understanding the ZL Special antenna

One answer to the problem of building small, lightweight directional antennas on small parcels of real estate is the ZL Special, a close-spaced version of the two-element driven array. The ZL Special has been around for a long time, but not much has been published about it except for empirically derived data. The ZL Special offers light weight and compact physical size with little compromise in forward gain, front-to-back ratio, or sidelobe levels.

description

The ZL Special basic configuration is shown in **fig. 1**. Two folded dipoles spaced one-quarter wavelength apart are driven 90 degrees out of phase. Typical characteristics are: forward gain, about 3 dB and front-to-back ratio, about 20 dB. Several sidelobes appear when the antenna is placed at heights greater than one-half wavelength above ground. Approximate dimensions are given below, in which F is frequency in MHz, L is element in length, S is element spacing, and P is the phasing-line length for 90 electrical degrees of phase difference between elements:

$$L\text{, element length (feet)} = \frac{468}{F}$$

$$\text{(meters)} = \frac{143}{F} \quad (1)$$

$$S\text{, element spacing (feet)} = \frac{245}{F}$$

$$\text{(meters)} = \frac{74}{F} \quad (2)$$

$$P\text{, phasing line length (feet)} = \frac{196}{F}$$

$$\text{(meters)} = \frac{60}{F} \quad (3)$$

In previous descriptions[1] the ZL Special is shown as six tubular pieces comprising two radiating elements driven 135 degrees out of phase. Spacing between elements is on the order of 1/8 wavelength, and a transposed 300-ohm line is used as a phasing section, **fig. 2**. Claims have been made that the feedpoint impedance is about 70 ohms with this arrangement and that the antenna can be fed with 72-ohm line, although this is probably true only in special cases. The design will work, however, and the dimensions usually given are:

fig. 2 dimension, feet	(meters)
A = $438/F$	$134/F$
B = $447/F$	$136/F$
C = $101/F$	$31/F$
D = $122/F$	$37/F$
E = $110/F$	$34/F$

design for optimum performance

A more modern design would use 300-ohm line throughout, with bamboo or fiberglas supports and a simple aluminum boom. However, in this case the phasing line will be physically a bit shorter than the desired element spacing. As shown in **fig. 3** maximum gain for a parasitic element will occur at about 0.11 wavelength for a director and 0.15 wavelength for a reflector. Since the ZL Special has a "driven director-reflector," you might expect that optimum forward gain would occur between 0.11 and 0.15-wavelength spacing. This is indeed the case, and maximum gain occurs at about 0.123 wavelength spacing. In no event should less than 0.1-wavelength spacing be used, because not only does gain drop rapidly but the characteristic (feed) impedance changes drastically.

Empirical designs using 300-ohm line have shown that director lengths of $447.3/F$ in feet ($136.3/F$ in meters) and reflector lengths of $475.7/F$ in feet ($145.0/F$ in meters) are nearly optimum. These dimensions are somewhat longer than those given for the tubing version, primarily due to the much narrower width dimension of

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the 300-ohm elements. For example, in free space one-half wavelength in feet is *492/F* (*150/F* in meters), whereas in practice a folded dipole at ordinary heights will resonate at *468/F* in feet (*143/F* in meters).

Using 14.2 MHz as a design example, a free-space half wavelength is *492/F* = 34.65 feet, or *150/F* = 10.6 meters, which is 5.19 electrical degrees/foot (17 degrees/meter). The ZL Special dimensions are then:

director *447.3/F* = 31.5 feet
(*136.3/F* = 9.6 meters)
reflector *475.7/F* = 33.5 feet
(*145.0/F* = 10.2 meters)

element spacing 0.12 wavelength
= 8.5 feet (2.6 meters)

Compared to a resonant dipole, the director is shortened by (468 - 447.3)/468 = 0.044 or about 4.4%. Similarily, the reflector is lengthened over the dipole by (475.7 - 468)/468 = 0.0165 or about 1.7%. While these numbers aren't sacred, the difference between them is very close to optimum at (475.7 - 447.3)/447.3, or about 6.3%.

Similarly, for 20 meters a phasing-line length of 7.75 feet (2.4 meters) nearly always proves to be optimum. Making the assumption that the velocity factor of typical 300-ohm line will approximate 0.7, a half wavelength of 300-ohm line is (492/*F*)(0.7) = 24.3 feet, or (150/*F*)(0.7) = 7.4 meters. Then 180 degrees divided by 24.3 yields 7.4 electrical degrees per foot (24.3 degrees per meter) in 300-ohm line. Also, 7.75 feet (2.4 meters) of phasing line yields 57.5 degrees of phase shift.

Since the phasing line transposition adds 180 degrees in phase, the difference in phase between director and reflector is 360 - (180 + 57.5) = 122.5 degrees. Thus in truth, most ZL Special antennas don't employ 135-degree phasing but rather something between 115 and 125 degrees, depending on phasing-line velocity factor and empirical pruning.

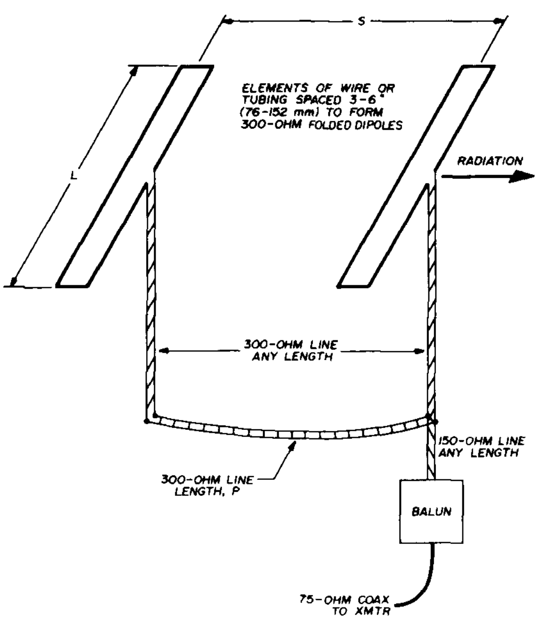

fig. 1. Basic arrangement of the ZL Special, a unidirectional quadraphased two-element array. (Essentially two half-wave antennas phased at 180 degrees.)

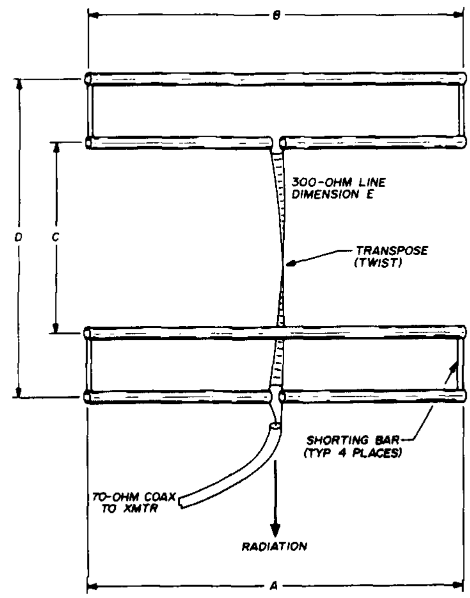

fig. 2. ZL Special using tubular elements. The two radiating elements are said to be driven 135 degrees out of phase; however this value is more like 115-125 degrees (see text).

construction

Construction may be as previously described, or as I prefer, using ordinary plastic plumbing pipe (known as PVC tubing). Placing the 300-ohm line into the pipe (no twists allowed) is easy, and T connectors provide additional rigidity for guying (**fig. 4**). **Fig. 5** shows a successful design at 14.2 MHz using the desired phasing line, but with the rear element bowed somewhat to allow for correct element spacing. You may think that the "delta" of the rear element aids in a smooth phase transition (as

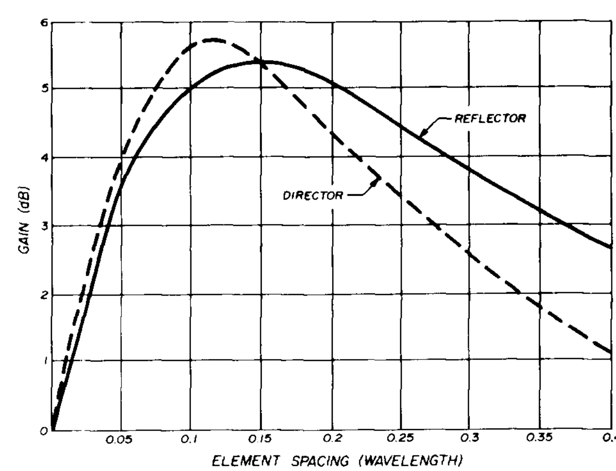

fig. 3. Maximum gain obtainable with a parasitic element over a ½-wavelength antenna alone, assuming parasitic element tuned for maximum gain at each spacing.

with a delta match), but this is a pure speculation. Construction is easy enough with bamboo or fiberglas supports, and still not too difficult with plastic plumbing pipe into which slots are cut to allow the rear element to pass forward to the phasing line.

Rather than simply feeding this balanced antenna with unbalanced coaxial cable, a balanced feed should be used. One method (other than using a balun transformer) is to make a 1/4-wave bazooka line as shown in **fig. 6**. Simply wrap aluminum foil around the last 1/4 wavelength of feed line, using plenty of overlap, then use masking tape to cover the foil. Apply several coats of

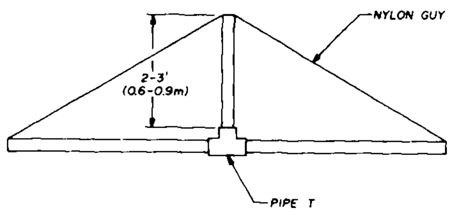

fig. 4. Suggested construction for a single element using PVC tubing and T connector (end view). The 300-ohm line feeds easily into the tubing (no twists permitted).

weatherproof compound to the tape. The foil may be secured to the coax shield by wrapping it tightly with a number of turns of wire.

performance

Performance should be quite broadband compared with a true parasitic beam, and the turning radius for the 20-meter example here will be only 17.3 feet (5.3m). Weight may be less than 10 pounds (4.5kg). Gain over a reference dipole should be 6 to 7 dB, with a front-to-back ratio of at least 15 to 18 dB. Don't forget to take into account the velocity factor of the coax when constructing the bazooka. The 1/4-wave bazooka length is about 11 feet 5 inches (3.5m) at 14.2 MHz. For those amateurs with more space, additional true parasitic elements may be added as in **fig. 7**, although the feedpoint

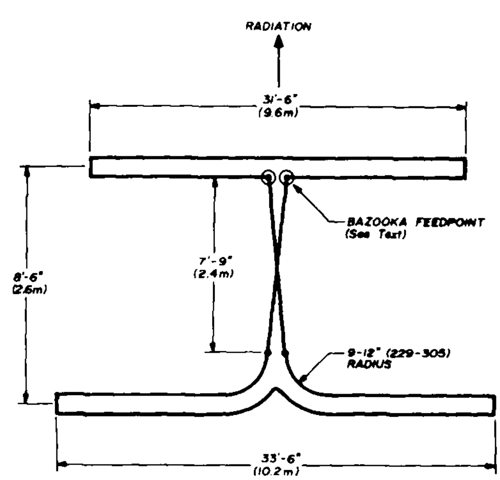

fig. 5. Top view of the ZL Special using 300-ohm twin lead. Design is for 14.2 MHz. Rear element is bowed slightly to allow for the desired element spacing.

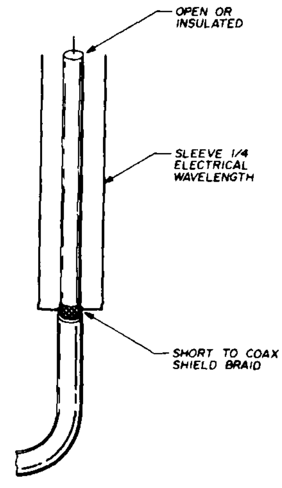

fig. 6. One-quarter wavelength balanced-to-unbalanced transformer for feeding the ZL Special with coax transmission line. Transformer is recommended for keeping antenna currents off coax, which degrade antenna pattern and may cause difficulty in transmitter tuning.

impedance will be lowered. For the basic ZL Special, feeding with 52-ohm line may require that the bazooka be made of 72-ohm line, which will yield a transformation of $(75)^2/52$ = 108 ohms to the antenna. This may be very useful, as the nominal 60 to 80-ohm feed-point

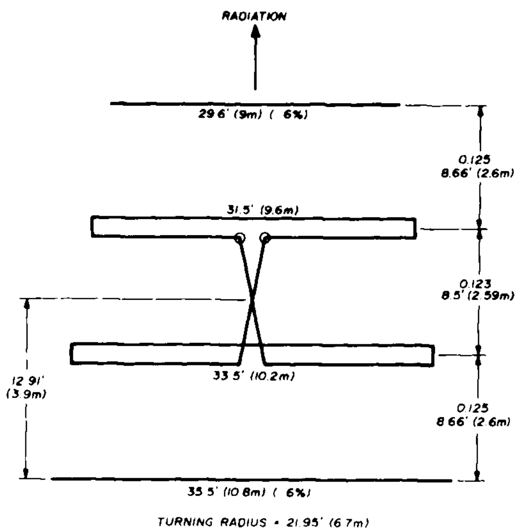

fig. 7. ZL Special antenna with parasitic elements. Typical parameters: input impedance approximately 40 ohms; gain referenced to a dipole at the same height about 13.6 dB; front-to-back ratio 28 to 35 dB. Space for slightly more turning radius is required for this version.

impedance might increase* for small heights (less than one wavelength) above ground. A 52-ohm line plus bazooka will match the ZL Special with parasitic elements reasonably well without further transformation.

The addition of true parasitic elements, when carefully tuned (not an easy chore), can yield gain and front-to-back ratios comparable with parasitic beams which have a greater number of elements.

*On the other hand, the reverse may be true.

reference

1. *The ARRL Antenna Book*, ARRL, Newington, Connecticut, ninth edition, 1960, page 214.

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