Planar UWB Monopole with Improved Pattern Shape

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***Abstract*—This paper summarizes the simulated and measured performance of a planar ultra-wideband (UWB) monopole with improved pattern shape at frequencies greater than 4:1. The presented monopole was designed for a ground penetrating radar that covers the frequency range of 0.3 to 2.0 GHz. The advantage of a planar monopole is that it can be more compact and low profile compared to other UWB antennas, although it will require a backing for broadside applications. However, most designs have significant gain variation due to it functioning as a traveling wave antenna which begins within the second octave of the monopole impedance bandwidth. The broadside gain of the presented monopole is improved over a 7:1 frequency range by reducing pattern tilt by combining a low and high frequency half circle element and additional geometric modifications.**

I. INTRODUCTION

The planar monopole is a popular antenna for ultra-wideband (UWB) applications that need a compact antenna, relative to most UWB antennas, without stringent pattern requirements. Planar UWB monopoles can be designed using many different shapes such as square, trapezoidal, triangular, elliptical, circular, and half shapes [1]. Regardless of the shape, planar monopoles are notorious for their pattern instability vs. frequency. While the antenna may be well matched over a wide bandwidth greater than 4:1, the broadside realized gain typically rolls off in the second octave (i.e., 2:1 – 4:1) as the beam peak tilts away from the feed and towards endfire. At these frequencies the planar monopole is more akin to a traveling wave antenna.

Monopole designs that have reduced pattern tilt are documented such as the quasi-electric, quasi-magnetic monopole in [2], but they still have significant gain roll off at frequencies greater than 4:1. The presented UWB monopole, which was designed to cover 0.3 to 2.0 GHz for a ground penetrating radar, has reduced pattern tilt, and so, its gain roll off does not occur until frequencies greater than 7:1. The next section presents the design and analysis of the monopole. Analysis was performed using the commercial computational electromagnetics code FEKO and the Method of Moments [3].

II. ANTENNA DESIGN AND ANALYSIS

The simulated model of the built monopole is shown in Fig. 1. The design began by combining a low frequency half-circle resonant at 0.3 GHz and a high frequency half-circle resonant at 1.0 GHz. The elements were designed individually but with the same ground plane dimensions, gap spacing, and substrate. The large element is stacked, in the plane, above the small element with a straight rectangle connecting them as shown in Fig. 1. This geometry has introduced a transition region where the electric current recedes from the combined outer edge to the outer edges of the small half-circle. For the shown monopole, the frequency range for the transition region is 0.8 to 1.2 GHz.

This behavior is not unlike that of a log-periodic dipole array (LPDA) from which the inspiration of the monopole design came [4]. The LPDA has logarithmically scaled and spaced half-wave dipoles all connected to some shared boom or parallel plate line. By feeding the LPDA from the end with the smallest dipole, the power is mostly radiated by the dipole that is resonant at the input signal frequency with the other dipoles functioning as directors and reflectors. Feeding the LPDA at the largest dipole will cause the signal power to be mostly radiated before the current reaches the resonant dipole.

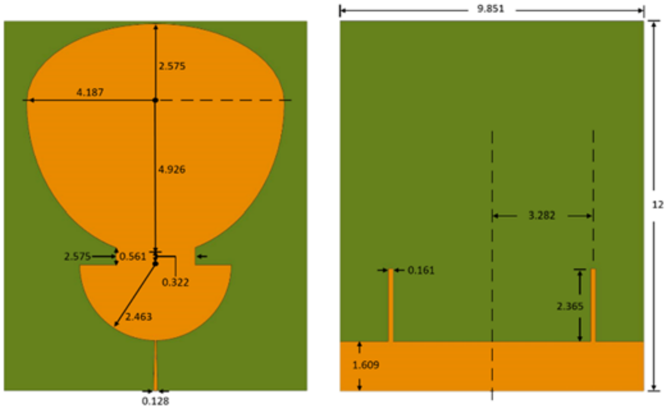

Fig. 1. Circular planar monopole schematic and dimensions. Units are in inches.

Within the transition region, the beam peak tilts towards the feed. The width of the straight section combining the two elements can be narrowed to reduce the tilt; however, narrowing the width also harms the impedance match at frequencies less than the transition region. Therefore, there is some optimal width that both minimizes the beam tilt and maximizes the low frequency impedance match. The height is not as critical.

At frequencies greater than the transition region, the small element is the dominant radiator, but the ground plane is far too large. This causes the pattern to split at broadside. To counteract this, a thin grounded stub is placed some distance away from the small element on both sides. The height and position of the stubs are critical with only a small change in either parameter producing a large effect on performance. The stub height is 0.95

times the small element radius plus the gap spacing, and its offset is 1.3 times the small element radius. The width is arbitrary and was chosen to be 0.25 inch before scaling.

The large element was modified to that of an ellipse with a major-minor axis ratio of 1.176, and the flat edge was rounded with a half ellipse to further improve the low frequency performance. The additional ellipse has a major-minor ratio of 1.625, and its major axis is equal to the minor axis of the low frequency element.

The substrate is Rogers 4350b with $\varepsilon_r = 3.48$, $\tan\delta = 0.0037$, and thickness of 0.060 inch. The antenna is fed with a tapered microstrip that has a straight section that extends across the gap separating the monopole and ground. The gap length is 0.025 inch. A microstrip was chosen instead of a co-planar waveguide as it was easier to mill the taper; that is, the microstrip does not have a narrow gap that needs to be milled. The width for 50 Ω is 0.128 inch and 0.052 inch for 85 Ω.

With the introduction of the substrate, the antenna needed to be reduced to account for material loading and for the much longer current path created by the element combination and geometry modifications. Additionally, a size constraint of 12 inches for the longest dimension was imposed. The material scale factor determined through simulation is 0.744 and the scale factor for the longer current path is 0.865. Cutouts in the large and small element were tried but were detrimental to the antenna performance particularly at low frequencies.

The simulated electric current distributions, Fig. 2, show that as frequency increases, the current density localizes to the outer edges of the small half-circle as intended. Within the transition region and at greater frequencies, the stubs have significant current which shows that the stubs are a critical radiating component of the monopole. Fig. 3 shows the broadside realized gain vs. frequency for the presented monopole. Simulated realized gain for a standard planar circular UWB monopole of similar size at broadside is shown for comparison. The measured gain for the monopole is limited by chamber interactions between the antenna under test and the back wall.

The new monopole shows significantly improved broadside gain vs. frequency compared to what would be typically built. The gain of the planar circular monopole rolls off at 0.6 GHz whereas the new monopole maintains good broadside gain up to 2.1 GHz. Additionally, the longer current path for the new monopole improves performance below 0.4 GHz compared to the baseline monopole.

Although not shown, the beam peak of the new monopole still moves towards the feed vs. frequency at frequencies greater than the transition region, but not to the extent that the gain rolls off. Within the transition region, the beam peak tilts towards the feed but not so much that the gain is degraded. There is a gain difference between broadside and the actual beam peak, but the difference is less than 1 dB. At frequencies greater than 2.1 GHz, the beam peak tilts towards endfire as any other planar monopole. The Voltage Standing Wave Ratio (VSWR) of the monopole is less than 2.0 over the 7:1 frequency range with the exception of the transition region where the VSWR is between 2.0 and 2.5. Further details are in the conference briefing.

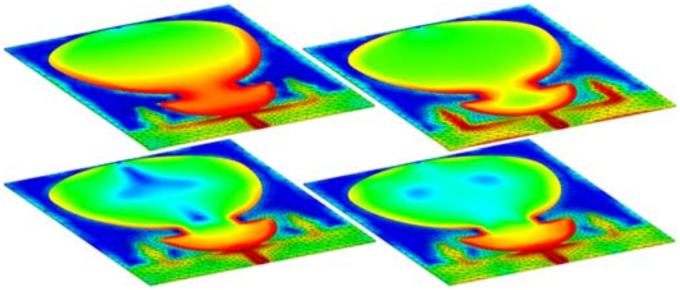

Fig. 2. Electric current distributions on a 40 dB scale at, clockwise from top left, 0.3, 0.9, 1.8, and 2.0 GHz.

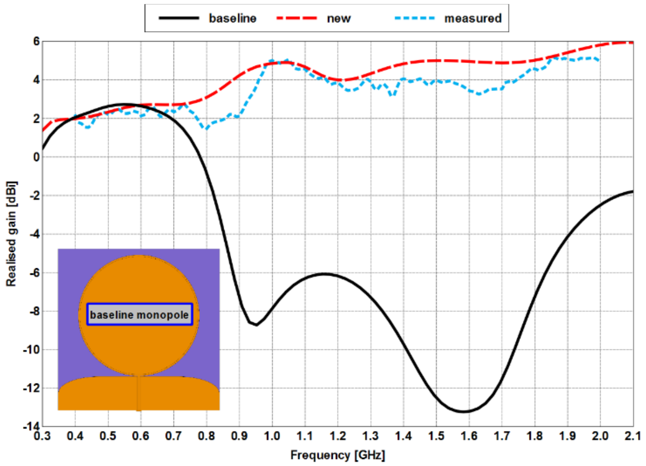

Fig. 3. Monopole broadside gain and baseline model.

III. CONCLUSION

This summary has shown that a planar UWB monopole can be designed to have reduced pattern tilt over a frequency range of 7:1 which leads to improved broadside gain. Typically, UWB monopoles have pattern instabilities vs. frequency due to traveling waves at high frequencies. The pattern instability leads to a gain roll off which typically occurs within the second octave of the impedance bandwidth. The pattern tilt and instability of the presented monopole was reduced thereby significantly improving the broadside gain compared to a typical design over a frequency range of 7:1. This was accomplished by applying some of the principles of a LPDA where a low frequency and a high frequency component are connected and then fed from the high frequency end. Additionally, grounded stubs were used to counteract beam splitting at high frequencies.

REFERENCES

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