The G5RV Antenna System Re-Visited
Part 3: The Almost-No-ATU G5RV-Type Antenna

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In the mid-1980s, Brian Austin (then ZS6BKW, now G0GSF) addressed the quest left as a nearly mythical heritage of the G5RV antenna system: to develop an antenna system that, for the maximum number of HF bands possible, would permit no-ATU operation of the system with a 50-Ohm coaxial cable as the main feedline. There had been other cousins of the G5RV, such as the W5ANB transmission-line translation featured in *QST* for November, 1981 (pp. 26-27). Serious researchers traced the overall design concept to the 300-Ohm based Collins version of the 1930s. However, virtually all of these cousins satisfied themselves--as did Varney--with moderate impedances that would fall easily in the range of the average antenna tuner. They did not seek to free the user completely from the ATU in multi-band operation.

The ZS6BKW/G0GSF Antenna System

Austin's amateur developments appear in *RADCOM* for August, 1985, and in *Radio ZS* for June 1985, with professional efforts reported in *Elecktron* for June/July, 1986, and the *Journal of IERE (UK)* for July/August, 1987. G3BDQ's *Practical Wire Antennas* volume reports on the amateur version of Austin's antenna on p. 22. Essentially, his task was to find a length and characteristic impedance for a matching section that will transform the impedance at the center of a wire of a given length to something close to 50 Ohms. So we have several variables (using Austin's notation) in combination:

L1: the length of the horizontal wire;

L2: the length of the matching section;

Z2: the characteristic impedance (Zo) of the matching section; and

Z4: the characteristic impedance of the main feedline, which is 50 Ohms for most amateur applications.

By computer calculation, Austin arrived at a workable set of relationships that permitted the largest number of bands to arrive at a direct 50-Ohm feed with an acceptable SWR value. Let L1 approximately equal 204/Flow meters or 669.3/Flow feet, where Flow is the lowest frequency to be used. For a Zo of 400 Ohms, let L2 approximately equal 92/Flow meters or 301.8/Flow feet. Of course, L2 must be adjusted according to the velocity factor of the actual parallel transmission line used. (A 400-Ohm Window line is available from The Wireman of SC).

It is interesting that the sum of the two lengths is about 1% under 1 wavelength. More significant than this accidental result is the fact that the combination of L1 and L2 provides a good 50-Ohm match in the following progression of ratios: 1 : 2.02 : 2.57 :

3.54 : 4.14, etc. If we let the lowest used frequency be about 7 MHz, then we may have acceptable matches on 20, 17, 12, and 10 meters. 5 bands with one doublet and no ATU is no mean feat.

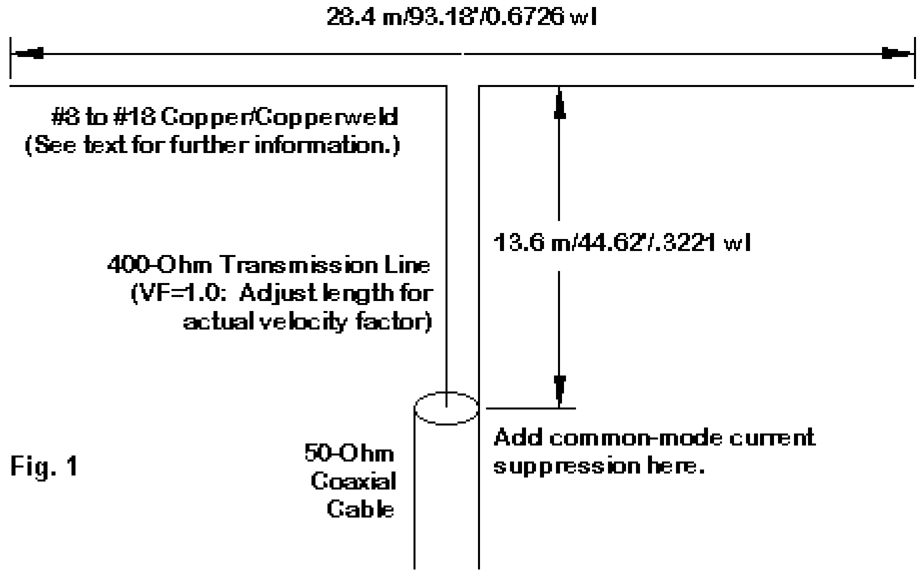

Fig. 1

The ZS6BKW/G0GSF Multi-Band Antenna System

Fig. 1 shows the outline for a ZS6BKW/G0GSF antenna system for 40 through 10 meters. The wire length is 28.4 m or 93.18'. The matching section uses 400-Ohm parallel line and a length of 13.6 m or 44.62'. We shall examine various wire sizes for L1 later, but for the moment we may note the following small table of values for constructing 400-Ohm open wire transmission line using common copper wire sizes.

400-Ohm Open-Wire Transmission Line

Wire Size AWG	Center-to-Center Spacing (inches)	Wire Size AWG	Center-to-Center Spacing (inches)
12	1.137	16	0.715
14	0.901	18	0.567

There are some commercially available vinyl-covered windowed lines that are closer to 400 Ohms than our expected 450-Ohm value. Therefore, if you do not wish to make up the 45' of 400-Ohm line, you may wish to check with vendors. Obtain the velocity factor to determine how much to physically shorten the line to achieve the required electrical length in **Fig. 1**. However, do not rely on the report. Whether you build or buy the match-section line, measure its velocity factor.

The Hayes volume reports the Austin results in the following manner with respect to SWR at the junction of L2 and the main 50-Ohm feedline.

50-Ohm SWR Values for the ZS6BKW Antenna System

Freq. MHz	50-Ohm SWR	Notes
3.65	11.8:1	poor

7	1.8:1	good
10	88:1	very poor
14	1.3:1	good
18	1.6:1	good
21.2	67:1	very poor
24	1.9:1	fairly good
29	1.8:1	good

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Austin used a free-space calculation of the impedance of L1 as the basis for his matching section calculations. It is not clear that the equations factor in either the effects of height or wire size on the quality of 50-Ohm match. As well, the spot checks of the match do not provide us with a good portrait of the operating bandwidth potential for each band.

Consequently, it may be useful to subject the ZS6BKW/G0GSF antenna system to the same sorts of NEC-4 modeling that we used for the G5RV. We shall begin with a basic model using AWG #12 copper wire, placing it in free space and then at heights of 20 m and 10 m (65.62' and 32.81') above average ground. The models produce the following results.

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Modeled Results for the ZS6BKW/G0GSF Antenna System

Free Space

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
80	3.75	13 + j 79	13.23
40	7.15	55 + j 6	1.15
30	10.125	502 + j 1506	>100
20	14.175	42 + j 16	1.47
17	18.118	68 + j 37	1.99
15	21.2	1333 + j 1783	74.36
12	24.94	65 + j 28	1.74
10	28.8	77 + j 7	1.56

20 m/65.62' Above Average Ground

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
80	3.75	16 + j 82	11.68
40	7.15	56 - j 4	1.14
30	10.125	490 + j 1576	>100
20	14.175	43 + j 13	1.37
17	18.118	67 + j 35	1.94
15	21.2	1381 + j 1783	73.69
12	24.94	64 + j 26	1.68
10	28.8	78 + j 6	1.57

10 m/32.81' Above Average Ground

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
80	3.75	11 + j 84	18.03
40	7.15	57 + j 19	1.47
30	10.125	598 + j 1460	83.33
20	14.175	43 + j 11	1.31
17	18.118	67 + j 30	1.81
15	21.2	1305 + j 1920	82.61
12	24.94	67 + j 31	1.83

10	28.8	75 + j 7	1.53

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The modeled values for the spot frequencies coincide quite closely with Austin's initially charted SWR reports. 80, 30, and 15 meters are essentially non-usable. 17 and 12 meters show 50-Ohm SWR values near the limits of where modern transceivers begin to reduce power. However, with most coax runs, the SWR values shown at the transceiver will be reduced as a function of line losses on these bands. The SWR values for 40, 20, and 10 meters are highly promising.

Side note: Examine the SWR values for the free-space and the 20-m models. In both cases, the reactance is identical and high. However, the free-space resistive component is lower than the 20-m value, but the SWR is higher. Newcomers often believe that higher impedance values automatically produce higher SWR values and fail to appreciate the role played in the complex SWR calculation equations of the ratio of reactance to resistance in yielding the final result.

Let's look a bit further into the usable bands by taking 50-Ohm sweeps at each height across the bands. This exercise will give us a bit of insight into the operating bandwidth for the antenna system.

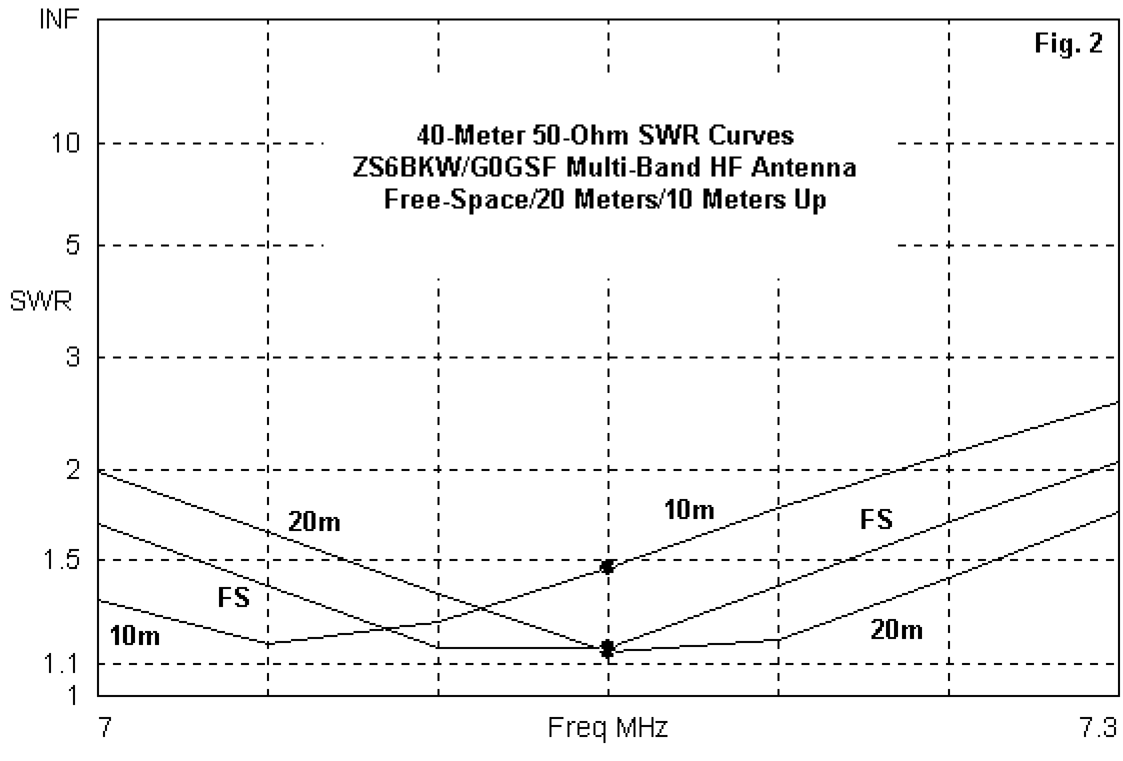
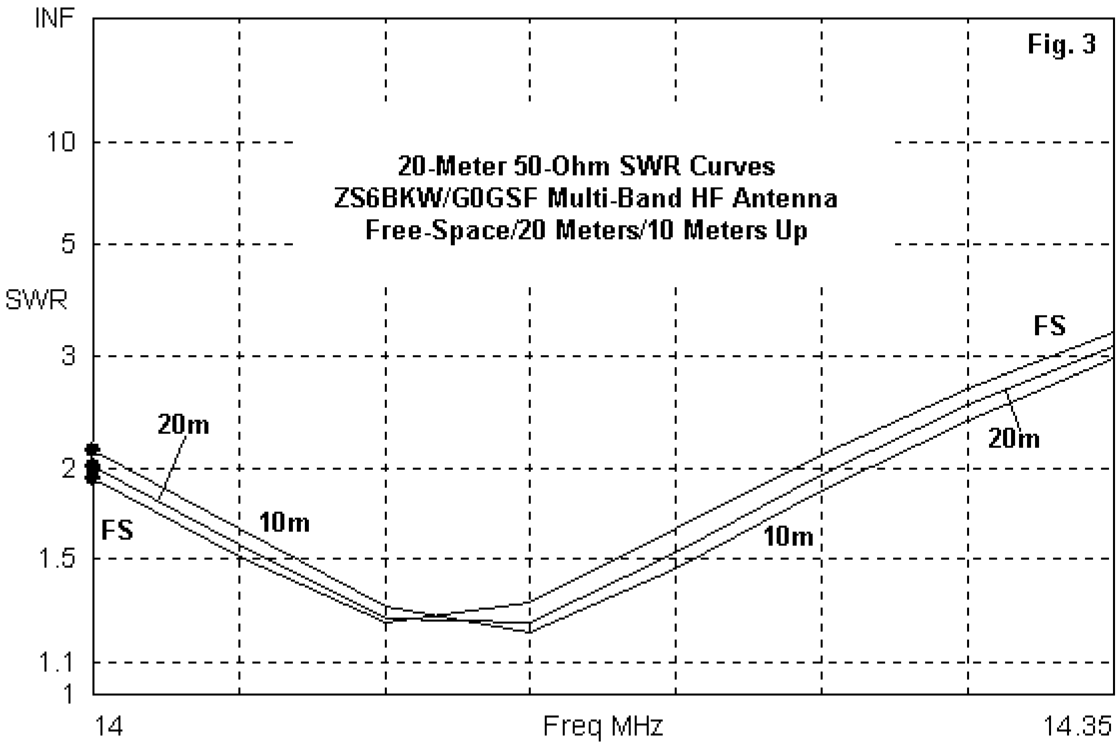
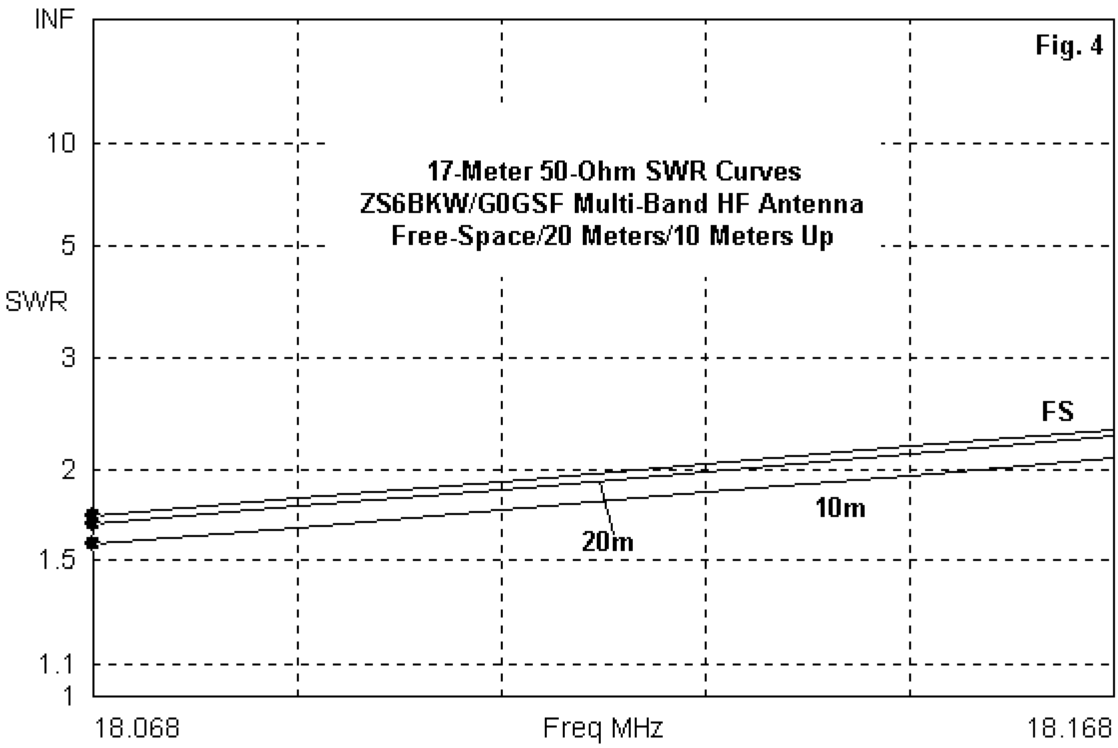


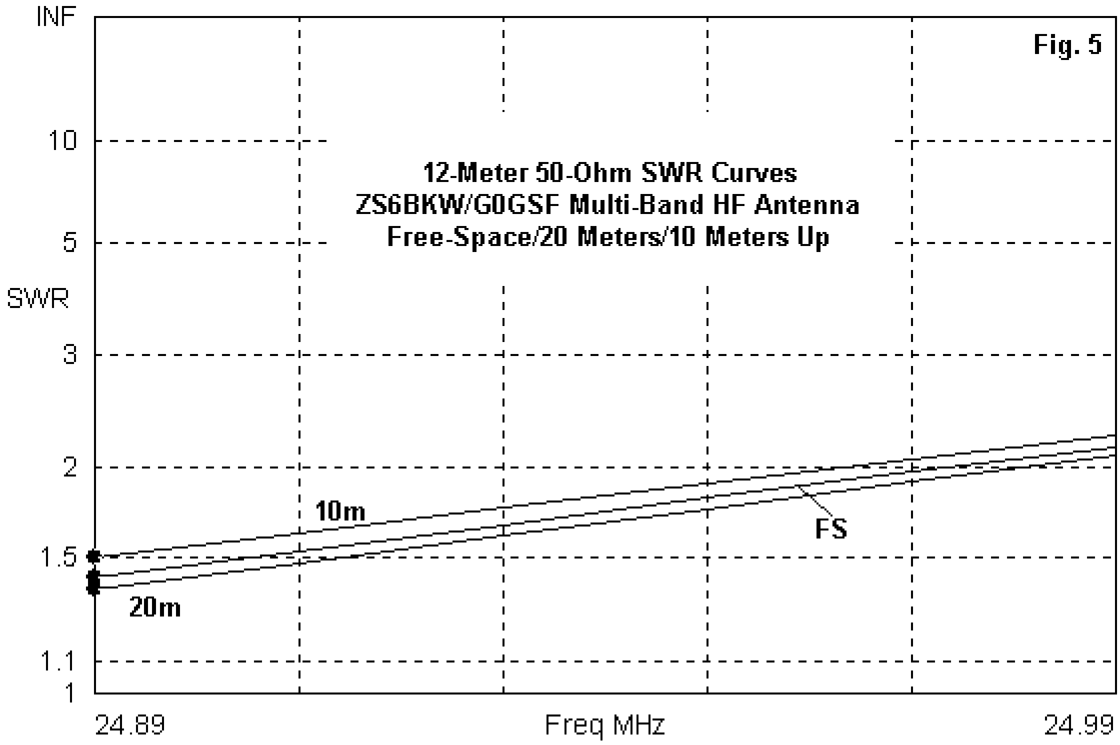
Fig. 2 provides us with a triple sweep of 40 meters. Only the curve for the 20-m height covers the entire band with an acceptable (less than 2:1) 50-Ohm SWR. On 40 meters, that height is about 1/2 wavelength up, while the lower 10-m height is only a quarter wavelength.



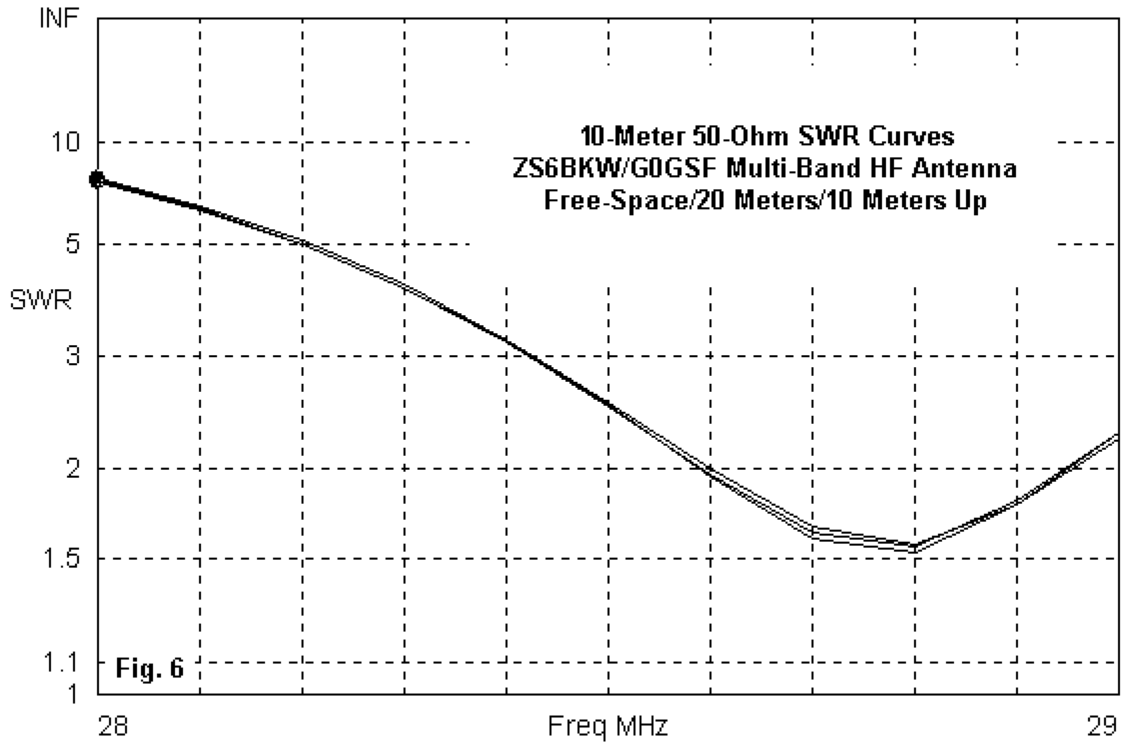
The 20-meter curves, shown in **Fig. 3**, coincide more closely, since the heights are 1/2 and 1 wavelength. The SWR bandwidth favors the low end of the band and is narrower than would be the SWR curve for an AWG #12 copper dipole resonated somewhere in the middle of the band.



The 17-meter band is marginal with respect to a 2:1 SWR bandwidth, as shown in **Fig. 4**. With a length of 50-Ohm coax between the matching section and the rig, the measured SWR near the transmitter would be a bit less, allowing the use of this band without triggering most power-reduction features associated with solid-state final amplifiers.



12 meters (**Fig. 5**) shows a similar phenomenon where the 50-Ohm SWR passes the 2:1 mark within the band. However, for most heights, the SWR is a bit lower than on 17, and the same length of coax would show a bit more loss and hence a bit lower SWR at the transmitter end of the line. Hence, the 12-meter band might prove a bit less problematical relative to triggering power reduction circuitry.



Because the "good-match" frequency ratios are not harmonically related, the ZS6BKW/G0GSF antenna system favors the upper end of the first MHz of 10 meters, as shown in **Fig. 6**. The window is small, but quite usable. If the transceiver has a built-in narrow range tuner, of course, the entire band would be usable, and the marginal and narrow band conditions on other bands would no longer be a problem.

The ZS6BKW/G0GSF antenna system is also somewhat sensitive to the wire diameter. To show this fact, I modeled the antenna using AWG #8, #12, and #18 wire. The #8 selection is fatter than almost all amateurs would use, but--in conjunction with the other wires--it provides a reasonably graphic illustration of the effects of wire diameter on the performance of the antenna system. The following tables provide the spot frequency data for the runs. For this set of models, the height is 20 m above average ground. The unusable bands have been omitted.

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ZS6BKW Performance Data with AWG #8, #12, and #18 Wire

AWG #82

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
40	7.15	61 - j 11	1.31
20	14.175	46 + j 26	1.73
17	18.118	73 + j 30	1.86
12	24.94	67 + j 41	2.11
10	28.8	86 + j 2	1.72

AWG #12

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
40	7.15	56 - j 4	1.14
20	14.175	43 + j 13	1.37

17	18.118	67 + j 35	1.94
12	24.94	64 + j 26	1.68
10	28.8	78 + j 6	1.57

AWG #18

Band Meters	Freq. MHz	Feedpoint Impedance R +/- j X Ohms	50-Ohm SWR
40	7.15	50 + j 7	1.14
20	14.175	40 - j 5	1.29
17	18.118	59 + j 42	2.18
12	24.94	60 + j 7	1.25
10	28.8	68 + j 13	1.46

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Like all other small adjustments to the ZS6BKW/G0GSF antenna system, including changes of wire length, match section length, and match section Zo, the 17-meter match and the 12-meter match tend to show opposite effects. An improvement to one is accompanied by a degradation of the other.

For the wider usable bands, we might again look at comparative 50-Ohm SWR sweeps using the three wire sizes for an antenna wire at 20 m above average ground.

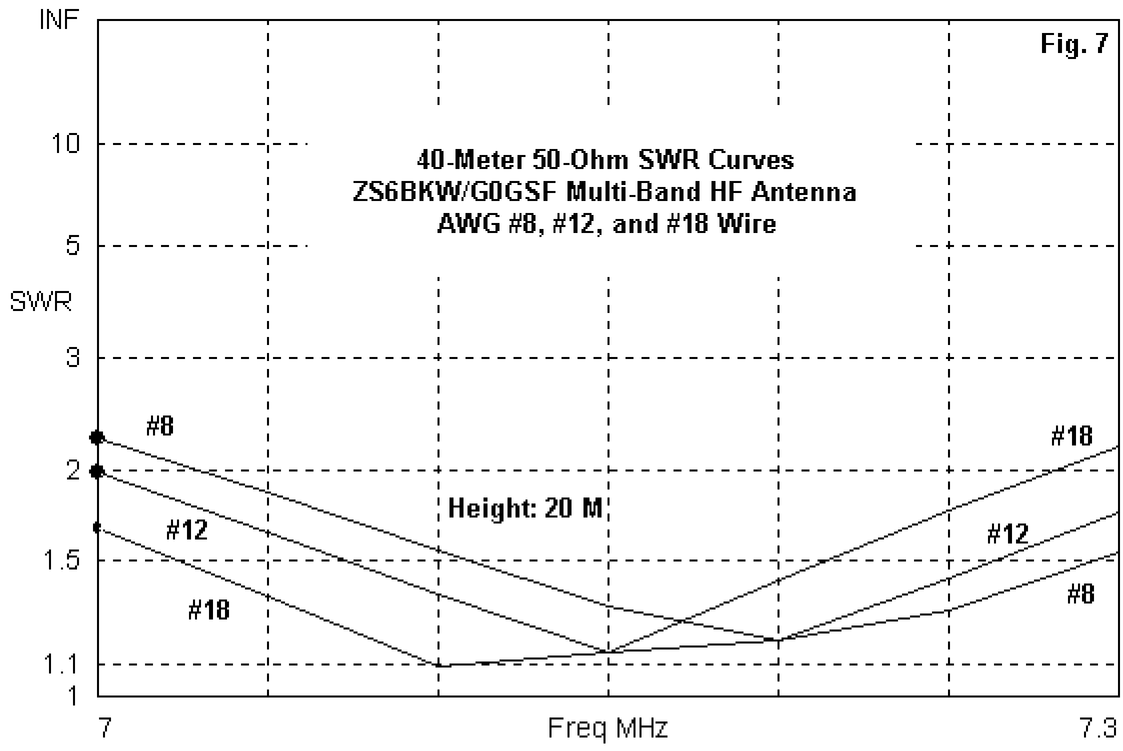
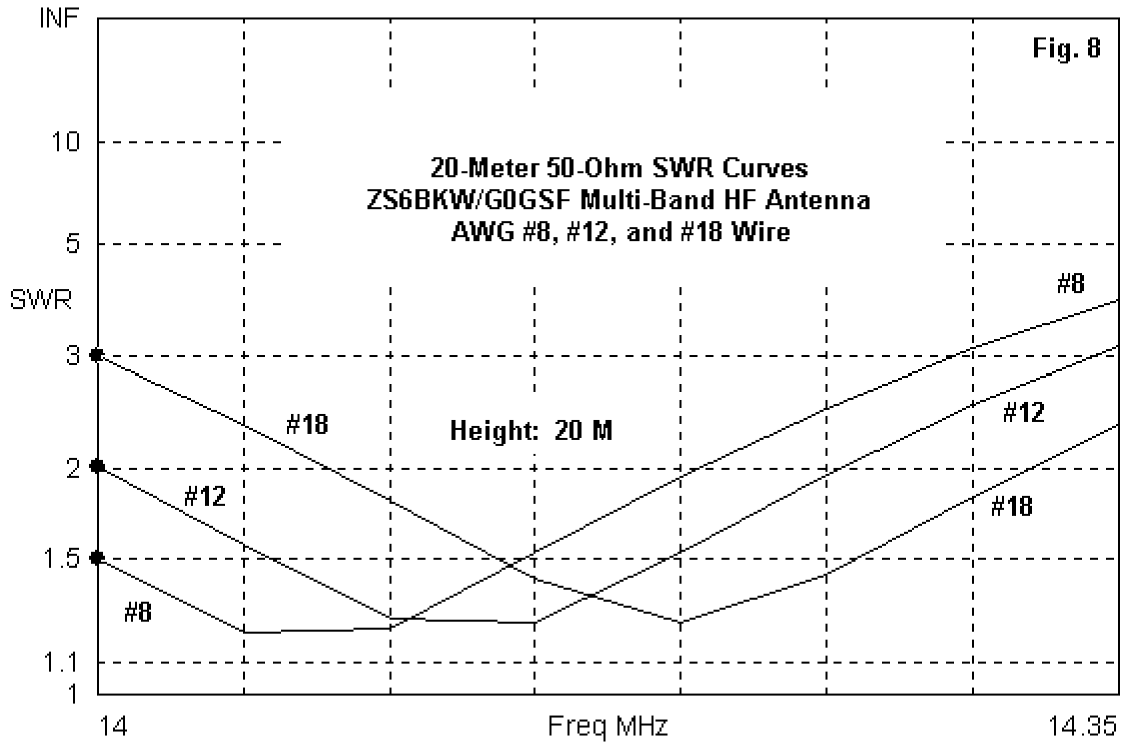
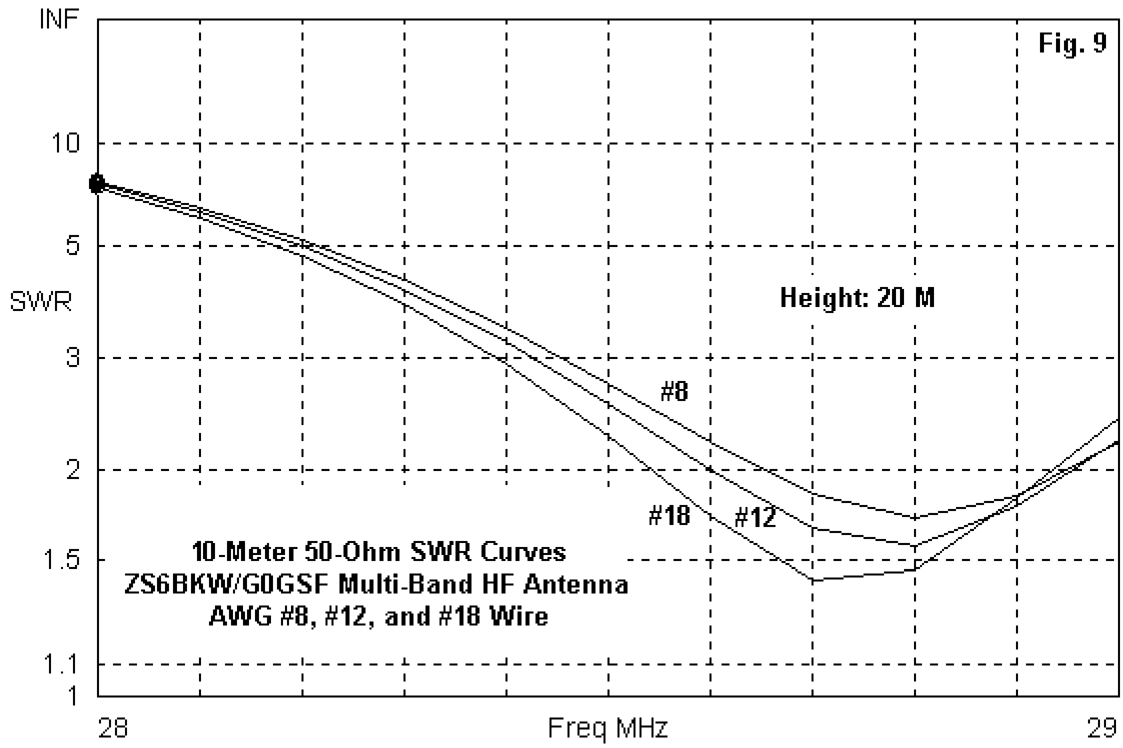


Fig. 7 shows the effects of changing wire diameter across the 40-meter band. #18 through #12 wire seem to show the best promise of full band coverage, although a wire as large as #8 is usable with an in-rig tuner.



See **Fig. 8**: on 20 meters, as the operating bandwidth narrows, the thinner end of the wire scale offer fuller band coverage, with the #18 wire favoring the upper end of the band. Those who use only the low end of the band for CW or digital work might prefer a larger diameter wire for the antenna.



On 10 meters, thinner is definitely better in terms of total operating bandwidth, as demonstrated by **Fig. 9**. However, all three curves miss the popular 28.3 to 28.5 MHz window of major 10-meter activity, along with the "CW" end of the band. In these regions, there is little to choose among the wire sizes, and an in-rig tuner would likely provide the necessary match.

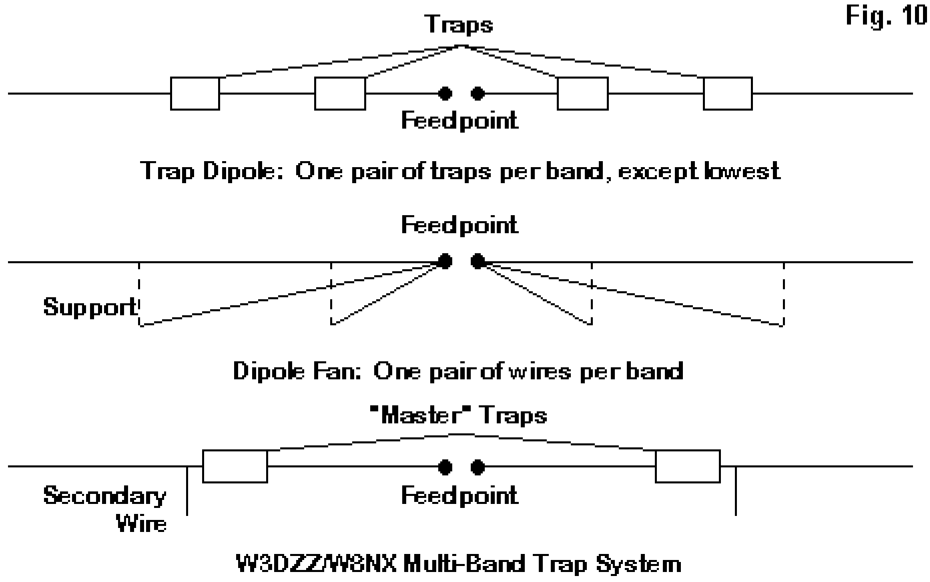
Of the unusable bands--80, 30, and 15 meters--a wide range external ATU would likely provide a usable match on 80 and 75 meters. Since the losses of coaxial cable are low in this band and the SWR loss multiplier for the 10:1 to 13:1 range is moderate, the band might prove to be feasible. The higher losses at 30 and 15 meters, accompanied by very high SWR values, do not bode well for effective use of these bands with the ZS6BKW/G0GSF antenna system. Cable losses may show a lower measured SWR at the transceiver end of the line, and a tuner may effect a match of some sort, but the losses in the cable will remain. As well, the tuner network may operate in a high-loaded-Q condition, further adding to overall losses.

I have not shown azimuth patterns for Austin's antenna system, since those patterns are a function of the radiating wire length. Patterns for a 93' wire and a 102' wire are too similar to need repetition. So you may refer to the patterns in Part 2 for a good idea of where the lobes will go on each usable band with the ZS6BKW/G0GSF system.

Conclusion to Part 3

Of all the G5RV antenna system cousins, the ZS6BKW/G0GSF antenna system has come closest to achieving the goal that is part of the G5RV mythology: a multi-band HF antenna consisting of a single wire and simple matching system to cover as many of the amateur HF bands as possible. From 80 to 10 meters, Austin's system provides an acceptable match on 5 out of the 8 bands under most conditions without an antenna tuner. This is the best result that has been achieved of any of the systems that has come to my attention.

Fig. 10



3 Alternative Multi-Band Doublet Systems for Coaxial Cable Feed

There are at least three other classic horizontal wire antenna designs that are proven performers in terms of using a coaxial cable as the feedline and in requiring no ATU. They are illustrated in **Fig. 10**. One is the trap doublet. One can make a dipole for as many bands as one wishes by using traps to terminate the wire at the desired length for a given band. Of course, the traps between the feedpoint and the termination for the band in use provided loads, so the antenna would be shorter than full size on the lowest band in use. How short it would be depends on the number of bands for which the builder installs traps.

Since the trap dipole or doublet is a semi-true dipole for each band used, it provides a resonant feedpoint impedance close to optimal for 50- or 75-Ohm cable. The exact feedpoint impedance depends in part on a. the terminating trap design and b. the amount of element loading provided by the interior traps relative to the band in use. The patterns will be broadside oval, peanut, or figure-8 shapes--depending upon antenna height in wavelengths above ground. However, when the ratio of the highest to lowest frequencies is greater than 3:1, there may be significant radiation from the outer portion of the antenna at the higher frequencies, resulting in odd lobes relative to dipole expectations.

The advantages that accrue to the trap dipole or doublet are a 50-75-Ohm feedpoint impedance and mostly true dipole patterns. However, the loading of interior traps creates user worries about losses. As well, the L-C traps are weighty and complex compared to the simple light structure of a single-wire doublet. As well, the bandwidth tends to be narrower than for a simple dipole using the same diameter wire.

The second classic design for direct coax feed on multiple bands is the fan of dipoles. One can support in the normal way a dipole for the lowest band to be used. Then, from the same feedpoint, one can run other dipoles suspended beneath the longest one. The more one allows the higher-band dipoles to droop beneath the longest one, the less the interaction of elements and the greater the ease of trimming each dipole to resonance.

As one adds bands to a single fan structure, the heavier it becomes, with more area to intercept the wind. Hence, durability becomes a significant issue relative to a simple doublet. As well, the initial trimming of the dipole lengths tends to become more finicky, and the operating bandwidth narrows relative to a single dipole for the same band.

A third system, pioneered by C. L. Buchanan, W3DZZ, uses a single trap each side of the feedpoint to provide multi-band coverage. Al Buxton, W8NX, extended the technique. The required traps demand careful construction and placement, and band coverage is not complete. Moreover, the patterns on all bands are not completely predictable by reference to the wire length, since interactions may exist between the inner and outer sections of the wire. Nevertheless, such antennas are capable of covering several bands with acceptable SWR levels on a single coaxial cable feedline.

These classic one-coax-feedline antennas provide part of the rationale for pursuing the G5RV myth of a single doublet for many bands with a single coax feedline and no ATU. A single doublet is mechanically simple for good durability. Operation without an ATU removes one box from the operating desk or field table. The belief that the G5RV antenna system itself could attain these goals--which it could not--literally invented the demand for an antenna that could. And that created the pursuit of techniques that would find a combination of wire length and matching section characteristic impedance and length to come closet to the goal.

These notes are not designed to recommend a particular multi-band wire antenna system to the potential user. There are too many situational variables for me to do much more than mislead someone. Instead, these notes are designed to clarify to some degree the capabilities of the G5RV and the ZS6BKW/G0GSF antenna systems so that you can have reasonable expectations of them. Understanding an antenna system is one way of overcoming the mythology that spreads itself in truncated conversational claims and in advertising.

The G5RV antenna system comes in many commercial packages, simply because it is cheap and easy to produce in a kit. A length of wire, a length of parallel feedline, a few insulators, and a couple of junctions form a low vendor cost high profit item. If all vendors were both honest and knowledgeable, they would label such kits with a warning to use with an ATU. If they wish to sell kits for use without an ATU, they might well consider packaging the ZS6BKW/G0GSF system instead. But even then, they should clearly identify the non-usable bands. (A commercial version of the ZS6BKW/G0GSF antenna system is available from The Wireman of SC.)

Antenna systems using a wire and matching system are but one route to HF all-band antenna service. A simple doublet, parallel transmission line, and an ATU is still an effective system, although truly balanced ATUs are difficult to find. For coaxial feedlines, we have briefly noted three alternative systems that move the complexity of a tuner to the antenna end of the line in the form of traps or multiple dipoles. Selecting the all-band wire antenna system, in the end, depends on the user's careful definition of his needs, limitations, and desires. Some understanding of the requirements of each competing system also goes a long way to assisting the decision-making process. These notes hope to have added a bit to understanding the single-wire-and-matching-section system of achieving multi-band HF operation.