Using WR90 and WR62 together for 10 GHz

by
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While the standard frequency range for WR62 is generally listed as 12.4 to 18 GHz, its cutoff frequency is 9.486 GHz so it passes 10.368 GHz without excessive loss. In the 1991 MUD proceedings Kent Britain WA5VJB reported in print that he has tested a length of WR62 pieces at 10 GHz frequencies and found the loss reasonable, and in that (and the many times he has repeated that experience at CSVHF and MUD) article he says he heard his first 10 GHz EME signals through a WR62 switch. Others have reported using a WR62 switch at 24 GHz butting WR42 flanges to the WR62 flanges.

The waveguide spectrum between the cutoff frequency and the lowest recommended frequency has a little more loss than the rated frequenty range but not seriously until the frequency is close to the cutoff frequency. The insertion loss at the cutoff frequency is serious but not inifinite. It increases going below the cutoff frequency so that at 1/10th the cutoff frequency the loss is about 10 dB per waveguide width of length. This has been used for VHF and HF adjustable attenuators for at least ¾ century. The LF pass frequency spectrum (between cutoff and the lowest recommended frequency) was not recommended because the wavelength changes more rapidly with frequency the closer to the cutoff frequency and below the minimum recommended frequency the change is rapid enough to wreck radar pulses by changing the velocity of propagation across the pulsed radar spectrum. Radar can't stand modified pulse envelopes and work. But for ham radio modes that diversity of wavelength vs frequency is not really a problem with typical bandwidths under 2 kHz even for digital data.

My question is how far is simply butting from a nice few wavelength waveguide taper? And is there an optimum position for the waveguide walls. Should a corner be aligned or should the smaller guide be centered on the larger guide. My RF Fields text book dosn't attack that, it just shows that a step in the height of a waveguide causes some shunt capacitance across the guide (top to bottom) at the step. And then uses that phenomena to make low pass filters with repeated steps in waveguide height.

I am sure that a several wavelength taper will have the least insertion loss and the greatest bandwidth without any tuning. Its just inconvenient to make well. I have seen literature that suggested such a taper needed to be something other than a straight taper for the greatest bandwidth.

I have considered making such a taper. Might start with a length of WR62 with a flange on one end. Split in the middles of the four faces with a thin saw blade. Then stuff in a wooden wedge to spread the cut ends out (after removing the paint from inside and outside at the large flange end) to fit into a WR90 flange. Then I'd figure on soldering the WR90 flange with high temperature solder. Then file the inside faces and cut edges of the tapered section. Thin I'd cut some copper foil to the tapers different in the two directions, and tin that well with low temperature solder probably on a high temperature hot plate. Then I'd flux the cleaned insides of the split and tapered guide and insert the four pieces (though with a little more calculation it could be fewer pieces and hold them in place with the spreading wooden wedge while heating the taper with that hot plate to solder the foil in place full length.

Or it would take more precision sawing but starting with WR90 and cutting tapers out of the four surfaces so it could be compressed to a WR62 flange. This has been proposed in years past and likely works. Such tapers have been made to extend the frequency range of vintage waveguide power heads so might be found surplus with enough shopping. They were in HP catalogs for a long time.

If the butted flanges prove to show a shunt capacitance that could be tuned out with a capacitive screw located ¼ wave (halfway around a Smith chart) from the flanges in either direction, shouldn't be needed in both directions. That screw could be located ¾ wave from the flanges if it interferred with the flange in the chosen waveguide. Kent admitted to using a three screw tuner in one of his projects. If the effect of the butted flanges is not a simple capacitance, the tuning screw might need to be more complex and in any case the tuned assembly bandwidth will likely be much less than the waveguide bandwidth for either guide. But then for 10.368 activity as I know it needs maybe a MHz or two (for digital operatores to move away from analog operators at the same site) and for only one mode, we need a few kHz bandwidth.

I think the second best adapter would be a short waveguide a quarter wave long (guide wavelength) with dimension A = SQRT (0.400 x 0.311) and B = SQRT (0.900 x 0.622) inches. 0.3537 high by 0.748 inches pretty close to the dimensions of WR75 (0.375 x 0.750 inside).which could probably be an option in experiments. For details see Rad Lab volume 9 page 363 for a WR90 to WR112 quarter

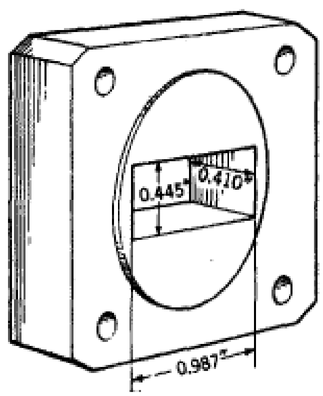


FIG. 6·50.—Quarter-wavelength transformer from 1- by ½-in. rectangular waveguide (0.050-in. wall) to 1¼- by ⅝-in. rectangular waveguide (0.064-in. wall). Army-Navy designation UG-80/U.

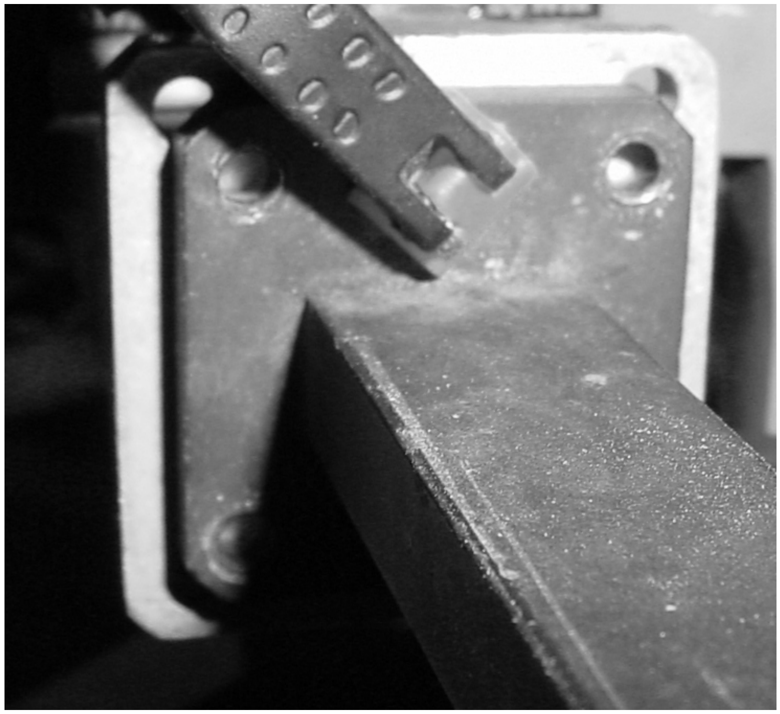
wave transformer.

In this the height is for sure the square root of the products of the two guide heights 0,445". The width is 98.2% of the square root of the products of the two guide widths. The adjacent text says the SWR was less than 1.03 from 3;13 to 3.53 cm. The 0.410 thickness is quarter wave guide wavelength at the center frequency of the design.

Since the flange holes of the WR90 and WR62 don't line up and the WR62 flange isn't small enough to clear the WR90 screws, this quarter wave plate would allow for tapping 8 screw holes to make a neat assembly.

The same page begins to discuss a longer taper and suggests the taper should be an integral number of half waves long. Of course as the guide dimensions change in the straight taper so there is a formula there for computing the physical taper length on page 364 of volume 9. It reports that half wave or full wave long tapers showed a VSWR of under 1.05 over the range of 3.15 to 3.52 cm.

Page 53 of volume 9 talks about the impedance ratio of butting two guides of different sizes.



It is only when one wishes to predict what will happen, when two different waveguides are joined, that the way in which the dimensions enter into an expression for characteristic impedance must be considered. Even in this case, the numerical constant involved need not be specified, since it will cancel out when the expression for the impedance of one waveguide relative to the other is written. Thus, let us join two waveguides whose dimensions are, respectively, a_1, b_1, and a_2, b_2. Assume the dielectrics filling them to have constants μ_1, ϵ_1, and μ_2, ϵ_2, and intrinsic wavelengths λ_1 and λ_2. By any of the relations given above, the impedance ratio will be

$$\frac{Z_1}{Z_2} = \frac{b_1 a_2}{b_2 a_1} \sqrt{\frac{\mu_1}{\mu_2} \frac{\epsilon_2}{\epsilon_1}} \frac{\sqrt{1 - \left(\frac{\lambda_2}{2a_2}\right)^2}}{\sqrt{1 - \left(\frac{\lambda_1}{2a_1}\right)^2}}. \tag{160}$$

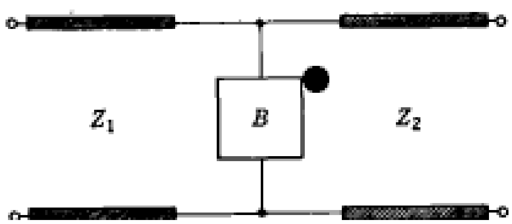
Inserting the dimensions for WR62 and WR90 gives a Z1/Z2 ratio of with a1 and b1 for WR62 and a2 and b2 for WR90. It doesns't compute. The first square root has a value of 1.00000 because the dielectric and magnetic constants are idential in the gwo guides. The WR62 guide wavelength is so much longer than the width of the guide that that comes out as square root of -4.14 of purely reactive, not a resistive ratio.

Volume 9 on page 362 shows an impedance that doesn't depend on such a guide wavelenth value.

Although the concept of characteristic impedance in waveguide is not so well defined as it is in coaxial line, it is convenient to use regular transmission-line theory in determining the dimensions of a quarter-wavelength transformer. Consequently, the following formula for the equivalent impedance of rectangular waveguide in the TE_{10}-mode may be taken from Slater.[1]

$$Z_{equ} = \sqrt{\frac{\mu}{\epsilon}} \frac{1}{\sqrt{1 - \left(\frac{\lambda_0}{2a}\right)^2}} \frac{b}{a} = \sqrt{\frac{\mu}{\epsilon}} \frac{\lambda_g}{\lambda_0} \frac{b}{a}. \tag{23}$$

If this formula is assumed, the equivalent circuit of the discontinuity between the different waveguides is that shown in Fig. 6-48 provided that the change from Z_1 to Z_2 is not too great and that neither waveguide will transmit higher modes.



To find the condition between

Using the right side the Z of WR62 at 10368 is 1.238812 and WR90 is 0.573758 a ratio of 2.159, not trivial.

From the large waveguide side of such a junction, the smaller guide looks like a resonant iris.

Southworth in his book "Principles and Applications of Waveguide Transmission" on page 254 shows a formula for computing the resonant frequency of such an iris.

The Resonant Iris.[24]

As suggested by the composite types of irises shown in Fig. 8.5–1, it is possible to proportion an iris so that at some prescribed frequency the magnitudes of its respective components of inductive and capacitive susceptance will be equal. The iris will then exhibit the properties of resonance and, at resonance, its admittance will be essentially conductive. At frequencies below resonance, it will appear as a substantial negative susceptance; whereas at the higher frequencies, it will appear as a positive susceptance. Such devices occupy very little space and may be incorporated in a waveguide structure to perform numerous useful functions.

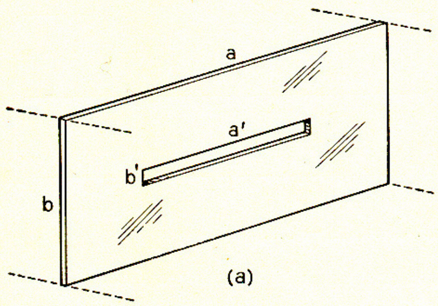


FIG. 8.5–10. Resonant irises of simple rectangular form.

In one simple form, the resonant iris may assume the proportions suggested by Fig. 8.5–10(a). It has been found experimentally that when such an iris is made of metal of moderately good conductivity and is symmetrically placed in a rectangular guide of internal dimensions a and b, resonance will prevail when the dimensions of the iris a' and b' satisfy approximately the equation

$$\frac{a'}{b'}\sqrt{1-\left(\frac{\lambda_0}{2a'}\right)^2} = \frac{a}{b}\sqrt{1-\left(\frac{\lambda_0}{2a}\right)^2} \qquad (8.5\text{–}4)$$

This means that the corners of the resonant iris will fall on two hyperbolas as shown in Fig. 8.5–10(b).

In this form of iris, the Q value, being the ratio of the effective reactance to effective resistance, is a function not only of the losses incidental to a

[24] The more important properties of the resonant iris were contained in a memorandum dated April 30, 1941 by one of the author's colleagues, Mr. A. G. Fox. This memorandum was circulated rather generally among the various research laboratories connected with the Allied war effort, both in this country and abroad. Some of this material will be found in Reference 9.1–1.

I have written a C program to run lambda from 1.2 to 4 cm and to quit when wavelength gets more that twice the a dimension of either guide. No resonance turned up for that frequency sweep. Then I solved the equation for b' to resonate at 10.3681 GHz. It says the height of such an iris would be 0.3655 cm or 0.1427" to look resonant. That might be a matching scheme not ever tried before.

Otherwise the iris appears as a shunt capacitance. So it can be tuned by a capacitive screw a quarter wave from the junction in the WR90 side or an inductive screw in the junction or a half wave wave from the junction.

I have acquired a collection of WR62 pieces including an HP model P810B slotted line, a WR62 termination, and a coax to WR62 adapter and lots more similar parts in WR90 including an X810B slotted line and I have a tunable detector and the main frame for those slotted lines. I use the slotted lines with a 1 Khz modulated signal generator and an HP415E SWR meter as my manual and inexpensive (far less than the price of a modern VNA, I'd rather have a house than one of those) Vector waveguide analyzer. It won't be instant but my time is cheap these days. I want to be sure the WR62 termination has a good VSWR at 10.368 GHz. If it doesn't I'll work on it or another. Then before changing out the slotted line I will try the WR90 termination on the end of the slotted waveguide and see if I can detect effects of alignment on the VSWR and the effects of the connection. Then I'll do the same with the WR90 slotted line and the WR62 termination. With those experiments made I should be able to advise whether butting the two sizes of wavguides needs more complication or that the practice is OK without added complications.

The basic results should also apply to mixing WR42 and WR62 at 24 GHz where WR42 switches are rare and expensive while WR62 switches are easly purchased.

EXPERIMENTS.

My initial experiments didn't go well. Using the WR62 slotted line and the WR62 FXR load the SWR was 1.68:1 at 10368 MHz and the WR90 load was 1.295:1 with the bottoms of the guides in line.

The WR62 load checked 1.76:1 at 10368, 1.4:1 at 11 Ghz, 1.45:1 at 12 Ghz, 1.40:1 at 12,286 MHz.

With the WR90 slotted line the WR90 load matched with a 1.02:1 SWR at 12.286 GHz, 1.001 at 12 GHz, 1.02 at 11, GHz 1.043 or better at 10.368 GHz.

The WR62 load centered on the WR90 slotted line flange had a SWR or 1.52:1 at 10.368 GHz, 1.54:1 with top aligned and centered sideways. 1.44:1 with the sidewall aligned, centered up and down.

I have disassembled the FXR WR62 load and sprayed the slightly conductive plastic terminatioin with graphite paint. That helped, but a long tapered wooden termination in a piece of WR-62 waveguide is giving better results. My good Narda WR90 load showss VSWR of 1.02:1 aat 12,286 GHz on the WR90 slotted line and 1.043:1 at 10.368 GHz.

The wooden load with the WR62 slotted line has a VSWR or 1.16:1 at 12.000 GHz and 1.18:1 at 10.366 GHz. Not perfect but pretty good. A longer taper on the wood insert showed 1.15:1 at both frequencies. With the WR90 slotted line the long taper showed a VSWR or 1.02:1 at 12 GHz but 1.64 @ 10.369 GHz with the apertures centered. So it appears the flange is looking like a resonance iris. Southworth page 254 noted above helps that solution but not completely. My wooden load taper is 3.5" long.

The WR90 flange top to bottom measures 1.625" and 0.620 flange edge to waveguide that is supposed to be 0.4" high. The WR62 flange measures 1.320" tall with it 0.806" from the bottom to the top of the inside of the waveguide. So to make the opening as seen from the WR90 side resonant means the top of the WR64 flange should be 0.348" below the top of the WR90 flange to give a height at the junction of 0.1437" for resonance at 10368. Didn't work, over most of the range of 10,002 GHz to 10.548 GHz the VSWR was over 1.9:1 except at 10.;499 and 10.548 where it was 1.55:1

Wioth the top of the WR62 flnge moved up to 0.294” below the top of the WR90 flange the VSWR at 10.364 was 1.40:1 and at 10.500 1.20:1 and at 10.527 GHz 1.18:1. As good as the load measured with WR62 slotted line.

With the WR62 flange moved up to 0.255” below the top of the WR90 fl;ange the VSWR at 10.370 was 1.38:1 with the best VSWR 1.21:1 at 10.472 GHz.

My last experiment was to align the bottoms of the two waveguides. Not a great result. VSWR at 10.367 was 1.75:1 and the same from 10.352 to 10.3865, 1.3:1 at 11.000 GHz and 1.07:1 at 12.000 GHz

There may be an offset that I didn't try that makes the match good at 10.368 GHz but I didn't fall onto it. I'm sure a tuning screw in the right place will make the match perfect, or the long or short tapers and simply butting the two guides together gives an almost tolerable 1.5:1 VSWR and many a maker of microwave parts claim 1.5:1 is as good as their products match.

I haven't tried the thin iris as illustrated by Southworth.`

The Rad Lab volumes full set are available on line at KO4BB.com and at https://www.febo.com/pages/docs/RadLab/

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