A Method to build your own Waveguide to Coax Transition

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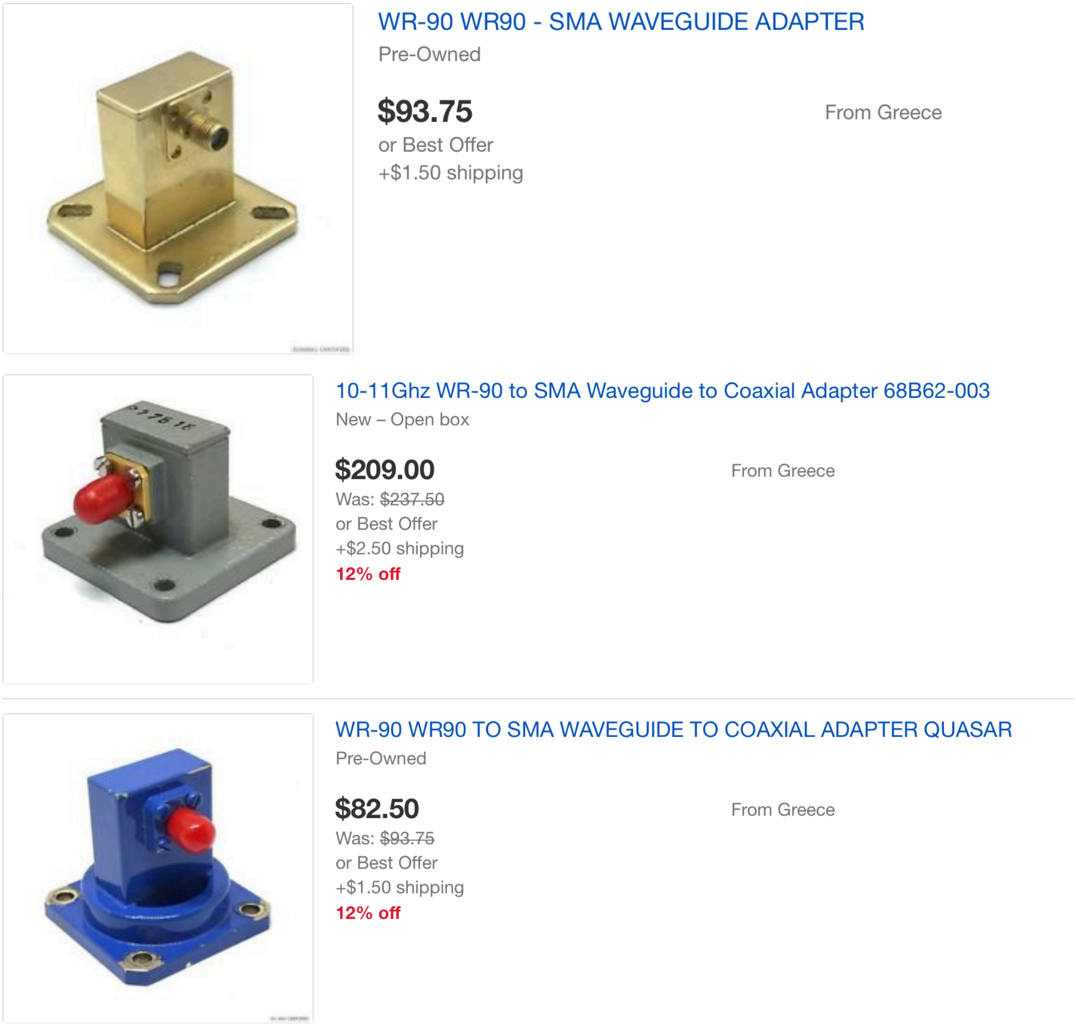
To operate in the microwave bands you typically use an antenna system that requires converting from coax to waveguide. In this paper I will refer to these devices as converters but they are also known as transitions and adapters. Converters can be found in flea markets and on eBay. If you find converters they typically range in price from $20 to $250. A few examples of converters available on eBay, as of this writing, are shown in Figure 1.



WR-90 WR90 - SMA WAVEGUIDE ADAPTER
Pre-Owned
$93.75
or Best Offer
+$1.50 shipping
From Greece

10-11Ghz WR-90 to SMA Waveguide to Coaxial Adapter 68B62-003
New – Open box
$209.00
Was: ~~$237.50~~
or Best Offer
+$2.50 shipping
12% off
From Greece

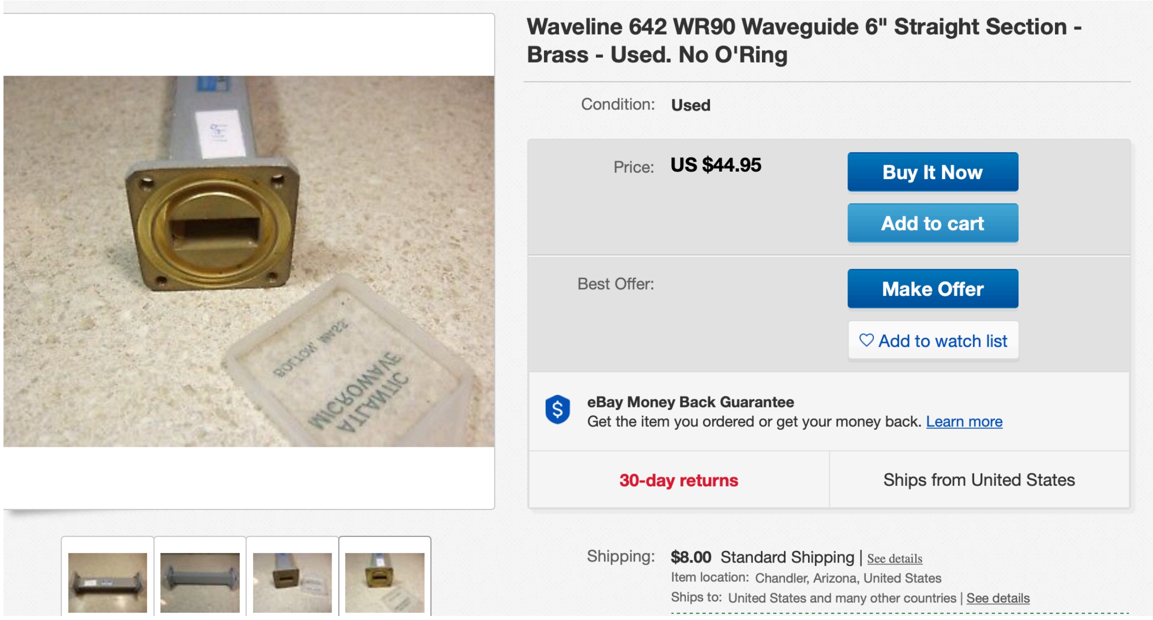
WR-90 WR90 TO SMA WAVEGUIDE TO COAXIAL ADAPTER QUASAR
Pre-Owned
$82.50
Was: ~~$93.75~~
or Best Offer
+$1.50 shipping
12% off
From Greece

Figure 1

When you make a purchase of one of these you are sometimes surprised to find the part is advertised as WR90 but the dimensions of the waveguide or the mounting holes do not match other WR90 waveguide pieces you have. In addition you have no idea what the real performance of the converter is until you test the device.

The purpose of this paper is to detail a method of building your own converters using readily available materials. If you have access to surplus waveguide this can be used as well. In some cases the inside surface of the waveguide is plated usually with silver and this will result in an improvement in performance by a few tenths of a dB. If you want to consider plating your own waveguides I have added a couple of references about plating. If you're near an industrial area you can find a business that does silver plating.

Paul Wade, W1GHZ published an excellent article (1) on building converters which covered his experience and gives details on an approach which may be used to build a microwave converter. I used Paul's article to help guide me in my efforts. Paul's approach was to start with a piece of waveguide made for the target band, WR 90 for 10 GHz as an example. If you want to follow Paul's approach you might look for waveguide or waveguide parts like the one shown in Figure 2 found on eBay. Then you could cut the waveguide section into two pieces and place a plate over the end of each of the pieces and add SMA connectors. The result would be two converters. Since you inherit the flanges from the existing piece this minimizes machining and effort. Finding a economical part to start with may be difficult.



Waveline 642 WR90 Waveguide 6" Straight Section - Brass - Used. No O'Ring

Condition: **Used**

Price: **US $44.95**

Best Offer:

eBay Money Back Guarantee
Get the item you ordered or get your money back. Learn more

30-day returns

Ships from United States

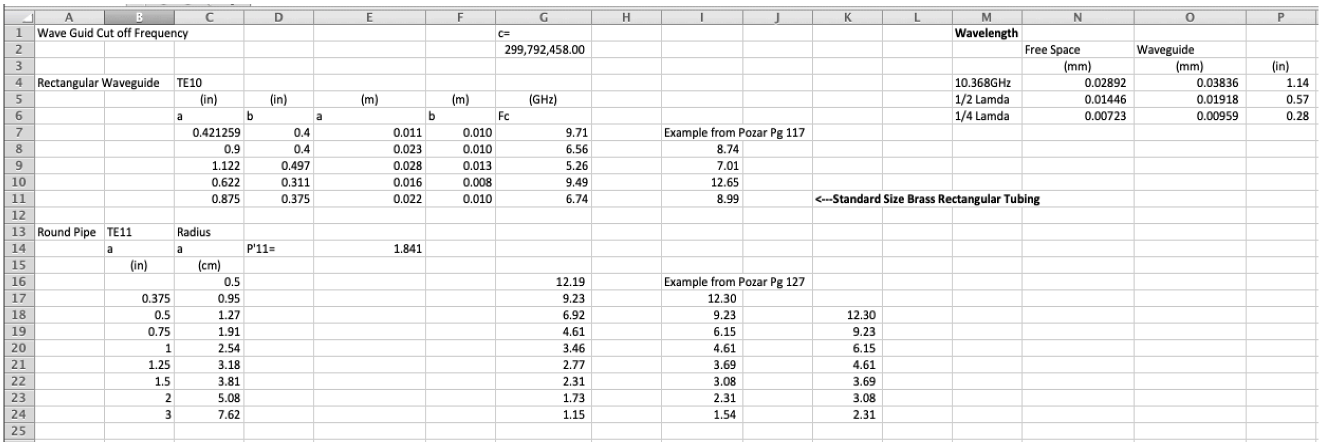
Shipping: **$8.00** Standard Shipping | See details
Item location: Chandler, Arizona, United States
Ships to: United States and many other countries | See details

Figure 2

Another approach to this is to use brass rectangular or square tubing and make your own flanges. Brass is chosen because it can be soldered. There are metal distributors like McMurry Metals in

Dallas Tx (2) or OnlineMetals.com (3). Selling various sizes of brass tubing, bar stock and other shapes. You can likely find a distributor in a city near you if not you can order the material on line.

To determine what size tubing will work for a particular band I studied David Pozars' book Microwave Engineering (5). In Section 3.3 he discusses Rectangular waveguide giving the detail formulas and physics involved. He also covers circular waveguide. From this reference I developed an Excel spread sheet to calculate the cutoff frequencies of various rectangular tubing sizes. By using the Excel spreadsheet as a guide I was able to consider the standard sizes of brass tubing made in industry today. Table 1 shows my results with some of these sizes along with the cutoff frequencies and the examples from the Pozar book. The goal is to select tubing with a cutoff frequency below your desired operating point. The upper limit of the tubing will be two times the cutoff frequency. At two times the cutoff frequency multiple emission modes can occur.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Wave Guid Cut off Frequency						c=						**Wavelength**			
2							299,792,458.00							Free Space	Waveguide	
3														(mm)	(mm)	(in)
4	Rectangular Waveguide		TE10										10.368GHz	0.02892	0.03836	1.14
5			(in)	(in)	(m)	(m)	(GHz)						1/2 Lamda	0.01446	0.01918	0.57
6			a	b	a	b	Fc						1/4 Lamda	0.00723	0.00959	0.28
7			0.421259	0.4	0.011	0.010	9.71		Example from Pozar Pg 117							
8			0.9	0.4	0.023	0.010	6.56		8.74							
9			1.122	0.497	0.028	0.013	5.26		7.01							
10			0.622	0.311	0.016	0.008	9.49		12.65							
11			0.875	0.375	0.022	0.010	6.74		8.99		**<---Standard Size Brass Rectangular Tubing**					
12																
13	Round Pipe	TE11	Radius													
14		a	a	P'11=	1.841											
15		(in)	(cm)													
16			0.5				12.19		Example from Pozar Pg 127							
17		0.375	0.95				9.23		12.30							
18		0.5	1.27				6.92		9.23		12.30					
19		0.75	1.91				4.61		6.15		9.23					
20		1	2.54				3.46		4.61		6.15					
21		1.25	3.18				2.77		3.69		4.61					
22		1.5	3.81				2.31		3.08		3.69					
23		2	5.08				1.73		2.31		3.08					
24		3	7.62				1.15		1.54		2.31					
25																

Table 1.

I have included the Excel file in the MUD 2019 data disk. If you would like to determine frequency cutoff for additional sizes of rectangular or circle tubing it is easy to expand the Excel file. You could also look at cutoffs of standard sizes of WR waveguide like WR90 which is 1.00" X 0.50" with wall thickness of 0.050" making inside dimensions 0.90" X 0.40".

After you have selected a tubing size that will propagate your wavelength you will need to build the proper size flange. My initial goal was 10 GHz and I will explain the process used to build a converter for this band. I purchased flat pieces of brass stock cut from a strip of 1 5/8" X 1/8" bar stock. The pieces received were 1.68" X 1.68 X .132". I also purchased a 2 foot length of rectangular brass tubing with outside dimensions of 1.0" X 0.5" and wall thickness was specified as 1/16". So the inside dimensions of the waveguide will be 0.875" X 0.375". The dimensions of the tubing I received was actually 0.875 X 0.380 X 0.058".

The distributor sheared the flat stock into 1.68 by 1.68-square pieces for me. The next step to make a flange is to cut the slot in the center and add the holes. I also used a file to round off the sheared edges and to break all the edges and corners around the outside of the part to make the flange. The best way to get the slot is to have them machined in by someone that has a milling machine. If this is too costly or difficult you could mark the slot and drill holes inside the area that must be removed and using a small flat file remove the material so the rectangular tubing will fit into the slot. I have included a drawing, Figure 13, with dimensions for a finished flange that will fit 1" X 0.5" brass tubing. If the slots are machined there is typically a radius (end mill radius) in the corners. This will need to be filed square or the corners of the rectangular tubing will need to be rounded to fit into the flange.

For the rectangular tubing I used a miter guide and a small tooth saw to cut the tubing to length. Then I marked drilled and tapped the holes needed in the tubing. The finished part needed is shown in Figure 11. The length on my tubing/waveguide was to help me handle it and mount later in front of a dish. The length can be short as long as you or more than one wavelength in front of the probe on the flange end. At high power there can be some internal surface resistance causing a small loss but we are typically not using so much power.

From brass bar stock I purchased which was 1" X 0.375" I machined a plug that would slip into the rectangular tubing. The finished drawing for this is shown in Figure 12. A hole was drilled and tapped at 2-56 in the back of the plug to add a screw to use as a handle for adjusting its position and tuning.

If you study Paul Wades paper and Table 4 in Paul's paper you will see the back wall of the WR90 converter ends up so close to the insertion probe that you may hit any screws that protrude inside the cavity or burrs from the holes drilled and tapped for the screws. To avoid this, clean away any burrs and be careful with your screw length. Try not to scratch up the inside of the tubing more than necessary.

The next step is to solder the front flange on the rectangular tubing. You can do this by lightly burnishing the surfaces that will receive solder with some fine sand paper or scotch bright. Then insert the tubing in the flange and using a flat surface make sure the front face of the tubing and the flange is well aligned. Using a square make sure you can get the flange face to be perpendicular to the length of the tubing. Then wrap about 8 turns of .025" diameter solder (adjust the turns for the solder size you have on hand) around the tubing and keep the solder close to the backside of the flange. The process I used was to double check the flange surfaces perpendicularity then place the assembly on a hot plate I purchased at Walmart for less than $20. Next I placed a bead of flux (Chipquik SMD291) around the solder. Then turn on the hot plate at a high setting and let it begin to heat up. The flux will smoke so do this in a ventilated area or outside. When it gets hot enough you will see the solder wet and flow. Some of the solder will wick down in the space between the flange and tubing and make sure you have enough solder to fill the void in the mating space. Add more solder by hand if needed. This can be a bigger issue if you hand milled the slot.

Don't touch anything while the solder is molten and as soon as you see the solder has melted well you can turn off the hot plate and let things cool down. If you must touch the assembled waveguide wait until the solder solidifies then use plyers or something to pick it up. Don't burn yourself and wear some safety glasses!! Several photos are shown in Figure 3 illustrating this process.

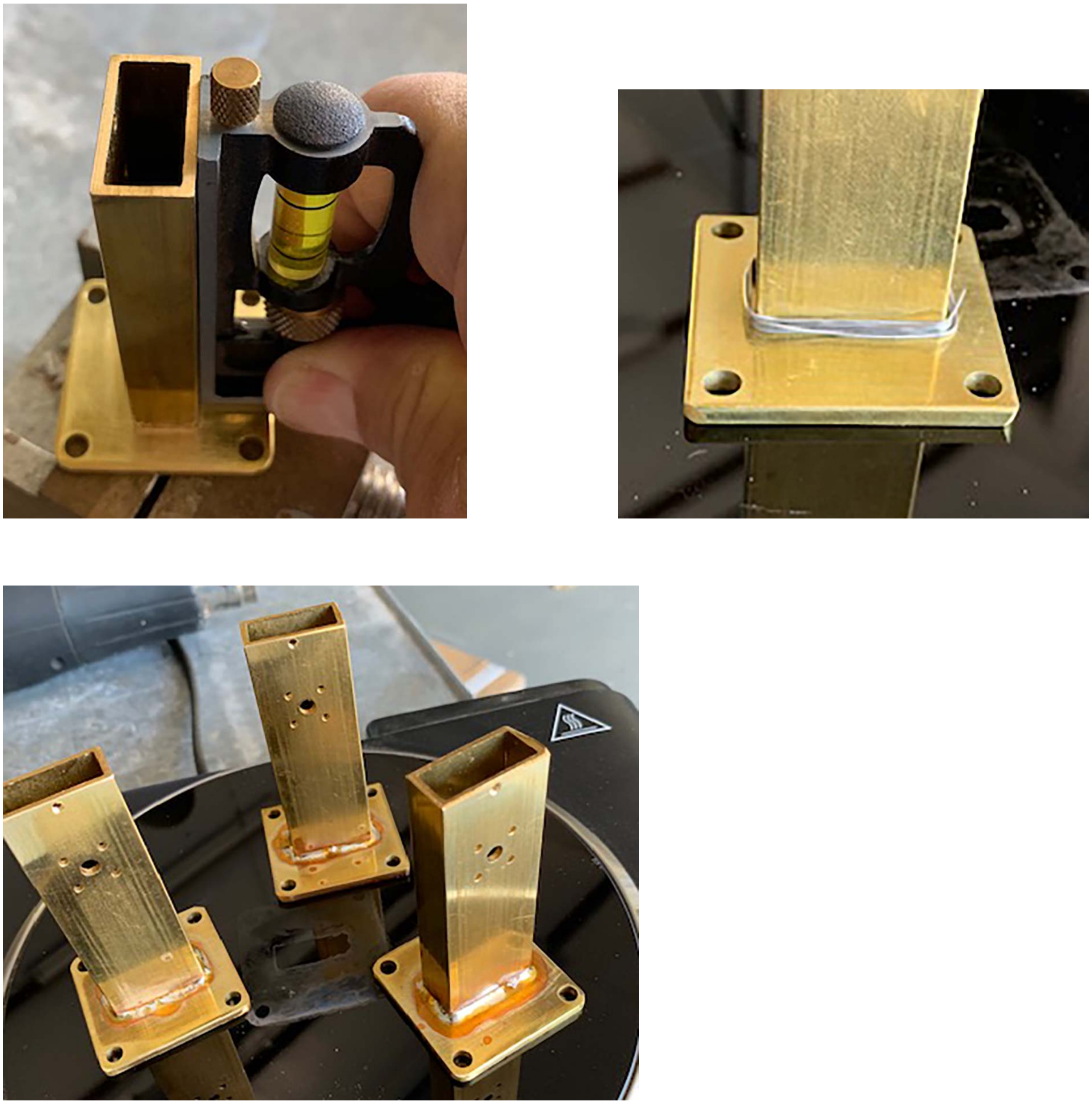


Figure 3.

When things have cooled down you should clean the part using a tooth brush or similar and some water or alcohol. I used some Q-Tips to clean the inside of the tubing. An alternative for cleaning would be to dip the part in toilet bowl cleaner for a few seconds and then clean the part thoroughly with fresh water. The bowl cleaner is a mildly acidic and it will shine up the brass.

The next step is to prepare the insertion probe on the SMA connector. If you can find an SMA connector with a 0.625" diameter pin more than 0.30" in length this will be ideal. If not, you may need to purchase some .0625" mm round brass tubing and solder this on a SMA connector that has a pin diameter which will fit inside your purchased round tubing. The goal is to get the pin to a length of 0.285" with a small flange of Teflon that is 0.056" extending from the base of the SMA. I have a drawing showing the finished SMA with probe in Figure 4.

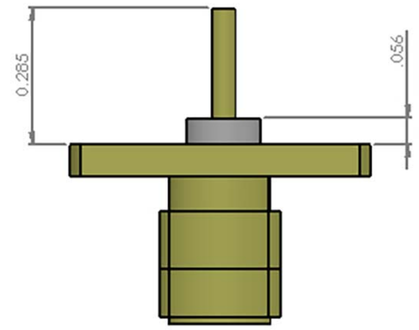


Figure 4.

Apply the probe to the waveguide and secure it with screws. Make sure the plug will slide into the backside of the waveguide freely. The tuning plug which will become the back wall of the waveguide. This plug must go down into the waveguide so the front face of the plug is very near the probe pin. You will position this by holding the screw placed in the back of the plug. The conductivity of this plug to the walls of the waveguide is critical. For adjustments you are using low power levels and may see some variation in readings but you can determine the best operating point. Later the plug will be soldered in place and conductivity will be good and support high power.

For testing and adjustment I attached a waveguide dummy load, purchased on eBay, to the flange. You could use something like this or you might attach another waveguide converter with a 50 ohm dummy load attached to the SMA connector. For a signal generator I used an HP8350A with plugin 83592A set to scan from about 9.5 GHz to 11 GHz and output +7 dBm of power. Then I monitored the reflected power using a directional coupler and a HP853A with plugin 8559A spectrum analyzer. I show this arrangement is Figure 5 block diagram and the photo in Figure 6. I placed a 3 dB attenuator in front of the directional coupler to be sure the signal generator would see a 50 ohm impedance load. I also used a 6 dB attenuator in front of the spectrum analyzer to protect the input and to make sure again that I had a 50 ohm impedance.

The test equipment shown was used because I have it available but you should be able to tune up the converter with a 10 GHz power detector of some sort to detect the power coming from the directional coupler and a W1GHZ personal Beacon setup for 10.304 GHz. You may also just leave the flange end open to the air and tune for minimum reflected power.

You will see my parts in the photos are machined for a SMA connector with four screw mount holes. I have included this drawing in the drawing files if you want to use this type of SMA. The two-screw mount SMA will be better for staying away from the tuning plug. This may depend on the SMA connectors you can find.

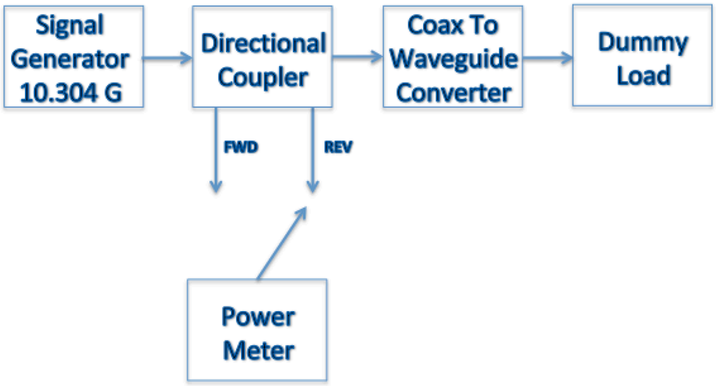
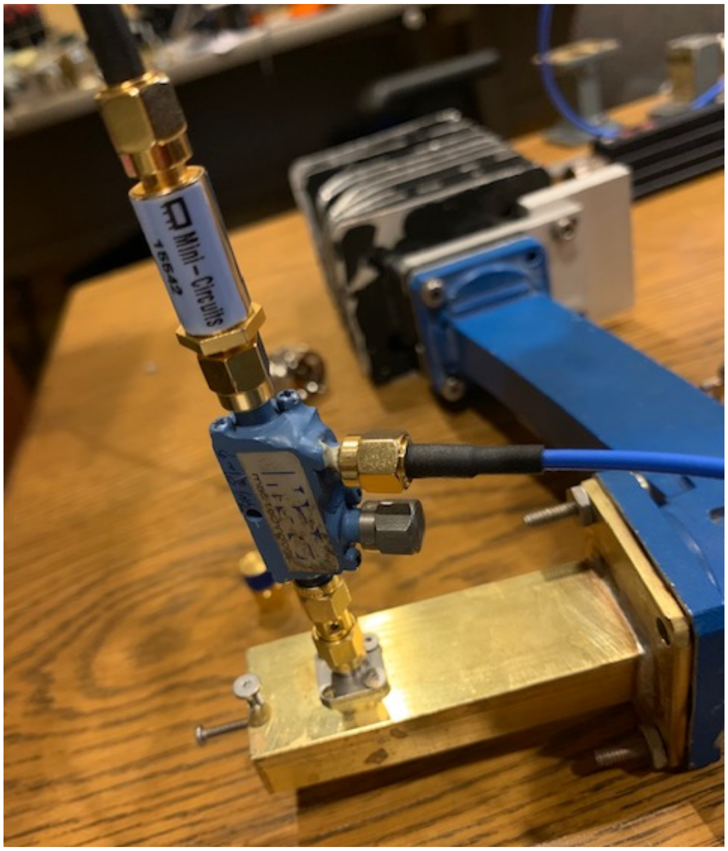


Figure 5



Setup with converter dummy load and directional coupler.
Figure 6

With everything connected I proceeded to adjust the location of the plug in the back of the waveguide looking for the lowest possible power level for the reflected power. Note my photo in Figure 6 has the directional coupler configured for forward power measurements. It's important to measure the reflected power first so the directional coupler would be reversed. When I found the lowest reflected power level I tightened the holding screw on top of the waveguide down against the adjustment plug to lock the plug in place. Then I rechecked the power level to be sure the power remained the same. Very small movements can make a lot of difference in the process so you have to just be patient and carefully adjust things.

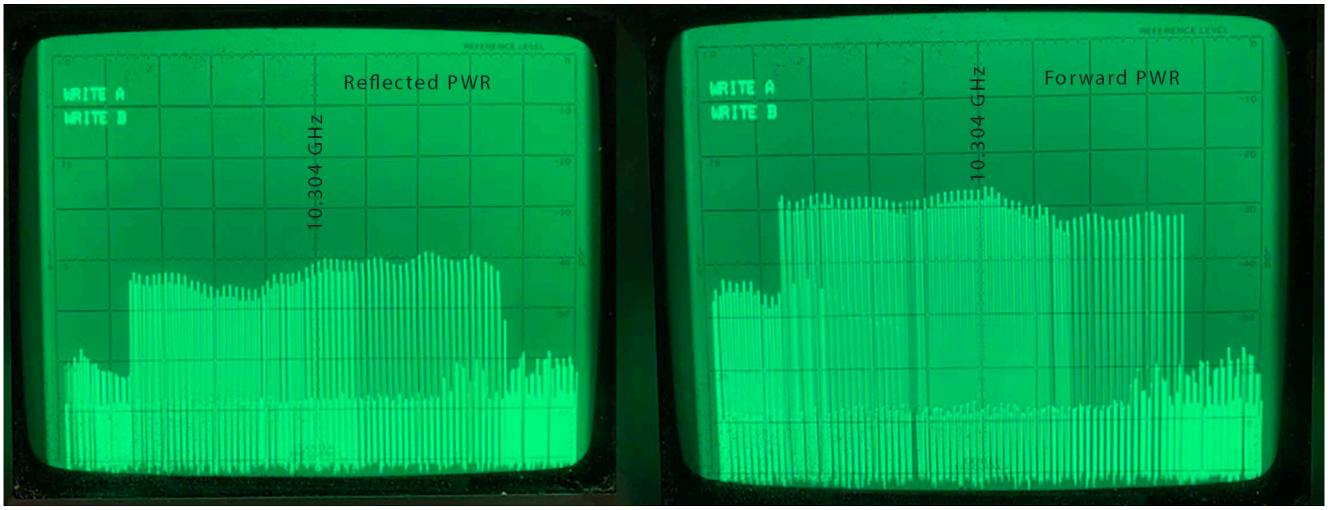


Image of HP853A/8559A with center at 10.304 GHz and 200 MHz per cm.
Figure 7

Next I reversed the directional coupler and measured the forward power delivered into the converter. With the reverse power measured in dB and the forward power measured in dB I can calculate the SWR. My results were a power difference of 12 dB which according to a table I found (3) is an VSWR of 1.68.

I then measured the distance from the back of the plug to the back end of the waveguide. With this measurement and knowing the dimensions of my plug I could determine the distance from the probe pin to the effective back wall of the waveguide. I was impressed to find the distance was 0.125 inches, which was very close to Paul Wade's table 4 numbers shown in his paper.

To check my setup I inserted an HP X281A converter I had and measured its VSWR and found it to be 2.0 similar to the one I just built. This was 2.0 using the waveguide dummy load. With the dummy load an ideal match would read very low SWR.

I should be able to improve the SWR of the finished converter by adding a tuning screw between the probe and the waveguide flange. This screw would add capacitance to the converter. If I tune with the screw using a waveguide dummy load, which should have an impedance of 377 ohms, I can lower the SWR more. I may be able to reduce the SWR to near 1/1, which would be an improvement in the signal of 0.47 dB.

Now that I had this working I tried different connectors and probe lengths but did not see any significant improvement in performance. In most cases it was worse. However, this process showed me that there might be a way to improve performance later by better targeting the converter physical dimensions for a frequency of 10.304 GHz. This may be a subject for a later paper.

The last step was to apply solder to the plug to lock the plug into position and seal the back of the converter. I applied a bead of the same flux used earlier around the back parameter of the plug. Next I used a 1500 Watt Dual Temperature Heat Gun I purchased from Harbor Freight for about $15 to heat the part hot enough to flow solder. I place the part on a metal table and propped it up using a large diameter screw head while heating. Important not to hold the part with a vice or something that will sink heat away. When the plug and the waveguide were hot enough I hand feed solder around the seam and filled it in. Turned off the heat gun and let the part air cool.

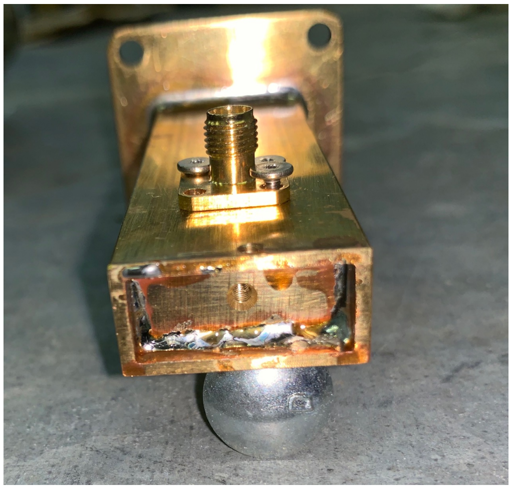


Figure 8.

Finally, I retested the part and verified its performance. The waveforms from testing the final part are shown in Figure 7.

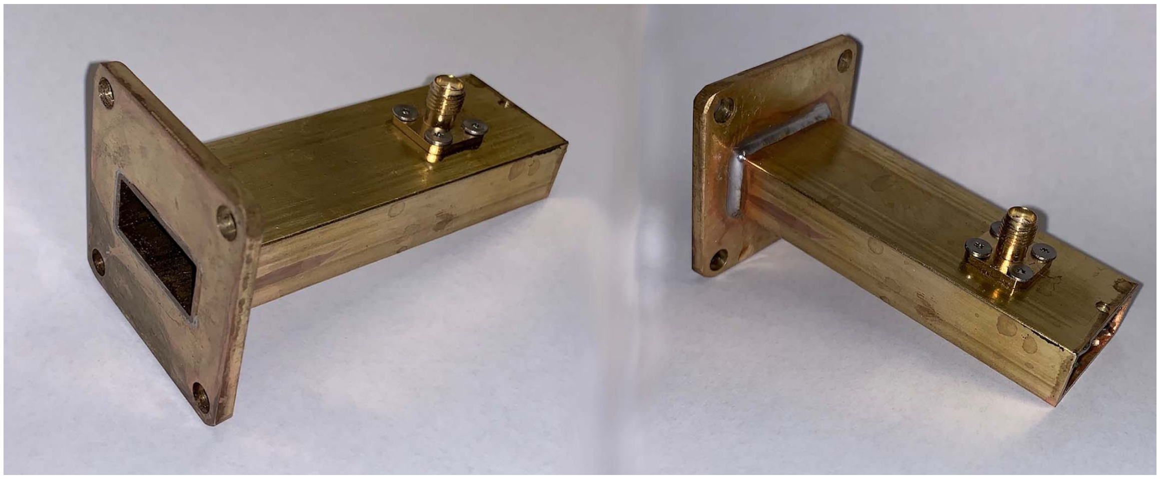


Figure 9.

I enjoy building things like this and I think others do as well. I have found several converts are needed for dish antennas and testing as I expand my operating capability and knowledge in the microwave bands. I will try to build converts for several more bands and hope to improve on their performance as time permits.

All the drawings needed to build the 10 GHz waveguide shown here are included in the distribution thumb drive for MUD 2019. Multiple cad file formats and PDF files are included.

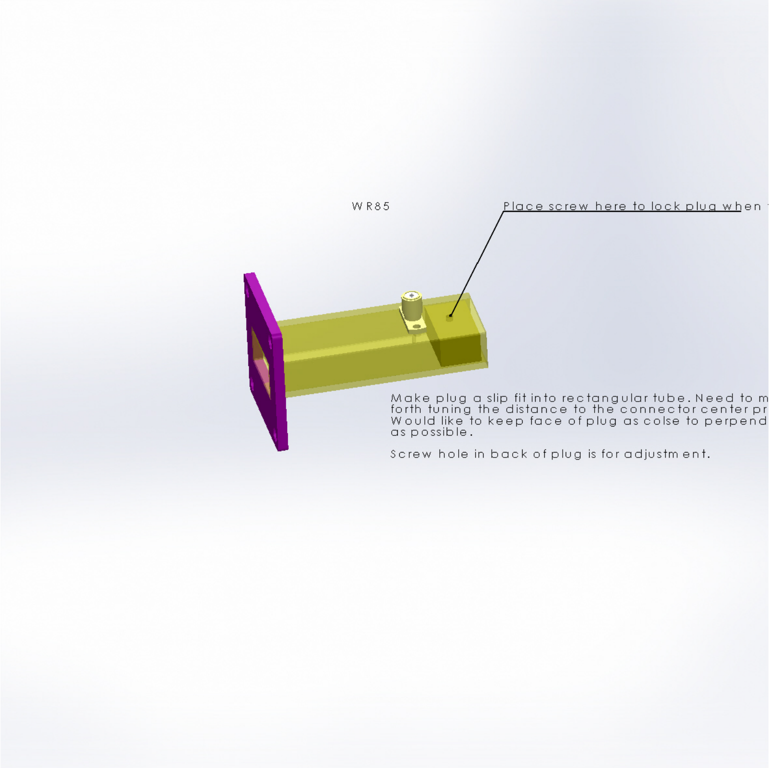
Special thanks to Harold Reasoner, K5SXK for reviewing this paper and the discussion and suggestions that resulted.

References:

1.http://www.w1ghz.org/QEX/Rectangular_Waveguide_to_Coax_Transition_Design.pdf
2. https://www.minicircuits.com/app/DG03-111.pdf
3. https://mcmurraymetals.com
4. https://www.onlinemetals.com
5. "Microwave Engineering" David M.Pozar 3rd or 4th edition ISBN-10: 0470631554
6 https://www.qsl.net/w1ghz/small_proj/small_proj.htm

Plating Waveguide: https://library.nrao.edu/public/memos/temp/Petencin_Plating_Inside_05.pdf
https://www.finishing.com/00/05.shtml
https://www.finishing.com/faqs/silverathome.shtml

Appendix:

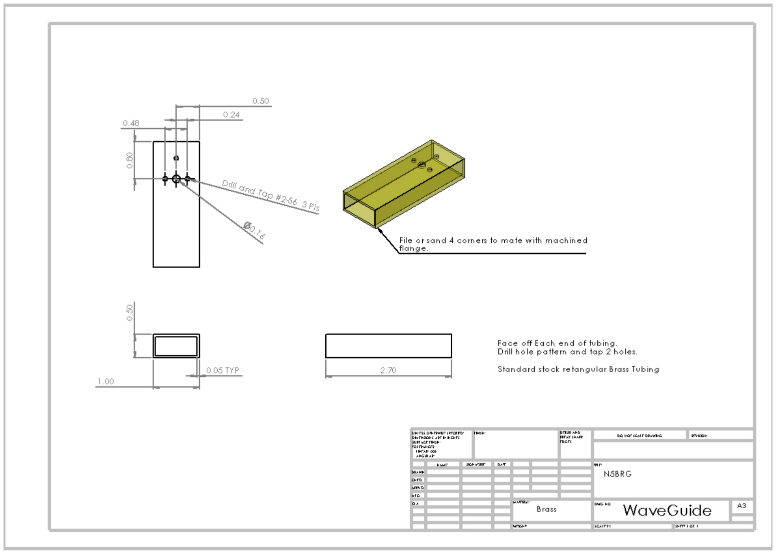


Place screw here to lock plug when

Make plug a slip fit into rectangular tube. Need to m
forth tuning the distance to the connector center pr
Would like to keep face of plug as colse to perpend
as possible.

Screw hole in back of plug is for adjustment.

Figure 10.



File or sand 4 corners to mate with machined flange.

Face off Each end of tubing.
Drill hole pattern and tap 2 holes.

Standard stock retangular Brass Tubing

Figure 11.

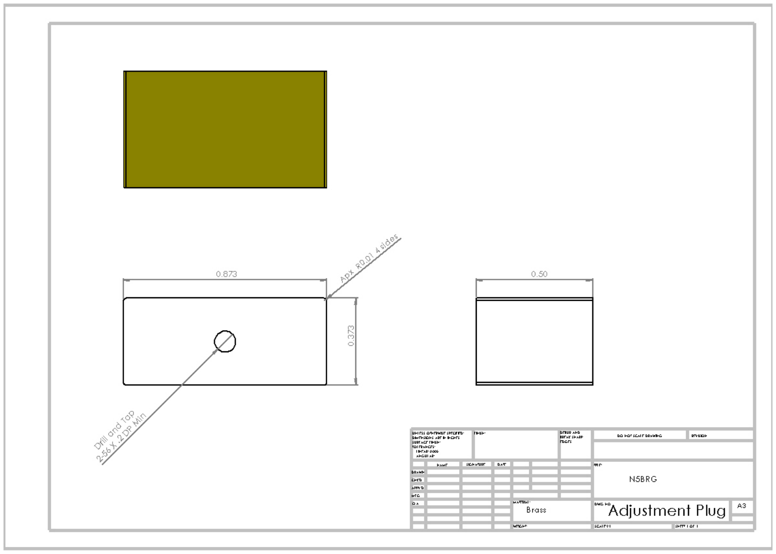


Figure 12.

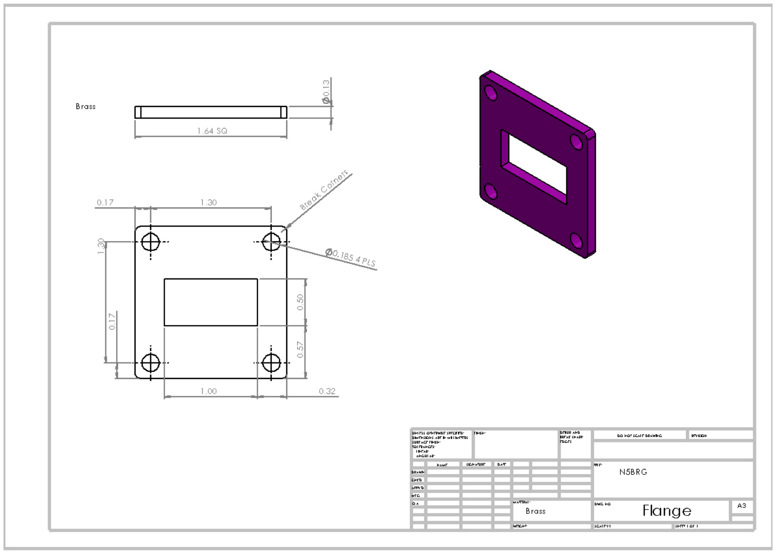


Figure 13.