Radio FUNdamentals

BY BILL ORR, W6SAI

THINGS TO LEARN, PROJECTS TO BUILD, AND GEAR TO USE

The G5RV Antenna Revisited—Again

Yes, you hear a lot of them on the air and they put out good signals, no doubt about it. But judging from some of the conversations I've heard, there's a lot of voodoo theory floating around about this unusual antenna. Is it really a multiband antenna? Does it have low SWR on all the bands? Does it need, or not need, a balun? Does it reduce TVI? Is it as good as a Yagi beam? What are the optimal dimensions of the antenna?

Well, being a true experimenter, I decided to try a G5RV, so I did what any true investigator would do: I bought one. This is the story of what I learned about this interesting sky wire.

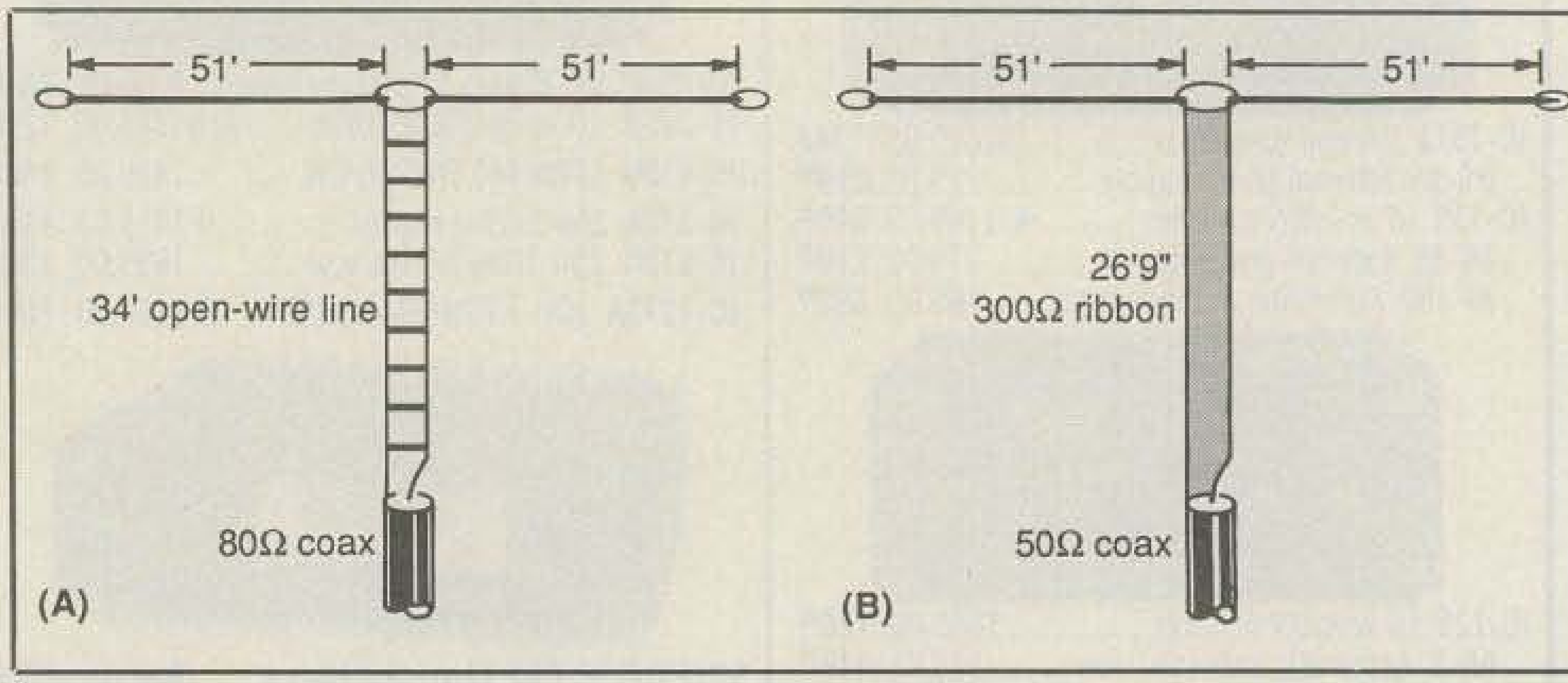

Fig. 1– (A) Original G5RV antenna with open-wire line and 80 ohm coax. (B) Revised G5RV with ribbon line and 50 ohm coax.

The Early "G5RV" Antenna

To go back a bit, the G5RV antenna is an offspring of a 3-band antenna (80-40-20 meters) designed by Art Collins (ex-W9CXX) and L.M. Croft and described in detail by Croft in the December 1935 issue of *Signal* magazine, the house publication of the old Collins Radio Company. (Thanks to Bill, K6HV, for supplying me with a copy of the article.) The idea behind the antenna was sound, but the execution was a failure because the antenna used a 300 ohm matching section made of two 82.5 foot lengths of aluminum tubing hanging from the center of the 103 foot flap-top. The weight of the installation made it heavy and impractical. Signal gain of this antenna was about 1 dBd.

In the early 1950s the antenna reappeared in modified form in England, redesigned and popularized by R.L. Varney, G5RV. The Varney antenna (fig. 1A) functions as a 3/2-wave antenna on 14 MHz with a feedpoint impedance slightly over 100 ohms. The matching section of heavy tubing is replaced by a 450 ohm open-wire half-wavelength line. This light-weight transformer closely matched the antenna feedpoint impedance to an 80 ohm transmission line on 20 meters. It is a single-band, practical antenna that can be built easily and cheaply by any amateur who can handle a tape measure and a soldering iron.

Although designed for 20 meters, it was quickly found that the G5RV antenna would function quite well on other bands if an antenna tuning unit (ATU or Transmatch) was used at the transmitter. No one worried much about SWR in those days.

By the time the antenna crossed the Atlantic, it was modified to use a 300 ohm ribbon matching line (no one built open-wire lines anymore) connected to a 50 ohm coax transmission line (80 ohm coax was not available in the USA). That's when problems developed, aided in part by the widespread use of the SWR meter.

A lot of amateurs built and used the modified G5RV (fig. 1B). Some of them reported good results, while others could not get the antenna to load properly. No one was sure what the SWR readings meant, as they varied from shack to shack for supposedly the same antenna design. What did this all mean? What was going on?

Various versions of the G5RV have been described in the amateur magazines and different designs are advertised for sale. Some use a balun transformer to match to coax, while others do not. No specific make of 300 ohm line was universally used,

Band	Freq.	SWR
80 m	3.5	6.3
	3.6	4.98
	3.7	4.47
	3.8	4.66
	3.9	4.76
	4.0	5.67
40 m	7.0	2.65
	7.1	3.05
	7.2	3.67
	7.3	4.50
20 m	14.00	1.83
	14.10	2.15
	14.20	2.64
	14.35	3.28
15 m	21.00	5.90
	21.10	5.86
	21.20	5.71
	21.30	5.66
	21.45	5.69

Band	Freq.	SWR
10 m	28.0	4.83
	28.2	4.81
	28.4	4.42
	28.6	3.99
	28.8	3.64
	29.0	3.34
	29.2	2.58
	29.4	2.29
	29.6	1.94
	29.7	1.88
WARC Bands		
30	10.1	8.50
17	18.11	1.84
12	24.95	4.52

Representative G5RV Antenna

Table I– Results of the G5RV checks on all bands (including 10 MHz).

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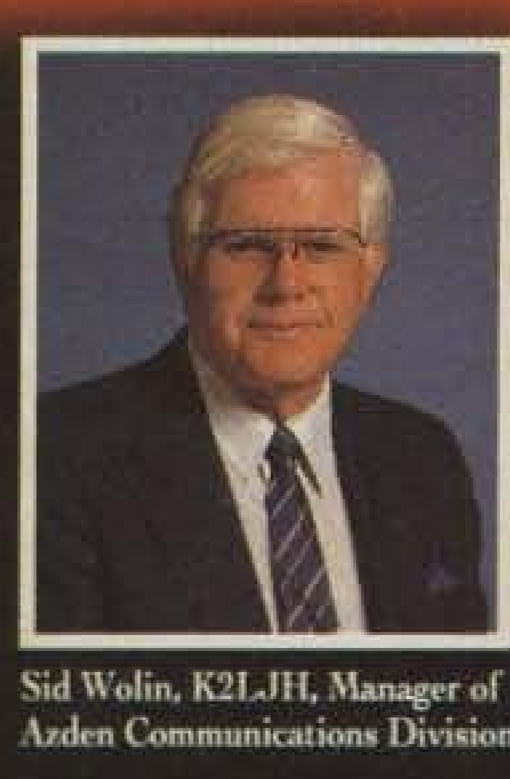

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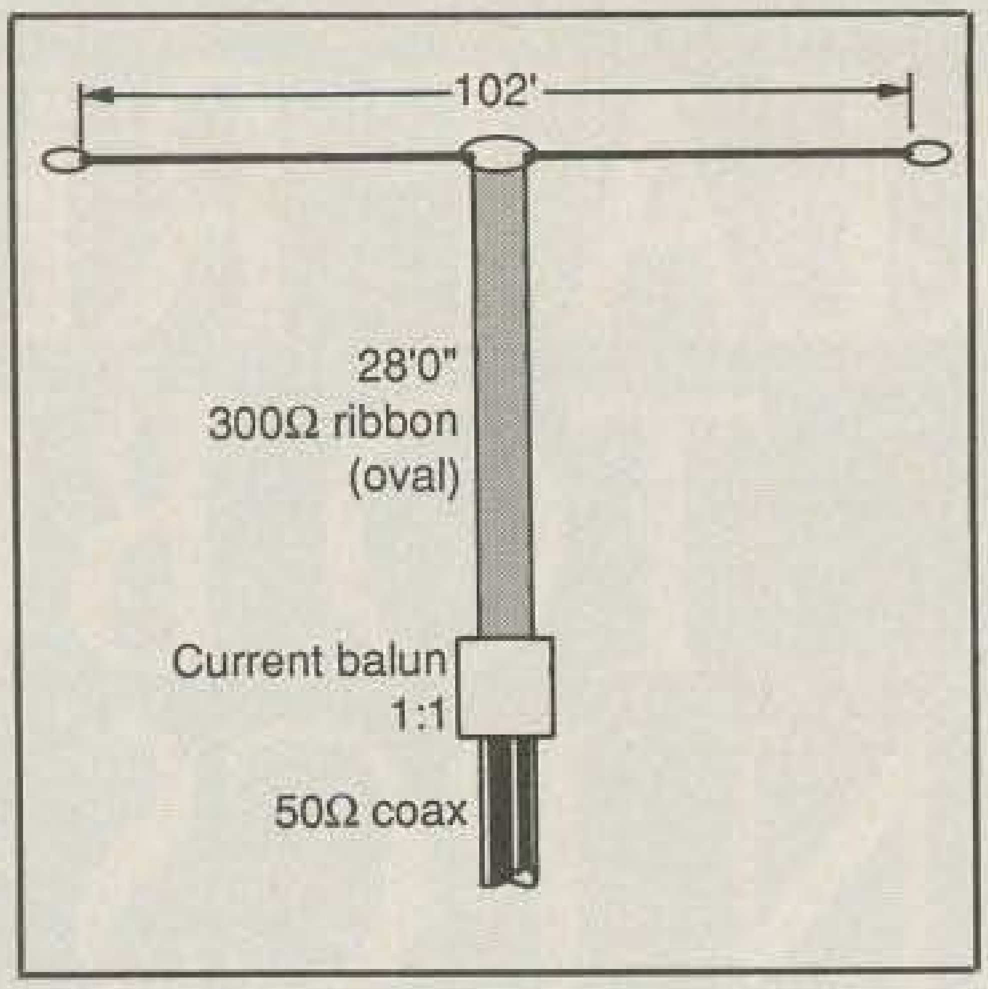

Fig. 2– Revised G5RV with current balun and modified ribbon line.

and there were as many different types of line as there are fleas on a dog. It all depended upon the economics of the manufacturer who built the line. And there was plenty of bad line available.

There didn't seem to be a single design I could point to and say, "That's the real G5RV antenna!"

Checking a G5RV Antenna

The antenna I bought had conventional dimensions plus an "in-line transformer" (balun) which went between the ribbon line and the coax (fig. 2). The instructions stated the antenna covered 3.5 through 30 MHz except 10 MHz. It suggested the antenna be mounted one full wavelength above ground on the lowest frequency for which the antenna is to be used. For 80 meters this would be about 270 feet in the air! The instruction sheet modified this suggestion, saying that this height is impractical in most installations, and urged the user to put the antenna as high in the air as he can. It also recommended that the feedline be brought down vertically to the ground before leading it away at an angle, or parallel to the antenna.

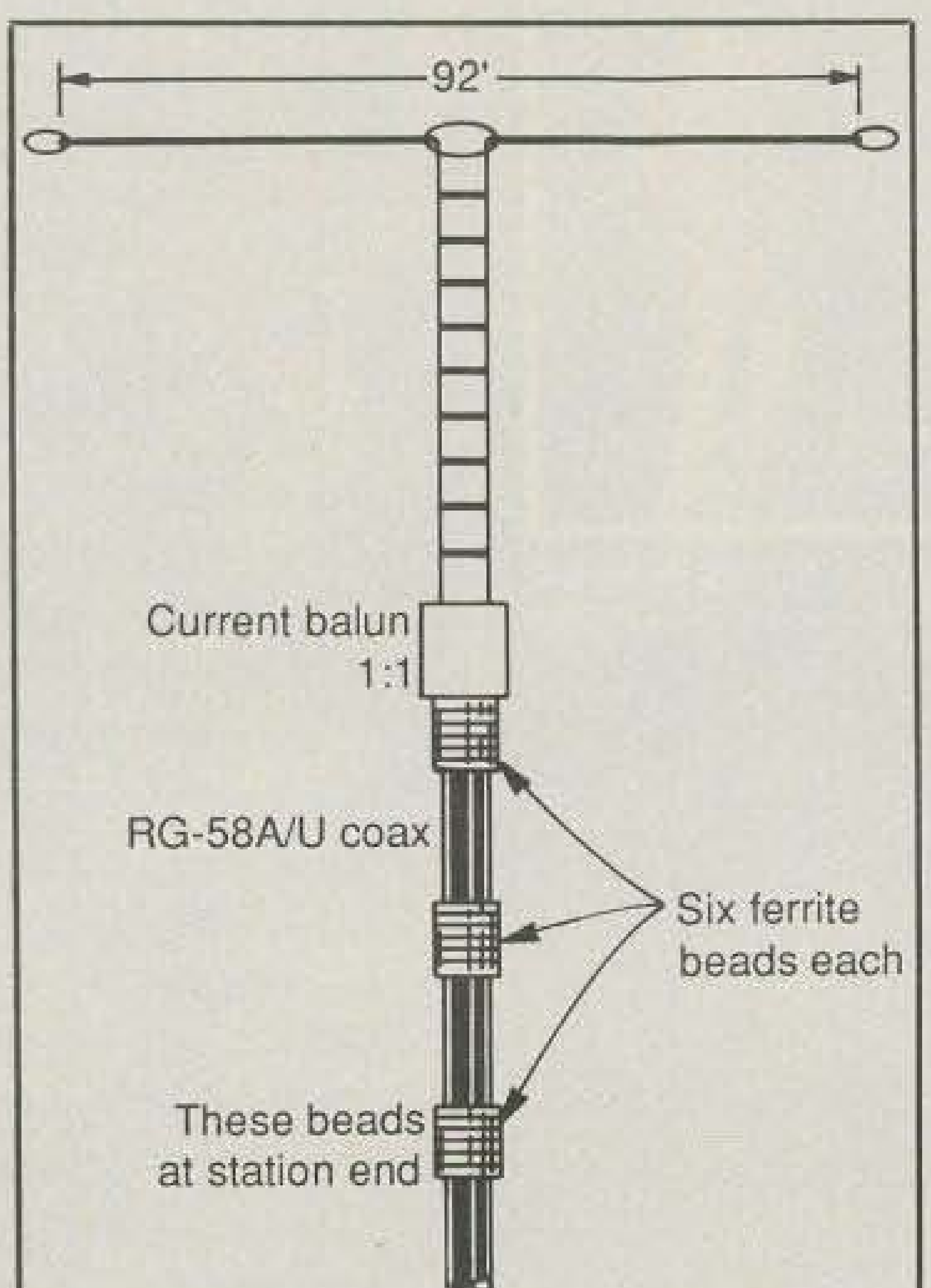

Fig. 3– The modified ZS6BKW multiband antenna with ferrite "sleeves" added to "cool off" coax line. Use Amidon 77-1024 (Type 43) beads for RG-58A/U coax, and Amidon 43-1024 for RG-8/U coax.

My installation of the G5RV was typical: almost 45 feet high at the center and about 30 feet high at the ends. I brought the feedline down vertically as directed and then ran the coax a few dozen feet to my test instruments. At no point did the line run parallel to the antenna. A little extra coax was coiled up into a simple RF choke to suppress extraneous currents that might flow on the outside of the shield.

My test equipment consisted of an HP-606A signal generator, GR-916A precision RF bridge, and a Kenwood R-2000 receiver which acted as a null detector. The G5RV was checked on all bands (including 10 MHz) and the results are given in Table I.

Interpreting the Results

The readout of the RF bridge is in terms of R (resistance) and X (reactance) at the instrument end of the coax line. A computer program changed these figures into SWR values. The coax line was about 50 feet long and to simplify matters it was assumed there was no signal loss in the coax. Measurements were made every 100 kHz across the bands (every 200 kHz on 10 meters). A separate program for my computer was at hand which would determine the feedpoint impedance at the antenna, provided the line constants and length were known, and also translate R and X into SWR.

On 80 meters the measured SWR across the band was quite high, but the G5RV worked well when used with my station equipment and an auxiliary ATU. Tuning of the ATU was very sharp, and the unit required readjustment when the operating frequency was over a few tens of kHz. Reports for the G5RV roughly corresponded to those received when a dipole was used.

On this band, a portion of the flat-top is folded back into the 300 ohm line. Possible heating of the line may be experienced if high power is used. I only ran 150 watts, so I had no such difficultly.

On 40 meters the SWR was much lower and the ATU was required only on the high end of the band. Reports were excellent. However, no comparison antenna was at hand. Stations on my weekly sked with southern California noticed no discernable difference from my signal of weeks previously using a dipole, as compared with another local amateur.

SWR on 10 MHz was very, very high. No wonder operation on this band was not recommended! I crossed this band off the operating list.

As for 20 meters, the SWR started out at less than 2-to-1 on 14.0 MHz and increased slowly as the operating frequency was raised. The ATU was required at the very high end of the band. Plenty of overseas DX was worked with the G5RV and it seemed as good as a dipole. Maybe slightly better.

Eighteen MHz operation was very good, with a low value of SWR. No ATU was required. Again, I could note no long-term difference between this antenna and a good dipole, except that the G5RV pattern was better than the dipole in the directions near the ends of the wires. Theoretical gain over a dipole in the favored direction is about 1.2 dB.

SWR was high on 21 MHz and an ATU was required. Even so, the antenna sounded "flat" on this band and signal reports received were poor. Operation was passable, but not a good as my quarterwave vertical. I'd rate the G5RV a "D" score on this band.

Twenty-four MHz also showed a high value of SWR. It seemed that the antenna was a poor performer on this band also. I did work a few stations, but the reports were mediocre.

Ten meters exhibited a very high SWR at the low end, gradually decreasing as the frequency was raised, until it fell below 2-to-1 at the high frequency end of the band. The band was poor, so it was difficult to evaluate the antenna. Theory says the antenna is quite directional off the ends on this band. Theoretical gain is about 2 dBd. An ATU is recommended for general operation.

What Does It All Mean?

Well, the bottom line is that the G5RV design functions on all amateur bands between 80 and 10 meters, with the exception of 10, 21, and 24 MHz. SWR is not really low on any band, despite some claims.

It was found that the SWR on any one band could be improved at the expense of the SWR on other bands by shortening or lengthening the 300 ohm ribbon matching section. It was also noted that the SWR could be changed for the better on a particular band by moving the coax about with respect to the plane of the antenna. Finally, it was found that an "isolation transformer" or 1-to-1 current-type balun is a necessary requirement at the point the ribbon line meets the 50 ohm coax line or SWR readings would change drastically with changes in coax cable length. Again, running the coax parallel to the antenna resulted in odd-ball SWR readings.

SWR readings at the station proved puzzling. On 20 meters they correlated nicely with the measurements made with the RF bridge. On 10 meters the readings were higher in the station; on 40 meters they were lower. On 80 meters they were higher at the high end of the band and lower at the 3.5 MHz end.

All this was very perplexing. The SWR readings seemed to be a function of coax line placement and length of the line. I believed the RF bridge readings more than the SWR readings as they were made under the best possible conditions (short coax line running at right angles to the plane of the antenna), whereas I doubted the reliability of the SWR readings taken with a traditional wattmeter at the far end of a long, randomly placed coax line.

I was finally able to reproduce the bridge measurements to a good degree on the wattmeter after I placed ferrite cores along the line to the shack. A group of cores were moved along the coax until they seemed to isolate the line from the antenna field (fig. 3). Readings settled down after that and generally resembled the readings made by the RF bridge.

Lessons Learned Regarding The G5RV Antenna

1. A current-type 1-to-1 balun should be used to connect the ribbon line to the 50 ohm coax.

2. Placement of the coax feedline with

relation to the antenna is critical, and SWR will change with line position.

3. If the G5RV is slung from a yardarm on a metal tower, the ribbon line should be spaced at least 3 feet clear of the tower.

4. A good match on any one band can be made by shortening or lengthening the ribbon line a few inches at a time. But this advantage is only achieved by a poorer match on some other band.

5. The SWR cannot be changed by changing coax length if the line is properly decoupled from the field of the antenna, but the impedance at the station end of the line can be altered by varying line length to provide the best match to the transmitter. If the SWR at the transmitter changes when line length is changed, it is an indication that there is coupling between the outer shield of the line and the antenna. Groups of ferrite slugs placed along the line at intervals will help reduce this effect if it annoys you.

6. Tube-type rigs with an adjustable output circuit have greater loading range than do solid-state transmitters. In many cases the tube-type rig can be used with the G5RV without requiring an auxiliary ATU.

7. It is a good idea to decouple the outside of the line at your transmitter. Do this by slipping six ferrite beads over the coax shield before you place the plug on the line. Type 43 beads (Amidon #43-1024 for RG-8 coax) will do the job. (Use Amidon #77-1024 for RG-58 coax.)

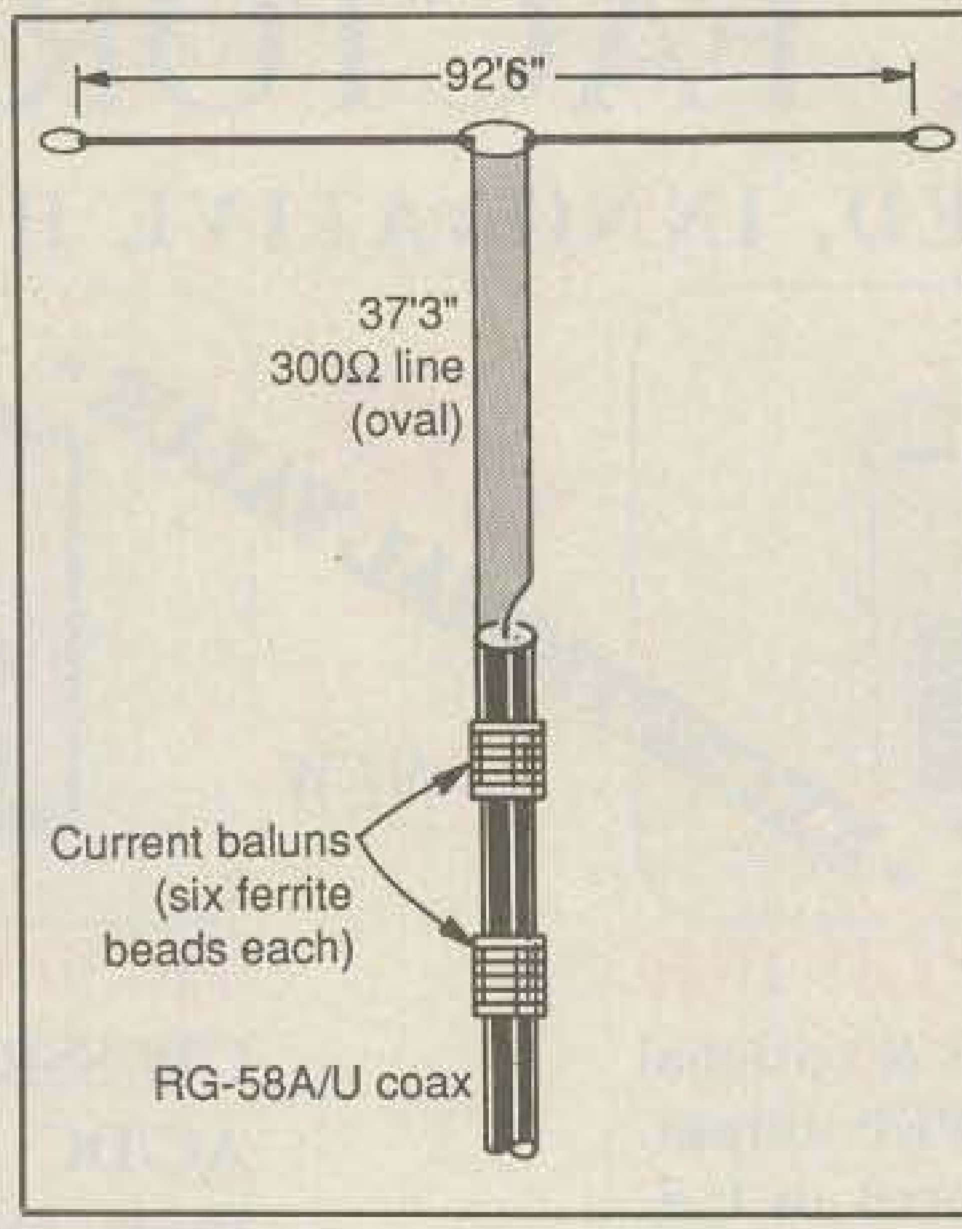

Fig. 4– The W6SAI version of the ZS6BKW version of the G5RV antenna! Normal details covering waterproofing of coax to ribbon connection apply.

8. Finally, the G5RV functions as an "all-band" antenna (less the 10, 12, and 21 MHz bands), but an ATU is usually necessary unless a lot of time-consuming pruning and trimming of the ribbon line is done. Even then, transmitter matching at the station will only improve one band at the expense of another.

Bottom line: The G5RV is a popular antenna and a lot of DX can be worked with it. It has a little gain over a dipole on the higher bands, but not much. If you have a modern rig, be prepared to buy an ATU to make the antenna work properly (unless your rig has an ATU in it).

A Different G5RV Design

Can the G5RV antenna be improved to reduce the SWR on the transmission line and/or provide better SWR bandwidth? The G5RV has been around a long time, and many attempts have been made to make it a better performer on the HF bands. The most promising results I know of are those of Dr. Brian Austin, ZS6BKW, of the University of Edinburgh, Scotland (see his article "Computer-aided Design of a Multiband Dipole," *Radio Communication*, RSGB, August 1985, pp. 614–617). Aided by a computer program and field tests, he varied dimensions of the G5RV design, trying to achieve a reasonably low value of SWR response on all major HF bands.

The ZS6BKW design utilizes a 50 ohm coax line and either a 400 ohm open-wire line, or a 300 ohm ribbon line. Unfortunately, the design does not incorporate a balun between the coax line and the balanced line transformer so the SWR measurements run on this design may be open to question.

Band	Freq.	SWR
	3.5	7.68
	3.6	6.26
80 m	3.7	5.25
	3.8	4.43
	3.9	4.36
	4.0	4.60
	7.0	1.72
	7.1	1.95
40 m	7.2	2.77
	7.3	3.00
	14.0	2.50
	14.1	2.20
20 m	14.2	1.76
	14.3	1.38
	14.35	1.42
	21.00	4.96
	21.10	4.94
15 m	21.20	4.72
	21.30	4.70
	21.45	4.70

Band	Freq.	SWR
	28.0	3.38
	28.2	3.49
	28.4	2.92
	28.6	2.53
10 m	28.8	2.11
	29.0	1.69
	29.2	1.48
	29.4	1.68
	29.6	2.40
	29.7	2.55
	WARC Bands	
30	10.1	8.11
17	18.11	1.11
12	24.95	2.75

Representative W6SAI Antenna

Table II– SWR data for the 40, 20, and 10 meter bands for the W6SAI version of the ZS6BKW version of the G5RV.

Alas, I could not by a ZS6BKW antenna, so as a last resort, I built one. As I went along, I discovered that the velocity of propagation of 300 ohm ribbon line varies from the accepted figure of 0.82, depending upon who manufactured the line and the physical shape of the cross-section of the line. I found I had to add 6 inches to the original BKW line dimension to get best results. Also, a 1-to-1 current balun at the bottom of the line is a necessity. My final dimensions are shown in fig. 4. The SWR date for the 40, 20, and 10 meter bands are shown in Table II. The SWR on both the 18 and 24 MHz bands is very good, but the SWR response on the 80 meter band is about the same as with the G5RV, and an ATU is required. Ferrite beads should be used to "cool off" the coax line.

As with the earlier G5RV design, physical placement of the coax line and its length can determine the SWR at the transmitter. For those amateurs wishing a slightly shorter antenna, or those dissatisfied with the generic G5RV design, this antenna may be an acceptable alternative. The ribbon line can be trimmed for best results on one band. Once the dimensions are adjusted for your particular installation, you will find this a very satisfying antenna.

The New MN 4.5 Antenna Analysis Program

Brian Beezley, K6STI, introduced his updated MN Antenna Analysis software (MN 4.5) at the ARRL National Convention in Los Angeles in late August. I managed to obtain a disk and have supplanted my old program with the new one, which incorporates many advancements. It features antenna plot overlays on the screen, faster loading of files, optional thick plot traces, and other features which make it easier to use and faster to run. A companion program, MNH, models very large antennas and complex antenna systems which otherwise would require the use of a mainframe computer. A second auxiliary program, GUY, makes it easy to investigate the effect of guy wires on antenna systems. If you tell GUY where guy wires are attached and anchored, and how they are broken up, GUY generates a complete system model when combined with an antenna file. Interaction between guy wires and the antenna can be fully investigated, and you'll quickly arrive at an optimum guy-wire configuration that won't screw up your beam pattern. (See Antennas & Accessories column this month.)

Shucks, the new programs spoil the whole idea of fiddling around for days, up and down the tower, back and forth, until things work—maybe! All the fun of antenna building is gone! However, if results count with you, the K6STI programs are the way to go. For more information, contact Brian Beezley, K6STI, 507½ Taylor St., Vista, CA 92084, or call 619-945-9824 during 0700–1800 Pacific Time.

The Dead Band Quiz

Well, every time I think I have outsmarted the readers of this column, I find they are ahead of me! It is a pleasure to know that I have such a bunch of heads-up hams who (sometimes) enjoy these little quizzes.

To bring things up to date, readers who knew their onions about peak, average, and effective values of line voltage include N8PTI KZ1R, K8KIR, WH6EQ, and KD4:'BS.

As far as the voltmeter circuit goes, the reading of the meter is zero, as the switch shorts out the meter circuit. Right? These hams solved the problem quickly: WØDOZ, W4LGK, Ian Johnson, KS2X/1, K6IPV, KL7CMN, W1UBG, K7FC, AA5WE, W2DU, AB4SW/VE3ATU, N5XUS, W6GBA, NW1N/9, W6NPY, W7FSP, AA4ZJ, WA8KNE, WA8MCQ, KM7U, KJ7I, and WB3L (Claudie, congrats on the Extra ticket!)

And how about the Scarlet Pimpernel? The missing words of the song were "elusive Pimpernel." The book, written in 1905 by Baroness Orczy, has been made into several movies, with Leslie Howard, David Niven, Marius Goring, and Anthony Andrews starring as the Pimpernel. These hams really knew this story in great detail: WØDOZ, KS2X/1, KA7OBU, K6IPV, KC4NHB, KL7CMN, K7FC, WD4CNZ, AA5WE, AB4SW, K1XA, W6NPY, AA4ZJ, WA8KNE, KC4TEO, KM7U, KJ7I, VE3ZQ/7, and VE6OA.

Finally, thanks to W2DU, W9WI/4, and KZ1R for their interesting letters.

A New Quiz For You

This one is so easy. I blush to give it. What character in what book and made-for-TV movie had the following names which he switched back and forth? Herr Lachmann, Barraclough, Alan Angel, Sampson (with a "p"), Standfast, and Max?

Good luck and keep smiling!

73, Bill, W6SAI