Designing PCB Log Periodic Antennas

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Over the last few years, I have developed many PCB Log Periodic antennas from 400 MHz to 11 GHz. I wish I could say I have a secret design process, but there were many variations and small pieces of metal tape on the early models. And while there are software programs such as IE3D and HFSS than can analyze a log periodic antenna on a dielectric surface,
I do not know of any programs that can design such an antenna. These antennas are the result of hours and hours of work on the Network Analyzer and out on the antenna range.
And now, a few of the problems designing PCB Log Periodics.

PCB Asymmetry:

A Copper trace resting on a dielectric has a velocity factor. That is, a 1/2 wave dipole is shorter resting on Fiberglas than it would be in free air. While the textbooks give you the velocity factor for a stripline over a groundplane, the elements are not over a ground plane! But it turned out to be close to the velocity factor of a normal stripline, about 60%. However that is in just one direction. While the elements are about half their expected length, the element to element spacing is only reduced about 20%. So you cannot simply scale a freespace Log Periodic by the PCB velocity factor and expect it to work well.
As they say, "Been There, Done That"

PCB Dielectric Constant:

I also learned the hard way that the dielectric constant of most PCB materials varies with frequency. So while FR-4 type materials have a dielectric constant (Er) of 4.2 to 4.4 at DC, it can drop to 3.9 at 2 GHz, and even lower at higher frequencies. As you move up in frequency, the relative thickness of the material increased. At 900 MHz the PCB thickness (1.6 mm) is about .5% the length of the element. By the time I was up to 11 GHz, the PCB material was up to 15% of the element length. So the Fiberglas dielectric has an ever increasing effect on the lengths of the elements, and companies just don't publish the Er of their non-Teflon PCB material above 1 GHz. So there are many factors in the PCB material that are distorting the dimensions of a free space Log Periodic.

Booms:

The velocity factor of a stripline varies with its impedance. That is, the wave travels at different speeds for wide lines and narrow lines. When the transmission line is soldered to the antenna, that side of the antenna effectively has less inductance and a higher velocity factor. You really don't want the waves traveling at different velocities on the opposite sides of the antenna! So the line trace on the transmission line side has been narrowed to allow for the effects of soldering on the coax.

Coax:

I recommend using either .085” semi-rigid coax on the 2.1-11 GHz antenna or one of the Teflon RG-174 style coax with a diameter of less than .1 inch, or 2.5mm. The coax only needs to be a millimeter longer than the antenna, and then you can transition to 7/8" Heliax if you like. Keep the free tip of the coax as short as possible, as shown in data sheet and the shield as close to the via as practical. This improves phasing, especially above 5 GHz.

Grounding via at the back of the Log Periodic:

Designing a Log Periodic to be grounded at the back of the boom helps solve many problems. The entire antenna is at DC ground and many low frequency response problems are eliminated. In high EMI areas, ungrounded LP's can look like a fat 1/4 wave ground plane to VHF signals and let in intermodulation sources. Removing the via will lower the lowest usable frequency slightly, but introduce many new resonance's into the antenna.
Removing the back grounding via is not recommended.

Power:

I wish I could test one of these antennas to destruction, but I just do not have enough power. At 400 MHz, the antenna has a relatively large active area and can easily take 100 watts. As you go up in frequency, the active area gets smaller and smaller, and the dielectric loss goes up. At 3.4 GHz one has been burned up with 40 watts of FM. At 10 GHz a 10 watt prolonged carrier smoked another 2-11 GHz LP. I am expecting some feedback on their power handling from local EME'ers.

Phase Center:

The phase center is the point on the antenna that does the radiating. On an LP style antenna, the phase center moves along the antenna as the frequency changes. Counting Elements from the small end, the 3 cm phase center is about element #3. 6 cm is about element #6, and 13 cm is about element #12. One effect of the dielectric is the compression effect on the antenna, making it physically smaller. The phase center does not move as much as it would with a Teflon or air dielectric design.

Why didn't you build them on Teflon?

The short answer is money. If you know a PCB house that can make double sided PCB's with plated through holes from CAD files on Teflon board for less than $500 a panel, let me know! Also, I cannot use the current artwork. The elements will get about 20% longer, the element to element spacing will increase about 10%, and the asymmetrical booms would change. The 400-1000 MHz, the 900-2600 MHz, the 2.1-6 GHz and the 2-11 GHz versions went though the PCB house 3 times before I was happy, and a Teflon version would probably make several trips too. So a Teflon version would easily cost another $2000 to develop.

As a Dish Feed:

A Log Periodic is a compromise dish feed. How far down it is from an optimized feed depends on many factors, f/d, frequency, etc. But in general, a 3ft dish with an LP feed has about as much gain as a 2.5 ft. dish with an optimized feed, and during contests you only have to carry one antenna. Mount the LP with the phase center of the highest frequency you plan to use at the focus of the dish. The lower frequencies are slightly beyond the best focus point, but the loss is usually less than a dB. Also the dielectric compresses the antenna, so the phase center does not move as much as it would with Teflon or an air dielectric Log Periodic.