavity, also made out of 1/8" brass like the top section, has a tuning screw that will tune the cavity and the 7/8" pipe section to resonance.

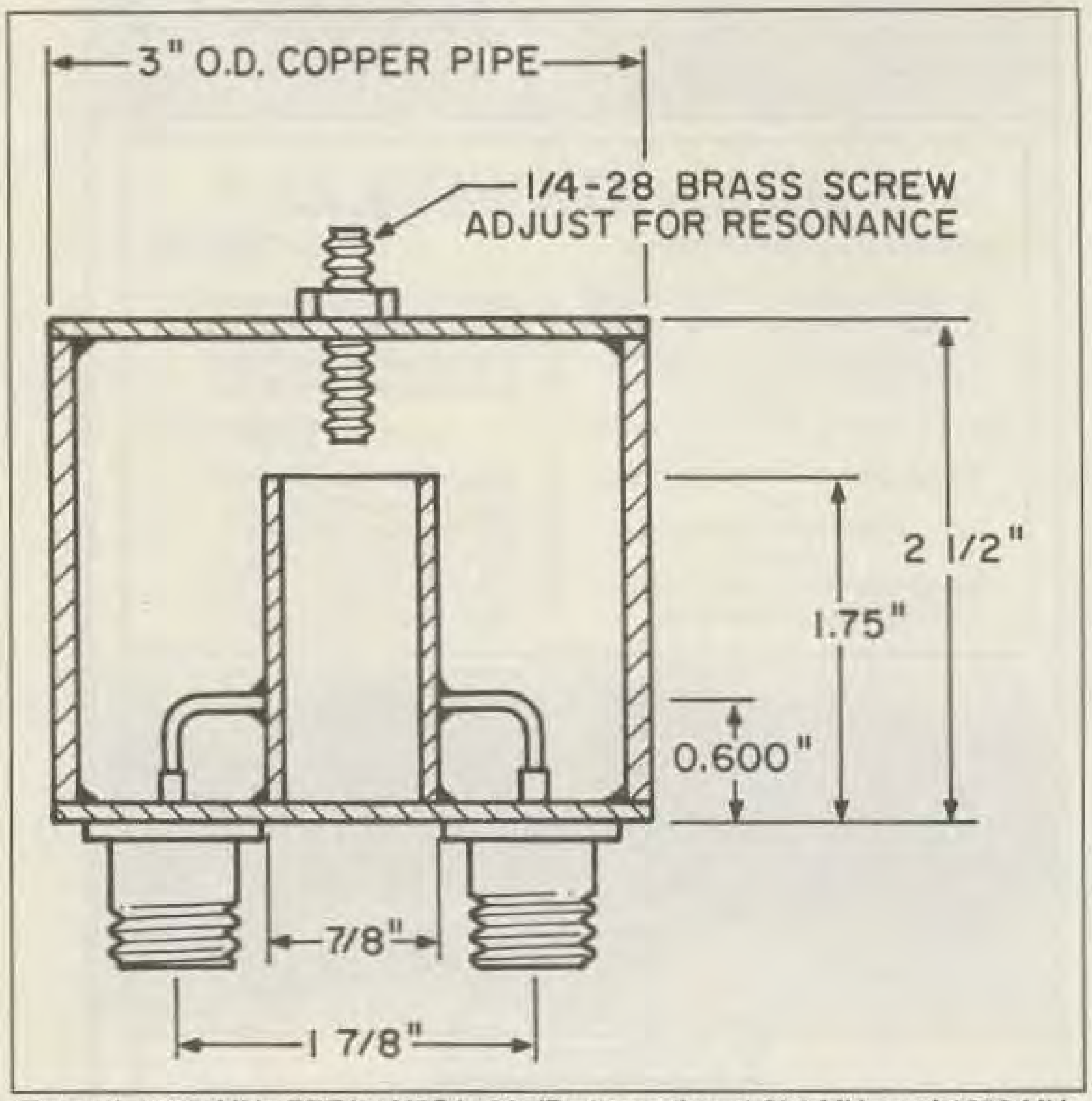

Figure 1. 1296 MHz BPF by N6CA; 30 dB attenuation at 800 MHz and 1800 MHz, insertion loss is 0.05 dB.

The tuning screw is made out of 1/4" rod that is tapped 1/4-28 to thread into the bottom cavity plate. Provide a lock adjust to make the tuning tight but not bound up. Then, when the cavity final adjustment is made, you can lock the adjustment in. Typical specifications are 6 MHz bandpass, 30 dB isolation at 800 and 1800 MHz, insertion loss less than 0.05 dB, and return loss greater than 30 dB.

The construction of this filter is quite simple with hand tools and a little patience. Commercial filters can be obtained for this same range and one that I got came from the Coleman Microwave Co. of Lebanon, New Jersey. It's a tunable cavity adjustable from 1.3 to 1.4 GHz. I have just enough room to make 1296 MHz in its tuning range before the stops take effect. The filter has a window and film calibration setting knob controlled with 1 MHz calibration marks about 1/8" apart, with real easy frequency setting. See Figure 2, the Coleman cavity. These are available in surplus in multitudes of frequency ranges covering several hundred MHz to just about 6 GHz. Usually at the higher microwave frequencies, 12 GHz and up, the cavity designs stop and waveguide-based designs take over.

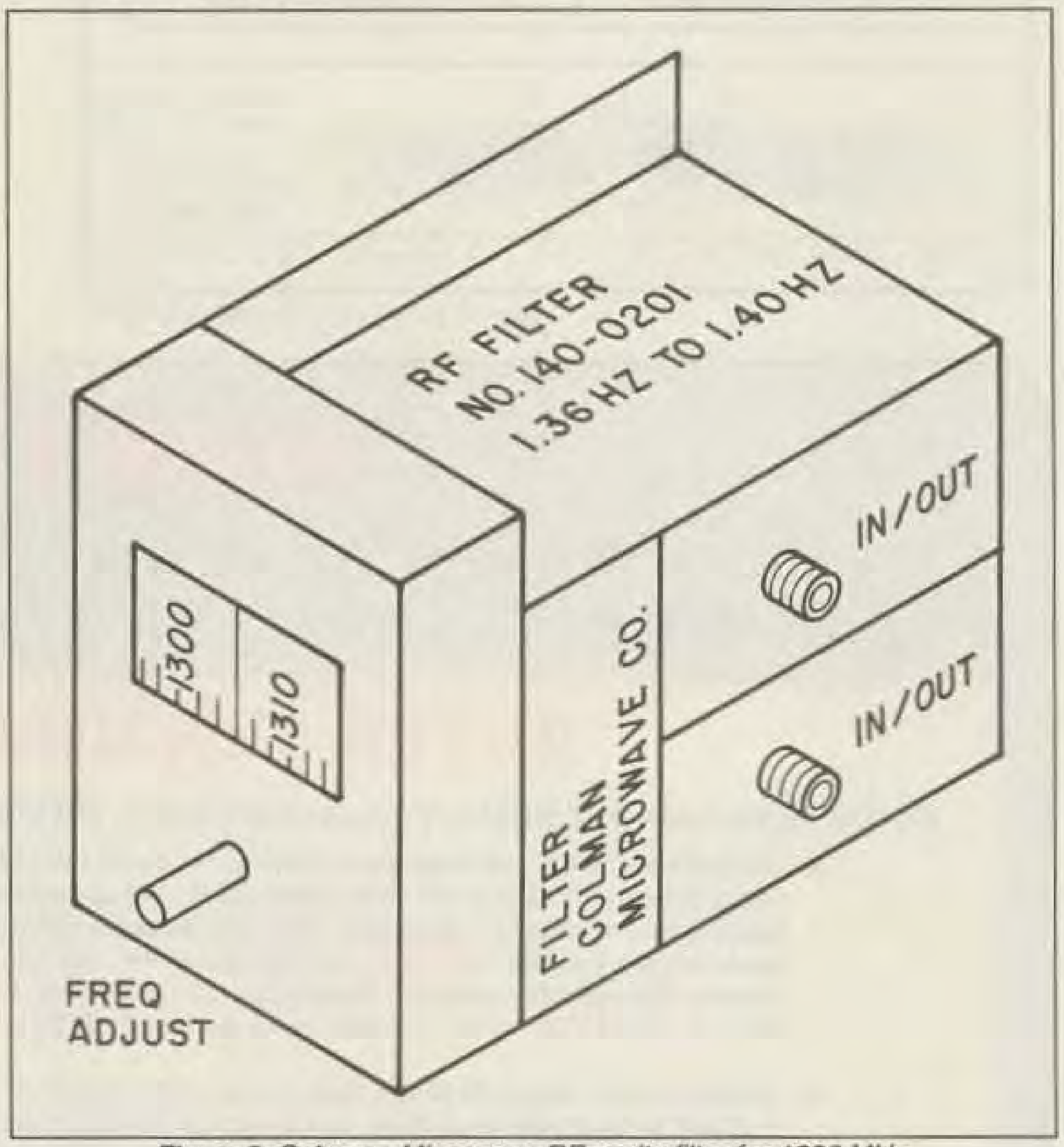

Figure 2. Coleman Microwave RF cavity filter for 1296 MHz.

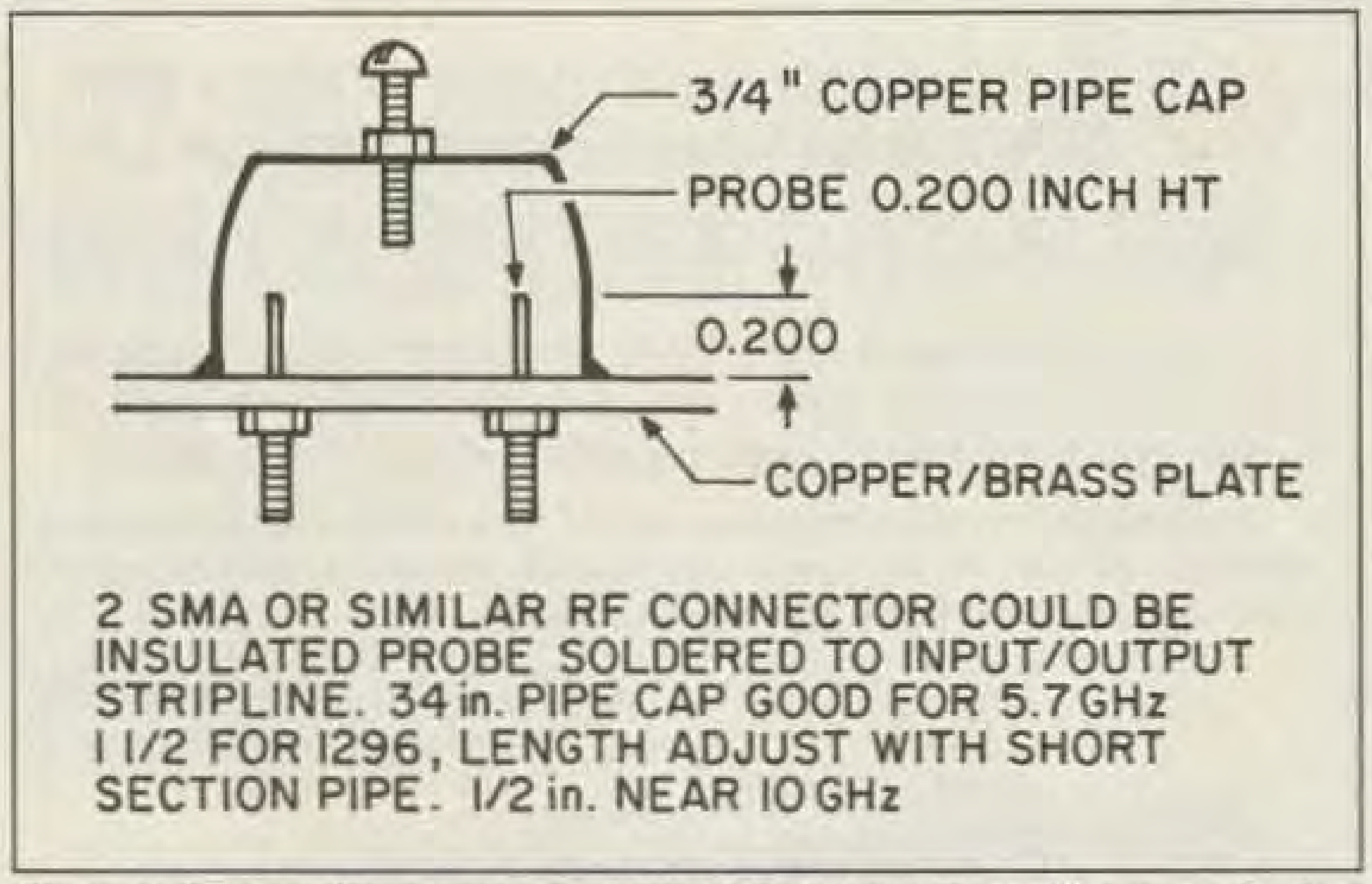

Figure 3. Pipe cap filters courtesy of WA5VJB @ North Texas Microwave Society.

Designs for filters that can be used in frequency ranges from 1296 MHz to 6 GHz can come from unusual materials. Reports of filters from Kent WA5VJB show that pipe caps for copper pipe can be selected to size and inverted and fitted with an adjust screw on the top of the cap. The cap is soldered to a copper or PC board material ground surface to which probes are added on the opposite side of the ground surface for input/output coupling. Filters of this nature have loss that is determined in part by probe length and spacing. These filters tend to exhibit a little excess loss but do work well from 2304 MHz to 6 GHz. This depends on the size of pipe cap: 3/4" for 6 GHz and 1-1/2" for 2304 MHz. See Figure 3 for details.

Waveguide Filters

Waveguide filter designs usually start at 5 GHz and work up in frequency, where they provide very high quality filters. A difficulty with them is that they require tightly controlled construction techniques because the dimensions are quite critical. I have not tried to construct one yet but when I do I will present this information and describe any troubles I encountered.

I have tried to re-adjust waveguide filters obtained from commercial sources to amateur bands. In both the 6 and 10 GHz waveguide filters I did not have very much success with retuning most filters when the designed frequency was over 500 MHz higher than where I wanted to use them. They did not have much frequency range in tuning or retuning. As they tuned downward they seemed to get balky and have high loss when lowering a 11.5 GHz waveguide filter to our 10 GHz band. I also encountered trouble in trying to lower in frequency 6 GHz filters to 5760 MHz. This did not work either. This is not to say it is all impossible, just that the filters I tried would not tune low enough to make them usable. My recommendation on waveguide filters is to stay away from them unless they are cut for your frequency or you make one yourself.

Interdigital Filters

There remain two basic types of filters to be covered: the interdigital filter and a more recent application of it, the hairpin filter. First the interdigital filter. This is the last of the "great block of metal" filters, or filters constructed out of or using substantial metal, forming a cavity. In their construction, fingers (quarter-wave sections) are interleaved and spaced with close coupling to allow the RF to flow through them, by nature of their resonance. A small adjust screw is positioned above the high impedance end of each finger to permit adjustment to the desired frequency. See Figure 4 for typical interdigital filter construction.

The size limits construction of this type filter from 400 MHz, or more typically 1300 MHz, to over 12 GHz in most commercial applications. A filter for 1300 MHz can measure 4" x 8". For 10 GHz, that equates to less than 2" long and 3/4" square for a six-element filter. These filters can be retuned quite far in frequency, namely 10% to 15%. For an 11 or 12 GHz filter it usually can be retuned to 10 GHz without too much difficulty.

The Hairpin Filter

Another type of filter that is becoming very popular is the hairpin filter. This is a printed circuit type of filter where each element of the filter, or hairpin, is a half-wavelength long. The actual length that can be constructed depends on what type of dielectric material it is constructed on, the velocity factor of the material, and what frequency you plan your filter for. Most filters of this type became very popular with the advent of the MMIC amplifier no-tune design for 1296 MHz and a variety of other frequencies. Printed circuit board fabrication of this type of filter demands that accurateness be tightly controlled or else the filter will be resonant off frequency, high or low, depending on the construction techniques. You can use math to a large degree, but be sure to add a little jiggling to make it fit your model, especially to hit a desired frequency without re-adjustment. Gremlins always seem to enter into the math stage and exact operation is not always proper. What I do with a particular PC board substrate is to have my stock "jiggling" or "fudge" factor to multiply by for each material to account for my particular construction techniques. This seems to work out OK. If you try some you will have to develop your own factor as it can vary quite a bit, depending on the board material you use.

A prime consideration when constructing these filters is what type of substrate you construct your filter on. For instance, the dielectric constant of the material has a lot to do with how large your filter will be. Low dielectric material like Teflon™ has a dielectric constant of 2.5 (E_r =2.5), and as such will produce larger filters than ceramic (E_r =10), where the filter's length will be quite a bit smaller. Well then, why did the PC board makers use G-10 epoxy when they designed these kits for their no-tune designs? Well, ceramic and Teflon PC board material is quite expensive and not a common everyday shop stock material. Board cost is quoted by the inch. However, high quality epoxy Fiberglas™ G-10 PC board material has a E_r =5 and is a good cost/performance alternative. (Note: The upper frequency for G-10 epoxy board is 3 GHz, where it gets lossy but is still reasonable.) While the Teflon and ceramic types have excellent RF loss factors and are highly recommended for microwave construction, the G-10 Fiberglas board shows good loss characteristics to 2 GHz. It gets a little bit of high loss near the top end of the frequency, but this problem is offset by the convenience of the easy availability of G-10 type PC board material. Teflon, and especially ceramic materials, are a lot more difficult to obtain. Ceramic materials at this time are out of reach of amateur construction budgets. The high dielectric constant of 10 or so makes circuitry very small when using this type of high dielectric constant (E_r =10 or greater) type ceramic board material.

Teflon dielectric PC board material, by comparison, also has excellent low loss at microwave frequencies—10 GHz and even higher, due to its lower dielectric constant, which can vary from about E_r =2.0 to E_r =2.6. This depends on who manufactured the board and how they constructed it. All Teflon board is excellent for microwave but there are distinct differences between different board materials.

Microwave circuitry constructed on Teflon material tends to be bigger when compared to the ceramic material. In either case, you can vary the material to suit your construction needs. For example, a 10 GHz type amplifier using ceramic can reach sizes of a quarter of an inch square for a push-pull commercial amplifier, while with Teflon the size nears one inch square for a single-stage circuit. The point to make here is that micro positioners and gold bonding equipment are mandated when working with some ceramic materials at 10 GHz, and standard soldering techniques are used with the Teflon board. This makes Teflon quite a bit easier to work with, at least at 10 GHz. Choose your board material carefully.

The converse is true when the frequency is reduced, say, to 1296 MHz. An amplifier constructed on G-10 (E_r = 5) and Teflon (E_r = 2.5) tends to make circuitry large, as we stated before. In this case, with G-10 material at 1296 MHz, a single stage stripline design would be two inches wide and four to five inches long. With ceramic this would be reduced to less than one inch wide and about two inches long. This is quite manageable and standard soldering can be employed. With Teflon PC board material bulk components such as adjustable capacitors and above-board inductors can make Teflon a good choice—it all comes together in one simple statement. Use what you have and make logical choices to maintain PC board circuitry, particularly stripline circuitry, small and workable to your application.

Make use of the engineering program PUFF I described in the May 1992 issue of *73 Magazine*. This program will give you some very good design information not only for amplifiers but for generating filter designs as well. I don't know what I would do without it. PUFF is a very powerful tool in engineering circuitry from stripline techniques.

Well, that's it for this month. If you felt we left out the 2 meter filter for your HT, well, we did, but I'll cover some of those designs next month. I will get into some simple effective ones and some inexpensive types that work quite well. As always, I will answer your questions concerning this and similar topics. Please send an SASE for a prompt reply. 73 Chuck WB6IGP. 73

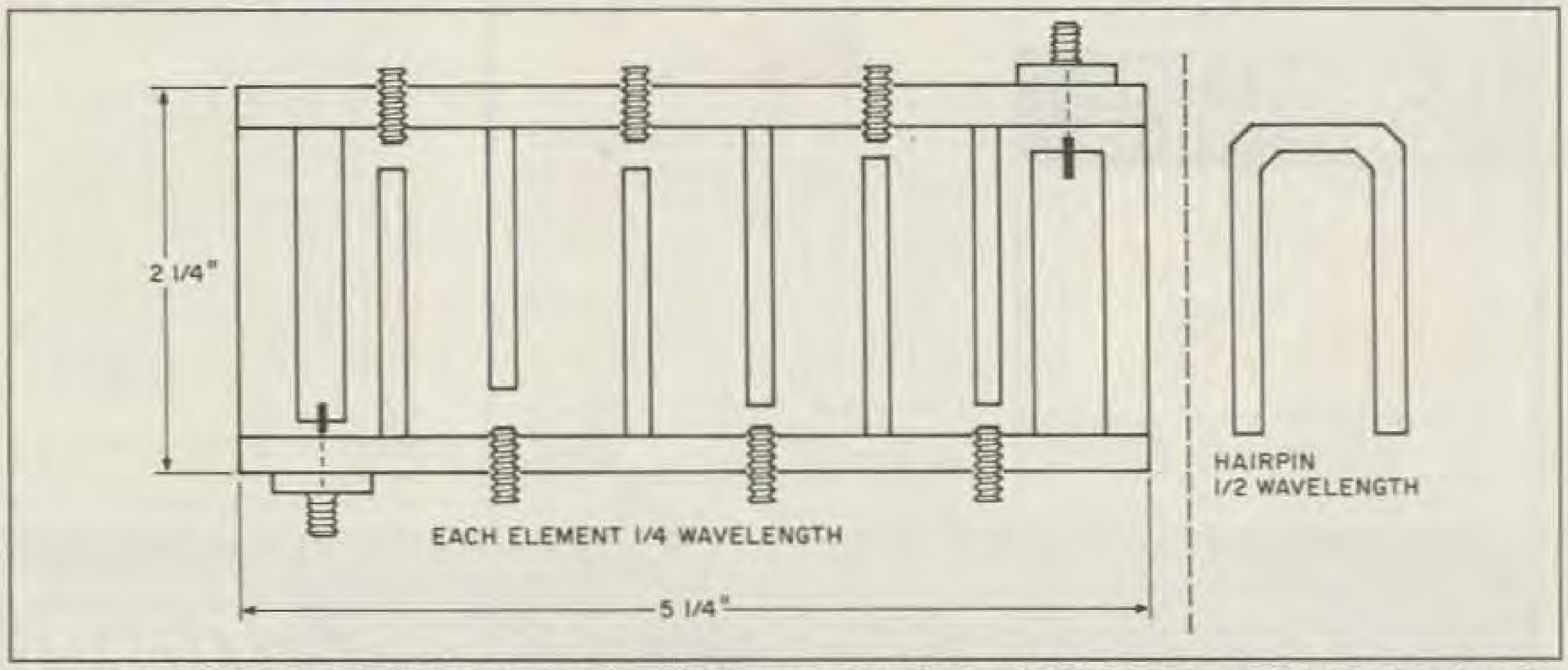

Figure 4. 1540 MHz interdigital filter with six adjustable elements. This filter has 20 MHz bandpass @ 3 dB points. Insertion loss is 0.4 dB. A 1/2 wavelength hairpin shown for comparison.