The Improved Telerana, with Bonus 30/40-Meter Coverage

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VE7CA revisits the Telerana, using computer modeling to improve the F/B on 20 and 15 meters. He also added 30/40-meter coverage in a clever fashion.

In the July 1981 issue of *QST*, YV5DLT, Ansyl Eckils, described an innovative method to construct a log-periodic dipole array (LPDA). Using four fiberglass poles emanating from a center hub and stringing rope around the perimeter of the ends of the fiberglass poles, he produced a light but strong framework to support an LPDA made of wire elements. This antenna was inexpensive to construct relative to purchasing a new triband Yagi antenna. Also, it was easily duplicated by anyone who has only limited experience with hand tools.

The antenna worked equally well on all amateur bands from 20 to 10 meters, including the WARC bands. Furthermore, only one length of coax was required to feed the antenna. Sounds too good to be true, doesn't it? Ansyl called it the *Telerana*, which means spider web in Spanish. The Telerana is described in the last three editions of *The ARRL Antenna Book*.

I constructed my first Telerana in 1987. The new antenna performed as expected with one exception—I was disappointed with the front-to-back ratio, particularly on the lower bands. This was confirmed by listening to local hams as I turned my antenna and made note of the S-meter readings. The front-to-back ratio on 20 meters was, at best, only 2 S units, increasing to approximately 3 S units on 10 meters. That equates to 12 dB on 20 meters.

Measuring the Telerana

I contemplated various possibilities to improve on an already-good antenna. Before attempting to modify the design of the Telerana, however, I felt it was necessary to be able to measure the radiation pattern before and after modifications were made. Otherwise, there would be no way of determining if the modifications were an improvement or not.

Wayne Overbeck, N6NB, described a method he used to determine the gain of VHF antennas when he was developing the Quagi antenna.[1] Wayne's method appeared simple and easy to duplicate. I will describe his method briefly, since the reference is no longer in print. The method requires:

1. A receiver with the ability to turn the AGC off.
2. A VU meter and a transformer to match the impedance of the VU meter to the output impedance of the receiver.
3. A stable signal source for the frequency range of the antenna to be tested.

To measure the radiation pattern of an antenna, connect the VU meter to the receive audio outlet and turn off the receiver AGC. Place a signal source several wavelengths away from the antenna to be tested. Turn the antenna so that the antenna's front lobe is pointed toward the signal source. Adjust the RF and audio gain controls so that the receiver is not saturated and the VU meter reads zero. It helps to have an accurate attenuator, as most VU meters have a scale that is only usable over a 10 dB range. I constructed the attenuator featured in both *The ARRL Handbook* and *The ARRL Antenna Book*. Turn the antenna and at every 10° or 15° record the reading from the VU meter onto an ARRL PATTERN WORKSHEET. These worksheets are available from ARRL order no. 1360 (100 sheets, 8.5 × 10 inches)[2] and should be part of any antenna experimenter's list of supplies.

The pattern produced by this method will show you a lot about the antenna you are testing. You can easily determine the front-to-side and front-to-back ratio, and you will quickly be aware of any sidelobes that are present. If two antennas are close to each other, and you suspect there is interaction between the two, you can run a pattern check first with both antennas in place and then again after removing one of the antennas.

The purist will say, and rightly so, that the radiation pattern depends upon the angle of arrival of the received signal. Further, because of surrounding antennas, power and telephone lines, there may be reflections affecting the shape of the pattern. Therefore this method does not always produce a totally accurate picture of the radiation pattern. However, the purpose of using this method is that it produces meaningful *relative measurements*. When changes are made to an antenna design, the experimenter knows with some certainty that the changes are either positive or negative.

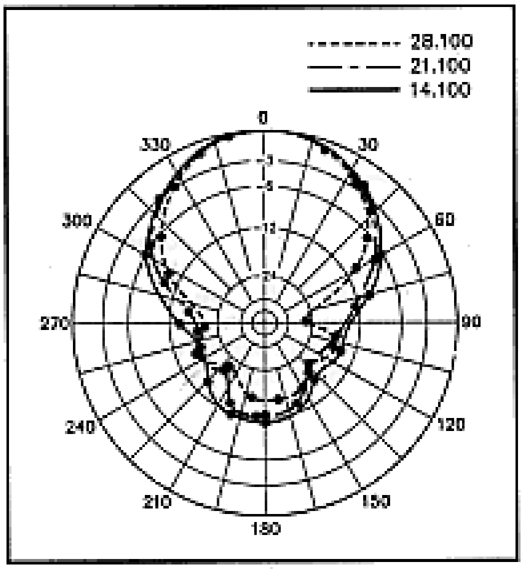

Fig 1—Measured azimuth patterns of original Telerana design, 60 feet high on tower, on three bands. The front-to-back ratio varies with frequency in a band, but is never very impressive.

The antenna being tested must always be in the same location and at the same height, and the signal source must always be in the same location when taking antenna field measurements. I cannot overemphasize this point. My QTH is located on the slope of a mountain, in a city environment. Electrical, telephone and cable TV lines are all overhead. You can just imagine the reflections occurring here.

For a signal source I constructed a 7 MHz VFO, followed by a low-power class C amplifier, rich in harmonics. Thus I could use the same VFO on 20, 15 and 10 meters. I coupled the output amplifier to two short horizontal lengths of wire using a few turns wound around the output transformer. Since the signal produced by the VFO is quite weak, I found that I have had to record my antenna pattern measurements at night when the bands are quieter.

The effect of the local environment became very evident when I moved my signal source to different locations, such as up the hill one block or down the hill one block. Though there was little change in the front lobe of the antenna pattern, the side and back lobes all showed different peaks and nulls. Make sure that you maintain your signal source in one particular location throughout the course of an antenna experiment!

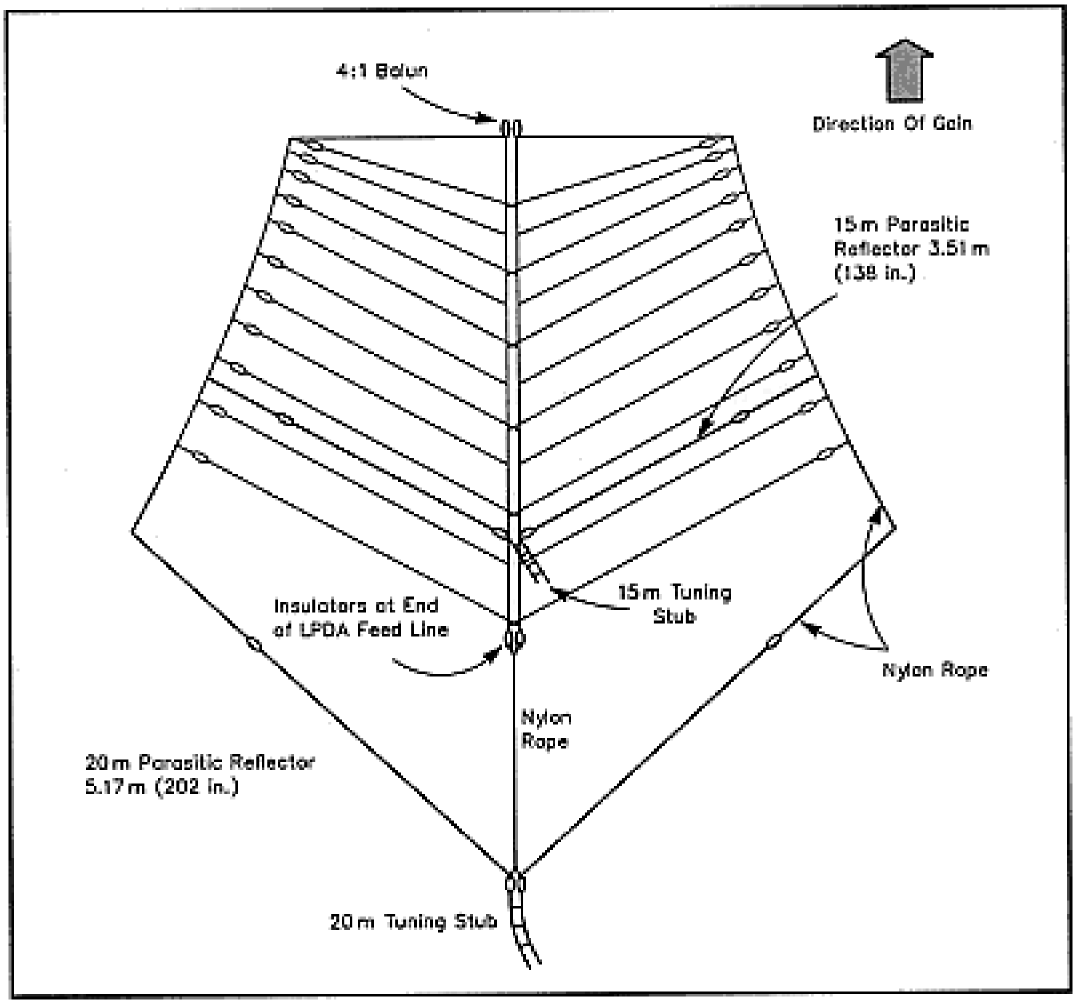

Fig 2—Physical layout of modified Telerana with 20 and 15-meter reflectors added. Note the tuning stubs for the added reflectors.

Fig 1 represents the measured patterns of the original Telerana on 20, 15, and 10 meters at my QTH. Notice that the front-to-back ratio decreases with frequency. Peter Rhodes, K4EWG, mentioned this in his article, "The Log-Periodic Dipole Array."[3] He recorded front-to-back ratios similar to those I measured on the Telerana.

Improving the Telerana

Since I wanted to improve the front-to-back ratio on 20 meters in particular, I modified the Telerana by removing the two longest elements (which are resonant below 20 meters) and added a 20-meter parasitic reflector. I used this approach because I wanted to use the existing framework supporting the Telerana. I estimated the length of the 20-meter reflector by adding 5% to the length of a standard 20-meter wire-element dipole, resonant at 14.2 MHz.

Much to my disappointment, when I put the array back on the tower, the SWR was very high at the bottom of 20 meters—only at 14.350 MHz did the SWR start to decrease below 3.1:1 Furthermore, the front-to-back ratio was now only about one S unit! It was obvious that the longest remaining element of the modified Telerana was resonant above the 20-meter band and the reflector was not tuned to the correct frequency.

I decided to recalculate the lengths of the LPDA so that the longest element was resonant near the bottom of the 20-meter band. I also had to find a way to tune the 20-meter reflector where I wanted it to be.

My friend Darrell Wick, VE7FCR, had taken a keen interest in the Telerana design and my experimenting. He offered to write a computer program so that we could easily try different design parameters for the LPDA. He used the design procedure outlined in the 15th edition of *The ARRL Antenna Book*. Darrell had also purchased an antenna software program called *MN*, a derivative of a powerful antenna-modeling program called *MININEC* and was anxious to try something other than the sample files that came with the program.

Darrell's program also creates antenna files that can be used in other programs, such as *MININEC3*, *MN*, *ELNEC* and *NEC*. This became very useful when we began altering different parameters of the Telerana design, because of the complex geometry of such a wire antenna. (Darrell's program is called *LPDA* and is available from him directly. See Notes.) If you have an old computer and no math coprocessor, be prepared to wait for a long time for the computer to print out a

Table 1
Element Lengths and Spacings in Inches

Element Number	*1/2 Element Length (inches)*	*Spacing (inches)*	*Total Distance (inches)*
R1	202.0	102.0	0.0
L1	210.1	38.7	102.0
L2	191.2	17.6	140.7
R2	138.0	17.6	158.3
L3	174.0	32.0	175.9
L4	158.3	29.1	207.9
L5	144.1	24.5	237.0
L6	131.1	24.1	261.5
L7	119.3	22.0	285.6
L8	108.6	20.0	307.6
L9	98.8	18.2	327.6
L10	89.9	——	345.8

Note: The reflector element lengths do not include the lengths of the stubs.

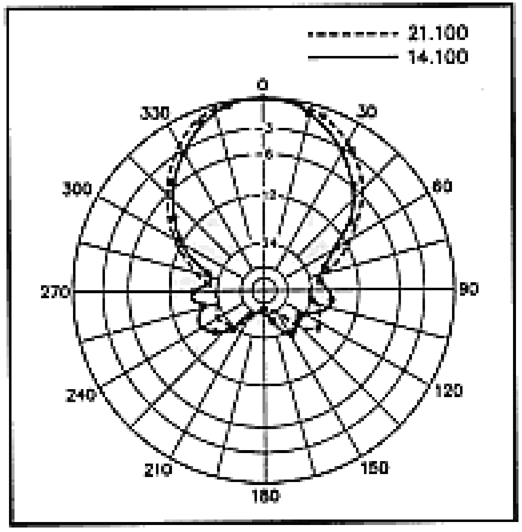

Fig 3—Measured azimuth patterns of modified Telerana after incorporating reflectors for 20 and 15 meters. These measurements are for the frequency showing maximum front-to-back ratio. Note that the peak rearward lobes are about 20 dB down from peak of forward lobe.

Table 2
Modified Telerana Design Parameters

Lower frequency	f1 = 14.05 MHz.
Upper frequency	fn = 30.00 MHz.
Design constant	tau = 0.91
Relative spacing constant	sigma = 0.046
Apex angle	2a = 52.1°
Cotangent of angle	Cot(a) = 2.0444
Design bandwidth (fn/f1)	B = 2.14
Active region bandwidth	Bar = 1.2275
Structure bandwidth	Bs = 2.621
Diameter of elements	= 14 AWG
Feed line impedance	R_0 = 208 Ω
Antenna feeder impedance	Z_0 = 433.81 Ω
Diameter of feeder wire	= 14 AWG
Feeder spacing	S = 1.9757 inches

pattern for a multi-element array such as the LPDA. The original Telerana design took *MN* over 8 hours to produce the pattern on an old IBM compatible XT 8088 computer! With a math coprocessor and a new 386-based computer it takes under 2 minutes.

Using Darrell's program and *MN*, we tried many different designs for the LPDA, with and without parasitic reflectors. The right parasitic reflector lengths gave a considerable improvement in the front-to-back ratio. Even on 15 meters, where the 15-meter reflector is positioned between elements of the LPDA, the front-to-back ratio increased by over 15 dB.

Fig 2 shows the location of the parasitic reflectors relative to the elements of the modified Telerana design. Refer to *The ARRL Antenna Book* for construction details of the support structure and feed line. The element lengths and spacings are shown in **Table 1**. These were chosen so that we could use the fiberglass pole lengths of the original Telerana design. This design has a spacing of 2.59 meters (8.5 feet) between the 20-meter reflector and the longest element of the LPDA, as measured along the transmission line connecting the elements. According to *MN*, this appears to be close to the minimum distance that both works and yet is not overly critical for dimensional tolerances. **Table 2** shows the design parameters for the new array.

Darrell spoke to the author of *MN*, Brian Beezley, K6STI, about whether the program can accurately model an array like the LPDA, with multiple driven elements fed with a transposed transmission line at each element. Brian indicated that trying to model transmission lines in *MN* by assuming multiple sources with a 180° phase shift at each dipole feedpoint probably is not entirely correct. However, there was good agreement between the pattern produced by *MN* and the measured results, despite not knowing the actual phase shift.

A new array was constructed using the element lengths shown in Table 1. This time, before mounting the antenna on top of the tower, I decided to tune the reflector by using a tuning stub in the middle of the reflector element, in the same way that Quad reflector elements are often tuned. The array was placed so that I could reach it when standing on the ground. Using a receiver connected to the array and my portable signal source placed several wavelengths away, I was able to adjust the length of the stub for minimum signal strength. I knew that the resonant frequency of the reflector would change when it was mounted on top of the tower, but I didn't know by how much. So I tuned it for 14.100 MHz. When the array was placed on top of the tower, I ran pattern checks on several frequencies. I found that the frequency where the front-to-back ratio was the highest decreased approximately 175 kHz when the array was raised 60 feet above ground.

Lowering the array once again, I added a 15-meter reflector and also readjusted the 20-meter reflector stub length so that when the array was on top of the tower the highest front-to-back ratio would be at 14.025 MHz.

Fig 3 shows the radiation patterns for 20 and 15 meters after the reflectors were added. The front-to-back ratio on both bands now exceeds 30 dB at the design frequency. Note that the worst-case lobes in the rear hemisphere behind the main lobe were down about 20 dB, as best I could measure

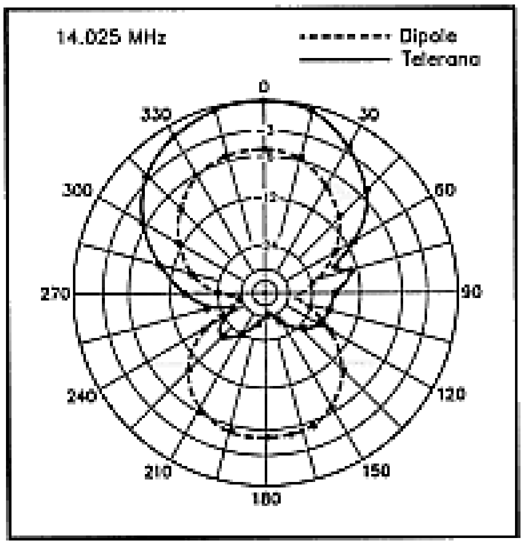

Fig 4—Measured 20-meter azimuth pattern for modified Telerana compared to reference trap dipole mounted 9 feet below Telerana. The height of antennas was made comparable for these tests by lowering tower to 48 feet for Telerana. The Telerana exhibits 5.25 dB more gain than reference dipole.

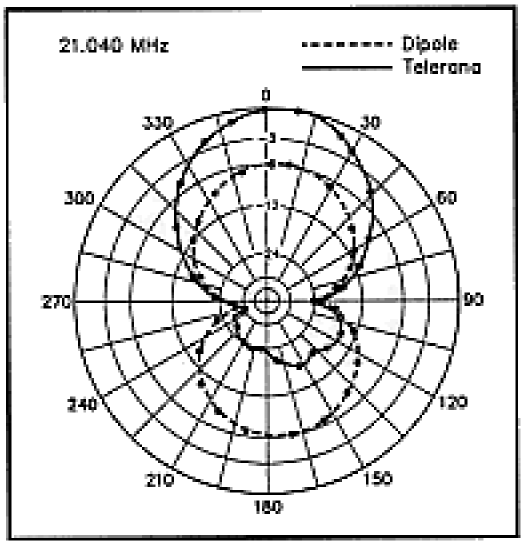

Fig 5—Measured 15-meter azimuth pattern for modified Telerana compared to reference trap dipole mounted 9 feet below Telerana. The height of antennas was made comparable for these tests by lowering tower to 48 feet for Telerana. The Telerana exhibits 6 dB more gain than reference dipole.

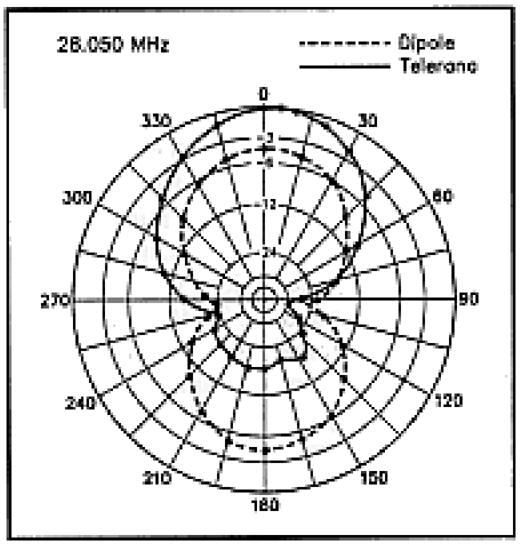

Fig 6—Measured 10-meter azimuth pattern for modified Telerana compared to reference trap dipole mounted 9 feet below Telerana. The height of antennas was made comparable for these tests by lowering tower to 48 feet for Telerana. The Telerana exhibits 4.25 dB more gain than reference dipole.

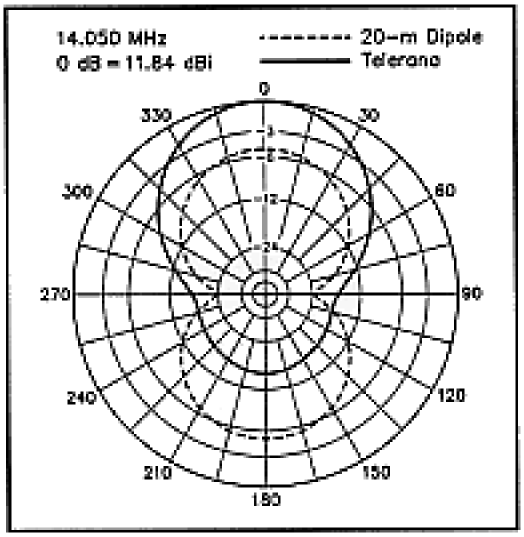

Fig 7—*NEC2* comparisons of Telerana's azimuth pattern on 20 meters, compared with reference dipole at the same height. Ground conductivity of 5 mS/m and dielectric constant of 13 were assumed for these computations. *NEC2* predicts that Telerana should have almost 5 dB of gain over reference dipole.

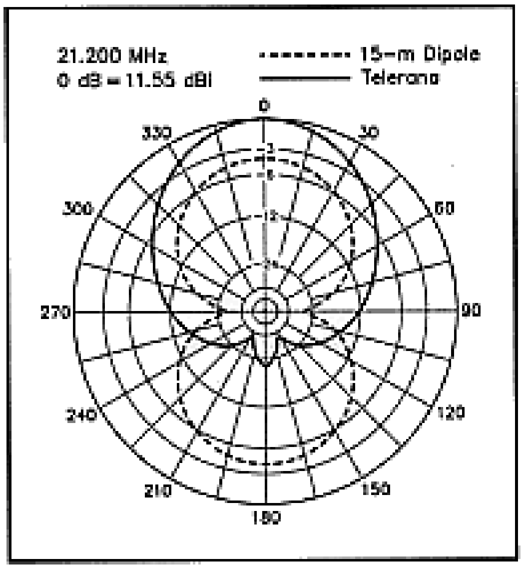

Fig 8—*NEC2* comparisons of Telerana's azimuth pattern on 15 meters, compared with reference dipole at the same height. Ground conductivity of 5 mS/m and dielectric constant of 13 were assumed for these computations. *NEC2* predicts that Telerana should have just over 4 dB of gain over reference dipole.

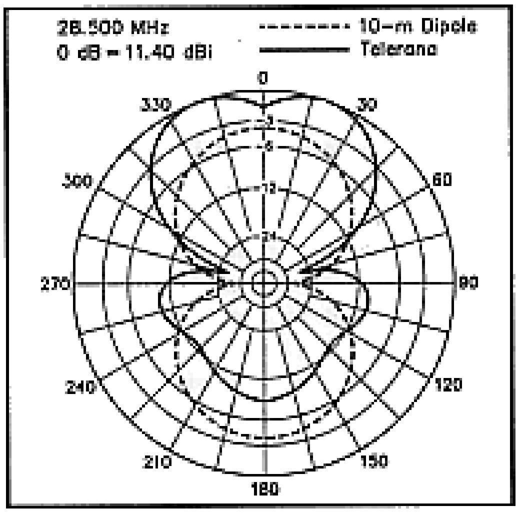

Fig 9—*NEC2* comparisons of Telerana's azimuth pattern on 10 meters, compared with reference dipole at the same height. Ground conductivity of 5 mS/m and dielectric constant of 13 were assumed for these computations. *NEC2* predicts that Telerana should have peak gain (on either side of small dip at nose of main lobe's response) of just under 3 dB of gain over reference dipole.

them. I tuned the 15-meter reflector when the array was on the ground. There was no change in the frequency of the 15-meter reflector when the array was mounted back on the tower. Presumably, this is because the 15-meter reflector has so much wire surrounding it that it is not affected much by proximity to the ground.

Antenna Gain

Have you ever wondered how much gain your new beam antenna really has over the dipole it replaced? Was it really worth the effort to put up a tower and build a new multi-element wonder? Until computer antenna-modeling programs came along, these kind of questions might have kept me awake at night. Modeling programs have done away with a lot of myth and wild exaggerations regarding antenna gain. Dean Straw, N6BV, Senior Assistant Technical Editor at HQ, offered to do some modeling of the modified Telerana using *NEC2*, the big brother to *MN*. As well, he suggested that I mount the driven element of my multiband beam and use it as a dipole underneath the modified Telerana. This way I could make a few hands-on comparative measurements.

I mounted the tribander's driven element 9 feet below and 90° to the front-back axis of the modified Telerana in order to minimize the interaction between the two antennas. My modified Telerana is mounted on a motorized tubular crankup tower, allowing me to easily change the tower height so that the antennas are at the same height when I make comparative measurements. **Fig 4, 5** and **6** show measurements for 10, 15 and 20 meters, comparing the modified Telerana to the triband dipole. **Fig 7, 8,** and **9** is what *NEC2* produced. There is a gain discrepancy between the field measurements and *NEC2*, but remember my QTH is anything but a proper antenna test range. A summary of gain measurements is shown in **Table 3**.

Table 3
Comparison of Gains Over Dipole, *NEC* Computations Versus Actual Measurements

Band	*Actual Measurements Compared to Dipole*	*NEC Peak Gain Compared to Dipole at Same Height*
10 meters	4.25 dB	4.5 dB
15 meters	6.00 dB	4.5 dB
20 meters	5.25 dB	3.9 dB

You will notice that on 10 meters *NEC2* predicts a notch in the middle of the front lobe. Though I never noticed this when taking actual field measurements, it may be that it is masked by interactions from surrounding house wires and the 30/40-meter dipole above the Telerana. As well, the *MN* or *NEC2* programs model antenna wires as being absolutely straight, with no bow in the center from the weight of the wire. The bow in the wire is only an inch or two, however this may account for some of the difference between the computer plots and the field plots.

The *NEC2* pattern plots in Fig 7, 8, and 9 are shown in dBi and are over real ground with the antenna at 60 feet. This adds another 6 dB of gain due to "ground reflection gain" at the peak elevation angle. **Fig 10** is a photograph of the completed Telerana with the reference dipole under it.

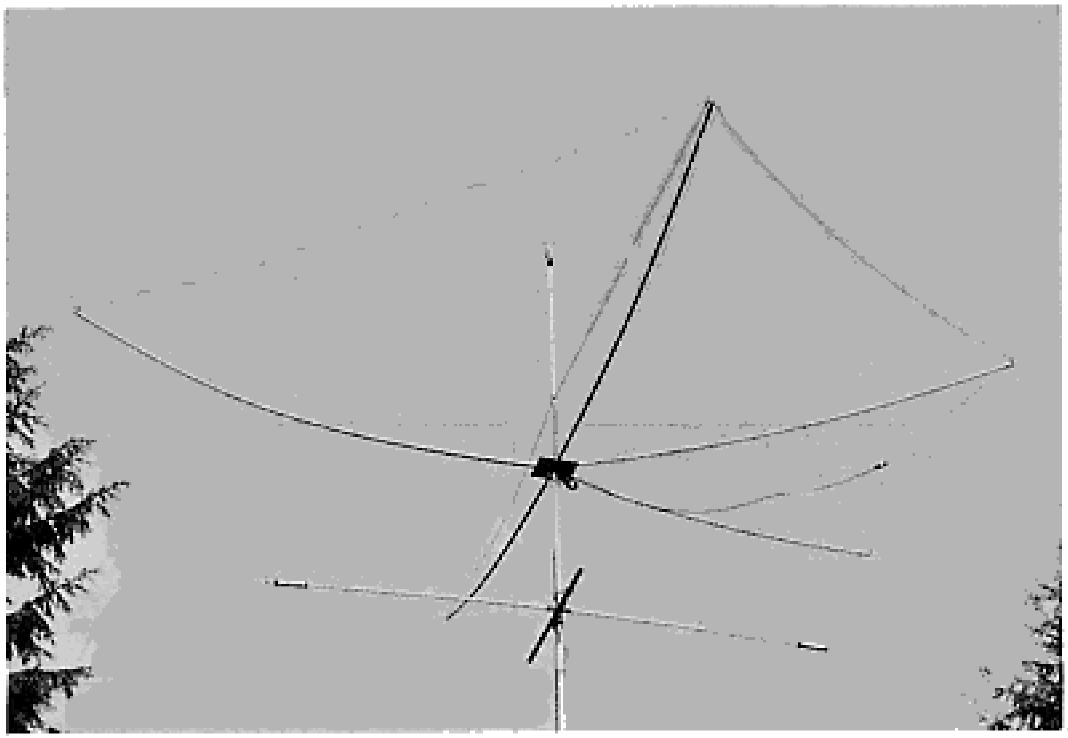

Fig 10—Photograph of modified Telerana in the air, with reference trap dipole mounted 9 feet below it.

Fig 11 is a *NEC2* plot of a Cushcraft 20-3CD 3-element 20-meter monoband Yagi compared to the modified Telerana. The Yagi has roughly 2 dB more gain than the Telerana for roughly the same boom length. In my case, I am willing to accept a 2-dB reduction in gain in order to have 5-band capability in one antenna. As well, the difference in the cost between the modified Telerana and five monoband Yagis is significant, not to mention the cost of mounting them on separate towers!

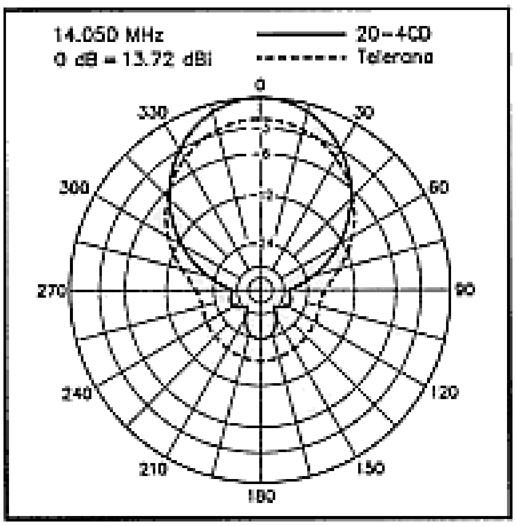

Fig 11—*NEC2* comparison of Cushcraft 20-4CD 4-element 20-meter Yagi at 60 feet with Telerana at same height. The boom lengths are comparable, but Yagi has about 2 dB more gain due to its narrowband response.

I am generally pleased with the comparisons between the computer models and the actual field measurements, considering that my QTH does not qualify as an antenna test range. Here are a few comments from ham operators who were asked to observe the difference between the dipole and modified Telerana without telling them in advance what antenna they were listening to:

"Sounds like you turned your linear on."

"The second antenna is sure stronger than the first" (when the second antenna was the modified Telerana!)

When talking with long-distance DX stations such as VKs and ZLs, the difference was even more pronounced. I observed similar differences on receive as well. On receive, the most obvious benefit of a directional beam with a high front-to-back ratio is the increase in signal-to-noise ratio and reduction in QRM and QRN off the sides and back of the antenna. This became very evident when comparing the dipole to the modified Telerana.

However, I was actually surprised how effective the dipole was when mounted at 60 feet. Other than the fact that the dipole was typically 1 to 2 S units less than the Telerana, when conditions were good the difference was hardly noticeable other than when I looked at the S meter. Where I really appreciated the gain and front-to-back ratio of the Telerana was when conditions were poor, or when listening to a DX station in a pileup. The difference is like night and day.

A Bonus—30 and 40 meters

During a storm, high winds whipped the fiberglass poles and the whole array inverted, just like an umbrella will sometimes do. To alleviate this problem I installed a vertical $^{3}/_{4}$-inch plastic PVC pipe extending upward from the central hub where the fiberglass poles are attached. I strung $^{1}/_{16}$-inch nylon cord from the top of the PVC pipe out to the ends of the fiberglass poles. Then I realized that I could replace two of the nylon cords with a 30-meter dipole. It turned out that the distance from the top of the PVC pipe to the end of the fiberglass poles was too short for a 30-meter dipole. I inserted an insulator in the wire nearest the end of the fiberglass poles and by extending the wire, brought it back to the antenna mast below the center hub of the Telerana. Later, I added 30-meter coaxial-cable traps to the ends of the 30-meter dipole and more wire to resonate the dipole on

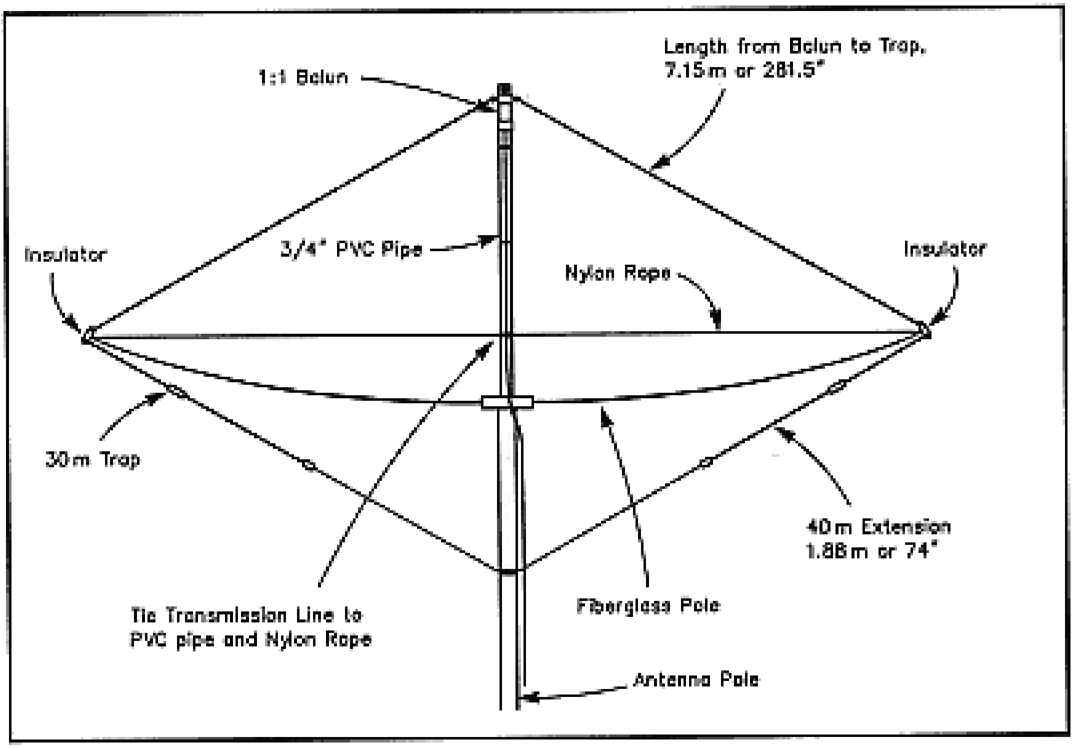

Fig 12—Side view of 30/40-meter addition to Telerana, using ¾-inch PVC pipe as vertical stabilizer and support for 30/40-meter trapped dipole.

40 meters. A separate transmission line is used to feed the 30/40-meter inverted V. See Fig 6 for dimensions and construction design.

Fig 12 shows the layout for the 30/40-meter inverted V dipole. When working Europe from this QTH, the null off the side is to the East Coast. This really helps decrease QRM. When listening to a weak signal, I can turn the dipole so that it points in the direction of the station, making a considerable difference. I checked the radiation pattern of the modified Telerana, by taking actual field measurements after installing the 30/40-meter dipole and I was pleased that the radiation pattern on 20 to 10 meters was not significantly affected by the addition of the 30/40-meter dipole. I did not model this addition on *MN*.

Conclusion

Adding parasitic reflectors to the Telerana for 20 and 15 meters has significantly improved the front-to-back ratio on these bands. When operating on 20 and 15 meters, I now have to be more conscious about where the antenna is aimed, otherwise I simply do not hear a weak signal if it is off the back of the array. When listening to DX stations arriving at very low angles, an S6 signal disappears into the noise when the array is turned 180°. Perhaps someone may want to add parasitic reflectors on 17, 12 and 10 meters as well.

The addition of the 30/40-inverted V with the apex at 70 feet has resulted in an increase in my DX totals on these bands, a good indication of the effectiveness of this addition.

Once again, computer antenna modeling has played an important role in optimizing an antenna design. Being able to make actual field antenna pattern measurements allows me to check whether my assumptions are true or not. A bands-on comparison with a dipole at the same height is the acid test. The modified Telerana really does have respectable gain and a high front-to-back ratio compared with a dipole. With the addition of 30 and 40-meter coverage, this is a very compact and effective antenna covering seven amateur bands!

Darrell also built the modified Telerana and he found that it was easy to duplicate the design. Radiation pattern checks of his array show similar results. Neither Darrell nor I would trade our modified Telerana for the narrowband triband Yagis they replaced! We both encourage anyone to build this excellent antenna.

I wish to thank Darrell for writing the LPDA design program, Joe Young, VE7BFK, for his helpful comments regarding this article, Dean Straw, N6BV, for modeling this array on *NEC2* and especially my wife and children for putting up with me and my constant raising and lowering of the antenna, wire and fiberglass poles and assorted clutter on the front lawn, during the last 6 years of intermittent antenna experimenting.

Notes

[1] "Measuring Antenna Gain with Amateur Methods," *The ARRL Antenna Anthology*, (Newington: ARRL, 1978), p 145. (Out of print.)

[2] Jerry Hall, "A New Look for *QST's* Antenna Patterns," *QST*, Jul 1980, p 26.

[3] Peter D. Rhodes, K4EWG, "The Log-Periodic Dipole Array," *QST*, Nov 1973, p 16.

[4] Darrell A. Wick, VE7FCR, 1491 Edgemont Rd, Victoria, BC V8N 4P7, Canada.