SM, the forward access point antenna location is better and is the preferred location. The approximate location of the access point antenna will be $x = 5.0$ m, $y = 0.0$ m, and $z = 5.5$ m in space station coordinates.

Based on the measured and computed data obtained from this study, the proposed WLAN system will provide adequate coverage using one access point located in the forward portion of the LAB module. Signal level and link performance will be affected by antenna orientation. Better signal level and link performance can be achieved by arranging the access point antenna and the laptop computer antenna pointing in the same direction (parallel to each other).

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Associate Editor

Multipath Effects on International Space Station Global Positioning System Performance

Shian U. Hwu*
Lockheed Martin Space Mission Systems and Services, Houston, Texas 77258
and
Susan F. Gomez† and Robert J. Panneton‡
NASA Johnson Space Center, Houston, Texas 77258

Introduction

THE International Space Station (ISS) will use the global positioning system (GPS) for providing position, velocity, attitude determination, and time reference. There are concerns about the multipath effects (signal interference due to reflections and diffractions) of the surrounding structure, as shown in Fig. 1, on the GPS performance. Multipath from the surrounding structures may degrade the accuracy of the GPS attitude determination.[1] To investigate the multipath effects on the space station GPS measurement accuracy, experimental and computational investigations were performed to estimate the carrier phase errors due to multipath. A series of GPS multipath tests using the ISS GPS hardware were conducted in the NASA Johnson Space Center GPS test facilities.[2,3] Computational investigations were also performed using the electromagnetic modeling technique.[4,5] Measured and computed data were analyzed and compared.

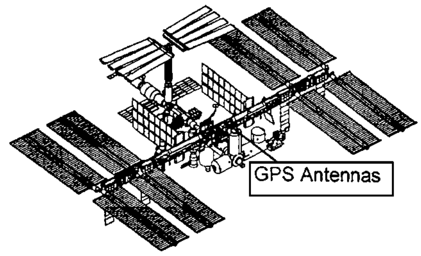

Fig. 1 ISS GPS antenna locations.

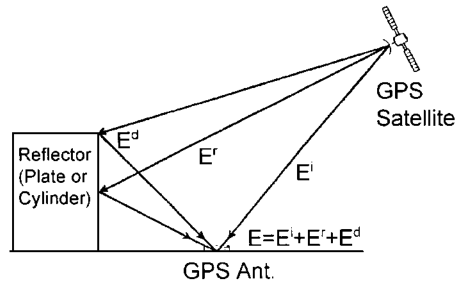

Fig. 2 GPS multipath ground-test configuration.

Experimental Investigations

A series of GPS multipath ground tests that simulated the ISS GPS multipath environment were performed.[2,3] Figure 2 shows the test setup. Each GPS receiver had a laptop computer to record the data. Data were collected with no intentional multipath producers and with intentional multipath producers (plate and cylinder) in place. Only selected data are presented here. A complete technical report with all configurations investigated and detailed calibration procedures can be found in Ref. 3. For Julian day (JD) 059, a 4×12 ft aluminum plate (multipath producer) was placed near the GPS antennas. For JD074, a 3-ft-diam, 4-ft-tall cylinder was placed vertically near the GPS antennas.

The multipath effects from the multipath producers were measured as differential carrier phase errors, which are the differences between the differential carrier phases measured by the GPS receivers with and without the multipath producers in place. The differential carrier phase errors are presented in millimeters as a function of time, given in GPS time of week in hours. The 190.5-mm wavelength λ, at the GPS L1 frequency of 1.575 GHz, corresponds to a 360-deg phase error.

Computational Investigations

The uniform geometrical theory of diffraction (UTD) technique was applied to compute the GPS carrier phase errors due to multipath from surrounding plate and cylinder structures.[3–5] In the field computation, the reflected and diffracted fields are determined by the field incident on the reflection or diffraction point multiplied by a dyadic reflection or diffraction coefficient, a spreading factor, and a phase term.[4] The reflected and diffracted field at a field point r', $\boldsymbol{E}^{r,d}(r')$, in general have the following form:

$$\boldsymbol{E}^{r,d}(r') = \boldsymbol{E}^i(r)\boldsymbol{D}^{r,d}\boldsymbol{A}^{r,d}(s)e^{-jks} \tag{1}$$

where $E^i(r)$ is the field incident on the reflection or diffraction point r, $\boldsymbol{D}^{r,d}$ is a dyadic reflection or diffraction coefficient, $\boldsymbol{A}^{r,d}(s)$ is a spreading factor, and s is the distance from the reflection or diffraction point r to the field point r'. $\boldsymbol{D}^{r,d}$ and $\boldsymbol{A}^{r,d}$ can be found from the geometry of the structure at reflection or diffraction point

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*Electronic Engineering Specialist, Communication Systems Analysis and Test Section, 2400 NASA Road 1. Senior Member AIAA.

†Project Engineer, Guidance and Navigation Branch, MC: EG2.

‡Chief Engineer, Avionics Test and Analysis Branch, MC: EV413.

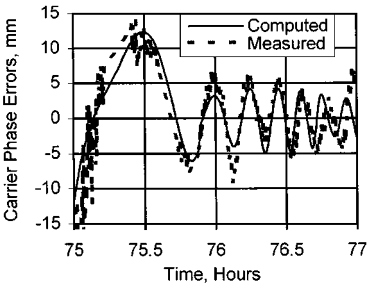

Fig. 3 Carrier phase errors due to multipath from a plate for satellite 16 on JD059.

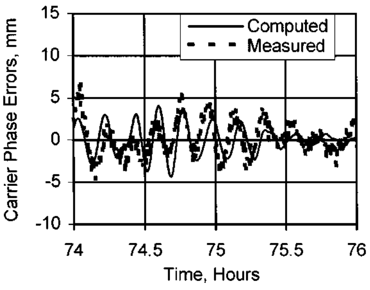

Fig. 4 Carrier phase errors due to multipath from a plate for satellite 24 on JD059.

r and the properties of the incident wave there. The resultant field is given by summing all of the complex contributing components:

$$E^{\text{tot}} = E^{\text{inc}} + \sum_{n=1}^{N} E_n^{\text{ref}} + \sum_{m=1}^{M} E_m^{\text{dif}} \tag{2}$$

where E^{tot} is the total field at the observation point, E^{inc} is the direct incident field from the antenna, E^{ref} are the reflected fields from plates and cylinders, and E^{dif} are the diffracted fields from plates and cylinders. Detailed information on the theory of this method can be found in Refs. 3 and 4.

The UTD calculated differential carrier phase errors are the differences between the differential carrier phases computed with and without the multipath producers in place. The UTD computed differential carrier phase errors due to multipath are computed by the following procedure: The carrier phase for all four GPS receiving antennas, one master and three slave antennas (ϕ_0, ϕ_1, ϕ_2, ϕ_3), without multipath producers in place, is first computed. Along each selected GPS satellite path, the carrier phase, including multipath from the multipath producers for all four antennas (ϕ_0^m, ϕ_1^m, ϕ_2^m, ϕ_3^m), is then computed. The carrier phase errors due to multipath producers are determined by $\Delta\phi_i^m = \phi_i^m - \phi_i$, where $i = 0, 1, 2, 3$. The differential carrier phase errors relative to the master antenna are determined by $\Delta\phi_{i0}^m = \Delta\phi_i^m - \Delta\phi_0^m$, where $i = 1, 2, 3$.

Results and Discussion

Figures 3 and 4 show the carrier phase errors due to the multipath from a plate near the ISS GPS antennas for satellites 16 and 24 on JD059. The carrier phase errors due to the multipath from a cylinder near the ISS GPS antennas for satellite 1 on JD074 are shown in Fig. 5. The UTD computed GPS carrier phase errors agree well with the experimental test results. Obtained results indicate that structural blockages cause more than 10-mm or 18.9-deg phase errors on the ISS GPS receiver. Reflections from the structures cause more than 5-mm or 9.45-deg phase errors.

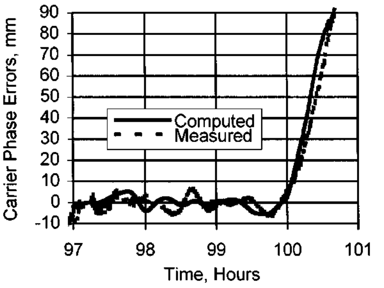

Fig. 5 Carrier phase errors due to multipath from a cylinder for satellite 1 on JD074.

Conclusions

Both test and computed results indicate that the multipath producers, located near the space station GPS antennas, can produce carrier phase errors of more than 10 mm from blockages and 5 mm from reflections. This study confirmed that the multipath is a major error source to the ISS GPS performance and can possibly degrade the attitude determination solution. An integrated GPS/inertial navigation system navigator is being developed to be used as a common navigation solution for the Space Shuttle and space station. It is demonstrated that the GPS antenna carrier phase errors due to multipath from a plate and cylinder can be analyzed using the UTD technique.

Acknowledgments

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A. C. Tribble
Associate Editor