THE USE OF MICROSATELLITES IN MONITORING THE IONOSPHERE/PLASMASPHERE

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ABSTRACT

The advent of microsatellites with their advantages of low overall cost in construction and launch and short time span between conception and launch has given a new impetus to the further study of the geosphere. By using a combination of space based and ground based receivers it is possible to undertake new and exciting experiments directed towards furthering our knowledge of the ionosphere. Combinations of high earth orbit satellites such as GPS and low earth orbit (LEO) micro satellites are providing the capability for satellite to satellite occultation experiments to reconstruct the vertical profile of the ionosphere. The topside ionosphere and plasmasphere ionisation content may also be explored with satellite to satellite experiments. This paper will describe some of the experiments proposed for future micro satellites such as those planned for the Australian FedSat1 satellite. Model studies of some of these experiments will be discussed.

INTRODUCTION

The various regions of the ionosphere have been monitored to different degrees on a long-term basis. Even instruments such as incoherent scatter radars, while providing profiles of both the topside and bottom side ionosphere, do not operate on a continuous basis and provides poor resolution for the lower ionosphere. The ground-based ionosondes provide non-homogeneous coverage of the bottom side ionosphere, as they are limited to observations from land. This is particularly true in the Southern Hemisphere where the oceans cover the majority of the Hemisphere. The topside ionosphere and the region above, the plasmasphere are not easily monitored on a long-term basis. Only a few instruments such as incoherent scatter radars, topside sounders and in situ satellite based diagnostics are able to provide details on the structure, composition and dynamics of the topside ionosphere. The properties of the plasmasphere are even less well known and techniques to explore it are very limited. The advent of the Global Positioning System (GPS) with 24 satellites in 12 hour orbits at 20,000 kilometres, provides the opportunity to monitor on a global basis the variation of the ionisation content of the ionosphere and plasmasphere. The recent deployment of space based GPS receivers have demonstrated the feasibility of using satellite to satellite experiments for monitoring the ionosphere. In this paper we discuss some of the satellite to satellite experiments proposed for FedSat1, the Australian satellite to be launched in 2001.

FEDSAT1

FedSat1, the first Australian satellite to be launched in over 30 years, will be a microsatellite of around 50 kg launch mass. It is planned to launch into a low earth orbit between 500 to 1000 km at an inclination of 60 to 70 deg. FedSat1's mission is basically a science and engineering one. The planned scientific payloads include fluxgate and induction magnetometers for geomagnetic field and current studies as well as a dual frequency GPS receiver for ionospheric and atmospheric research. The following sections detail some of the proposed experiments to be carried out using the on board GPS receiver.

IONOSPHERIC MEASUREMENTS

Observing the GPS constellation of satellites in space from a low earth orbit (LEO) satellite such as FedSat1, orbiting at 700km provides a powerful means of imaging the ionosphere and the inner magnetosphere, the plasmasphere. The provision of occulting geometry from a space based receiver enables effectively a horizontal scan through the ionosphere to be obtained (Hajj et al 1994). The lack of horizontal scans from ground based observations of GPS satellites has limited the current development of computerised ionospheric tomography. Because of the geometry, there is a lack of horizontal total electron content (TEC) information that causes a lack of information along the vertical direction in the reconstructed tomographic image. To overcome this problem most researches use some form of a priori information (Villani and Essex 1996). A review of ionospheric tomography algorithms may be found in Raymund (1994). In the planned experiment for FedSat1, this problem will be overcome by using a combination of ground based as well as space based GPS occultation data which will provide both vertical and horizontal information for the application of the tomographic reconstruction. The principal advantages of the tomographic reconstruction techniques lie in the large geographic coverage and the cost effectiveness. Incoherent scatter radars are only able to provide the information from a smaller geographical area at the cost of millions of dollars to build and operate. Recent interest in the development of space based tomography has seen the launch of the first LEO, GPSMET and its use in the radio occultation experiments. Various researchers have recently performed ionospheric reconstruction from the GPS occultation data. (Ruis et al 1997, Hajj and Romans, 1998).

PLASMASPHERE MEASUREMENTS

A further area of interest is the electron content of, as well as the irregularities in, the plasmasphere between FedSat1 and the GPS satellites orbiting above FedSat1. With a GPS antenna located on the top of the satellite, it will be possible to undertake TEC measurements vertically above FedSat1 to the GPS satellites for coincidence occurrences in the orbits. For a cone of 5 degrees above FedSat1 these coincidences would enable information to be obtained on the topside ionosphere and the plasmasphere. Figure 1 shows model calculations of the TEC content for three cases: below 500km, between 500km and 1000km and above 1000 km. The model plasmasphere used in these calculations is based on diffuse equilibrium and in combination with the International Reference Ionosphere (IRI), forms a global ionospheric-plasmasphere model (Webb and Essex, 1997). At low latitudes at sunspot maximum, there is clearly significant ionisation above 500km. For the high latitudes in the Australian region of the Southern Hemisphere, where the magnetic pole is offset from the geographic pole toward Australia, the plasmapause is located at lower geographic latitudes. Hence for coincidences at higher latitudes, it will be possible to estimate the location of the plasmapause. As at these locations the ray paths from the GPS satellites to the FedSat1 satellite will not intersect the plasmasphere and there would normally be only a negligible amount of ionisation above 500km, the TEC should approach zero (Klobuchar et al, 1994). Recent analysis of ground based GPS TEC data has shown the existence of a large build up of ionisation equatorward of the mid latitude trough in the plasmapause region. This increase in ionisation may be related to heating of the topside ionosphere by turbulent dissipation of ring current energy at the plasmapause (Horvath and Essex, 1998, Titheridge, 1976). FedSat1 may also be used to investigate this ionisation buildup, especially over the Southern Hemisphere where the ground based measurement are sparse.

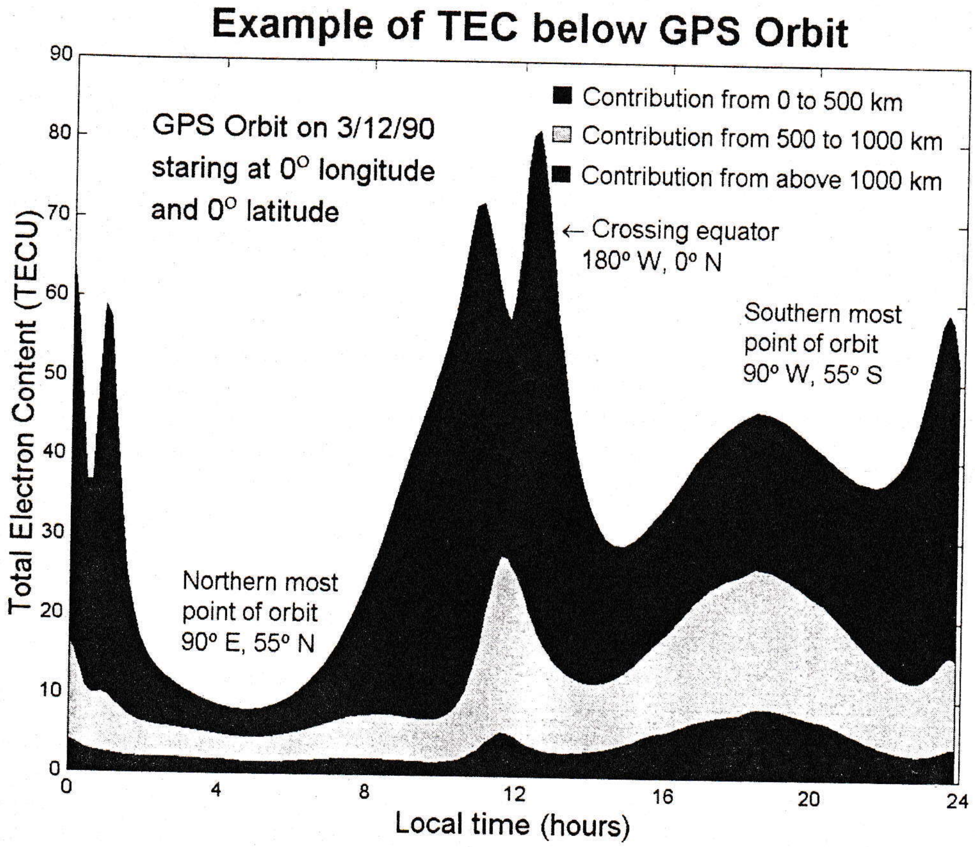

Figure 1. Electron content contributions from 0 to 500km, 500km to 1000km and from above 1000km to the total electron content for a GPS satellite orbit commencing at 0^0 longitude and 0^0 latitude.

IRREGULARITIES

Irregularities in the plasma between FedSat1 and the GPS satellites should also be detectable as scintillation in the phase path data. These irregularities may be located in either the topside ionosphere or the plasmasphere. Jacobson et al (1996) has used sensitive ground based techniques to investigate field aligned irregularities in the plasmasphere. Scintillation activity in the nighttime equatorial anomaly regions of the low latitude ionosphere is known to peak at sunspot maximum, the next maximum being around 2000. Hence the incidence of scintillation in the S band signals from GPS measured in both the occultation experiments and in the vertical direction is another area for study. There is some indication that the occurrence of well developed equatorial anomaly crests and their location is a precursor of the development of nighttime equatorial irregularities (Jayachandran et al, 1997). The combination of both ground based and satellite-based measurements would provide an excellent opportunity to further our understanding of the low latitude ionosphere.

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CONCLUSIONS

LEO micro satellites such as the planned FedSat1 provide the opportunity for researchers in Space Sciences to further investigate those regions of the ionosphere for which existing equipment and techniques are either difficult or impossible to apply. In the future, constellations of microsatellites may provide a global coverage of the ionosphere, previously not possible with ground based equipment.

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