Feeding and Phasing LFA Antennas

By: Al Rabassa, NW2M

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Abstract

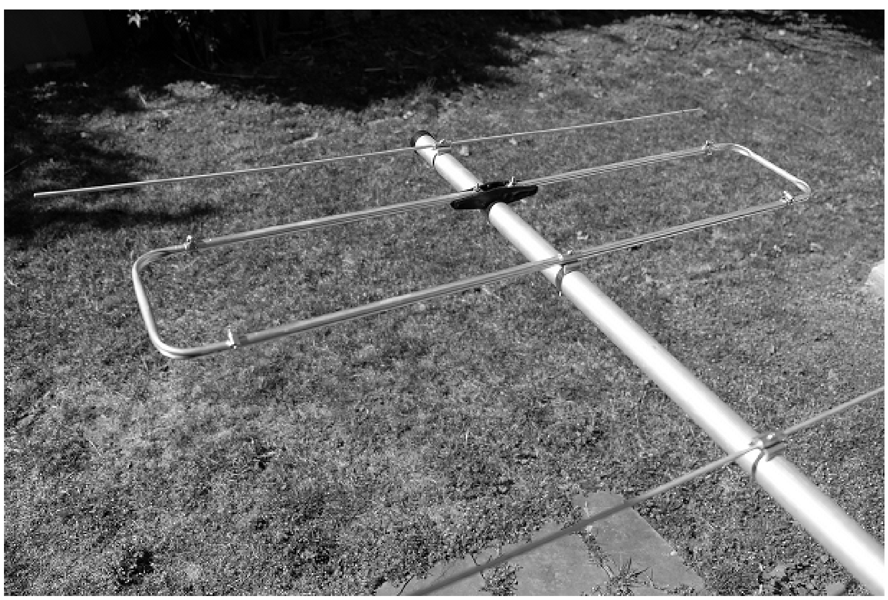
Loop Fed Arrays (LFA) are a new generation of high-performance yagi antennas hitting the amateur market. They are offered for sale from HF thru the UHF bands. The Loop Fed Arrays have Driven Elements that behave differently from other full-wave loop antennas. Special care must be taken when feeding this type of balanced antenna with unbalanced coax. When stacking LFA antennas, additional measurements are required when designing phasing harnesses that are multi-wavelength long with respect to their electrical and physical length. The stated Velocity Factor may prove insufficient for high-performance applications such as: contesting, weak-signal, and EME. This is an introductory and how-to article on Feeding and Phasing LFA antennas designed for the Amateur 2M VHF band.

Driven Element Loop

The driven element on yagi antennas have been offered in various shapes and sizes. These have included: a simple dipole, folded dipole, multi-element folded dipoles, full-wavelength loops, quad/quagi designs, and now the LFA (Loop Fed Array). Regardless of the geometry, the function of the driven element is to transfer power to and from the antenna and the transmission line with low loss with a desired impedance.

Out of Phase Segments

Computer modeling has shown that the specific shape of the LFA's driven element loop exhibits a slight pattern change when compared to traditional list of driven elements listed above. Figure-1 shows a close-up of a LFA driven element. The upper and lower "flattened" segments create an out-of-phase condition which tend to further cancel off-axis radiation. The resulting computerized polar plots are somewhat flattened- which indicates decreased off-axis directivity resulting in suppressed sidelobes. Using this information, computer modeling can now determine the optimum parasitic element lengths (Reflector and Directors) and parasitic element spacings to exploit this pattern behavior on a full-sized antenna.



(Figure-1. Photo of a full-wavelength driven element loop on a 12 element LFA 2M yagi antenna. The 50Ω feedpoint faces the reflector. The opposite side of the feedpoint is electrically and physically grounded to the boom. Full symmetry must be maintained for optimal antenna performance. Photo: NW2M.)

Direct 50Ω Feedpoint

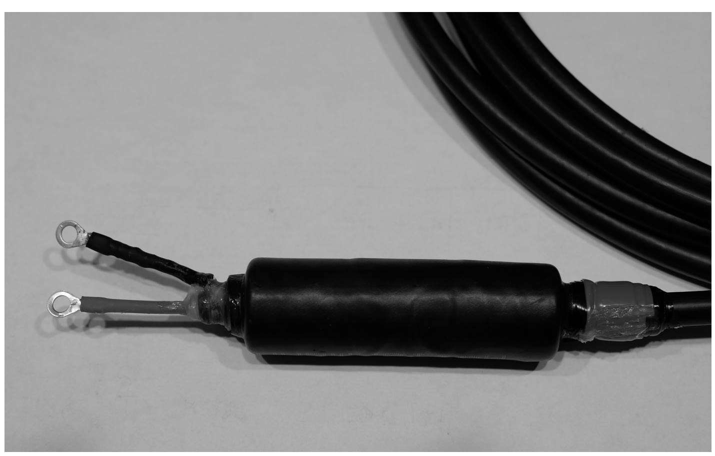
One of the characteristics of a LFA driven element is that it exhibits a 50 Ohm characteristic impedance. No matching networks or other "lossy" RF components are required to provide a direct match to 50 Ohm coaxial cable. This means that the RF power ratings for this type of feed system can easily exceed the full legal-limit. While there are no transformers or baluns required for impedance matching, we cannot ignore the issue of common-mode currents flowing across this interface. Luckily, these are easily resolved.

Balanced to Unbalanced Transitions

The driven element loop of a LFA antenna is highly symmetric. That is to say- the left side is a mirror image of the right side. The top is a mirror image of the bottom. It is completely "balanced". This symmetry must be maintained as you adjust the lengths of the loop for best SWR. In contrast, coaxial cable is not balanced. The center conductor does not see a mirror image of itself, but rather, it sees a coaxial shield, and vice versa. If we simply attach a coax cable to the LFA loop, the outside of the coaxial shield can act as part of the antenna resulting in a highly undesirable condition: propagation of common mode current. This common mode current will negatively impact the antenna's performance and must be eliminated.

Coaxial Chokes

While it is possible to use a balun (balanced-unbalanced) device at the transition between the unbalanced coax cable and a balanced driven element, another technique is to present a high impedance pathway for common mode currents by creating a "RF choke". I chose to simply place three large ferrite cores with sufficient permeability at the feedpoint creating a RF choke to stray common mode currents flowing on the outside shield of the coax cable. Figure-2 shows what this looks like for a 2M LFA antenna.



(Figure-2. Three ferrite beads placed at the feedpoint of a LFA antenna to create a RF choke on the 2M band. The ferrite beads are placed as close to the feedpoint at practicable and held in place with glue-infused heat shrink tubing. The size of the coax cable and ferrite beads can easily handle full legal-limit power levels. Photo: NW2M.)

Weight Distribution

The weight of 13 feet of large-diameter coax cable, the ferrite beads, heat shrink tubing, etc., added weight to one end of the antenna. I found that this added weight had shifted the balancing point by 1-foot on a 23-foot boom. The boom-to-mast clamp had to be moved 12" toward the rear of the antenna to achieve a static balance.

Stacking LFAs

LFA antennas may be stacked to increase your system's performance. I have room on my tower for two LFA antennas for 2M weak-signal/EME work. This was by design. By definition, "room" on the tower means- within the weight limits and wind loading for: the tower, thrust bearing, mast, and rotator. It also means that there is sufficient distance to physically separate the antennas for optimal performance. In my example, the stacking distances are 12 feet vertically for two horizontally polarized LFA antennas on the 2M band. The boom length of each antenna is 23 feet.

Feeding and Phasing

As described, feeding a single LFA antenna is a very straight forward process. High quality coax and a RF choke are all that are needed. SWR adjustments are also quite easy- remembering to keep both halves of the driven element perfectly symmetrical. That said, things change when you add a second LFA antenna.

50 + 50 = 25

You cannot connect two 50Ω antennas in parallel because your transmitter will no longer see a 50Ω load. The signals must also arrive at the antennas at exactly the same time so they appear "in-phase" and therefore "add-up" for increased system performance. After all of your hard work, you do not want to accidentally steer your signal electrically into the ground! Therefore, all measurements and cutting errors must be less than 0.25 inches, which represents one electrical degree (1°) of error on the 2M band.

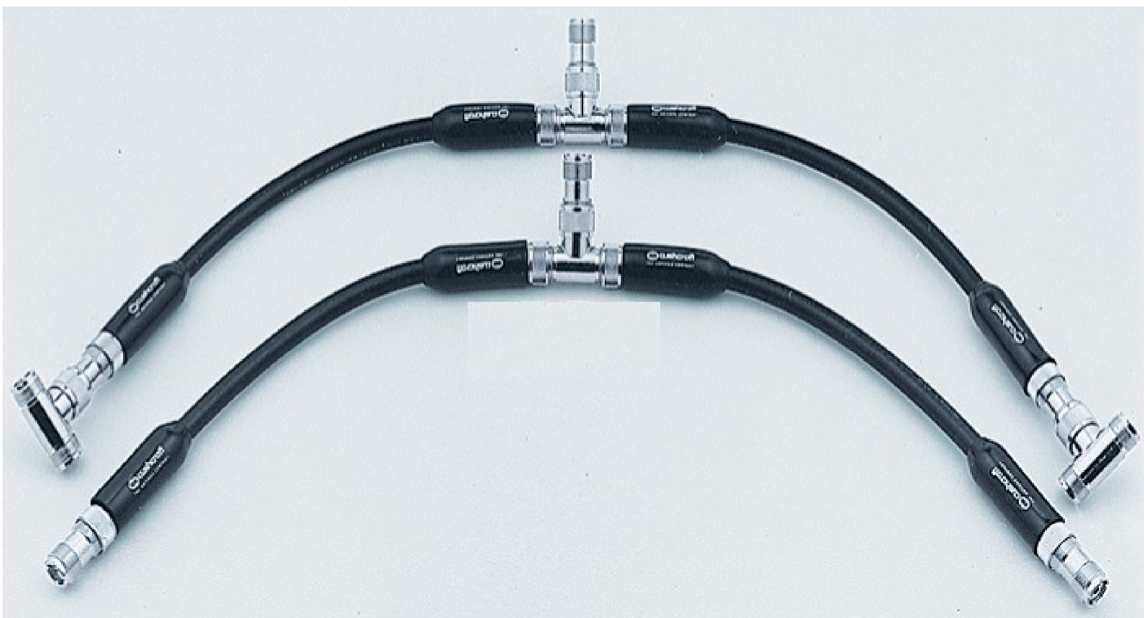
Coax Transformers

It has been shown that odd quarter wavelength multiples of 75Ω coax exhibit the impedance transformation needed for connecting a single 50Ω transmitter to a pair of 50Ω antennas. The odd numbers refer to: 1,3,5,7... quarter wavelength multiples of coax. Please note- The length of the coax transformer needs to be its electrical length, not its physical length, so knowing the velocity factor (VF) of the coax is critical for success. Typical values are: 0.66, 0.77, 0.84, 0.88, etc. for popular coaxial cables. Consult the manufacture's spec sheet for the correct value. I decided to use high quality

RG-11/U coax (75Ω) with a 0.66 velocity factor at a design frequency of 144.1 MHz. I soon found out there is much to learn.

Minimum Requirements

The minimum coaxial transformer length occurs at the 1st odd quarter wave electrical length of 75Ω coax. See Figure-3. The quarter wave formula for a specific frequency and the coax's velocity factor must be known. In my example, this is: 246/FMhz * 0.66vf. This yields 13.5 inches at a design frequency of 144.4 MHz. A coaxial T-connector and a pair of 13.5" lengths of 75Ω coax cables bring our system impedance back to 50Ω. From this point, any length of 50Ω coax may be used as long as they are <u>exactly</u> the same length and the antennas exhibit a 50Ω impedance. Additional connectors and barrel connectors are needed to complete the assembly.



(Figure-3. A 1st electrical odd quarter wavelength of 75Ω coax as a 2-port phasing harness (bottom) and 4-port phasing harness (top). Image: Cushcraft Corp.)

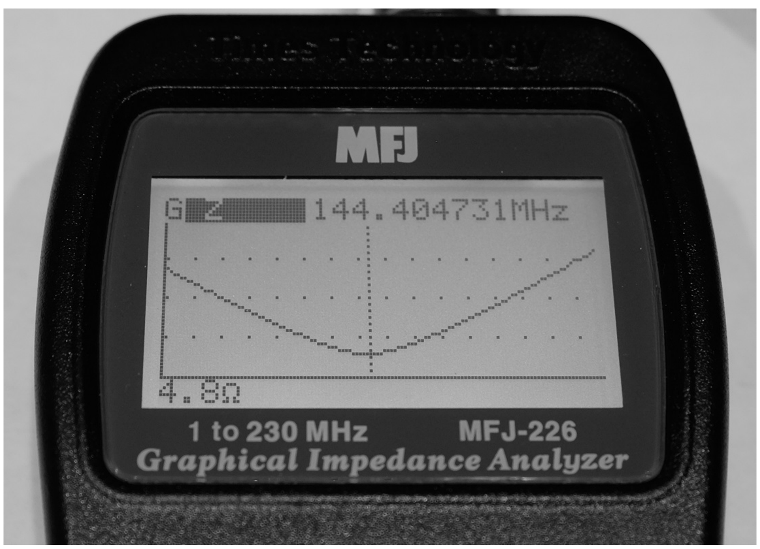
Multiple Wavelength Harnesses

I decided not to incur the additional signal loss across a pair of RF connectors and barrel connectors (as shown in Figure-3) on my 2M weak signal array. Too many connections and perturbations. This means that my two equal length runs of 75Ω coax, acting as a phasing harness, will be <u>many</u> odd quarter wavelengths long. My phasing harness will consist entirely of 75Ω coax. The length of coax had to span half the boom length plus half the stacking distance. Anything shorter or longer would require electrical multiples of 15 or 19 respectively. A roll of 50 feet of RG-11/U coax was enough to get me started.

Errors Multiply

With a 17x multiple, I started to wonder about errors. Anything multiplied 17 times could be loaded with accumulated errors. Even a 1/8 inch error becomes 2-1/8 inches of error when multiplied 17 times. I started to question: How accurate is the "246" numerator in the quarter wavelength formula and the generic 0.66 velocity factor for PE dielectric coax?   I needed help.

To remove all of the guesswork, I used a Vector Network Analyzer (VNA). With this handheld device, I was able to accurately measure the electrical length of coax with great precision. I cut and trimmed the coax until the 17th electrical odd quarter wavelength multiple measured 144.000 MHz. After I exposed the center conductor and shield to create two pigtails, the resulting (shorter) length of coax resonated at 144.400 MHz. See Figure-4. I repeated the process for the second phasing harness. High quality RF connectors and excellent weather-proofing techniques are mandatory for years of high-performance operation.



(Figure-4. A MFJ-226 Impedance Analyzer sweeping from 143.5-145.5 MHz while measuring Impedance. Both 2M phasing harnesses have been tuned using this meter and exhibit matching nulls, impedances, and lengths. A matched pair. Photo: NW2M)

Results

My VNA device measured the actual velocity factor (VF) for this production run of RG-11/U to be 0.676. This is a 2.5% error that would have been multiplied 17 times- almost 6" of error in physical coax length.

Parts and Materials:

- Design frequency: 144.400 MHz.
- Odd quarter wavelength multiple: 17x.
- Stated Velocity Factor: 0.66.
- Measured Velocity Factor: 0.676.
- 1° of electrical error = 0.15" physical error.
- Coax type: RG-11/U, 75Ω, Carol Mfg[1].
- Connector type: N-connector, solder-crimp[1].
- Overall coax length: 235-1/2" (corrected).
- Length of Pigtails with Ring Terminals: 1.25" each.
- Ferrite Beads (3x), 31 Mix, Palomar Engineers[2].
- Heat Shrink Tubing, 3:1, 1" ID, Glue Infused[1].

[1] The RF Connection, Gaithersburg, MD. www.therfc.com.
[2] FB102-31 - 1/2" ID, RFI Range 1-300 MHz,

Conclusion

In the spirit of experimentation, I decided to roll-my-own 2M VHF phasing harness rather than purchase a ready-made commercial unit. Looking back, this was a resounding success. I was able to leverage handheld instruments to provide accurate and precise measurements. Knowing the actual velocity factor proved critical in this activity, as was measuring the true electrical length of each harness leg. Attention to detail is critical for success as physical errors as small as 0.15" represent 1° electrical degree of error. I am confident that there is no electrical steering of my signal. 73, Al, NW2M

Bio:

Al Rabassa, NW2M, is a member of the ARRL and the Montgomery Amateur Radio Club in Rockville, MD. He is an Extra-class licensee and has been licensed since 1985. He has a Masters of Science in Management of Technology from the MIT Sloan School of Management, a Masters of Science in Information Systems and Technology from the Johns Hopkins University, and a Bachelors of Science in Computer Science from Monmouth University in NJ. He is active in the operation and restoration of vintage Yaesu FT-101 series radios from the '70s. He operates the latest FT8 digital modes on HF and the emerging digital/Fusion modes on the 2M band. With his newly built 2M antenna array, he will be actively chasing low-elevation EME using JT65. Al may be reached via email at nw2m@arrl.net.