WGFIL v1-3 Waveguide Band-Pass Filter Program

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Introduction

At the Microwave Update 1989 in Arlington, Texas, I published a paper that described WGFIL. It is a program that will design a wide variety of post and aperture coupled bandpass filters in rectangular waveguide. The program was made available for amateur use. What follows is information on a revised version of WGFIL. Appended to the end of this paper is a slightly edited version of the original Microwave Update paper.

A lot has happened since this paper was published at the Microwave Update in 1989. There has been correspondence from all over the world on WGFIL and the occasional story of an application. One of the more interesting applications was the heating duct sized waveguide filter used in a 1296 MHz ATV repeater. While a bit lossy (~3 dB), a 4 section filter in WR75 waveguide with co-axial input/output that is only 60 MHz wide at 10368 MHz was designed with WGFIL. It was built with the aid of a milling machine and required only minimal tuning. This filter is part of a 10 GHz transverter that uses a 28 MHz IF. While marginal for the 28 MHz IF, it offers outstanding performance for a 144 MHz IF. This filter is described in the example section below along with the author's 10 GHz transverter rig.

In 2009-2010, Paul Wade, W1GHZ, published a series of articles in QEX on microwave filters that included some very useful insight into using WGFIL. These are excellent articles and they should be required reading for anyone serious about building filters. The these articles and the original WGFIL software is available on Paul's website. (http://www.w1ghz.org/10g/QEX_articles.htm) Thanks Paul.

Need for Revised Software

WGFIL was originally published as a DOS executable. The source code was not released. The main reason for this was that there was no support for the software and it was to be used only for amateur applications. Unfortunately, that version will only run now on Windows XP and older Windows operating systems. There are some work arounds but Microsoft took the 16 bit code out of newer versions of Windows. It won't run on the Mac or on Linux either.

In order to address support issues and allow WGFIL to run on newer computers, the source code is now being made available under General Public License (GPL). GPL wasn't available in 1989 or at least the author didn't know about it. While the GPL does not preclude commercial use, it means that you use it at your own risk and the well tested WGFIL engine can't disappear into some proprietary software. The intent is for anyone to be able to use it and it is not intended or supported as a commercial product.

The newest version of WGFIL (WGFIL6_v1-3.pas) is now available. The source code has some commenting to help document the algorithms used. There are also some minor edits so it will compile with the Free Pascal Compiler (FPC) (https://www.freepascal.org/) plus a couple of new features. A copy of the current WGFIL source code is a available on the Blue Ridge Microwave Society group site.: groups.io/g/brms or the group site: groups.io/g/10GHz-Up or you can email the author at wa4lpr@arrl.net.

WGFIL was originally written in Borland's Turbo Pascal (the BASIC GOTO statements have not been missed!) and, although Pascal is not as popular as it once was, the FPC is a modern Pascal complier that is cross platform. You can compile WGFIL for Windows, MAC or Linux. It should even be possible to compile WGFIL for the iPhone or Android! There is a light weight, easy to use integrated development environment (IDE) called Geany (http://www.geany.org/) that makes running and/or editing WGFIL easy. Install the free pascal complier and then install Geany. Open WGFIL6_v1-3.pas in Geany and use Geany's commands to compile and run it. Geany will open a terminal widow and run the program. That's it! You can also use Geany's "build" command to create an executable. There is a much more sophisticated IDE called Lazarus (https://www.lazarus-ide.org/). It is somewhat more difficult to use but it mimics Borland's Delphi and it will create Windows like GUI software.

Windows and Linux executables are also available on the group sites above for those who don't want the bother of compiling the program. WGFIL6_v1-3.exe is a Windows executable. Save it somewhere convenient and then click on it. It should open a terminal window and run. The Linux executable is a bit more involved. The following works in my Ubuntu but other Linux flavors may be different. Most Linux users are aware of the specifics of their distro and you may have to adjust the permissions so your distro will treat it as an executable. The Linux executable is WGFIL6_v1-3. Again, put it in a convenient directory, open a terminal window, navigate to that directory. Typing ./WGFIL6_v1-3 will cause the program to execute in the terminal window. Linux is case sensitive. In both cases, the output is text in a terminal widow with minimal error checking. That works but it is pretty crude. It is hoped that someone might write a nice GUI for WGFIL and give it a new life.

WGFIL New Features

v1-3 adds two new features. WGFIL will now calculate the 3 dB bandwidth for Chebyshev filters. When you specify the bandwidth for a Chebyshev filter, you are specifying the bandwidth between equal ripple points but most folks would like to know the 3 dB bandwidth. WGFIL will also calculate the minimum return loss in the passband for Chebyshev filters. For a passive lossless networks, power is either transmitted through the network or reflected from it. Formally this is:

$$1-|S_{21}|^2=|S_{11}|^2$$

$|S_{11}|^2$ is the ratio of the reflected power to the incident power. It is often referred to as return loss and given in dB units. Since the ripple you specify for a Chebyshev filter is an insertion loss, there will be a corresponding reflection. If you are lucky enough to have access to a network analyzer, return loss is a very sensitive way to tune filters. Caution: in the literature, return loss is often presented as a positive number of dB but it important to remember that it is really a number less than one. If needed, you have to know when to add the negative sign.

v1-3 also restores a bit of functionality lost with later versions of Turbo Pascal and the FPC. You can now type <return> to accept the calculated post diameter or you can enter a new post diameter and then type <return> and WGFIL will correct as described in the original paper. Caution: WGFIL will not correct the passband bandwidth. If you enter an incorrect format, i.e. a non numerical value, WGFIL will return an “input error” message and the current calculated post value will be accepted.

New WGFIL Example

Below is an example filter. This filter was made for a 10 GHz transverter with a 28 MHz IF.

```
Post Coupled Filter     Center: 10399.977 MHz    BW:    44.000 MHz
                        Fractional BW    0.42 %   Guide BW    0.99 %
                        Chebychev response, ripple:   0.10 DB

Post diameter         Cavity length
  0.0932"
                      0.9238"
  0.2211                                  Caution:   D/a > 0.25
                      1.0158"
  0.2302                                  Caution:   D/a > 0.25
                      1.0158"
  0.2211                                  Caution:   D/a > 0.25
                      0.9238"
  0.0932

Do you wish another design (y/n)?
```

Figure A1 WGFIL run for the 10 GHz 4 section filter in Figure A1. The 3 dB BW and return loss feature is not implemented here. See below.

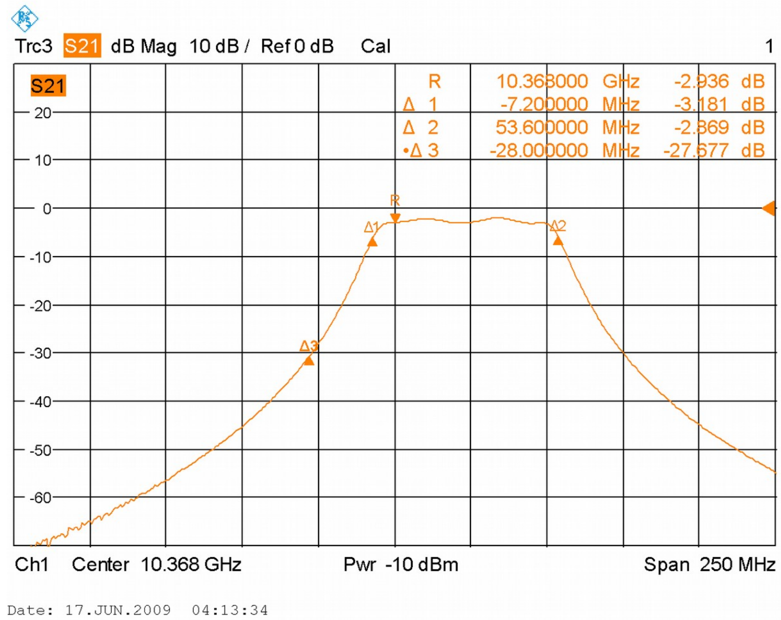

Figure A2: 10 GHz 4 section WR75 waveguide filter made with WGFIL The input/outputs are SMA co-ax to waveguide transitions. The 3 dB bandwidth is ~60 MHz. The 0.1 dB ripple BW was specified as 44 MHz.

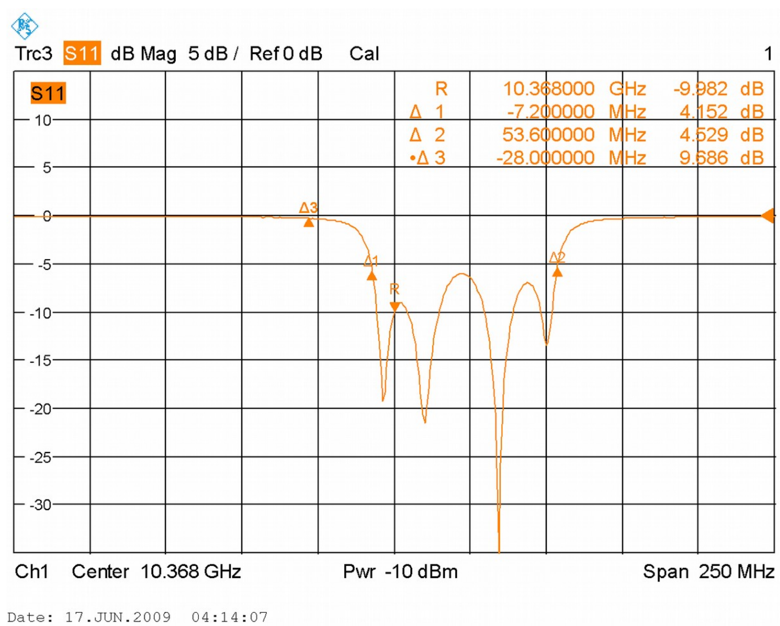

Figure A3: Return loss for the 4 element 10 GHz filter. It was designed with a 0.1 dB ripple. The return loss should be approximately 16 dB. It is significantly worse than that although the position and shape of the nulls are about right. The poor return loss is probably due to the mismatch in the coaxial input output transitions.

This filter is tuned “high” so 10,368 MHz is at the bottom end of the passband. The LO is 28 MHz below 10,368 MHz and it is suppressed by ~27 dB. The image is suppressed by ~45-50 dB. Both of these spurious are in the amateur band so this level of suppression is probably adequate. If they fell out of band, it would be desirable to suppress them by 60 dB or better. A 144 MHz IF will result in spurious outputs suppressed well in excess of 60 dB.

Figure A1 is the WGFIL output for this filter. Note that the “Fractional BW” is specified between the equal ripple (0.1 dB) points). The 3 dB BW is approximately 60 MHz. The “Guide BW” is the bandwidth using the wavelength in the waveguide at various frequencies. Recall that the wavelength in waveguide changes non-linearly with frequency, i.e. waveguide is dispersive. The center frequency was specified as 10400 MHz so the filter could be tuned down to 10368 MHz with metal screws. WGFIL reports the center frequency as 10399.977 MHz. This slight difference is a result of how WGFIL calculates the center frequency. WGFIL specifies the center frequency as the geometric mean rather than the arithmetic mean of the upper and lower passband frequencies.

Below is the output of WGFIL with the new features. Notice the addition of the 3 dB BW and the Ripple Return Loss. The measured 3 dB BW is approximately 60.8 MHz. This is a bit more then the 53.38 MHz predicted by WGFIL.

```
Post Coupled Filter    Center: 10399.977 MHz   BW:    44.000 MHz
                       Fractional BW   0.42 %   Guide BW   0.99 %
                       Chebychev response, ripple:   0.10 DB
                       3 dB BW:  53.38 MHz    Ripple Return Loss: 16.3 dB

Post diameter       Cavity length
  0.0932"
                    0.9238"
  0.2211                               Caution:  D/a > 0.25
                    1.0158"
  0.2302                               Caution:  D/a > 0.25
                    1.0158"
  0.2211                               Caution:  D/a > 0.25
                    0.9238"
  0.0932

Do you wish another design (y/n)?
```

Figure A4: Revised WGFIL output.

The author wishes he could keep the Rohde & Swartz ZVL network analyzer that was used to make the plots! He now has an HP 8720D network analyzer. While it is older (larger and heavier!) and requires a bit more skill to use, it offers almost the same functionality.

10 GHz Transverter Rig

Below is a short description of the 10 GHz rig that employs this filter. Most of the parts for the transverter were obtained on eBay. The LO uses a phase locked Stellex YIG oscillator. A DIP 10 MHz OCXO is the reference. Its fast warm up puts you within a 100 Hz or so at 10 GHz within a minute. The phase noise of the YIG is somewhat disappointing. A more conventional LO multiplier chain is under development.

The IF is 28 MHz. A Radio Shack HTX-100, a President HR2600 and a Flex 1500 have been used as IF rigs. The HTX-100 and the HR2600 were modified for separate RX/TX input/outputs. The TX output was set to output approximately 50 mW and the transverter is keyed through the TX output line. The Flex has been paired with a well used but tough Panasonic Toughbook computer. While the Toughbook is heavy, it is ideal for the field. You don't worry about dirt or moisture or dropping it, and it allows the waterfall display and digital modes with the Flex.

The antenna is a refugee from Dish TV with a gain of about 30 dB. The original feed horn was used. However, in its original configuration, the circular waveguide feed would not support 10.4 GHz. The horn was chucked up in a lathe and bored out 0.050 inches to lower the waveguide cutoff frequency to about 9.8 GHz.

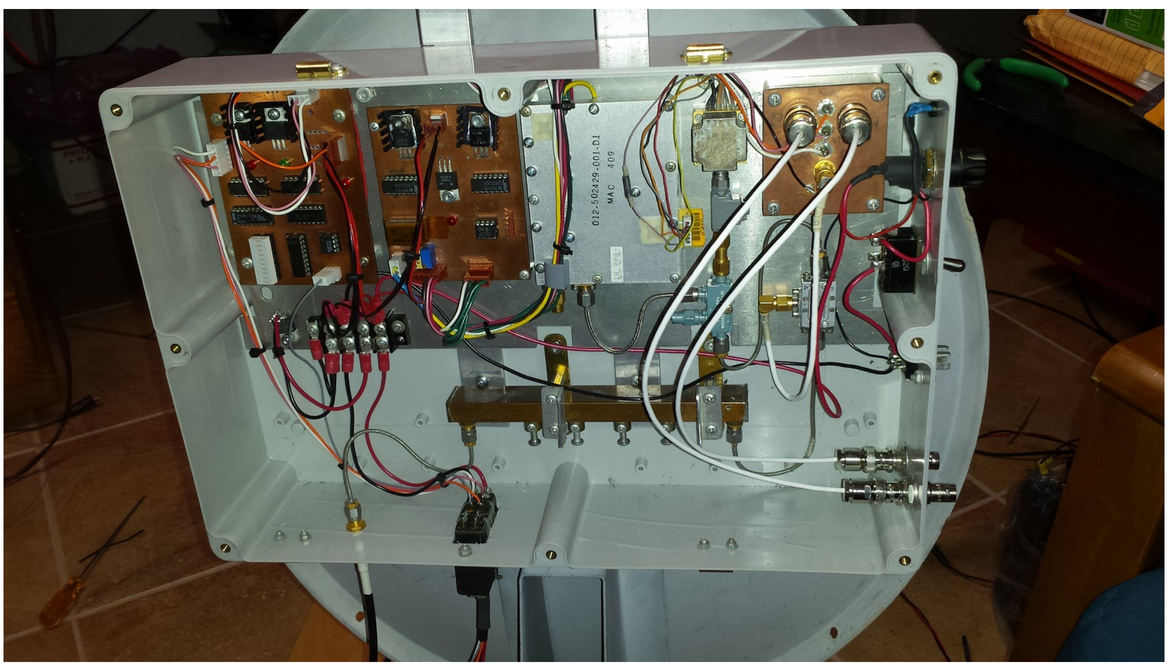

Figure A5: 10 GHz transverter interior. The filter is in the lower center. The YIG phase lock is the aluminum box in the upper center. The YIG is just to the right of the phase lock box. The card to far left is the sequencer and an output bar graph display. The center left card contains a PIC processor to load the YIG PLL, the reference OCXO and a couple of low noise voltage regulators.

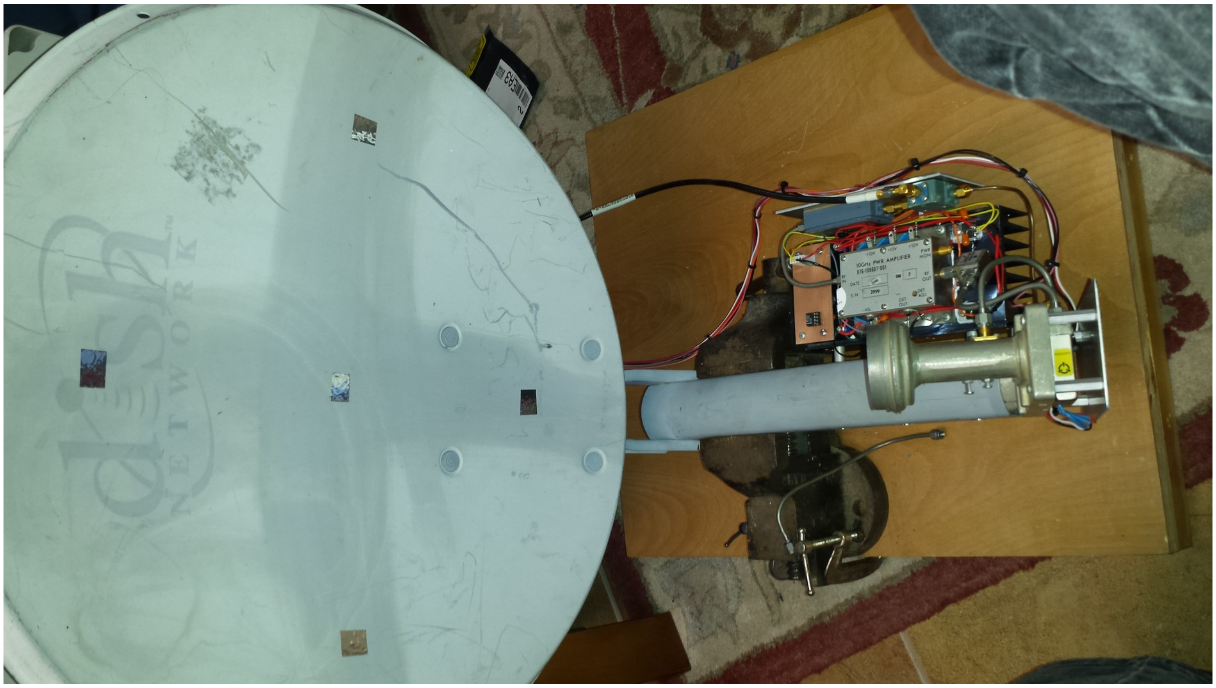

Figure A6: 10 GHz transverter front end. The rectangular box just above the feed horn is a 2.5 watt amplifier.. The LNA and the antenna relay are mounted behind the horn. The NF at the antenna feed is approximately 3 dB. Five spots of shiny tape are arranged on the antenna so the focus can be found by pointing the antenna at the sun.

Original Microwave Update 1989 paper

What follows is an updated version of the original Microwave Update 1989 paper.

DESIGN AND CONSTRUCTION
OF WAVEGUIDE BANDPASS FILTERS

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ABSTRACT

This paper describes the computer program WGFIL that synthesizes a wide range of post and aperture (iris) coupled waveguide bandpass filters. A construction technique for these filters that does not require machine shop facilities is described. Three and five section filters for 10 GHz and a 3 section 24 GHz filter built using WGFIL are included as examples.

INTRODUCTION

For operation at 10 GHz and above, waveguide filters become an attractive alternative to microstrip or interdigitated filters. Unfortunately there are a limited number of published waveguide filter designs [1][2]. Much surplus gear uses WR-75 and WR-137, and there is a need for WR-42 designs for 24 GHz. LO filters are needed for frequencies removed from the amateur band. The techniques for the design of post and aperture coupled waveguide filters are available in the professional literature [3] but they are too involved to undertake conveniently with a pocket calculator.

WGFIL: WAVEGUIDE FILTER PROGRAM

WGFIL was written to overcome these difficulties. The program will design either a post or aperture coupled filter with one of three different responses: Butterworth, Chebyshev, or Equal Element given the desired center frequency, bandwidth, and waveguide broadwall dimension. Bandwidths for the Butterworth and Equal Element filters are specified at the 3 dB down points. Bandwidth for the Chebyshev is specified between equal ripple points. This means the 3 dB bandwidth is greater than the specified ripple bandwidth. The relationship between the two can be calculated:

$$e=\sqrt{\left(10^{(ripple/10)}-1\right)}$$

$$BW_{[3dB]}=\left(BW_{ripple}\right)\cosh\left[\left(\frac{1}{n}\right)\operatorname{arcosh}\left(\frac{1}{e}\right)\right]$$

Where n is the number of filter elements and the Chebyshev passband ripple is in dB.

The Equal Element filter may be unfamiliar to amateurs. An Equal Element passband response looks like Butterworth with a “nose” on it. Its stopband response approaches that of a Butterworth filter. It is possible to estimate the number of filter sections for Equal Element filters by looking at the Butterworth filter curves [4]. Equal Element filters have the least loss for a given number of sections, although small ripple Chebyshev is close [5], and all the sections are the same. They require only two different size posts for the entire filter where the Chebyshev requires a different post for each pair of resonators.

The filters that WGFIL generates consist of series lengths of transmission line, in this case waveguide, with shunt inductive reactances placed between each transmission line section. The shunt reactances are either inductive posts placed across the broad wall of the guide or inductive apertures as shown in Figure 1.

WGFIL calculates the electrical length of the transmission line sections and the shunt reactances for the desire filter response. If inductive apertures are used, they are assumed to be of zero thickness. This is a reasonable assumption if the aperture thickness is less than a few percent of the distance between apertures. The posts have a finite "thickness" so the program must compensate the electrical length of the transmission line to correct for this. WGFIL then calculates the physical distances between the inductive obstacles and the physical dimensions of the obstacles. The approximations for the obstacle dimensions are taken from Marcuvitz [6].

If you build aperture-coupled filters, generally the apertures will be made the specified width. With post-coupled filters, it may be desirable to use a post diameter somewhat different than that calculated by the program. Posts can be made of standard sized hobby brass tubing, which comes in 1/32-inch steps, and even if the posts are turned from rod stock, one is limited by standard fractional or number sized drills.

WGFIL will calculate the post size and then request a post size. If anything other than the calculated size is desired, WGFIL will go back and correct the distance between posts to accommodate the new post size. Use this feature with prudence since the post size affects the passband as well as the center frequency of the filter. WGFIL corrects only the center frequency. Experience gained from test filters seems to indicate that a 10% change in post diameter can be tolerated. It is often possible to select the center frequency and the filter bandwidth to get the posts to come out close to a standard drill or tubing size. If thin apertures are used, their center-to-center separation can be the dimension given by WGFIL. The result will be cavities that are short by an aperture thickness. The center frequency will be high. Metal screws placed in the broadwall of the waveguide halfway between each aperture will tune the filter down in frequency.

Tuning screws can also be placed half way between each post. Metal screws will tune the filter down in frequency and good results have been obtained by choosing the center frequency 1-2% higher than desired. The best screws were silver plated screws with rounded ends that were salvaged from old microwave gear. Plating is not necessary, but keep screw penetration to a minimum to keep losses low. Screw sizes are not critical: 8-32 screws were used in WR-90, 6-32's in WR-75, and 4-40's in the WR-42 waveguide.

WGFIL uses several approximations that limit the range over which it will give valid results. Fractional bandwidth in terms of guide wavelength should be less than 20%. WGFIL calculates and reports this as "Guide BW." It is difficult to make post filters much wider than 5% because the posts become too small, and bandwidths much less than 1% will probably not give good results since the program does not account for filter losses. One approximation requires that post diameter, D, divided by the waveguide broadwall inside dimension, a, be less than 0.25. WGFIL will report a caution when D/a is greater than 0.25. Several of the test filters exceed this limitation but good results were still obtained. In general, the approximations fail gracefully so usable results may be obtained beyond these stated limits.

USING WGFIL

Figure 3 shows a typical run of WGFIL. The example is the 3 section 24 GHz filter described later in this paper. The first screen contains the sign-on message and a series of prompts requesting various filter parameters. The second screen contains the calculated post diameters and a request for the desired post diameter. If the calculated post size is acceptable, pressing <Enter> will accept the post size and WGFIL will display the next post size. If a different sized post is desired, it maybe entered at the prompt followed by <Enter>. The third screen displays the completed design. Note the D/a caution message. If a new design is requested, the program will prompt you for a new center frequency and bandwidth. It will then do a new calculation and return you to the second screen.

BUILDING WAVEGUIDE FILTERS

The test filters were constructed with standard waveguide and flanges. Waveguide can often be found at hamfests or guide and flanges can be purchased new at a fairly reasonable cost [7].

The most elegant way to build these filters is with a milling machine. Several test filters were built this way, however such equipment is not available to most amateurs. A hand technique came from a retired machinist friend. It requires a set of vernier or dial calipers, a drill press, scriber, machinist's square, and some C-clamps. The calipers cost $25-150 and are available from machinist's supply or by mail-order [8]. They are a good investment if you plan to do much microwave work.

First, cut a convenient length of guide for the filter. Use the machinist's square and a flat file and file the ends of the guide reasonable square. You can check your work by holding the piece up to the square and then holding them both up to the light. If the end is perfectly square, you will not see any light between the end of the piece and the blade of the square.

Scribe a line down the center of the filter piece and then mount the scriber tip in the drill press. Place the filter piece next to a long straight section of metal. A piece of the filter waveguide is ideal. Place the long section on the drill press table so that the scribe tip will come down on the centerline of the filter piece. Use C-clamps to hold the long section in place on the table. Study Figure 4 for a typical setup. The centerline of the drill press should pass through the line scribed down the center of the filter piece as it is moved along the straight section.

Clamp a piece of metal perpendicular to the straight section at some location removed from the filter section. Measure between this reference block and the end of the filter section as shown in Figure 4. Adjust the filter section so the first hole is in a convenient location, clamp the filter piece to the straight section, and measure the distance between the end of the filter and the reference block. For example, if this distance is 4.426” and the next hole must be 0.332” down the guide, after drilling the first hole, unclamp the filter section and move it 0.332” toward the reference block. The distance between the block and the end of the filter section should now be 4.094”. Reclamp the filter section and drill the next hole.

Check your measurement after clamping. “Measure twice and drill once!” With a little practice and care you should get within 0.001” or two. Practice on some scrap pieces first. When you drill, first drill a starter hole with a center drill and then drill the desired size. Drill the starter hole and the final size without moving the filter section. For holes 1/8” of less, use a #1 center drill, otherwise a #2 drill is fine. A center drill is a stubby stiff drill used for starting holes. They only cost $1-2 and they can be obtained from any machinist’s supply house. Drill only one side of the guide for a tuning screw and both sides of the guide for a post. When you set things up, you may wish to position the drill press table so that you will drill over a table hole so as not to drill into the table itself. You can check your work by pressing the posts into the holes and measuring the distance between the outside of the posts with calipers. Now subtract half the diameter of each post from the measurement and you will have the center to center dimension of the posts. In general, it is better to have the posts a bit too close that to have them too far apart since metal tuning screws will lower the center frequency of the filter.

Clean the burrs from the guide with a small file before soldering the posts in. The posts should just press into the holes. If they are too tight, solder will not flow around them, too loose and the dimensional accuracy suffers. A ding with a center punch on an end edge of a loose post will hold it in place while soldering. A small torch and plenty of flux is recommended. After soldering, clean the filter with flux remover.

If you have access to a lathe, you can make some holders for the tuning screws. The holder shown in Figure 2 was used for the 10 GHz test filters. Brass rod stock for holders or posts can be obtained by mail-order [9]. These holders give the finished result a professional look and make for smooth tuning. The little bit of plastic under the setscrew permits continuous friction on the tuning screw. It came from a milk jug but most any soft plastic will do. Instead of the holders, you can tap the waveguide for the screw and solder a nut on the guide to give greater strength. Hold this nut in place with a stainless steel screw while soldering. Solder won't stick to the stainless and you can remove the screw after soldering. You can then use a plastic nut as a lock nut and this will apply a smooth tension to the screw while tuning.

TUNING WAVEGUIDE FILTERS

Filter adjustment can be a problem. A simple signal source and a detector will probably work for two or three section filters as their stopbands are not very strong and you can blast through a badly mistuned filter. Care in construction will produce a filter that is close to the desired tuning. A more sophisticated tuning technique is described in [10] or in Chapter 11 of [3]. This is the so-called "peak-dip" method of Dishal, but it requires a slotted line.

The accuracy of the center frequency appears to be limited more by the construction technique than by the approximations in WGFIL. With care on a milling machine, it is possible to build filters that require little or no tuning. Very narrowband filters are more susceptible to construction errors. The author has constructed 29 GHz 2% BW filters in WR28 that required no tuning. The milling machine used by the author tends to be on the short side so the filters come out slightly high in frequency. A ding with a center punch in the broadwall of the waveguide between two posts will bring the resonator frequency down.

TEST RESULTS

A number of test post filters were constructed. No aperture filters were built since the apertures were too difficult for the author to fabricate. However, WGFIL will accurately reproduce the aperture-coupled example in [3]. Table 1 tabulates the test filters constructed.

Table 1: Test Filters

WG Type Sections	Design	Sections	Center Frequency	3 dB BW	Measured 3 dB BW	Loss
WR-90	0.1 dB Chev	3	10.368 GHz	138.8 MHz	111.4 MHz	0.67 dB
WR-90	0.1 dB Chev	5	10.368 GHz	130.5 MHz	140.8 MHz	1.64 dB
WR-75	Equal Elem	5	10.368 GHz	102.4 MHz	118 MHz	1.10 dB
WR-42	0.1 dB Chev	3	24.125 GHz	448.5 MHz	441 MHz	1.32 dB

Figure 5 is a photo of several of the test filters. Figure 6 shows the response of the 5 section WR-90 filters. This filter has a waveguide port at one end and a co-axial port at the other. The waveguide to co-ax transition is very similar to the one described in [1]. Figure 7 is the response of the WR-42 filter. Two WR42 filters were constructed. One was made on the milling machine and the other using the technique described above. The filter built with the mill was measured without the tuning screws. It had a properly formed passband centered about 0.5% higher than the design frequency. No tune for 24 GHz anyone?! The two different WR-42 filters are shown in the Figure 5 photo.

CONCLUSION

WGFIL should be a useful tool for anyone desiring to build transverters and use waveguide. WGFIL is available for non-commercial amateur use for the price of a computer disk and postage if necessary. It can be supplied either on 5.25” or 3.5” MS-DOS formatted media and it should run on PC type computer.

ACKNOWLEDGMENTS

I would like to thank Ken Backer KC4LOL for doing the HP8510 network analyzer plots, Mike Barts, N4GU for the photos and helpful suggestions, and Joe Hurley for the drilling technique. Also thanks to AL Ward WB5LUA who encouraged me to search for a simple construction technique.

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2. Gannaway, J.N. G3YGF, and Davies, S.J., G4KNZ ed, The Microwave Newsletter Technical Collection, RSGB.

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4. Taub, Jesse J., “Design of Minimum Loss Band-Pass Filters,” Microwave Journal, September 1963, pp. 67-76.

5. Blinchikoff, Herman J. and Antatol I. Zverev, Filtering in the Time and Frequency Domain, John Wiley, New York, 1975, pp. 281-286.

6. Marcuvitz, N., Waveguide Handbook, Peter Peregrinus Ltd, London, 1986, Ch 5.

7. Lectronic Research Labs, Inc., 665 Winks, Bensalem, PA 19020, 800-358-8378. LRL accepts credit cards. Waveguide must be ordered in 5-foot minimum lengths. The author’s last purchase of WR-90 was $3.90/ft. *(Unfortunately, it appears that Lectronic Research Labs is now out of business.)*

8. Rutland Tool & Supply, 2225 Workman Mill Rd., Whittier CA 90601-1437. 800-289-4787, website: www.rutlandtool.com. Rutland accepts credit cards. *(Rutland Tool was bought out by MSC Industrial Direct, www.mscdirect.com. MSC appears to be much more expensive than Rutland. Try Victor Machinery Exchange, www.victornet.com, as an alternative.)*

9. Small Parts Inc., 13980 NW 58th Court, PO Box 4650, Miami Lakes, FL 33014-0650, 800-220-4242, website: www.smallparts.com. Small Parts accepts credit cards. *(Small Parts got bought out by Amazon and it is no more.)*

10. Dishal, M., “Alignment and Adjustment of Synchronously Tuned Multiple- Resonator-Circuit Filters,” Proceedings of the IRE, No. 39, November 1951, pp. 1448- 1455.

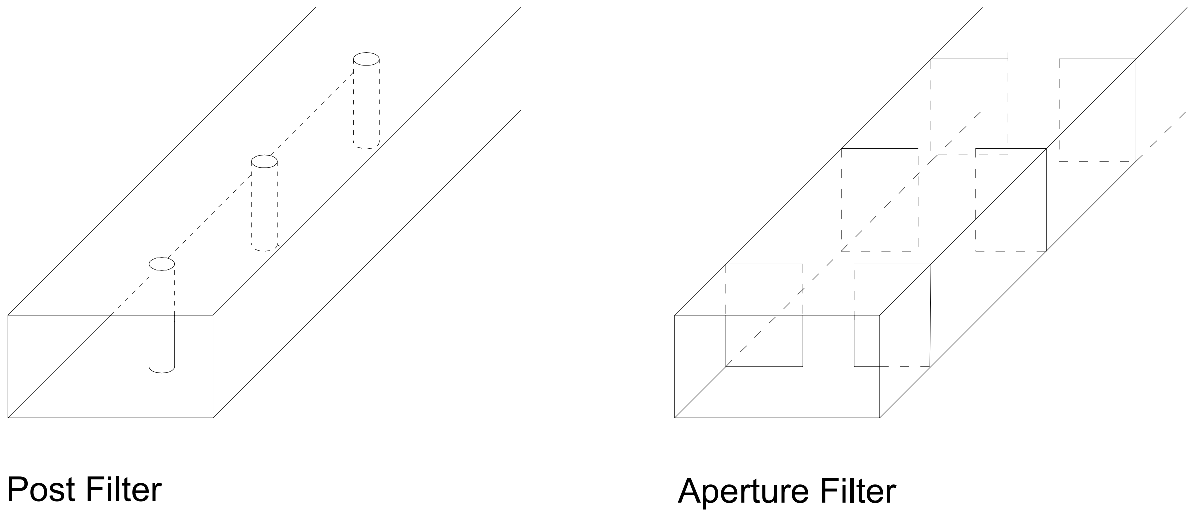

Figure 1: Waveguide bandpass filters using either posts of inductive apertures

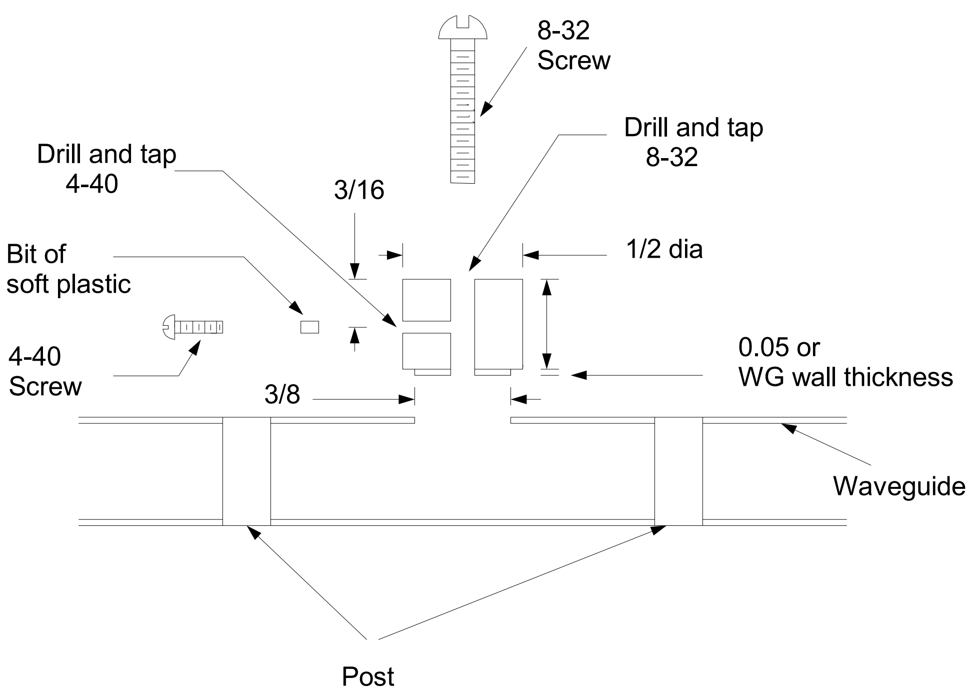

Figure 2: Tuning Screw Holder

Waveguide Filter Synthesis Program
written by Dennis Sweeney WA4LPR
Version 1.1

```
Filter type:        Butterworth       : 1
                    Chebyshev         : 2
                    Equal Element     : 3
          Enter # of desired type     : 2
          Enter passband ripple in dB      : 0.1

Filter structure :  Post : 1
                    Iris   : 2
     Enter # of desired type:  1

Enter waveguide width (inches)    0.42

Enter # of elements : 3

Center frequency in MHz = 24362
Bandwidth in MHz = 325
```

WGFIL screen 1

```
Post Coupled Filter

Calculated Post dia     Desired post dia
Post[0] = 0.0624             0.0625
Post[1] = 0.1251             0.1250
Post[2] = 0.1251             0.1250
Post[3] = 0.0624             0.0625
```

WGFIL screen 2

```
Post Coupled Filter          Center :   24361.458 MHz     BW: 325.000 MHz
                    Fractional BW      1.33 %     Guide BW   2.00 %
                    Chebychev response, ripple:        0.10 DB

Post diameter            Cavity length
 0.0625”
                    0.3316”
 0.1250                       Caution: D/a > 0.25
                    0.3735”
 0.1250                       Caution: D/a > 0.25
                    0.3316”
 0.0625

Do you wish another design (y/n)? y
Center frequency in MHz = 24300
Bandwidth in MHz = 300
```

WGFIL screen 3

Figure 3: Typical run of WGFIL. The example is the 24 GHz filter in Figures 5 and 7.

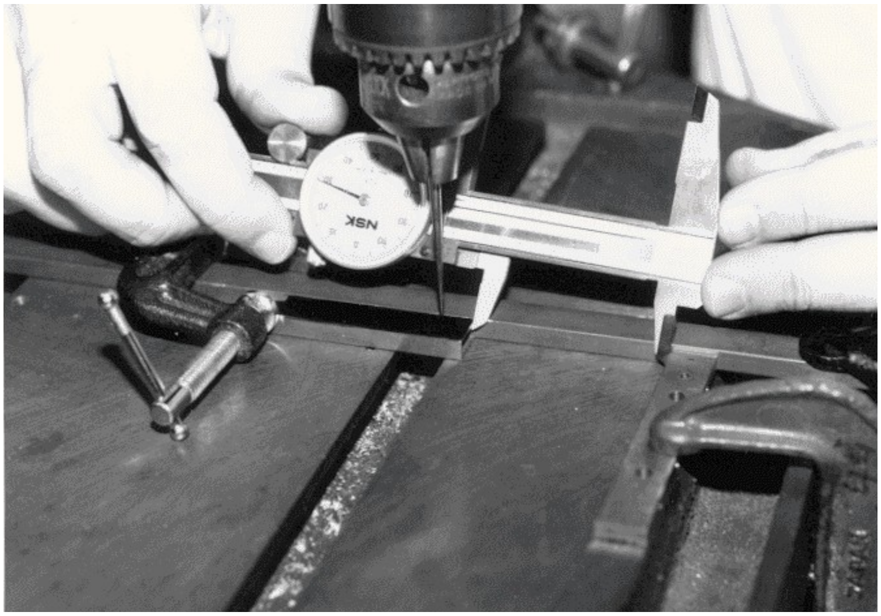

Figure 4: Drill press set up for accurately drilling waveguide filters.
The dark object in the center is the filter to be drilled. The reference block is in the foreground to the right.

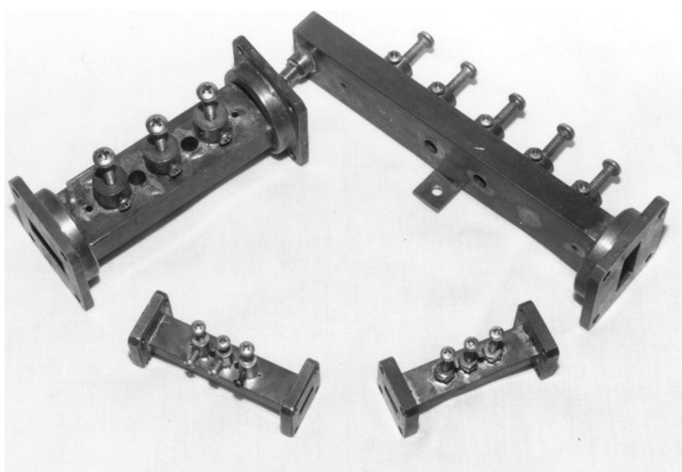

Figure 5: Test filters. In the upper left is a 3 section 10 GHz WR-90 filter.
In the upper right is a 5 section 10 GHz WR-90 filter with a co-ax input.

A 3 section WR-42 24 GHz filter made on the milling machine is in the lower left and the same filter built with the described technique is in the lower right.

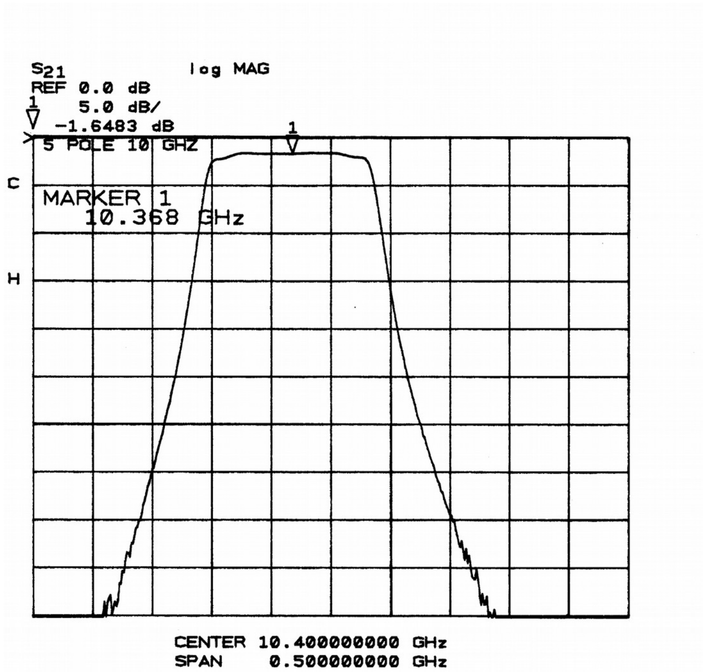

Figure 6: Frequency response plot of the 5 section 10 GHz filter. The x-axis is 50 MHz/div. centered at 10.4 GHz. The y-axis is 5 dB/div., top is 0 dB.

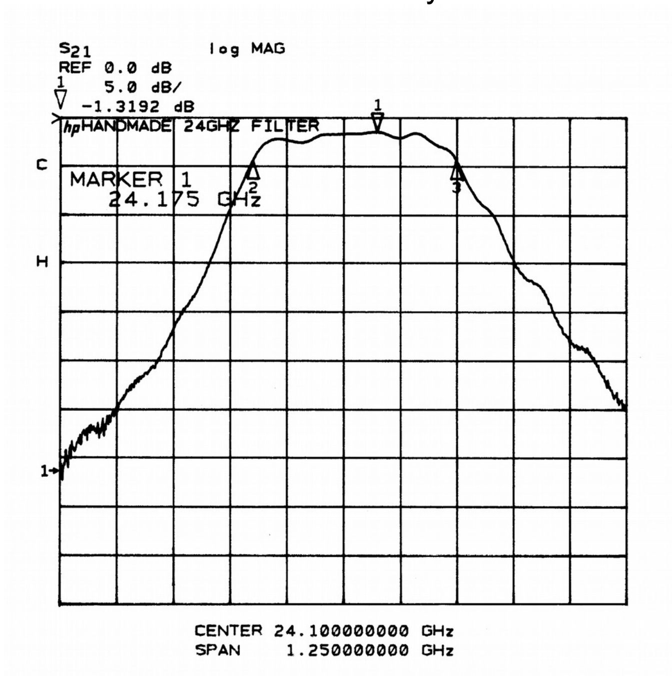

Figure 7: Frequency response plot of the handmade 3 section 24 GHz filter. The x-axis is125 MHz/div. centered at 24.1 GHz. The y-axis is 5 dB/div, top is 0 dB. Markers 2 and 3 are the 3 dB points 441 MHz apart.