Thoughts on the “Mystery” Antenna

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The W5GI Multiband Mystery Antenna[1] is simply a linear array of dipoles fed “in-phase” to create a gain broadside to the antenna. There are some interesting aspects of the physical implementation that are of interest and could be better optimized for performance plus some limitations. This is the subject of this paper.

Background

Driving dipoles that are spaced in a linear arrangement, i.e., in a straight line can create gain. This is called a collinear array. The typical gain possible with 2, 3, and 4 dipoles is well known and provided in the literature[2].

The mystery antenna is simply 3 one-half wavelength dipoles placed side-to-side[3]. The center dipole is fed with one-half wavelength of ladder line, which ideally transfers the dipole feed point impedance to the far end of the ladder line. In the mystery antenna implementation, the far end of the ladder line (away from the feed point) connects to coaxial cable that then connects to the transmitter.

Phasing the Array

One of the design efforts in phase arrays is determining how to drive the adjacent dipole sections from the main driven element. Three separate feed lines could be used with all 3 driven from a common transmit source. Some implementation use a Wilkinson power divider to split the transmit signal and feed each of the dipole elements.

Other designs use a phasing section to change the phase of the center driven element by 180° and then connecting to adjacent dipole elements. The phasing section can be made form one-half wavelength of wire that droops down and then back up two the adjacent dipole ends. The length of this wire folded back on itself is ¼ wavelength. The unsightly dropping wire does not radiate since currents flowing in the down direction is balanced with a current flowing in the up direction.

Sometimes the drooping wire is replaced with open wire feed line (300, 450 or 600 ohm). Remember that the electrical phase needs to be shifted by 180°, so the physical length of the actual line used must take into account the velocity factor (VF) of the phasing section.

The drooping wire could also be replaced with coaxial cable that provides the same 180° phase shift. Again, the VF must be accounted for in the length. The VF of coaxial is typically 0.67 for regular cable, 0.8 for foam dielectric, and 0.9 for open wire ladder line. This means the VF must reduce the physical length of each cable type proportionally.

The drooping phasing section (that creates the required phase shift) does not have to be dangling at right angles to the antenna to work. The section can be coiled up to reduce its size, making it more attractive. One implementation in the literature[4] gives a tight twist to the dangling wire and the twisted wire is then coiled into a diameter of about 5 inches. The important feature of the phasing section is that any current than flows into the phasing section exits with a phase shift of 180° (accounting for the VF).

Coaxial Phasing Element

It is a known fact that coaxial cable can also be used as a phasing section. Just like a tightly twisted wire, coax cable can have its center element driven by an RF source and current will flow into the center conductor. As the current flows into this conductor, it will flow to its opposite end that, if shorted to the inner shield, will then continue flowing until it emerges from the inner shield. In other words, a shorted piece of coax that is 1/4 wavelength long (electrically) will create a phase shift of 180°. This can be proven by connecting an RF generator to the center conductor of a ¼ wavelength shorted line, and measuring the phase shift of the signal that comes out of the coax shield.

However, there are some limitations to using coax.

> First, the velocity factor must be known to generate the proper phase shift. Otherwise, the phase shift will not be the 180° required to optimize the current flow into the adjacent dipoles in the array.
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> Second, the coax does exhibit loss in terms of dielectric heating at the high voltage points (highest voltage at the center conductor and shield) and I^2 R heating due to Ohmic losses (maximum at the shorted end of the coax).
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> Third, the coax can breakdown due to the high voltages present or due to losses. A 100 W transmitter will generate about 600 volts RMS AC at the phasing section with about 1-1/2 ampere of current maximum at the short. A kilowatt would be much higher.

The coaxial phasing section discussed above has all of its RF current flowing on the inside of the cable; down the center section and back out the inner shield. This is where the phase is changed by 180°. The outer shield is not excited by the RF energy and is available to be used as a portion of an antenna.

Remembering the VF for the coax is typically 0.66, the physical length of the coax is therefore 34% shorter for it to develop a 180 degree phase shift. What this means is if the outer shield is to be used as a portion of a radiating dipole, then it is physically short compared with a 1/4 wavelength of wire. This should not be a problem because the rest of the wire portion of the antenna can be made longer so the overall length of the wire plus the coaxial shield dipole is ½ wavelength.

In the mystery antenna implementation, the coaxial phasing section was designed to be ¼ wavelength of physical length. This means to model the phasing section requires something other than a 180° phase shift. This reduces the effectiveness of the collinear. The feed point impedance of the antenna would also not be the same. This is something W5GI was using as a discriminator when he made changes to the antenna (he stated he first accounted for the VF for the phasing section but thought it worked better when he just used the physical ¼ wavelength for the phasing section).

A more optimized implementation would have the phasing section produce a 180° phase shift and the outer dipole lengths be adjusted so they become exactly ½ wavelengths at the operating frequency. The resultant feed point impedance would then have to be transformed to 50 ohm using a matching network. The matching network could be an antenna tuner. If the VSWR is too high, the matching should be done at the antenna (or use open wire line from the antenna to the tuner) prior to connecting the transformed impedance to the transmitter through an arbitrary length of coax cable. This keeps the higher VSWR portion in open wire feeder line where dielectric and Ohmic losses are minimum.

Future Efforts

Some interesting areas of future work for the experimenter are:

1. Demonstrate the coaxial phase shifter works as described by connecting an RF generator to a shorted ¼ electrical length of line and use an oscilloscope to show the waveform going into the coax center conductor and returning from the inner shield.
2. Model the phased array using the W5GI implementation where the phasing section is actually a ¼ wavelength physically, giving a different phase in the outer dipoles. Show how this affects the design frequency of the array in pattern and impedance. Show how the out of band impedance varies in this implementation
3. Model the phased array using the proper 180° phase shift and show the pattern and impedance performance at the design frequency and out of band.

Reference

1. The W5GI Multiband Mystery Antenna, CQ Magazine, July 2003.
2. Broadside Arrays, ARRL Antenna Handbook, 20th Edition, p. 8-35
3. http://www.w5gi.com/mysteryantenna.htm
4. Collinear Phase Antennas for the HF Bands, QST, March 1989