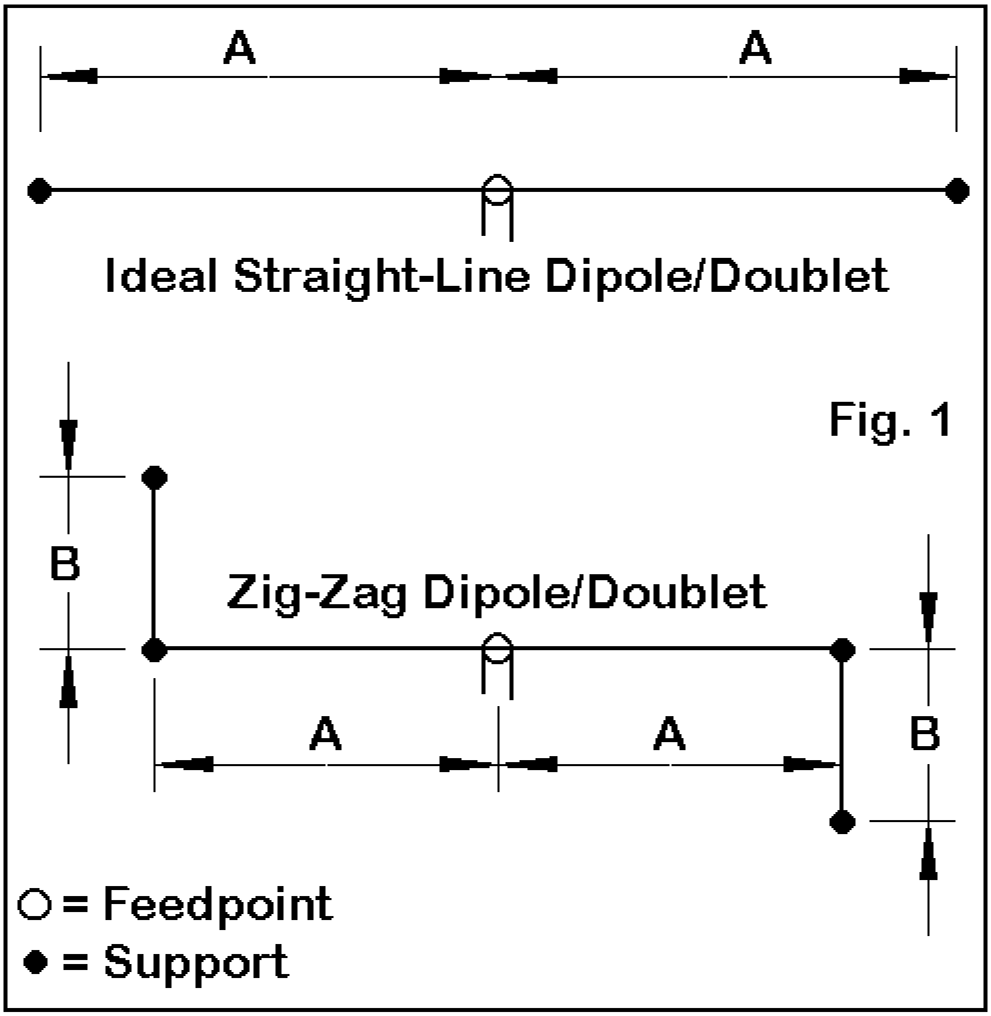
# The Zig-Zag Dipole-Doublet

**L. B. Cebik, W4RNL**

One over-age myth about wire antennas is that they must be straight. Ideally, we would like them to be truly linear. However, even a kinky wire can perform quite well.




Consider the scenario sketched in **Fig. 1**. A standard 1/2 wl dipole for 80 meters--about 135' long when about 50' up--would look like the upper sketch if we had the room for a 67.5' long wire runs on each side of the feedpoint. However, suppose that we do not have the room for the full length of the wires. We can settle for a shorter wire antenna, but we do have another option if supports are available: the zig-zag special. What we did with dimension A in the top drawing, we shall now do with A + B in the lower drawing.

The antenna could have been made into a U, but the loss of gain would have been slightly higher than with the zig-zag--due to the partial cancellation of the radiation from the facing end sections. However, the amount is small enough that, if a U is all that you can manage on a site, "U"se it.

To see what happens when we zig-zag our traditional dipole I ran a series of models, each of #12 copper wire over average soil. Modeling is limited in that it assumes clear, level terrain, and so it cannot take into account the hills, valleys, and ground clutter of the typical ham installation. Nonetheless, the trends are quite useful for comparative purposes.

If the antenna is set 50' up, the typical dipole pattern at an elevation angle of about 20 degrees is an oval at right angles to the wire. Let's see what happens as we turn more and more of the antenna into opposing end pieces. For the example, I used 5% increments of the half length, thus shortening each side of center by 3 3/8' with each move. Theoretically, the end piece should grow by that amount to keep the antenna resonant. Actually, we shall have to lengthen the ends slightly with each change in order to compensate for coupling between the wires near the corners.

The following table lists the wire lengths each side of center (A) with both the calculated and actual end pieces (B) need to restore resonance at 3.5 MHz. The feedpoint resistive impedance at resonance is also shown, along with the maximum gain. The final figure is the number of degrees off broadside that the pattern tilts as a result of the zig-zag ends.

| End (B) % | Calc. Feet | Act. feet | Length A feet | Gain dBi | Pat. Tilt degrees | Feed R Ohms |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 67.5 | 0.06 | 0 | 70.0 |
| 5 | 3.4 | 3.7 | 64.2 | 0.06 | 0 | 67.6 |
| 10 | 6.8 | 7.3 | 60.8 | 0.04 | 1 | 66.4 |
| 15 | 10.1 | 11.0 | 57.4 | 0.02 | 1 | 64.9 |
| 20 | 13.5 | 14.5 | 54.0 | -0.01 | 2 | 62.3 |
| 25 | 16.9 | 18.2 | 50.6 | -0.05 | 2 | 59.7 |
| 30 | 20.3 | 21.7 | 47.3 | -0.09 | 5 | 56.2 |

The total loss in gain within the situation set up is 0.15 dB for the entire spread from a linear wire to an antenna with 30% of each side turned at right angles to the main wire. If the zig-zag happens to be more open than the right angle used in the example as an extreme case, the loss will be less. However, it is already so low as to be undetectable in operation.

Had we bent the ends to form a U, the gain in the most extreme case would have been very slightly lower than for the zig-zag dipole, and so too would have been the source resistance at resonance. Another comparison of note is between the 20% zig-zag model and a wire 108' long and linear--something close to the traditional G5RV length. The G5RV would have shown about 0.1 dB less gain than the zig-zag, which would have been far less operationally significant than the high capacitive reactance at the feedpoint. However, if we feed the antenna with parallel feedline and an antenna tuner, all of these differences fall among the trivial.

The greater the amount of antenna devoted to the zig-zag ends, the longer the wire must be to restore resonance. Again, a more open zig-zag will show smaller amounts of required lengthening. Likewise, the feedpoint resistance goes down more rapidly as the zig-zag becomes more extreme.

The amount of pattern tilt is very mild, even at the 30% zig-zag mark. **Fig. 2** below sows an overlay of the straight wire and the zig-zag azimuth patterns for the 20-degree elevation angle. Again, in real operation, the difference will be unnoticeable. Notice that the pattern tilt is away from the bent ends.

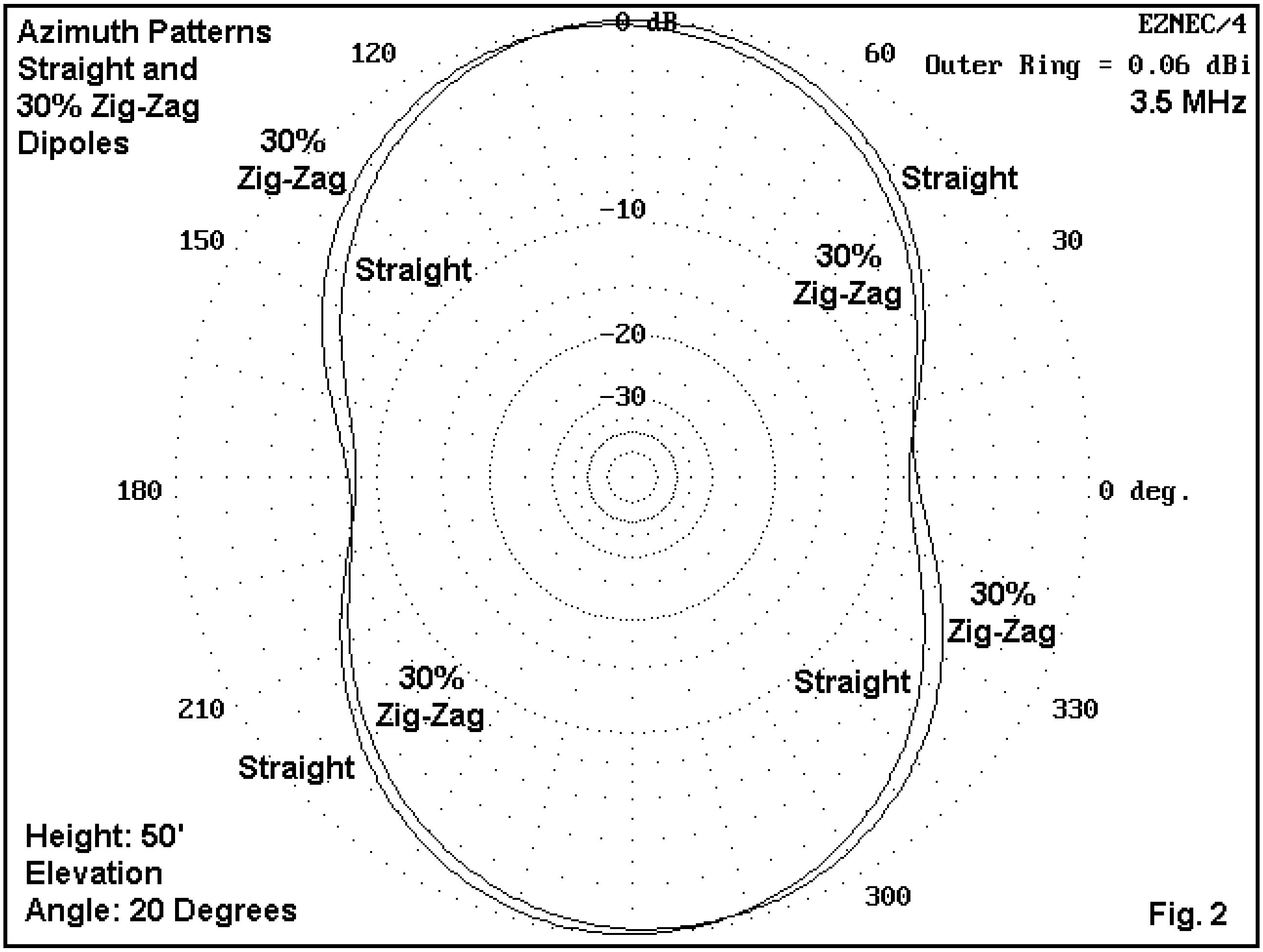


Fig. 2

As the zig-zag involves more than 30% of the wire on each side of center, the pattern tilt becomes more extreme, exceeding 10 degrees as the lengths A and B approach each other. We can view this amount of tilt as a disadvantage, or we can put it to use. Suppose the main supports we have will place the broadside pattern some 10 degrees off target for our desired operation. Making the antenna into a zig-zag dipole can put us back on target.

**The Dipole Becomes a Doublet**

If we choose to use the zig-zag on other HF bands, what happens?

The first thing that happens is that the antenna is no longer a dipole. A dipole is an antenna with a single current maximum at its center and voltage maxima at its ends. It is a center-fed dipole in the version with which we are working. However, since its length will no longer be apt to produce the current and voltage conditions along its length once we increase the frequency of operation, it will no longer be a dipole. Typically, a multi-band single (simple) wire is best termed a "doublet," a term that implies nothing in itself about the current and voltage distribution along the length.

The second thing that happens is this: the exact length is no longer of great consequence. Our first tests intentionally strove for resonance at 3.5 MHz in order to see what happened to the length of the end pieces. In multi-band use with parallel feeders and an antenna tuner, the length is no longer critical. The patterns will not significantly change with up to 5% differences in overall length, and antenna resonance is no longer a serious consideration.

A third phenomena is the variation of the patterns of lobes and nulls from those that we are used to associating with a straight-wire doublet. To see what happens, let's use 40, 20, 15, and 10 meters as test bands to compare the patterns of a straight-wire doublet and our 30% zig-zag doublet--both of #12 copper wire 50' up. Of course, if we use a smaller amount of zig- zagging, then any deviations of patterns from the normal doublet pattern will be that much less.

In each of the patterns shown below, the antenna extends from one side of the pattern to the other. The zig-zag legs bend downward (relative to the page) on the left and upward on the right. Hence, most of the pattern tilting will be to the upper left corner of the page, at least at lower frequencies.

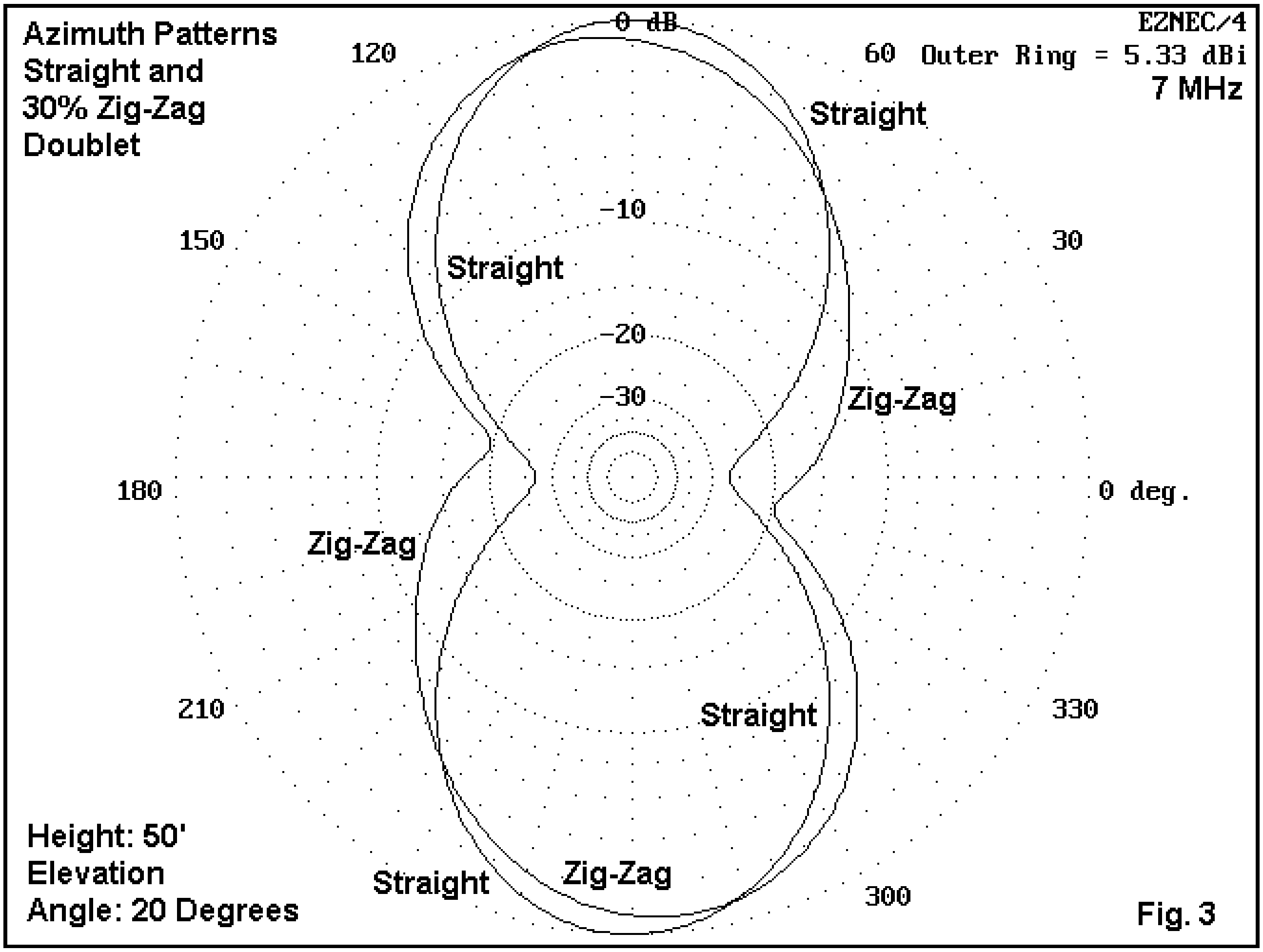


Fig. 3

At 7.0 MHz, the zig-zag pattern shows a 5-degree tilt relative to the broadside lobes of the normal doublet. The elevation angle of maximum radiation is still very high, so a 20-degree elevation angle has been selected for the comparison to reflect something approximating normal skip angles. The gain of the zig-zag is slightly less (by about 0.5 dB) than that of the straight wire and is accompanied by a broadening of the beamwidth in both directions. Since the antenna is about 1 wl long, the feedpoint impedance is very high. The zig-zag side nulls are shallower than those of the normal doublet. However, none of these differences are likely to result in any gained or lost contacts.

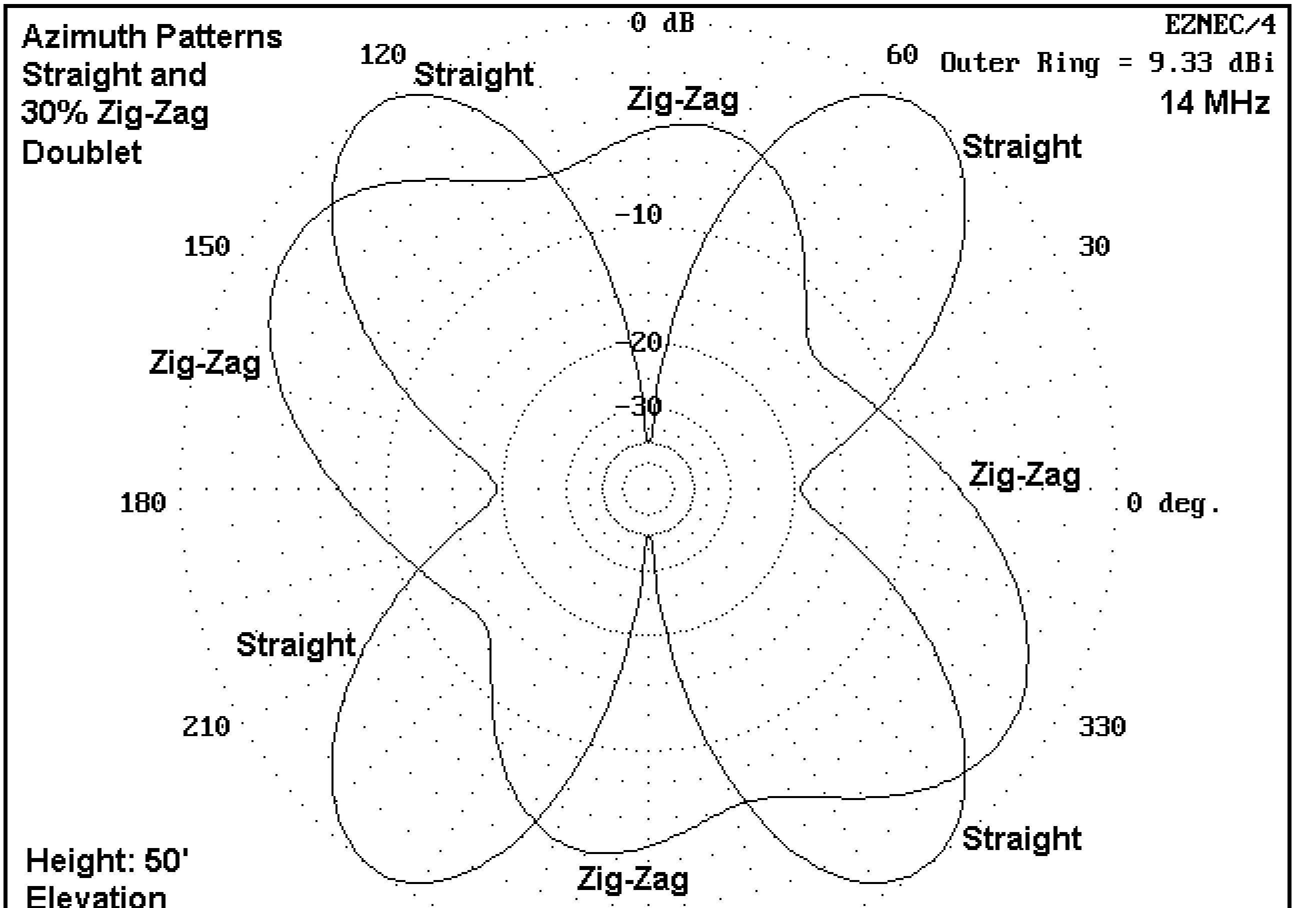
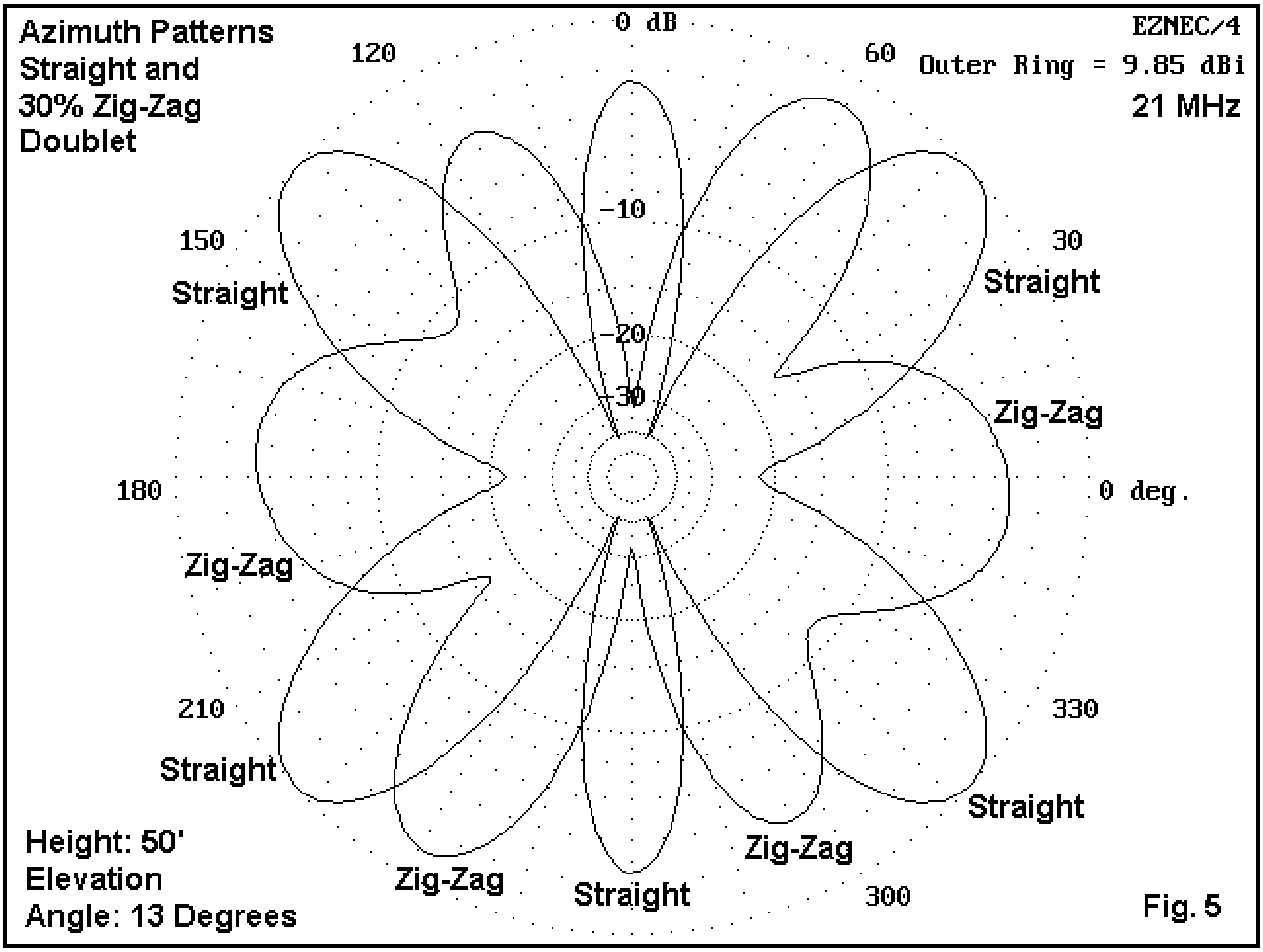



Fig. 4

Lest we simply presume that the remaining HF bands will show essentially similar parallels between the straight and the zig-zag doublets, operation of the antennas at 14.0 MHz serves as a reminder that difference might emerge at any frequency. The elevation angle of maximum radiation on 20 meters is 20 degrees with the antenna at the 50' mark. Hence, the patterns show the maximum gain of the antenna. The straight-wire doublet shows the familiar 4-leaf clover pattern typical of a wire 2 wl long.

In contrast, the zig-zag antenna shows much greater tilt, with the peaks being about 20 degrees distant from those of the normal doublet. The nulls are just barely perceptible, but with that improved coverage comes a price: the lobes are weaker than those of the normal doublet by about 1.3 dB.




At 21 MHz, the normal and the zig-zag patterns almost oppose each other, with zig-zag lobes filling normal nulls and vice versa. Once more, the normal doublet shows a higher maximum gain (by about 1 dB), but the zig-zag doublet tends to have shallower nulls.

Part of the reason for the especially strong zig-zag lobes off the ends of the antenna is that each bent section of the zig-zag is approximately 1/2 wl long at 15 meters. Had the zig-zag "B" length been shortened, the end radiation would have decreased rapidly. When operating the antenna at multiples of its initial frequency, the current magnitude shows a number of peaks, and the geometric configuration plays an increasingly significant role on the ultimate azimuth pattern generated.

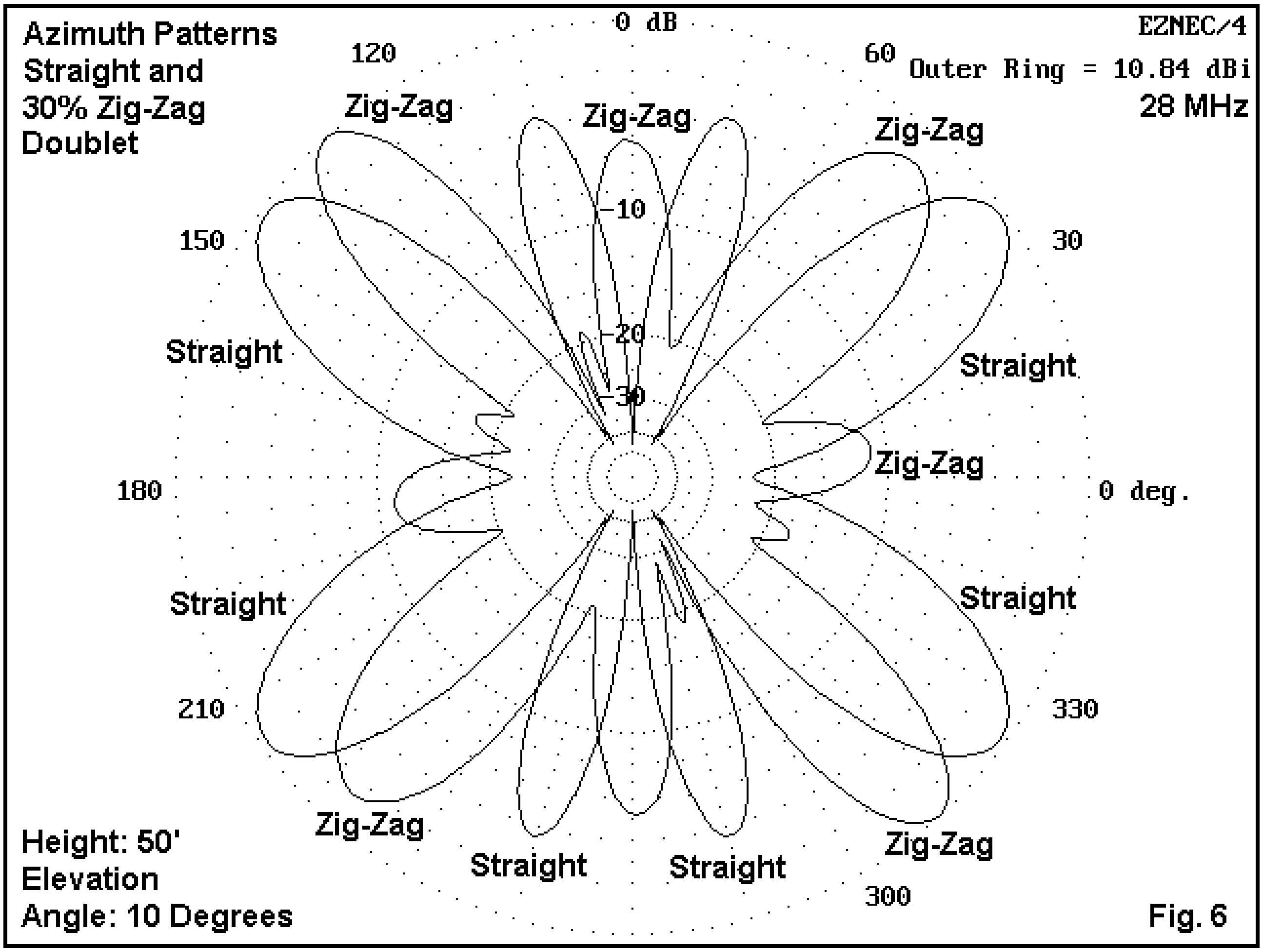


Fig. 6

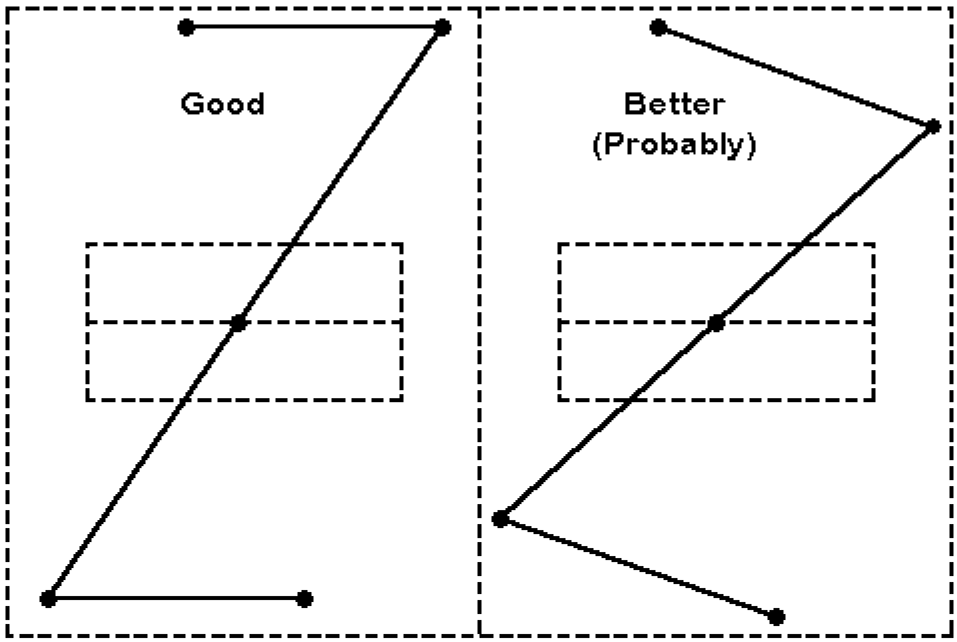
On 10 meters, at 28 MHz, there are so many lobes that the differences in the two patterns becomes less significant operationally. In fact, there is no significant difference in the strength of the largest lobes of the two antennas. However, we may note the two small lobes off the end of the zig-zag antenna. Because the end of "B" lengths are no longer close to 1/2 wl long, they develop lesser lobes. Some of the versions of the zig-zag with shorter "B" dimensions might well show stronger radiation off the antenna ends.

The feedpoint impedance of both antennas at the even harmonics of the original 1/2 wl frequency of the antenna will be high. The exact figures will be functions of the antenna's exact length. At harmonics, effects of the zig-zag will vary slightly from band to band, and hence the feedpoint impedances will not be identical to those of the straight wire. Values of resistance in the 1,000 to 4,000 Ohm range and values of reactance from 500 to 1200 Ohms are likely to be common for both the straight-wire and the zig-zag doublets. What values appear at the antenna tuner terminals will depend not only on these load values, but as well on the characteristics and length of the feedline used. If a tuner cannot handle the values presented on a certain band, insertion of a short length of additional feedline will usually correct the situation.

**Other Variations**

We have already noted that when the ends of the antenna are bent in the same horizontal direction, the resulting U-shaped antenna is only a tiny bit lower in gain than the 30% zig-zag. A more common scenario is to droop both ends downward. At the fundamental frequency, this configuration tends to lower gain still further, since the ends are closer to the ground. However, the result is far from disastrous. At higher frequencies of operation, the ends may show significant vertically polarized radiation, but the net effect will not be sufficient to alter the basic horizontally polarized patterns for each band.

Fig. 7




Two Configurations of a 135' Doublet: Zig-Zagged

Perhaps the ultimate utility of the zig-zag doublet is to fit a full 80- meter length into a fairly restricted yard size, as suggested in **Fig. 7**. running the antenna diagonally across the yard for the available space and then tilting the wires back along the yard lines (assuming supports are available) can make a multi-band doublet available to almost anyone.

The principle can also be applied to hidden roof-top or attic antennas. The ends can be run along the rafters and roof trusses, if appropriate care is taken to give clearance to conductive materials.

The urban dweller can still operate effectively even if circumstance seems to dictate undersized antennas. The key is to think in designer shapes, of which the zig-zag is a perennial winner. The losses, compared to traditional straight-line designs, may be far smaller than initially imagined.