IMAGING THE IONOSPHERE OVER SOUTHERN AFRICA USING GNSS SIGNALS: APPLICATIONS IN RADIO ASTRONOMY AND SPACE WEATHER

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1. INTRODUCTION

The fully ionised ionosphere extends from the limb of the neutral atmosphere (~90 km) to about 2000 km above the Earth and consists of electrically charged electrons and ions dissociated from neutral upper atmosphere atoms and molecules by extreme ultraviolet and X-ray radiation. The dissociated ions and electrons are collectively known as *space plasma* and are subject to Maxwell's laws of electromagnetism; being affected by external magnetic fields whilst generating electrical fields and currents due to atmospheric and geo-dynamics. The ionosphere exhibits geographical, diurnal, seasonal and solar cycle variations with peak electron density concentrations occurring around midday in the summer close to the magnetic equator at the height of the 11-year solar cycle. The electrically charged ionosphere modulates all radio signals propagating through it and during periods of disturbed geomagnetic conditions associated with heightened solar activity, the instable ionosphere may cause disruptive behaviour of safety-of-life devices such as GPS navigation, aircraft automatic landing systems, terrestrial HF communications and satellite communications – systems dependent on the ionosphere for proper functioning. Historically the state of the ionosphere was determined from measurements by expensive vertically-sounding ionosondes (HF radars) which only give a partial picture of the local ionosphere.

2. IONOSPHERIC IMAGING BY GPS

A novel approach to imaging the ionosphere followed from exploiting the ionospheric refraction error on GNSS signals. GNSS signals in the L1 and L2 bands propagating from 20 200 km above Earth through the ionosphere experience an apparent longer signal path length which is proportional to the Total Electron Content (TEC) along the signal path. Using dual frequency GNSS receivers, the TEC along each satellite signal path may be quantified to render an ionospheric measurement. A spherical harmonic model is used to combine more than 600 TEC observations per second from a dense South African GNSS receiver network to image the electron density concentrations in the ionosphere. The subsequent TEC images reveal underlying structure and dynamics of the ionosphere not previously observed in South Africa.

3. RADIO ASTRONOMY AND THE IONOSPHERE

In the context of the proposed Square Kilometre Array (SKA) radio telescope, knowledge of the state of the ionosphere is imperative as the ionosphere significantly affects the lower frequency spectrum signals through Faraday rotation and influences calibration procedures of the antennas. Results illustrating the effect of the ionosphere on radio astronomy observation opportunities are presented.

4. SPACE WEATHER

Civilisation's increasing dependence on space-based technologies renders it vulnerable to near-Earth space phenomena coupled to extreme solar events such as X-ray flares and coronal mass ejections which may damage or misguide satellites, disrupt radio communications and damage national power grids. The effects of such solar events are observed in rapid and sustained changes in the ionosphere and results from the ionosphere's response to the November 2004 solar storm, following the development of a complex series of sunspots, X-ray flares and coronal mass ejections, are presented.