The ILZX as an 80-Meter Vertical

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In 1997, I suggested for lower-HF use in sites with limited space for an antenna an interrupted loop dipole using folded-dipole construction in a vertical configuration. (See http://www.cebik.com/content/wire/ilzx.html.) With some modifications, the antenna is adaptable to 80-meter use over an extended portion of the band. These notes are an 80-meter update to the original material.

We shall proceed in three steps. First, we shall look at the standard ¼ λ vertical monopole—ground mounted with buried radials—to set up some performance expectations for a reasonably good 80-meter antenna. Next, we shall look at the basic properties of both single-wire and double-wire versions of the interrupted-loop dipole, including the inevitable limitation to operating bandwidth. Finally, we shall look at an extremely simple way to extend the frequency coverage. While the resulting antenna will not quite cover the entire 80-75-meter band, it will come close enough to make it a potentially useful basic antenna for the band.

The Vertical Monopole Standard

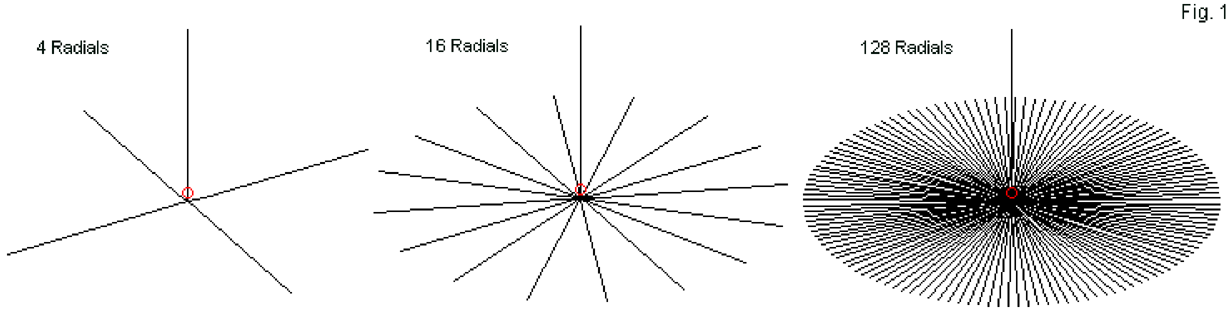
The ¼ λ vertical monopole is perhaps the standard 80-meter antenna against which we measure all other antennas. This is not a universal fact, since a few amateurs have the wherewithal to erect very high towers to support horizontal beams. However, serious (and moderately affluent) amateurs tend to use towers in the 70' to 95' range. A horizontal antenna for 80 meters at either height tends to radiate at very high elevation angles, with little radiation at the very low angles needed for long-distance communication. Therefore, most amateurs with a passion for 80-75-meter operation resort to vertical antennas.

Unfortunately, most monopole users have very little idea of the performance numbers that attach to the antenna. Hence, they rarely are able to evaluate other vertical antenna designs, since they lack a basis for comparison. Such comparisons will be vital to evaluating the ILZX, since they will play a role in deciding whether or not to move in the ILZX direction. To provide some background data, I extracted some models used in developing *Ground-Plane Notes* as a vehicle for looking at the old favorites among basic antennas.

My models originally used metric dimensions, so the translations into feet and inches may seem to produce odd numbers. However, the dimensions are not far off of the values we might use in actual installations. Let's begin with a 20-mm (0.79") diameter vertical element. If we were building an actual monopole, we likely would use a segment taper whose equivalent diameter would be close to this value. The element length is 20.11 m or 66.0'. The length results from resonating the antenna with a very large radial field.

In fact, we shall use radial fields with many different numbers of radials, from 4 to 128. Each radial is an electrical quarter-wavelength (20.82 m or 68.3') and uses 2-mm (0.08") diameter wire. The radials are buried 10 cm (3.94") below the ground surface in NEC-4 models. (NEC-2 will not allow buried wires, and approximations of such radial systems in NEC-2 show deviations from NEC-4 models that can actually bury the radials.) For the purposes of later comparisons with the ILZX antenna, we need only a single ground quality. Average ground (conductivity 0.005 S/m, permittivity 13) will do very well. **Fig. 1** outlines 3 of the models in the test sequence, while **Table 1** contains the numerical data gathered from the models.

Fig. 1



A Vertical Monopole with Various Size Buried Radial Fields

Table 1. Modeled performance data for a ¼ λ vertical monopole with varied radial fields

No. of Radials	Max. Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω
4	-1.70	24	62.3 + j11.4
8	-0.94	24	52.9 + j8.0
16	-0.30	25	46.1 + j5.6
32	0.20	25	41.0 + j3.2
64	0.49	24	37.6 + j1.0
128	0.62	25	35.8 – j0.7

As we increase the number of radials, the monopole shows lower resistive losses, as revealed by both the decreasing feedpoint resistance and the rising maximum gain value.

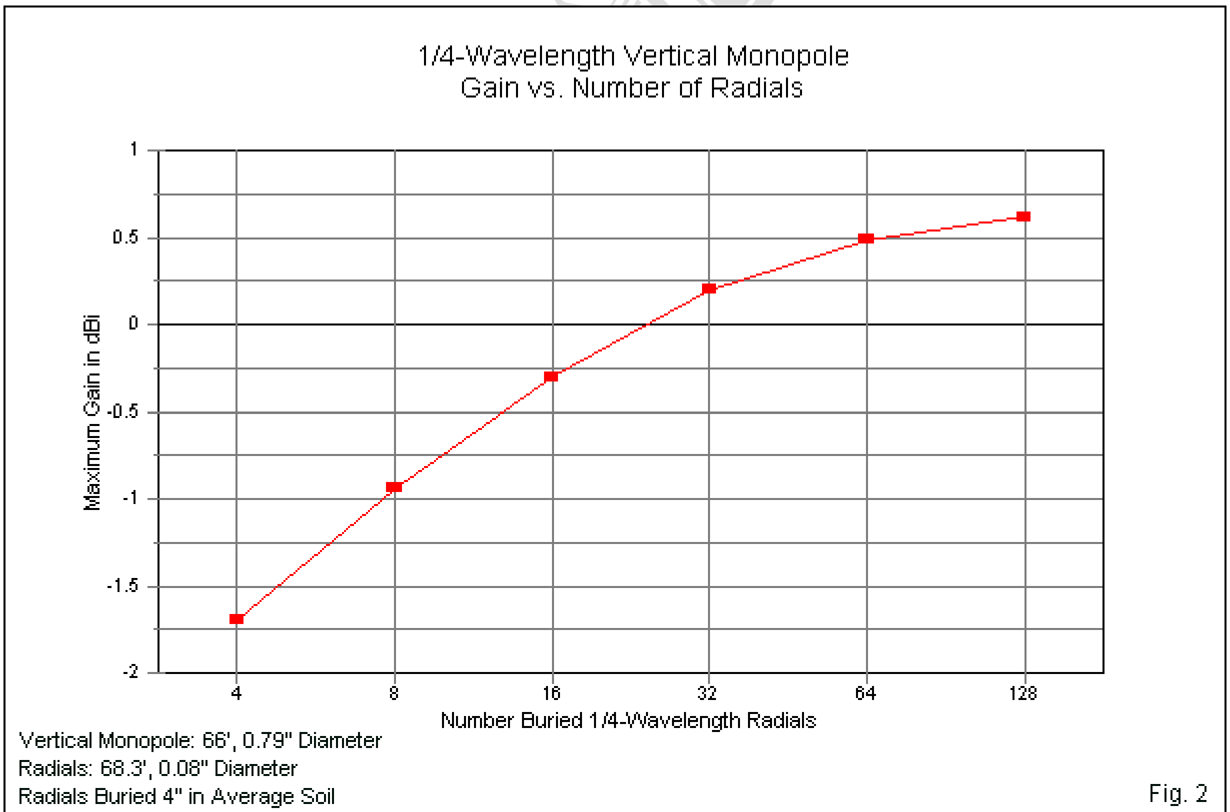
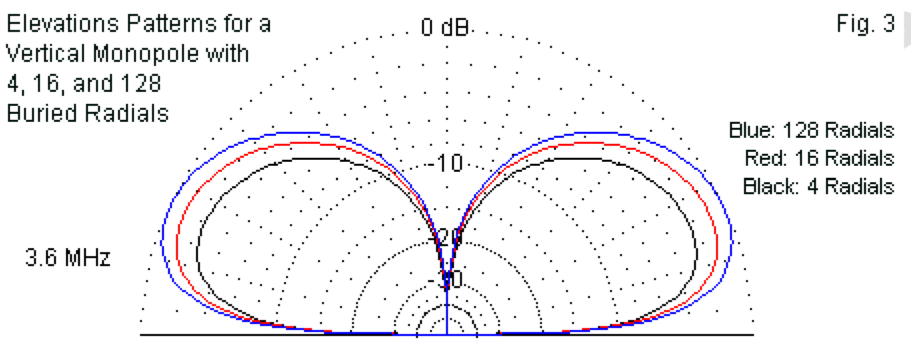


Fig. 2

Fig. 2 graphically displays the rising gain. The radial increment is a factor of 2 for each new entry, but the curve does not show a linear curve even on that basis. Indeed, the gain increases taper significantly so that more than 128 radials are rarely, if ever, used. As shown in the table, the rising gain curve flattening is reflected in the diminishing increment between resistive components of the feedpoint impedance values. The wobbling of the take-off (TO) angle value is a function of the true value being quite close to 24.5° for all cases.

The patterns for the common vertical monopole are also interesting, as suggested by **Fig. 3**. These plots overlay the elevation patterns for systems of 4, 16, and 128 radials. The gain differences are evident, but the shape of the elevation lobes is perhaps more significant. Regardless of gain, the near-ground position of the monopole feedpoint and the resultant high current magnitude in this region of the vertical element produce considerable high-angle energy. The strength of the field does not drop to –10 dB relative to maximum gain until an elevation angle of nearly 80°.

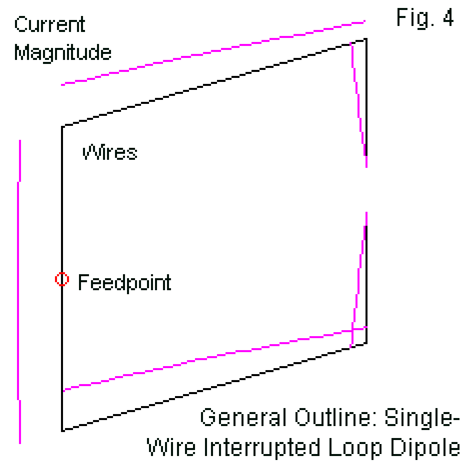


The data applies to a highly conductive full-length vertical radiator. All shorter elements used on the band over the same radial fields and ground quality will have lower maximum gain values. Top-hat methods of element shortening are the most efficient, since they suffer only small losses associated with element shortening. Inductive loading, whether placed at the feedpoint or at some distance above it, will add further losses to the system due to the finite Q of the inductors (or their transmission-line stub substitutes, sometimes called linear loads).

The vertical monopole standard does not set up a singular performance reference, since the gain varies with the number of radials. In fact, over average ground, the gain differential between the smallest and the largest radials fields is about 2.3 dB. The benefit of burying many radials is clearly apparent. We might fine-tune the basic monopole system by trying other radial lengths, by slightly elevating the radials, or by selecting a fatter vertical element. However, these measures would make only small changes in the data. As a standard for our needs, the basic monopole models just surveyed will suffice.

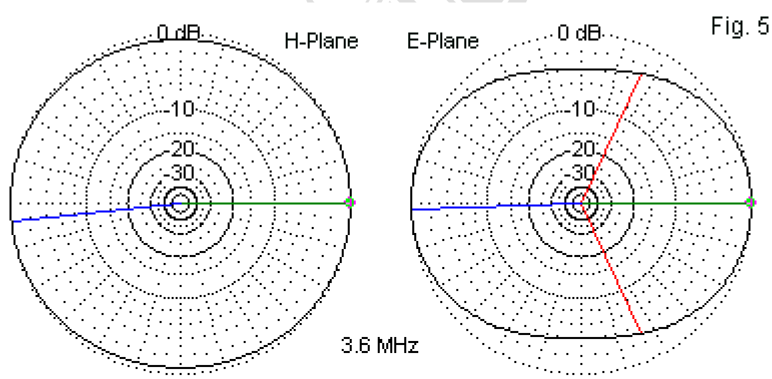
The Basic Interrupted-Loop Dipole

The classic dipole element may undergo considerable folding, bending, and other forms of mutilation and still be quite serviceable. One form of the dipole creates a square shape, but with a separation between the ends of the dipole. Hence, the antenna gives the appearance of a loop with an interruption. A single-wire version of the antenna appears in **Fig. 4**, along with the relative current magnitude along each section of the antenna. Even though not perfectly clear, the current magnitude decreases from the feedpoint toward the ends in almost perfectly normal fashion, reach zero at the element ends. Any imperfections in the current magnitude progression occur at the corners, where we find coupling between adjacent sections of the antenna at 90° angles to each other.



General Outline: Single-Wire Interrupted Loop Dipole

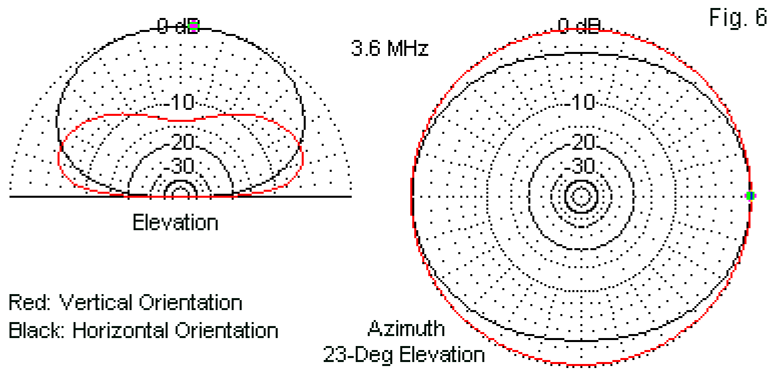
Because we find a small amount of capacitive coupling between the dipole tips, the label of "interrupted loop" has a modicum of validity. However, the amount is very small, and the element remains essential a dipole folded into a square shape. Because the sides still carry appreciable current, the E-plane pattern for the antenna (in **Fig. 5**) does not show the side nulls exhibited by a linear dipole. In a free-space model, the E-plane pattern would be "vertical" to the outline in **Fig. 4**, that is, in the plane of the wire. The stronger lobes in the pattern are along a line from the feedpoint through the center of the gap.



Free-Space Patterns of an Interrupted-Loop Dipole

The H-plane pattern is broadside to the square. It is nearly circular, with the slightly stronger point in line with the feedpoint and gap. We shall call this line the antenna centerline. As the antenna appears in **Fig. 4**, the interrupted-loop dipole would produce a nearly perfect omni-directional pattern similar to a monopole if placed over ground.

Most users of interrupted loops for higher bands (20 meters and up) tend to place the square parallel to the ground to make use of the resulting horizontally polarized signal. Unfortunately, we cannot obtain sufficient height in the lower HF region to make this orientation effective for low-angle radiation and reception. Let's overlay the patterns for both horizontal and vertical versions of the single wire interrupted loop dipole by placing the centerline at 50' above average ground. All wires of the horizontal version will be at a height of 50'. However, the vertical version will have wires both above and below this height. The lower wires will be more than 30' above ground. We may then compare the patterns, as shown in **Fig. 6**.

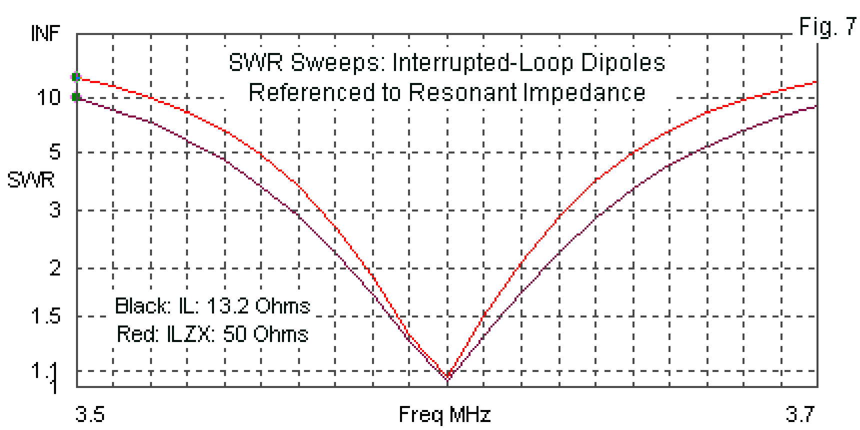


Elevation and Azimuth Patterns of Vertically and Horizontally Oriented Interrupted-Loop Dipoles Centered 50' above Average Ground

The elevation patterns are taken along the antenna centerline. The maximum gain of the horizontal version is higher than for the vertical version, but with most of the energy appearing at very high elevation angles. The horizontal interrupted-loop dipole would serve mainly as an antenna for near vertical incidence skywave (NVIS) propagation. Although the vertical version of the antenna has less maximum gain, the radiation is concentrated at much lower angles. In fact, below about 25°, the gain of the vertical squared dipole is stronger.

The azimuth pattern for the vertical is virtually omni-directional for patterns at the specified elevation angle (the TO angle of the vertically oriented version). The horizontal version shows almost as much gain in the favored directions, but about 3 dB less gain off the side wires. The sum of these modeling experiments suggests that perhaps the best 80-meter orientation for an interrupted loop is as shown in **Fig. 4**.

One facet of interrupted-loop performance remains a disadvantage. The antenna shows a very narrow operating bandwidth. **Fig. 7** provides SWR curves for slightly different versions of the antenna. The single-wire dipole has a very low feedpoint impedance at resonance—just above 13 Ω. Assuming perfect impedance transformation to match a feedline, the operating bandwidth with an SWR of less than 2:1 is only about 40 kHz. The ILZX version increases the bandwidth to about 50 kHz as it raises the resonant feedpoint to 50 Ω.

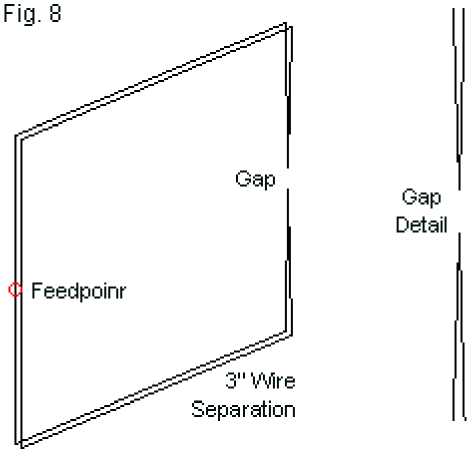


Raising the feedpoint impedance to a more usable value without introducing potentially lossy matching devices is desirable, despite the narrow operating bandwidth. Therefore, let's examine the ILZX configuration in advance of tackling the bandwidth issue.

Basic ILZX Properties

The designation ILZX arose partly from the labeling of the squared dipole as an interrupted loop. The last two letters abbreviate "impedance transformation." Let's construct the interrupted loop from a folded dipole rather than from a single wire. If both wires have the same diameter, then the assembly should show 4 times the impedance of a single-wire version of the same antenna. Any reasonable wire spacing will do, since equal diameter wires are not dependent upon spacing for the 4:1 impedance step-up.

Fig. 8



General Outline and Gap Detail
Vertically Oriented ILZX Element

The outline for the ILZX appears in **Fig. 8**. The only departure from normal folded dipole structure is the fact that the wires join to form points rather than blunt ends at the gap. The points reduce the small amount of element end coupling that occurs and thus reduce the sensitivity of the antenna to small changes in the gap distance. The models used for these notes have a 3" spacing between AWG #12 copper wires for all versions of the ILZX.

Using a resonant frequency of 3.6 MHz, we can install the models at two representative heights above average ground. The lower height places the antenna centerline 50' above ground, while the upper height uses 75' as the mark. The top and bottom wires are in both cases less than 19' away from the centerline. Therefore, the lower height has a top level below 70' with about 30' clearance from the ground. The upper height has a top height that is less than 95', while the bottom wire clears the ground by about 55' or so.

Fig. 9 provides the elevation patterns for the antenna at both heights. We may ignore the azimuth patterns, since they are circles within less than 0.4 dB variation. As we might expect, the lower height has a higher TO angle (23°) with a maximum gain of 0.30 dBi. The gain compares to the gain of a vertical monopole with between 32 and 64 radials. The gain of the higher version falls in the same range at 0.42 dBi with a TO angle of 17°. A good reason for choosing the upper height is not the gain, but the lower TO angle.

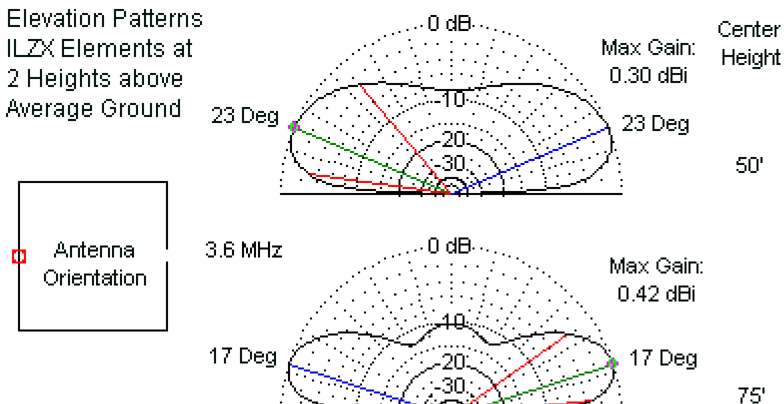


Fig. 9

Compared to the monopole patterns, the ILZX patterns lack the deep null at the zenith angle. However, the overall level of high-angle radiations is lower. The upper height shows significantly less radiation strength at an angle of 45° than the monopoles.

Like all dipoles, the performance changes very slowly across the band in terms of gain and TO angle. The resonant impedance, depending upon height, falls between 50 Ω and 75 Ω, with the lower version showing the higher value due to closer coupling with the ground. Nevertheless, the SWR sweep in **Fig. 7** reminds us of the narrow operating bandwidth of the antenna if we connect its feedpoint directly to a standard 50-Ω coaxial cable.

Increasing the ILZX SWR Bandwidth

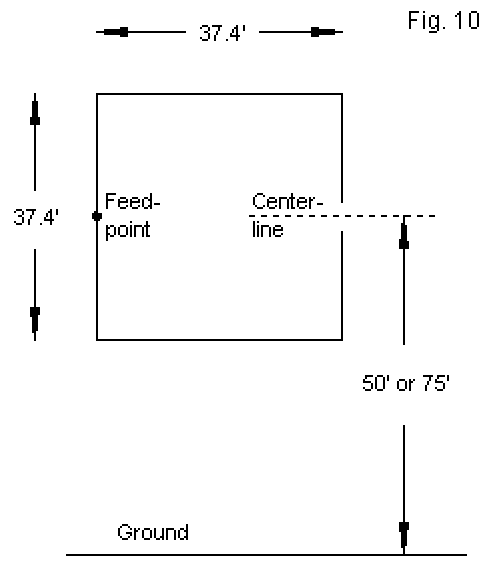
If we explore the actual impedance of the ILZX both above and below resonance, we discover that the resistive component at the feedpoint changes very slowly across the 80-75-meter band. The reactive component—capacitive below resonance and inductive above resonance—increases at a much faster rate. These facts provide us with the means to increase the operating bandwidth using a very simply one-component matching system with a very high Q and therefore a very low loss. However, adding that component is the second step in the process.

The first step is to redesign the ILZX for a lower resonant frequency so that across the entire 80-75-meter band, the feedpoint shows (prior to matching) an inductive reactance. Using the free-space model as a foundation, I enlarged the ILZX. **Table 2** shows the original and revised dimensions.

Table 2. Initial and revised dimensions of an ILZX for 80 meters

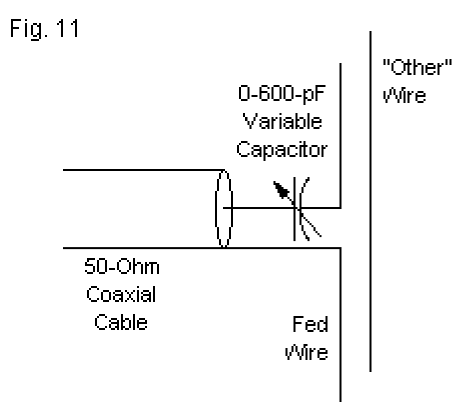
Model Version	Resonant Frequency	Side Length Feet	Gap Feet	Total element Length Feet
Initial	3.6 MHz	35.75	2.50	140.5
Revised	3.44 MHz	37.42	2.66	174.0

Fig. 10 shows the situation of the revised ILZX (sketched with only a single wire for clarity) as it sits above ground. The gain and TO of the antenna do not change significantly with the small increase in size. However, the impedance across the band is wholly inductive. Moreover, the size increase is large enough to avoid very low values of inductive reactance.



Sketch of Revised ILZX above Ground

The reason for avoiding very low inductive reactance values is that they equate with very high and impractical values of compensating capacitance. The reactance is in series with the feedpoint. Therefore, as sketched in **Fig. 11**, we may compensate for the inductive reactance by placing a remotely tuned variable capacitor in series with the feedpoint to cable line. The test situation requires a variable with a range of about 40 to 600 pF to provide the required compensating reactance.



Simple Method for Extending the ILZX Frequency Range

The capacitor may be an air variable or a vacuum variable, depending upon what may be available by way of both components and resources. A stepping motor is a likely candidate for rotating the plates or moving the internal structure. I recommend the addition of end-stop switches to prevent over-rotation. Weatherproofing and bug-proofing the assembly is crucial to system durability. (Although the simple capacitor will do the job with the revised ILZX size, a remote network tuner at the feedpoint will also work well, although its inevitable nductor will increase losses slightly.)

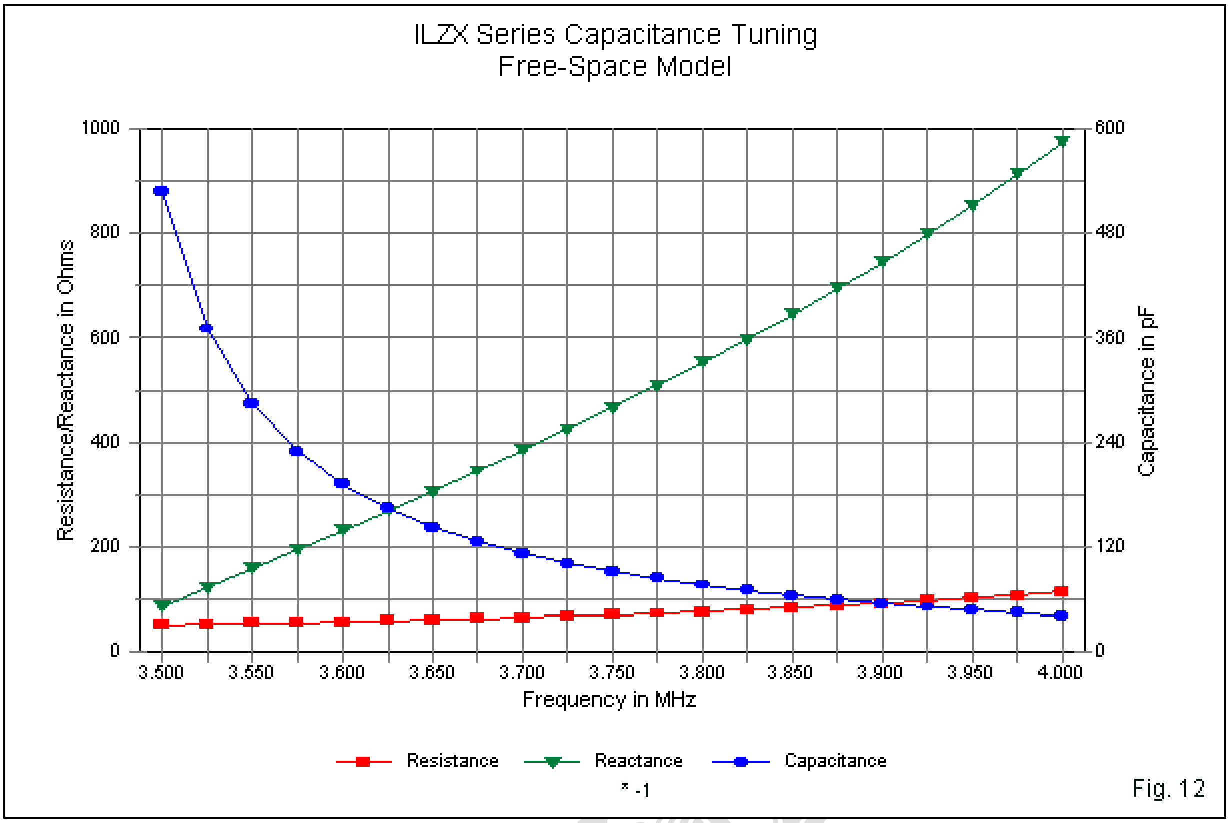

ILZX Series Capacitance Tuning
Free-Space Model
Resistance/Reactance in Ohms
Capacitance in pF
0
200
400
600
800
1000
0
120
240
360
480
600
3.500
3.550
3.600
3.650
3.700
3.750
3.800
3.850
3.900
3.950
4.000
Frequency in MHz
Resistance
Reactance
* -1
Capacitance

Fig. 12

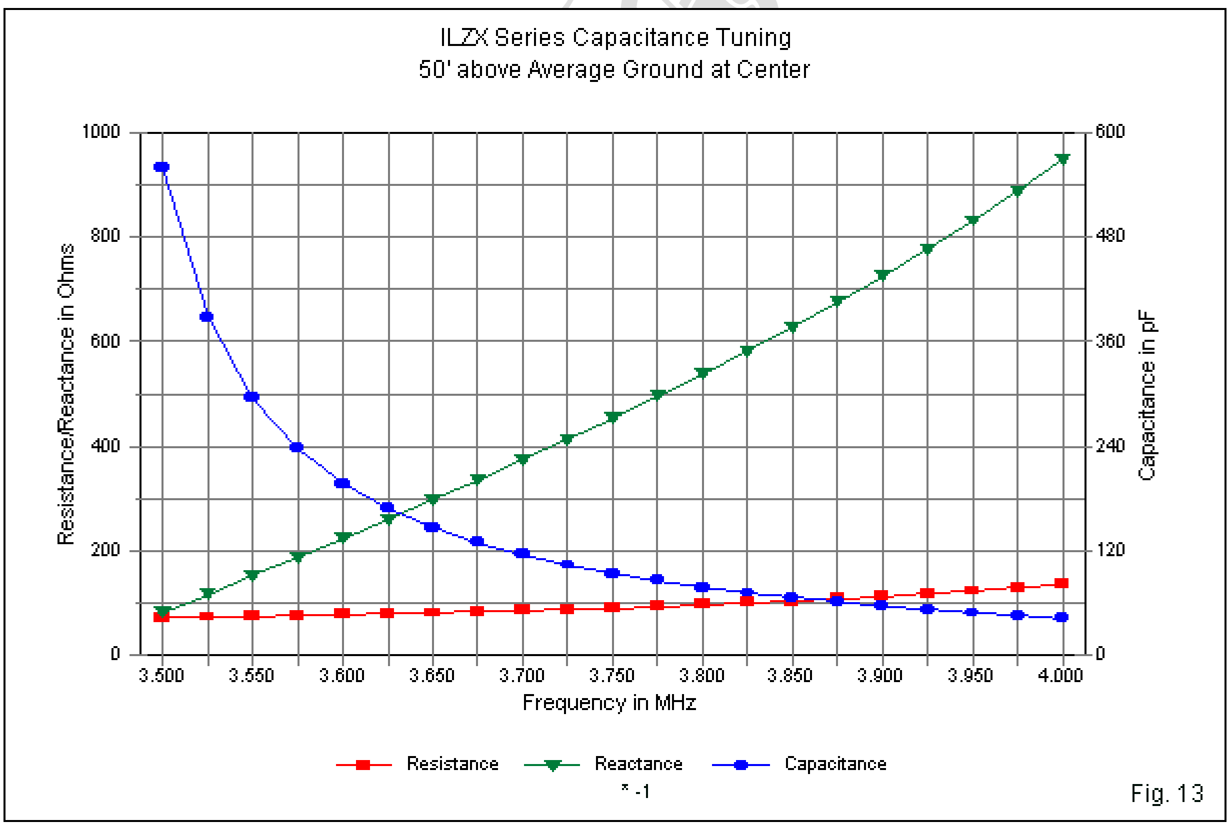

ILZX Series Capacitance Tuning
50' above Average Ground at Center
Resistance/Reactance in Ohms
Capacitance in pF
0
200
400
600
800
1000
0
120
240
360
480
600
3.500
3.550
3.600
3.650
3.700
3.750
3.800
3.850
3.900
3.950
4.000
Frequency in MHz
Resistance
Reactance
* -1
Capacitance

Fig. 13

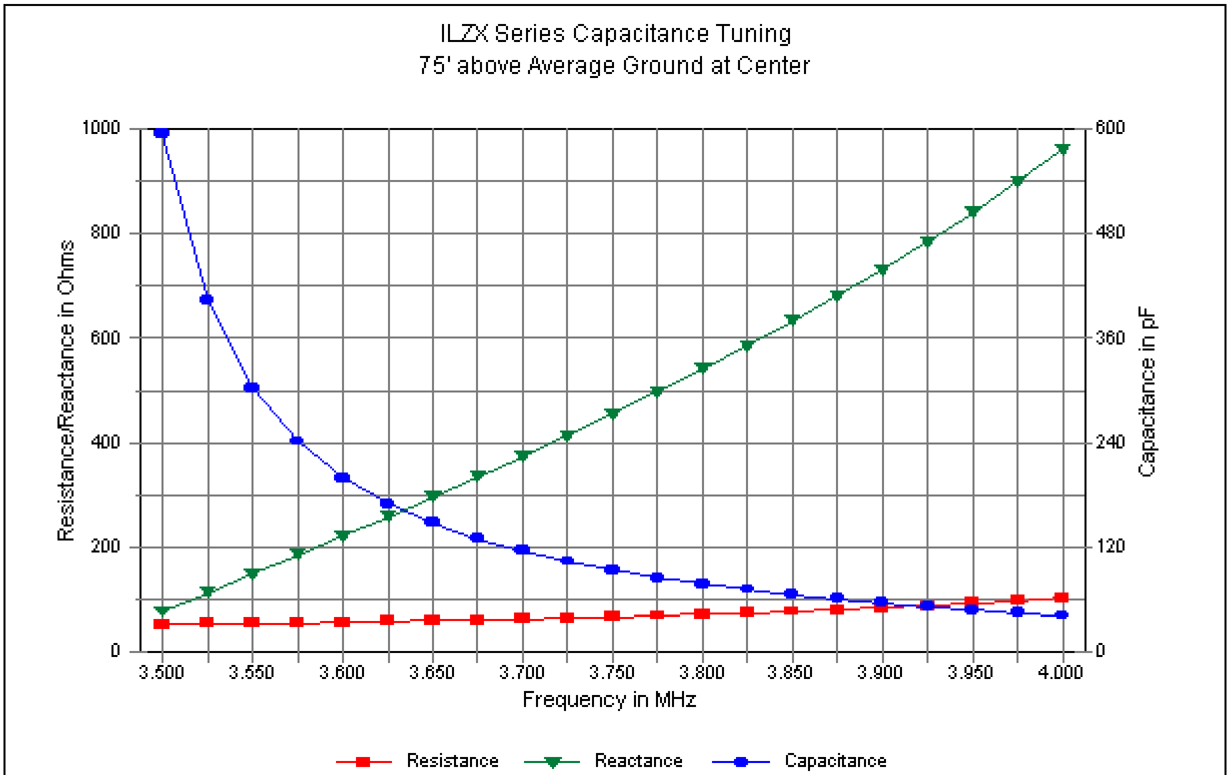


Fig. 14

Because ground interactions modify the feedpoint impedance profile, we find different curves for the free-space model and for the models using 50’ and 75’ heights. **Fig. 12** surveys the free-space situation, while **Fig. 13** and **Fig. 14** provide curves for the two heights above average ground.

Although all three sets of curves show a high level of parallelism, there are some critical differences in both the resistance and reactance curves that result in different required capacitor setting and in the degree of band coverage. **Table 3** provides some selected data to make those differences more evident. The key to the tabular data is that the upper frequency limit of coverage is where the resistive component reaches 100 Ω, a 2:1 SWR for 50-Ω coaxial cable on the assumption that the capacitor allows a net reactance at each frequency of 0 Ω. (The numbers, of course, are prior to SWR reductions at the equipment end of the line due to transmission line losses.)

Table 3. Performance of three models of the ILZX across the 80-75-meter band

Free Space	3.5 MHz	Limiting Frequency		4.0 MHz
Resistance Ω	51.3	3.925	96.0	113.9
Reactance Ω	-86.0		-798.9	-975.8
Capacitance pF	529.0		50.8	40.8
50’ Centerline	3.5 MHz	Limiting Frequency		4.0 MHz
Resistance Ω	71.5	3.825	99.8	135.0
Reactance Ω	-81.1		-582.7	-949.5
Capacitance pF	560.6		71.4	41.9

75' Centerline	3.5 MHz	Limiting Frequency	4.0 MHz
Resistance Ω	52.6	3.975 96.6	101.9
Reactance Ω	-76.4	-899.7	-961.7
Capacitance pF	595.0	44.5	41.4

As the table shows, conditions will vary with the antenna mounting height above ground. Depending upon height, one may vary the size of the ILZX to obtain the best span of operating frequency consistent with the available capacitor for tuning the array to effective resonance. As well, if the resistive component of the feedpoint impedance is higher than 50 Ω, one may use two different wire sizes for the fed and unfed wires of the folded dipole. A fatter fed wire and a thinner unfed wire will lower the impedance.

Miscellaneous Cautions and Conclusion

Like any vertically polarized antenna for the lower HF region, the ILZX is sensitive to the proximity of vertical structures and objects in the immediate vicinity of the vertical wires. I have studied objects with various levels of resistivity at distances from vertical dipoles up to about 1/8 λ (about 35' at 80 meters) and found that even semi-conducting objects may have an affect on both the antenna pattern and the feedpoint impedance. Trees are not insulators, but variable semi-conductors with a resistivity that changes with both the immediate weather and the season. The rule of thumb applicable to all vertically polarized elements is to keep supporting structures as far from the element as the site allows. (On how vertical objects may affect vertical dipoles, "The Slippery Sloper Argument," http://www.cebik.com/content/wire/sloper.html, provides some suggestive ideas.)

Ideally, the feedline should run at 90° to the fed wire, that is, horizontally, for as far as feasible. If you add the remotely tuned variable capacitor as an aid to improving bandwidth, the support should be horizontal. How finicky the ILZX is to bring to satisfactory operation may depend upon the number and types of vertical objects near the antenna.

Despite these limitations, which challenge the ingenuity of most antenna builders, the ILZX has some advantages, even over the basic vertical monopole. It requires no ground radial system, and screening the ground for a half-wavelength in every direction will only raise the feedpoint resistance and increase radiation at higher elevation angles. The gain and impedance variation with changes of soil quality—ranging from very poor to very good—parallel the changes that we find in a vertical monopole.

The ILZX for 80 meters as revised provides for compensated coverage of the lower end of the band well past mid-band. The initial version, cut for a resonant frequency of 3.6 MHz, would provide equivalent coverage of the upper half of the band for 75-meter phone service using a similar capacitor range.

Although not perfect by any means and not suitable for every installation, the ILZX is one interesting solution to the problem of installing an unloaded full-size vertically polarized antenna in somewhat limited installation space. It provides service equivalent to a vertical monopole with at least 32 radials without using a single buried wire.