Fragmented Aperture Antenna Design of Miniaturized GPS CRPA: Model and Measurements

***James G. Maloney[1], Bradford N. Baker[1], James J. Acree[1],John W. Schultz[1], John A. Little[2], Daniel D. Reuster[2]**

[1] Signature Technology Lab / Georgia Tech Research Institute
Georgia Institute of Technology, Atlanta GA 30332, USA
jim.maloney@gtri.gatech.edu, brad.baker@gtri.gatech.edu, jim.acree@gtri.gatech.edu, john.schultz@gtri.gatech.edu

[2]Spectra Research
Dayton, OH 45440, USA
jlittle@spectra-research.com, dreuster@spectra-research.com

Abstract: A new approach to developing miniaturized GPS antennas suitable for use in CRPA anti-jam arrays is presented. The approach leverages recent advances in fragmented aperture antenna design and manufacturing. This approach uses a combination of FDTD simulations combined with genetic optimization.

Keywords: Fragmented Aperture, Antenna, GPS, CRPA

1. Problem Description

Developed originally for military applications, the global positioning system (GPS) is now ubiquitous in commercial applications. However, the relatively low power signal levels in GPS require considerable integration in the receiver chipsets to achieve the needed signal to noise ratios. For military applications, these low power signals make GPS systems especially susceptible to radio frequency interference (RFI) or jamming [1]. Jammer-resistant GPS can be achieved through the use of controlled reception pattern antenna (CRPA) arrays, which use multiple receive antennas to actively control the gain profile. A common implementation of CRPA arrays consists of a central antenna element surrounded by six auxiliary antenna elements, as shown in Figure 1a. The auxiliary elements combine with the central element to form pattern nulls in the direction of jamming devices. These shaped patterns improve system robustness in the presence of strong radio frequency sources.

With ever-smaller vehicles and competition from other sensor needs, many platforms often do not have available the approximately 16 x 16 inch area that a seven element CRPA of conventional patch antennas requires. Thus reduced area CRPA arrays are needed with areas closer to 6 x 6 inches, as shown schematically in Figure 1, to enable greater deployment of these arrays on space-limited platforms. This paper describes a new CRPA array with a quarter the area of the traditional array, designed using the fragmented aperture methodology. This array is based on a new two inch, reduced-footprint antenna element that maintains the same gain performance of the more traditional larger elements over both GPS frequency bands (L1 & L2).

Work performed under US Navy Contract: SBIR N68335-06-C-0020, TPOC: John Asvestas and Saad Tabet

1-4244-0878-4/07/$20.00 ©2007 IEEE

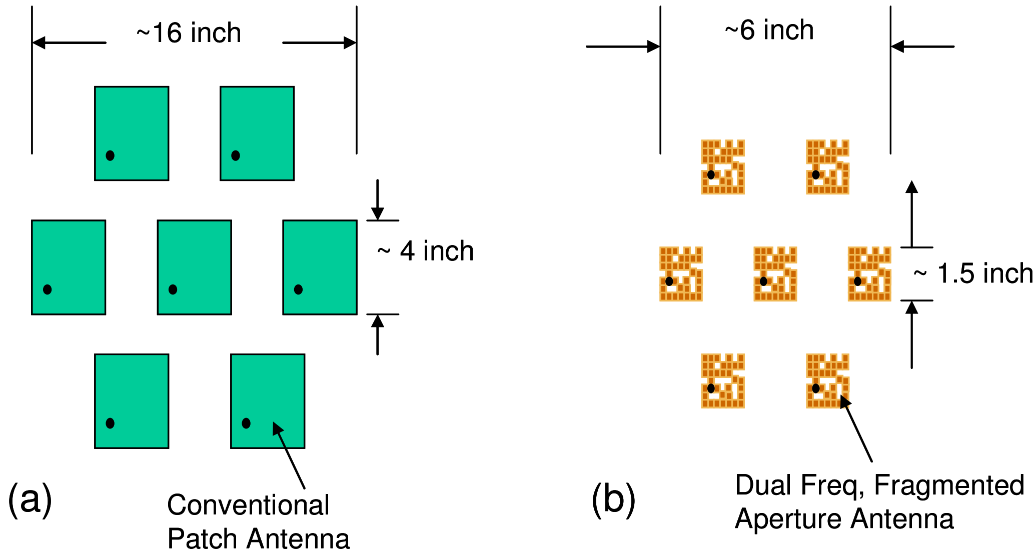

Figure 1 (a) Schematic representation of a CRPA consisting of conventional dual frequency patch antennas. (b) Notional CRPA consisting of miniaturized dual freq fragmented GPS elements.

2. Development of Miniaturized Dual Band Fragmented GPS CRPA

In the late 1990's, fragmented antennas were developed at the Georgia Tech Research Institute in response to a need for aperture efficient, low frequency communication antennas. [2-4]. The key to achieving these aperture efficient fragmented apertures lies in the computational based design procedure [5,6]. This methodology iterates through a series of computer-generated antenna designs to optimize over antenna performance variables such as gain, steering, bandwidth, dimension, etc. A finite difference time domain (FDTD) code is applied to computationally model each antenna incarnation and a Beowulf cluster is used to enable a sufficient population sampling of antenna designs at each iteration.

The reduced-footprint GPS element design had to meet the same performance requirements as the original 4-inch traditional elements. In particular, these elements must operate at both the L1 and L2 frequency bands with a minimum of 24 MHz bandwidth at each band. Further, the realized gain requirements for these elements are greater than -3.5 dBiC at all angles from zenith to 80 degrees from normal. Finally, these elements must have the ability to receive right-hand circularly polarized signals.

Figure 2a shows the designed fragmented aperture antenna in the seven-element CRPA array configuration. These elements were designed on dielectric substrates with a permittivity of 6.15. The red indicates the dielectric substrate and the green indicates metallic conductor. Figure 2b shows the broadside radiation of an individual antenna element calculated by FDTD simulation. The predicted gain for these elements is close to or greater than 5 dB at both L1 and L2 bands. Figure 3 shows the predicted radiation at other elevation angles from zenith for L1 and L2 bands. At each angle shown in these plots, a sequence of azimuth angles are plotted. Thus there is a typically a 1 - 2 dB variation in gain along each circular elevation cut. These data show that the element gain pattern exceeds the requirement of -3.5 dBiC out to 80 deg from zenith.

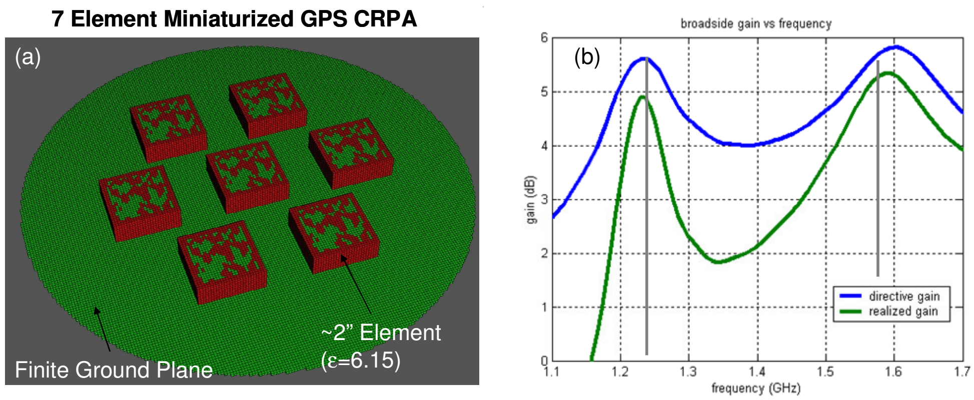

Figure 2 (a) FDTD model of 7 element miniaturized GPS CRPA of 2" fragmented aperture GPS elements, (b) Predicted broadside directive and realized gain vs frequency. The two gray lines show the locations of the L1 and L2 GPS frequency bands.

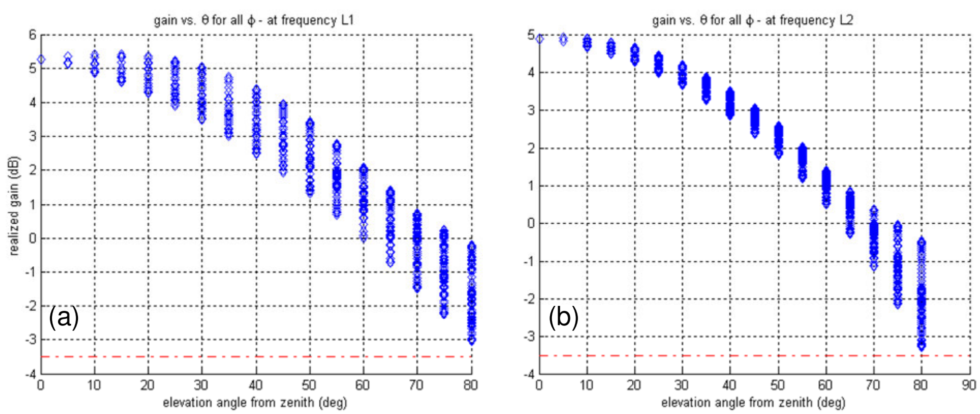

Figure 3 Predicted realized gain at L1 (a) and L2 (b) band showing hemispherical coverage. At each angle of zenith, a sequence of azimuth angles is shown.

3. Experimental Verification

Based on the design simulated in Figure 2, a series of miniaturized fragmented aperture GPS elements were fabricated. The initial fidelity of each antenna was checked through S11 measurements. The antenna design was robust, with seven out of eight fabricated elements matching model predictions. The seven "good" fabricated elements were mounted onto a groundplane and into a CRPA array geometry as shown in Figure 4a. Figure 4b shows a comparison of model predictions (dotted) and measured reflection coefficient (solid) as a function of frequency for one of these elements. These data show good agreement over both GPS bands.

In addition to S11 testing, radiation patterns of the individual elements and of the array were also measured. These pattern measurements also generally confirmed the model predictions and demonstrated hemispherical coverage in compliance with performance specifications. These additional measured data will be shown in the presentation.

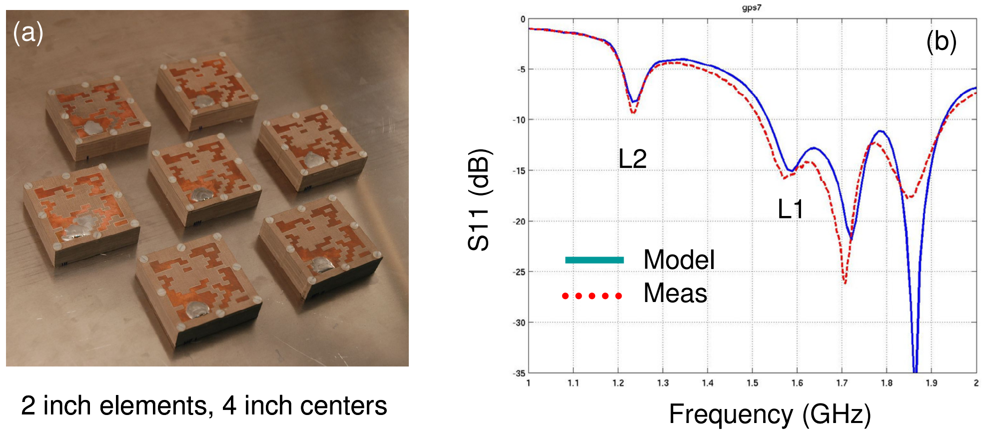

Figure 4 (a) Fabricated 7 element fragmented GPS CRPA, (b) comparison of measured (dotted) and modeled reflection coefficient (solid) as function of frequency showing operation at both L1 and L2 bands.

4. Conclusions

This paper discussed the development of a new miniaturized GPS CRPA array using fragmented aperture based antennas. The model predictions and measured data demonstrate that this new antenna meets the challenging requirements of full hemispherical coverage at both L1 and L2 bands. The good model-measurement agreement also shows that the fragmented aperture methodology is an effective way to design highly optimized antennas.

References

[1] E. Kaplan, C. Hegarty, "Understanding GPS, Principals and Applications", pp. 243-297, Artech House, 2006

[2] P. Friederich, et al, "A new class of broadband, planar apertures," *Antennas and Applications Symposium*, 2001

[3] J.G. Maloney, M.P. Kesler, P.H. Harms, T.L. Fountain, and G.S. Smith, "The Fragmented Aperture Antenna: FDTD Analysis and Measurement," *Millennium Conference on Antennas and Propagation* (AP 2000), Davos, Switzerland, April 2000.

[4] J. G. Maloney, M.P. Kesler, L.M. Lust, L.N. Pringle, T.L. Fountain, P.H. Harms, and G.S. Smith, "Switched Fragmented Aperture Antennas," *2000 International IEEE AP-S Symposium*, Salt Lake City, UT, pp. 310-313, July 2000.

[5] J.G. Maloney, P.H. Harms, M.P. Kesler, T.L. Fountain, and G.S. Smith, "Novel, Planar Antennas Designed Using the Genetic Algorithm," *1999 USNC/URSI Radio Science Meeting*, Orlando, FL, pg. 237, July 1999.

[6] US Patent #6323809, "Fragmented aperture antennas and broadband antenna ground planes," J. G. Maloney, M. P. Kesler, P. H. Harms, and G. S. Smith, Nov 27, 2001