Mitigation of Multipath Through the Use of an Artificial Magnetic Conductor for Precision GPS Surveying Antennas

W. E. McKinzie III*, R. B. Hurtado, B. Klimczak, J. D. Dutton
wmckinzie@titan.com, rhurtado@titan.com, bklimczak@titan.com, jdutton@titan.com
Etenna Corporation
6100 Frost Place, Suite C
Laurel, Maryland

I. Introduction
The Global Positioning System (GPS) allows surveyors to make static measurements with sub-centimeter accuracy. To achieve these levels of precision, however, requires the mitigation of multipath signals. While signal processing software in the receiver does a good job of correcting for multipath, further improvement can be gained by reducing such unwanted signals before they reach the antenna, such as with a ground plane. While conventional conducting ground planes can shield the antenna element from signals below the horizon, they can also propagate surface waves that can produce significant edge diffraction. Choke rings (circularly corrugated ground planes) provide excellent electrical performance, but are large, heavy, and very expensive. This paper will show that an artificial magnetic conductor (AMC) can provide a solution which has good electrical properties, as well as being relatively lightweight, thin, and inexpensive.

II. Motivation for use of an AMC ground plane for precision GPS
In precision GPS surveying, it is desirable to make measurements with sub-centimeter accuracy levels. While the receiver’s signal processing software can greatly reduce multipath errors [1], augmenting the antenna system with a ground plane can shield the antenna from unwanted multipath signals arriving from low grazing angles down to nadir, increasing the overall accuracy of the system. One common cause of this form of multipath is reflection off the earth, and such signals are known as “ground bounce.”

An obvious approach to reducing ground bounce would be to use a conducting ground plane to shield the antenna. However, conducting ground planes suffer from surface waves and edge diffraction, which cause phase distortion, pattern nulling at zenith, and amplitude variations in the azimuth pattern. Choke rings provide excellent electrical performance for GPS antennas, but they are usually very large. A typical choke ring is about 15” in diameter, 2.5” tall, and weighs more than 10 pounds. While size and weight are not issues for most base station applications, for a GPS surveyor carrying one around in the field, size and weight are important factors. Choke rings are also expensive, sometimes costing thousands of dollars.

An artificial magnetic conductor (AMC) is a periodic structure which simulates the boundary conditions of a magnetic conductor over a limited frequency band [2]. Its defining characteristics include (1) a +/-90° reflection phase band over which a high surface impedance is realized, and (2) TE and TM mode surface wave bandgaps (which are independent of the reflection phase band). AMC’s are typically made from printed circuit board materials, hence they are relatively lightweight and inexpensive. Figure 1 shows a photograph of the G200a, and Figure 2 shows a typical choke ring.
III. **Design of the G200a Ground Plane**

At e-tenna Corporation, several AMC’s have been developed for GPS surveying applications. The one presented in the paper is the G200a, which is a broadband AMC whose +/-90° reflection phase band covers both GPS bands, L1 (1565 – 1585 MHz) and L2 (1217 - 1237 MHz).

The G200a consists of a two-sided frequency selective surface (FSS), a dielectric spacer layer, and a ground plane. The FSS is a periodic array of overlapping copper patches, made from double-clad 32 mils Rogers RO4350 material. The spacer layer is 500 mils of Nomex honeycomb material. An array of vias with the same period as the FSS provides RF connection between the FSS and the ground plane. The footprint is circular, with a 15.13” diameter. The weight is 1.4 lbs, and total height is about 0.55”.

IV. **G200a Measurements**

Reflection phase measurements were performed using two broadband horn antennas and a vector network analyzer (VNA). Figure 4 shows the +/-90° reflection phase band of a G200a as predicted by full-wave simulations, and Figure 5 shows the measured reflection phase band.
The band edges and zero crossings of the simulation and the measurement are shown below in Table 1.

<table>
<thead>
<tr>
<th>Reflection Phase</th>
<th>+90°</th>
<th>0°</th>
<th>-90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>1.151 GHz</td>
<td>1.393 GHz</td>
<td>1.665 GHz</td>
</tr>
<tr>
<td>Measurement</td>
<td>1.160 GHz</td>
<td>1.368 GHz</td>
<td>1.797 GHz</td>
</tr>
</tbody>
</table>

Table 1. Comparison of simulated vs. measured reflection phase data

Gain and phase measurements of a Dorne & Margolin precision GPS antenna were made in e-tenna’s Satimo chamber, which is a spherical near field chamber. The antenna was installed and tested on both the G200a AMC ground plane and a choke ring. The results shown in Figures 6 – 9 are median gain over elevation, for elevation angles of 0° < \( \theta \) < 180°. At each elevation angle, an azimuth cut is taken, and the gain value shown is the median value of all the gain values around the azimuth cut for the given elevation. Since GPS uses RHCP, a specularly reflected signal will be LHCP, and both polarizations are of interest. LHCP is of primary interest below the horizon, where ground bounce is a problem. Little variation in phase was detected over all three cases, with the phase pattern being smooth in azimuth, as expected of a GPS antenna.

The results at L2 band show RHCP (see Figure 6) with the G200a equals the choke ring at zenith, with the G200a pattern rolling off faster by about 2 dBiC as it approaches the horizon. The LHCP data in Figure 7 shows the G200a to be at least 14 dBiC down, at least 17 dBiC down below the horizon, and within 7 dB of the choke ring all across the band. At L1 band, Figure 8 shows the G200a RHCP gain to be within 3 dBiC of the choke ring at zenith, and Figure 9 shows that below the horizon, the LHCP pattern is at least 15 dBiC down, and less than the choke ring by as much as 3 dBi from 100° to 160°.
V. Conclusions
The G200a AMC ground plane provides good mitigation of multipath for precision GPS antennas. The example shown demonstrates pattern shaping at both L1 and L2 when used with a precision GPS antenna, allowing good antenna operation above the horizon and good cross-pol rejection below the horizon. In comparison to a choke ring, this AMC ground plane is about 7 times lighter, 5 times thinner, and 2 to 8 times less expensive.

The high impedance surface presented by the AMC has also proven to be useful in a number of other applications, where significant attenuation of surface waves is desired in a short distance, such as base station antennas, handset antennas and diversity arrays.

References