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THE EFFECTS OF MAGNETIC STORM PHASES ON F-LAYER IRREGULARITIES FROM AURORAL TO EQUATORIAL LATITUDES

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A. THE GLOBAL POSITIONING SYSTEM AND SCINTILLATION

For the quarter being reported there were continuing studies of middle latitude irregularities, including the reduction of data from Hawaii and Puerto Rico. However the primary work by J. Aarons was a review of data relevant to problems of ground and airborne systems' acquisition of the Global Positioning System signals. This study was done with partial support from the FAA.

The fading of signals for relatively long periods of time has been outlined in previous reports with emphasis on fading in the 54 to 400 MHz range. The loss of intelligence on digital messages has been amply shown in auroral, polar and equatorial latitudes. However in some geographical areas and during some geomagnetic conditions, there is fading on the GPS signals at 1.6 and 1.2 GHz. The regions subject to this problem are the equatorial anomaly region, the polar region, and the auroral region. One of the principal investigators (J. Aarons) was asked by the Federal Aviation Administration to survey available relevant data on this problem. With the previous studies performed under the ONR grant by J. Aarons and M. Mendillo, the principal investigators had acquired the background data and physics to be leading contributors to the study of how scintillation affects acquisition of the Global Positioning System's signals. The survey was made in collaboration with Dr. S. Basu of the Phillips Laboratory. A review was made of the literature and in in-house reports of several groups doing work at 1.5 GHz and higher frequencies. A paper on these observations was presented at the Institute of Navigation's Meeting in Salt Lake City (GPS-94). A 10 page summary was also prepared for the Proceedings of GPS-94. While the funding and report have been separated from the ONR program, the use of GPS signals to pursue the aims of the ONR contract has become of interest. Each area of the globe, has now continuously in sight the signals from at least 4 satellites (but most frequently 7). If one can record scintillation and total electron content, it will be possible to plot these parameters for a large portion of the sky. This will be explored in a later portion of this report.

The abstract for the paper given in Salt Lake City and funded by FAA is given below:

Ionospheric Amplitude and Phase Fluctuations at the GPS Frequencies

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ABSTRACT

The F-region of the ionosphere at times becomes turbulent and develops small scale (< 500 m) irregularities of electron density. When sufficiently intense, these irregularities scatter radio waves at L-band frequencies and generate amplitude and phase scintillation of GPS signals. Amplitude scintillation causes cycle slips and data losses to occur and phase scintillation generates fast variations of frequency with which the receiver has to cope. We have utilized the available data sets to establish the constraints imposed by scintillation on the operation of GPS receiving systems. This will help GPS users to correctly distinguish receiver problems from ionospheric scintillation.

The worst source of scintillation is the equatorial anomaly region. This region corresponds to two belts, each several degrees wide, of enhanced ionization in the F-region at approximately 15° north and 15° south of the magnetic equator. In this region, during the solar maximum periods, amplitude scintillations at 1.5 GHz may exceed 20 dB for several hours after sunset. Ascension Island in the Atlantic, Diego Garcia in the Indian Ocean, Hong Kong and Taiwan in the Pacific are some of the stations that fall directly under the anomaly region. However, areas within a few degrees of the magnetic equator may show only 5-7 dB fades. Occurrence of scintillation in the equatorial region is a function of longitude. For example the region between 0 and 30 West Longitude can have severe fading from September to May while the region from 110 to 130 East has maximum occurrence in the equinoxes with minimum occurrence from November to January (in solar maximum years).

The other potentially active regions are at auroral and polar cap latitudes. In the central polar cap in years of solar maximum, GPS receivers may suffer >10 dB fades during the solar maximum period. Relatively rare effects of magnetic storms noted in Japan will be outlined.

GPS satellites offer a unique source for measurements of amplitude and phase scintillation on a global scale. One receiver can record scintillation magnitudes and spectra at multiple propagation paths in the overhead sky. The data can be used to study ionospheric plasma structures, develop weather models of scintillation and can be scaled in frequency to support many operational systems. However the interpretation of the fading structure and scintillation spectra for GPS is not straightforward since both the ionospheric motion and the velocity of the satellite control the fading rate of scintillation. With the use of more data the problem of amplitude fading could be organized for the user's benefit.

The studies of Jules Aarons are supported by the Office of Naval Research with partial support from the Federal Aviation Administration.

B. GPS SIGNALS AND FORECASTING FADING ON FLEETSATCOM

In the equatorial region, the plumes which produce fading on 250 MHz transmissions from FLEETSATCOM develop as the sunset line goes west. Once developed the patches which maintain their integrity for many hours move eastward. If one has the entire sky covered in real time by what might be termed scintillation sensors, short term forecasting might be possible. These sensors would be recordings of the scintillation on the paths to the 4 to 7 satellites in view. If the path to FLEETSATCOM is for example directly overhead, one might look at a GPS satellite path or a FLEETSATCOM satellite signal to the east to see if this night might be termed an active night for irregularities. In the hours after overhead sunset, if scintillations were observed in real time recordings of a satellite on a western path, then it would be reasonable to expect the wind to bring these patches eastward. One could then forecast for the latter part of the night that there would be scintillation activity on the overhead path to FLEETSATCOM. This is a simplification of the output which might emerge from a warning system of this type.

C. MIDDLE LATITUDE IONOSPHERIC STUDIES

J. Aarons has started to work on the subject of middle latitude irregularities. These F layer irregularities even if less severe in intensity than high or equatorial F layer irregularities have effects on satellite transmissions at 250 MHz. In addition to reviewing the literature on ionosondes, satellite scintillation, and in situ observations, he is reducing and analyzing scintillation observations at middle latitudes for two longitudinal regions, 125 degrees East and 70 degrees West.

D. THE ONR AASERT PROGRAM IN UPPER ATMOSPHERE AND IONOSPHERIC PHYSICS

In the past quarter, Ms. Colerico has continued work in the cataloging and data analysis of incoming data taken in the equatorial region. She has been working on identifying events of F-region irregularities which cause scintillations. We hope to correlate these events with data taken from GPS satellites. Ms. Colerico is continuing to monitor the operation of the Goose Bay imager. Over the next month, the Goose Bay imager will be modified to use a multiple filter mode which collects data in a six filter cycle. Two phone lines have installed at the Goose Bay site to allow for remote control and monitoring of the Goose Bay imager.

E. PUBLICATIONS

Aarons, J., "Mitigation of the Effects of F Layer Irregularities by Using Multiple Paths", AGARD Conference Proceedings 543, October 1993

Mendillo, M., "The Altitude-Latitude Extent of Equatorial Plasma Depletions" in COSPAR Colloquia Series Volume, Low-Latitude Ionospheric Physics, editor F-S. Kuo, 7, 5-13, 1994

Sahai, Y., J. Aarons, M. Mendillo, H. Takahashi, M.A. Abdu, and E.R. de Paula, "Studies of Storm-Time Equatorial F-Region Irregularities" COSPAR Colloquia Series Volume, Low Latitude Ionospheric Physics editor F-S Kuo 7, 135-142, 1994