Test Results of a Dual Frequency (L1/L2) Small Controlled Reception Pattern Antenna

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BIOGRAPHY

Huan-Wan Tseng is an Antenna & RF Engineer at NAVSYS Corporation. He has a Ph.D. from Ohio State University, an ME from University of Florida, and a BS from Tatung Institute of Technology (Taipei, Taiwan), all in Electrical Engineering.

Randy Kurtz is the Production Manager at NAVSYS Corporation. He holds a BS in Electrical Engineering from Colorado Technical University. He has eight years of experience in manufacturing and materials management and was a key team member on the Kaman Aerospace/Lockheed SDIO Starlab Wavefront Control Experiment

Alison Brown is the President and CEO of NAVSYS Corporation. She has a PhD in Mechanics, Aerospace, and Nuclear Engineering from UCLA, an MS in Aeronautics and Astronautics from MIT, and an MA in Engineering from Cambridge University. In 1986, she founded NAVSYS Corporation. Currently she is a member of the GPS-III Independent Review Team and Scientific Advisory Board for the USAF and serves on the GPS World editorial advisory board.

Dean Nathans is the Head of the GPS and Navigation Systems Product Development Team Branch at SPAWAR Systems Center. He holds a BSEE from Rutgers College of Engineering and an MEE from Villanova University. Mr. Nathans' responsibilities include Navy Navigation Warfare programs in support of the Navy's Navigation Systems Program Office at SPAWAR, as well as the Office of Naval Research and the GPS Joint Program Office. Mr. Nathans has been employed by the Navy in the Communications and Navigation Technology areas as an Engineer, Project Manager, and Supervisor for twenty three years.

Francis Pahr is a Project Manager for the GPS and Navigation Systems Division at SPAWAR Systems Center, San Diego. He holds a BS in Electrical Engineering from Ohio State University. He has 18 years systems design and manufacturing experience and has held positions as Test engineer, Program Manager and supervisor.

ABSTRACT

The large size of conventional GPS L1/L2 controlled reception pattern antennas (CRPA) has prevented them from being installed on vehicles where available space for antennas is limited. NAVSYS Corporation has developed a miniaturized GPS L1/L2 Small CRPA (S-CRPA), under contract to SPAWAR Systems Center (SSC) in San Diego. This includes a 7-element L1/L2 antenna array packaged in a 7-inch form factor. A single-frequency L1 version of the S-CRPA has been tested by SSC to evaluate the antenna array performance when integrated with GPS antenna electronics.

This paper will present the design of the dual-frequency L1/L2 S-CRPA and the measurement results of the antenna elements.

INTRODUCTION

This paper will present the design and test results of a GPS dual-frequency (L1/L2) S-CRPA based on the miniature antenna array technology developed at NAVSYS. The test parameters include the antenna reflection coefficient, voltage standing wave ratio, and input impedance of individual antenna elements, the mutual coupling between the antenna elements, and satellite tracking measurements of the center antenna element.

MINIATURE ANTENNA ARRAY TECHNOLOGY

The main ideas of the miniature antenna array technology are to reduce the footprint of the antenna array and at the same time to preserve the half-wavelength (at L1 frequency) phase difference between the antenna elements.[1, 2] In order to achieve the above two objectives, the size of each individual antenna elements has to be small and the wavelength of the incoming GPS signal has to be reduced before reaching the antenna elements in the array. The wave front of the GPS signal needs to be bent before reaching the antenna element in such a way that the phase difference between the antenna elements has the same characteristic as when the antenna elements are located in the free space.

In the current implementation of the dual-frequency (L1/L2) miniature antenna array, NAVSYS uses planar microstrip antenna elements above high dielectric substrates and a solid hemispherical high dielectric lens above the antenna elements.

DUAL-FREQUENCY S-CRPA DESIGN

The NAVSYS dual-frequency (L1/L2) S-CRPA is shown in Figure 1. This S-CRPA has been designed to fit within a 7” diameter footprint. This footprint is a 50% reduction in size from the existing 7-element GPS Antenna System (GAS), in use by the Department of Defense, which has a 14” diameter. The configuration and physical dimensions of the array are shown in Figure 2.

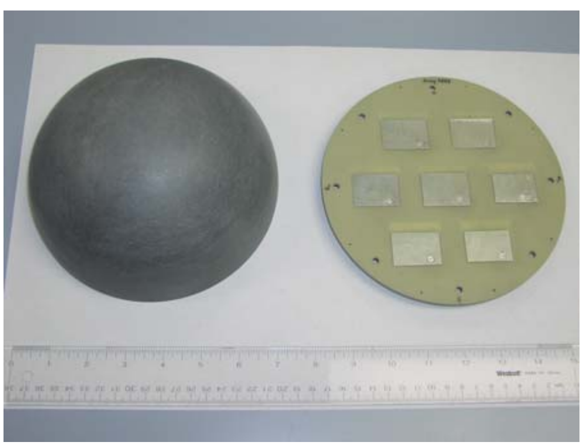

Figure 1 Seven-inch seven-element dual-frequency (L1/L2) S-CRPA (superstrate hemisphere on the left and substrate on the right)

The specifications of the 7-inch 7-element dual-frequency S-CRPA are summarized in Table 1. The antenna elements are designed to operate in the GPS L1 and L2 frequency bands with sufficient bandwidths to receive the C/A code, P(Y) code, and future M-code versions of GPS signals. The seven elements are arranged in a hexagonal pattern with a center reference element, which is similar to the conventional CRPA.

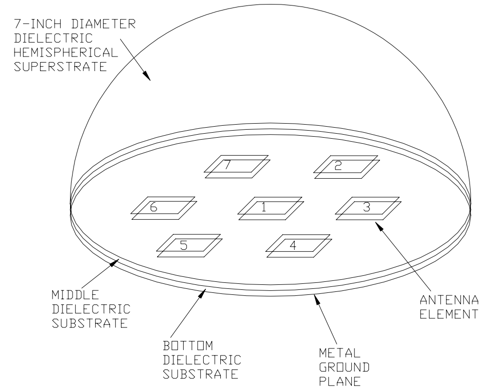

Figure 2 Configuration and dimensions of NAVSYS’ seven-inch seven-element dual-frequency (L1/L2) S-CRPA

Table 1 Summary of specifications of NAVSYS’ dual-frequency (L1/L2) S-CRPA

Center frequencies	1575.42 MHz (at L1) 1227.60 MHz (at L2)
Bandwidth	24 MHz at L1 (1575.42 +/- 12 MHz) 24 MHz at L2 (1227.60 +/-12 MHz)
Input impedance	50 Ω
Polarization	Right-hand circular polarization (RHCP)
Array size	7 inches diameter
Array height above metal ground plane	3.7 inches
Array configuration	Hexagon
Number of elements	7
Element type	Stacked rectangular microstrip patches
Feeding structure of each dual-frequency antenna element	Single probe-feed
Element size	$\propto \lambda/2$ by $\lambda/2$ inside substrate materials
Element spacing	$\propto \lambda/2$ inside superstrate at L1
Number of substrate layers	2
Number of superstrate layers	1 (solid hemisphere with a diameter of 7 inches)

ANTENNA ELEMENT MEASUREMENT RESULTS

<u>Reflection Coefficient</u>
The measured reflection coefficients of the seven antenna elements are shown in Figure 3 to Figure 8.

Voltage Standing Wave Ratio (VSWR)

As shown in Figure 9 to Figure 11 the measured VSWR of each of the seven antenna elements is less than 2.0:1 within the frequency bands of 1227.60 +/- 12.0 MHz and 1575.42 +/- 12.0 MHz. The measured impedance bandwidths (for VSWR < 2.0:1) are wider than the specified 24 MHz in both L1 and L2 bands.

Input Impedance

The input impedance of each of the seven antenna elements is shown in Figure 12 to Figure 17.

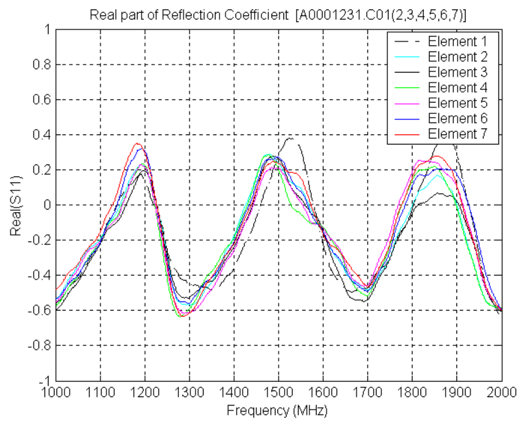

Figure 3 Real part of the reflection coefficient of the seven antenna elements in the frequency band from 1000 to 2000 MHz

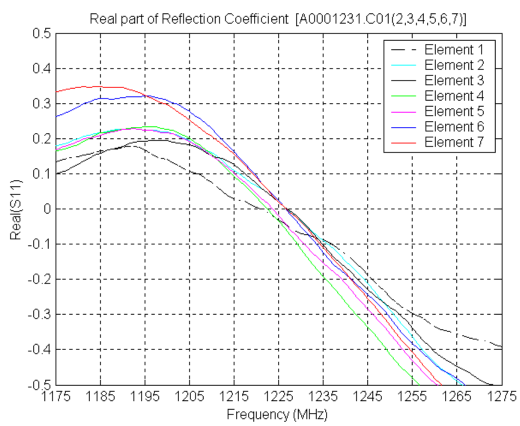

Figure 4 Real part of the reflection coefficient of the seven antenna elements in the frequency band from 1175 to 1275 MHz

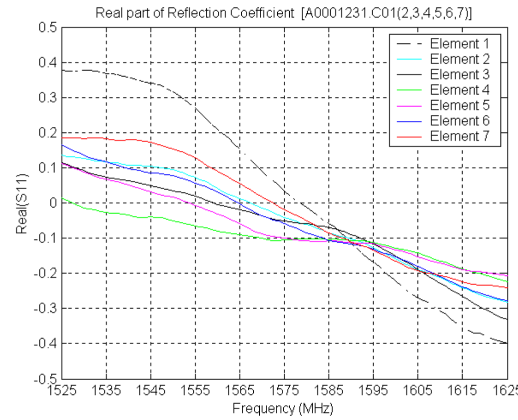

Figure 5 Real part of the reflection coefficient of the seven antenna elements in the frequency band from 1525 to 1625 MHz

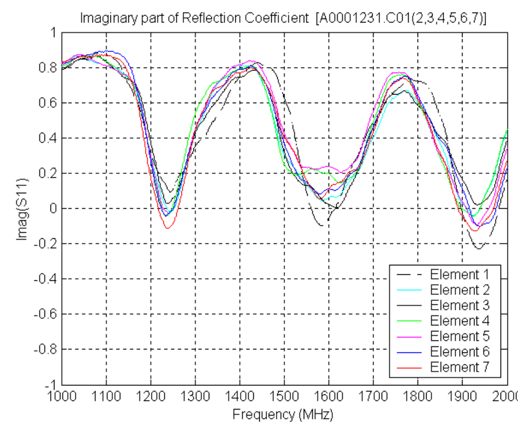

Figure 6 Imaginary part of the reflection coefficient of the seven antenna elements in the frequency band from 1000 to 2000 MHz

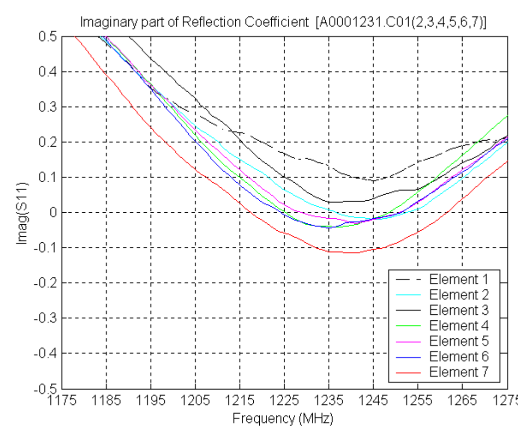

Figure 7 Imaginary part of the reflection coefficient of the seven antenna elements in the frequency band from 1175 to 1275 MHz

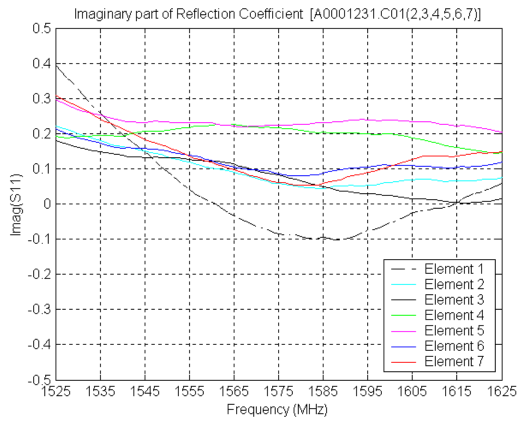

Figure 8 Imaginary part of the reflection coefficient of the seven antenna elements in the frequency band from 1525 to 1625 MHz

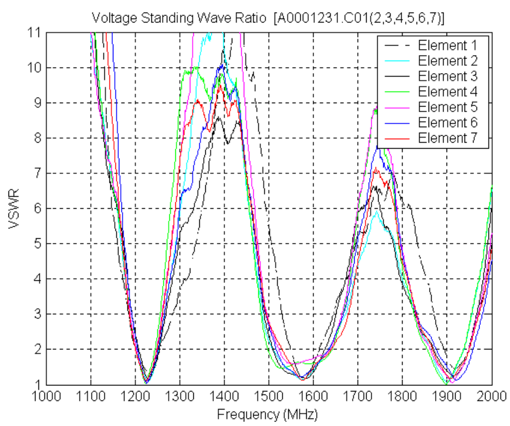

Figure 9 Voltage standing wave ratio of the seven antenna elements in the frequency band from 1000 to 2000 MHz

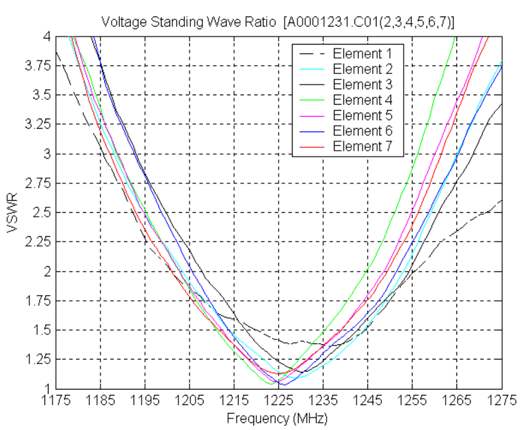

Figure 10 Voltage standing wave ratio of the seven antenna elements in the frequency band from 1175 to 1275 MHz

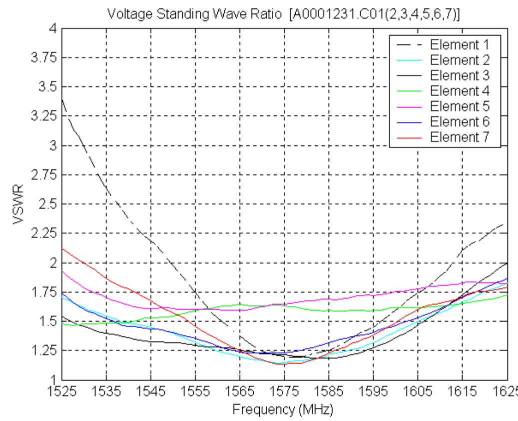

Figure 11 Voltage standing wave ratio of the seven antenna elements in the frequency band from 1525 to 1625 MHz

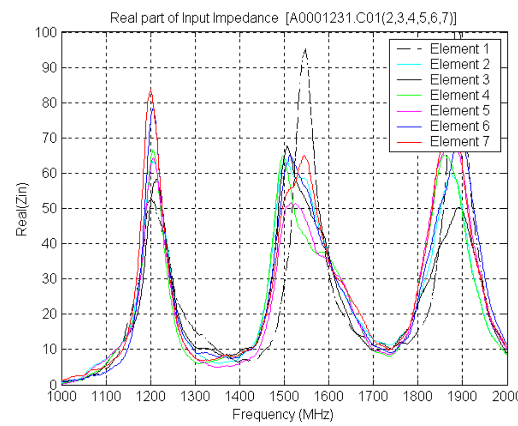

Figure 12 Real part of the input impedance of the seven antenna elements in the frequency band from 1000 to 2000 MHz

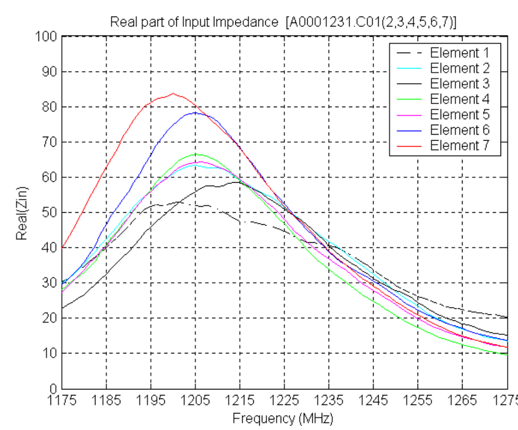

Figure 13 Real part of the input impedance of the seven antenna elements in the frequency band from 1175 to 1275 MHz

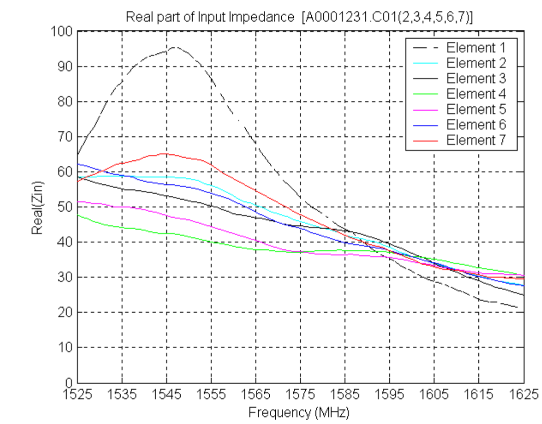

Figure 14 Real part of the input impedance of the seven antenna elements in the frequency band from 1525 to 1625 MHz

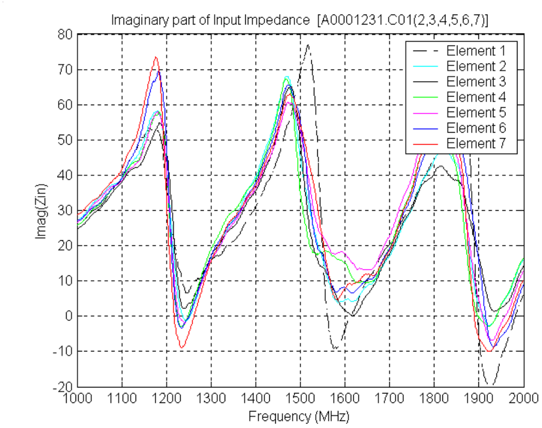

Figure 15 Imaginary part of the input impedance of the seven antenna elements in the frequency band from 1000 to 2000 MHz

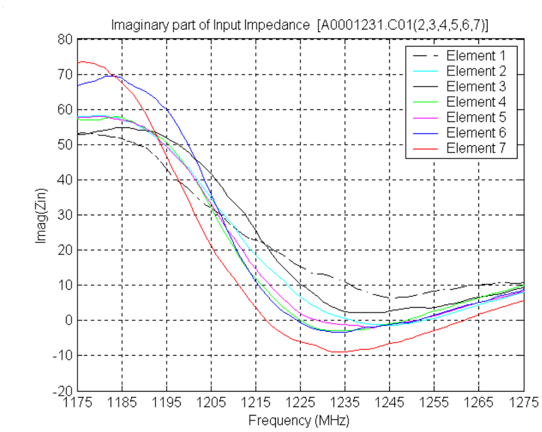

Figure 16 Imaginary part of the input impedance of the seven antenna elements in the frequency band from 1175 to 1275 MHz

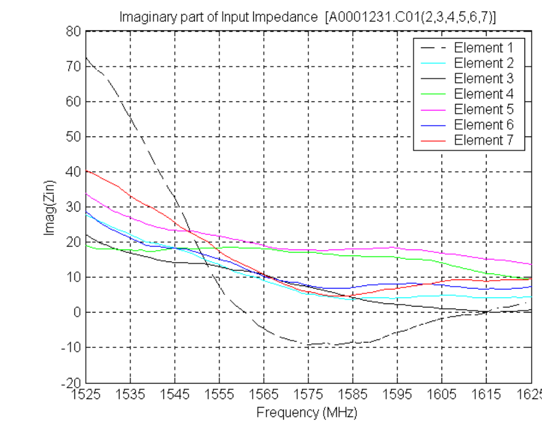

Figure 17 Imaginary part of the input impedance of the seven antenna elements in the frequency band from 1525 to 1625 MHz

MUTUAL COUPLING BETWEEN ANTENNA ELEMENTS

The transmission coefficient between the elements is used to indicate the mutual coupling between them. The 21 mutual coupling measurements among the seven antenna elements are shown in Figure 18 to Figure 23. The strongest mutual couplings occur between three pairs of diagonal antenna elements (between Element 2 and 5, between Element 3 and 6, and between Element 4 and 7). The worst case is between Element 4 and 7 at L2 band with a mutual coupling of approximately –9.5 db. Except for the diagonal pairs of antenna elements, the mutual couplings between all the other pairs are always below –14 dB.

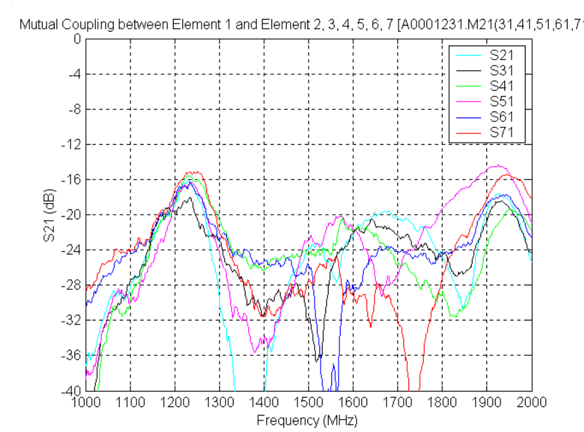

Figure 18 Mutual coupling between Element 1 (center element) and Element 2, 3, 4, 5, 6, and 7

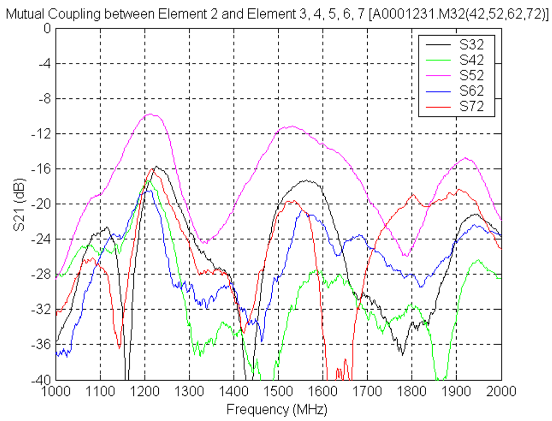

Figure 19 Mutual coupling between Element 2 and Element 3, 4, 5, 6, and 7

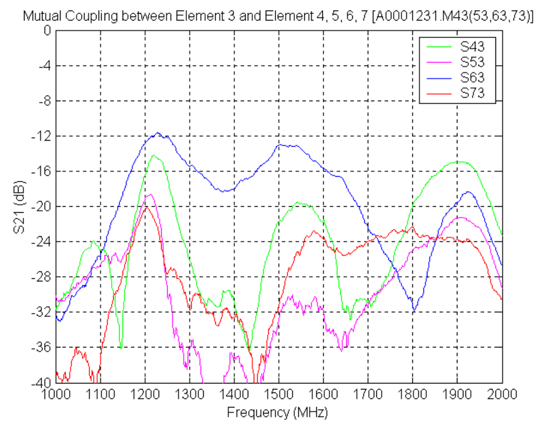

Figure 20 Mutual coupling between Element 3 and Element 4, 5, 6, and 7

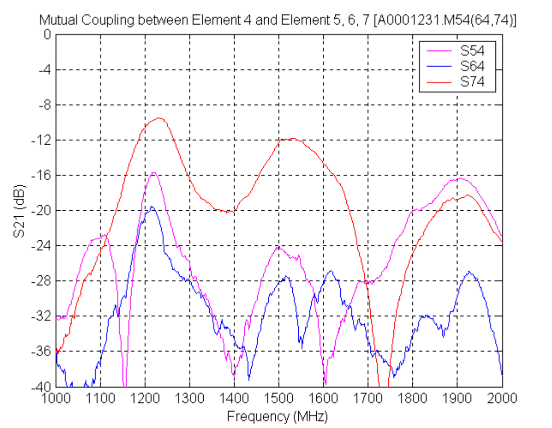

Figure 21 Mutual coupling between Element 4 and Element 5, 6, and 7

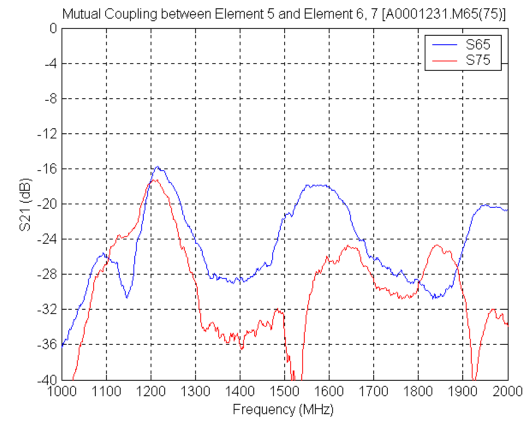

Figure 22 Mutual coupling between Element 5 and Element 6 and 7

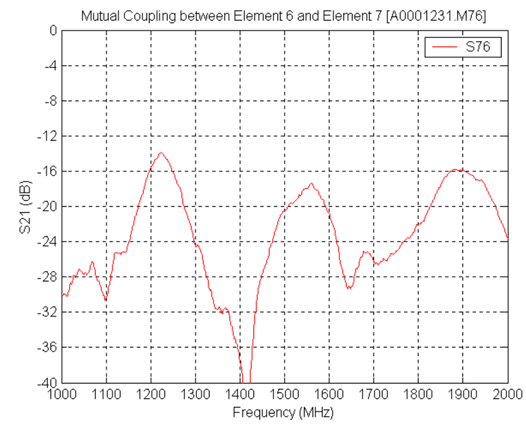

Figure 23 Mutual coupling between Element 6 and Element 7

S-CRPA GPS SATELLITE TRACKING TESTS

Some of the preliminary results of GPS satellite tracking tests with the dual-frequency (L1/L2) S-CRPA are shown here. An L1/L2 GPS receiver from NovAtel is used in these measurements. Since this is a codeless receiver, the observed signal/noise ratios on the L2 channel are lower than would be expected from a P(Y) code PPS receiver. For comparison purposes, a reference L1/L2 antenna (AT2775-16 from AeroAntenna Technology, Inc.) is used with the same receiver right before the measurements with the S-CRPA. Figure 24, Figure 26, Figure 28, and Figure 30 show the measured C/N_0 of PRN 4, 9, 24, and 5, respectively, with the center element of the S-CRPA. Figure 25, Figure 27, Figure 29, and Figure 31 show the measured C/N_0 of those four PRNs, respectively, with the reference antenna. As shown in these figures, the center element of the S-CRPA can provide equivalent tracking performance as a conventional GPS dual-frequency (L1/L2) antenna.

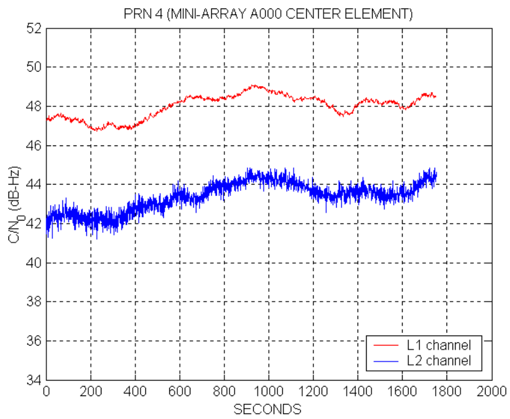

Figure 24 Measured C/N_0 of PRN 4 with Element 1 of S-CRPA

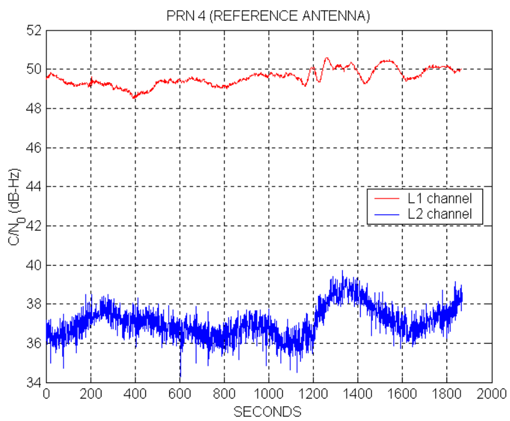

Figure 25 Measured C/N_0 of PRN 4 with a reference antenna (AT2775-16 from AeroAntenna Technology, Inc.)

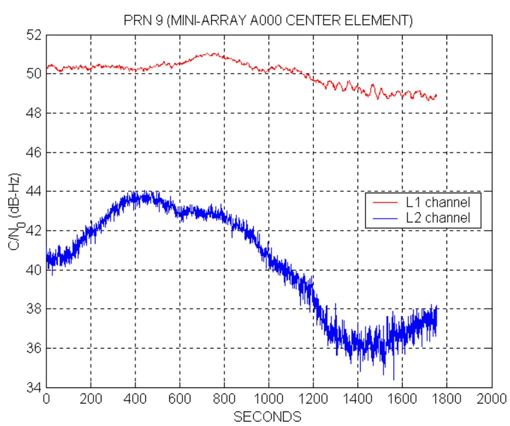

Figure 26 Measured C/N_0 of PRN 9 with Element 1 of S-CRPA

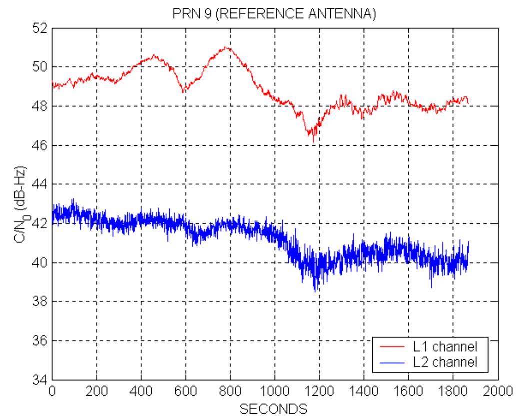

Figure 27 Measured C/N_0 of PRN 9 with a reference antenna (AT2775-16 from AeroAntenna Technology, Inc.)

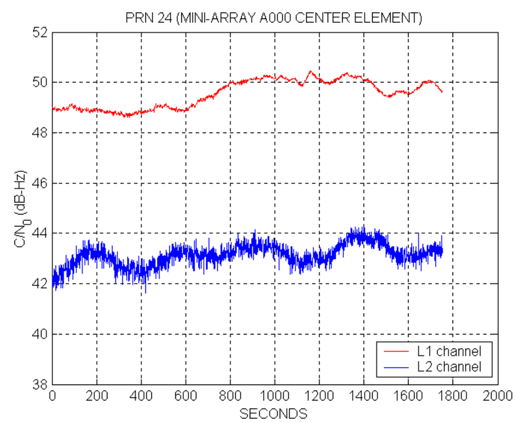

Figure 28 Measured C/N_0 of PRN 24 with Element 1 of S-CRPA

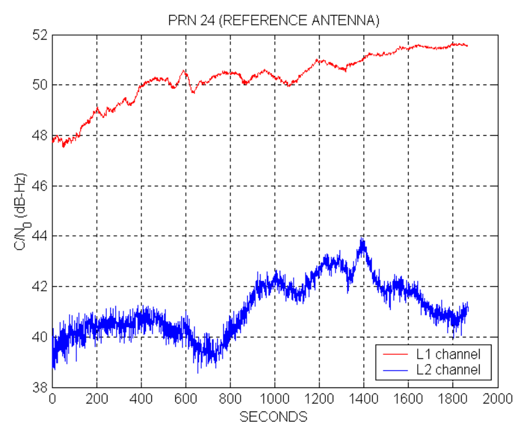

Figure 29 Measured C/N_0 of PRN 24 with a reference antenna (AT2775-16 from AeroAntenna Technology, Inc.)

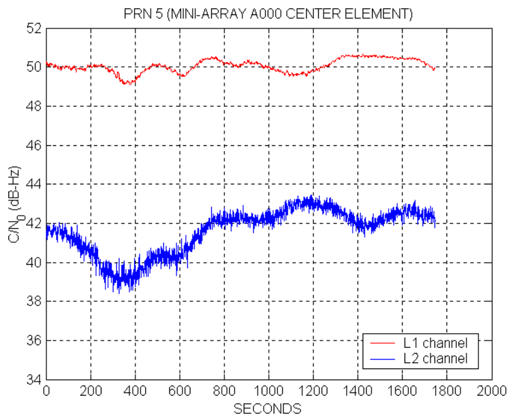

Figure 30 Measured C/N_0 of PRN 5 with Element 1 of S-CRPA

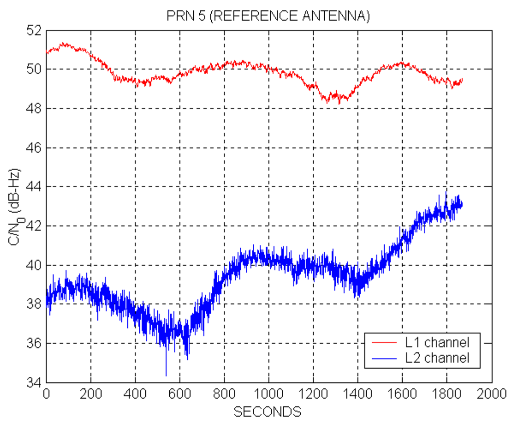

Figure 31 Measured C/N_0 of PRN 5 with a reference antenna (AT2775-16 from AeroAntenna Technology, Inc.)

CONCLUSION

The test results shown this paper demonstrate the performance of NAVSYS' dual-frequency (L1/L2) 7-element Small CRPA (S-CRPA). Previous testing and modeling and simulation efforts have demonstrated the performance advantages of the L1 version of this S-CRPA antenna[3,4,5]. The test results presented in this paper show that the L1/L2 S-CRPA design can provide the same performance advantages for dual-frequency GPS operation while maintaining the advantage of the small form-factor compared with a full-size CRPA antenna array.

ACKNOWLEDGMENTS

The authors would like to recognize the valued support of the Office of Naval Research, who sponsored this research.

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