CHAPTER 1

INTRODUCTION

The dependence of society to technology increased in recent years as the technology has enhanced. Moreover, in addition to technology, the dependence of society to nature also increased.

Today's space technology is based on electrical and electronical circuits which is vulnerable to sudden changes in temperature, pressure, radiation, etc. Thus, the Space Weather, which can be defined as the collective, often violent, changes in the space environment surrounding Earth, plays an important role on space-based assets for navigation, communication, military reconnaissance and exploration[7]. Space Weather effects on technology can be experienced both in deep space and on the surface of the Earth. Some of the effects are surface charging, internal charging, displacement damage, single event effects (single event upsets and single event latchups) and radiation dose.

Today's challenge is to learn quantitatively predicting and forecasting the state of the magnetosphere and ionosphere from measured solar wind and interplanetary magnetic field conditions. Engineering and life sciences are needed to evaluate the hazards and risks on the technology and mankind[1]. In this work, telecommunication point of view for the effect of Space Weather was investigated with two methods of analysis. First method was employed for the characterization of the effect and the other method was employed for the construction of model for forecasting effects of some specific cases.

1.1 Solar Wind and Interplanetary Magnetic Field

The Sun is the source of most of Space Weather effects. The Sun's outer most layer, Corona, does not have a rigid boundary, instead it has a ragged structure blending into the background[9]. The extension of the Solar Corona to large distances is named as "Solar Wind"[14]. The effects of the Sun are carried with a continuously streaming Solar Wind to the Earth. The high conductivity of the Solar Wind traps the magnetic field in itself, then the supersonic flowing frozen-in magnetic field of Solar Wind forms the Interplanetary Magnetic Field, which is crucial for the formation and the variability of the Magnetosphere.

1.2 Magnetosphere

Solar Wind which is a moving conducting surface is not allowed by Earth's internal magnetic field to penetrate, thus, in order to oppose the Earth's internal magnetic field, a current system is generated on the boundary. On the sunward boundary, some of the magnetic field lines are broken and pushed away from the Sun [14]. Since the Maxwell's Equation, $\nabla \cdot \vec{B} = 0$, where $\vec{B}$ is the magnetic field vector, states that there cannot be any monopoles, it can be said that these pushed back magnetic field lines connect to their conjugates at a point that can be imagined as infinity. Figure 1.1 shows the structure of the Magnetosphere.

During disturbed conditions (i.e. Magnetospheric Storms and Substorms), most of the time, the z component of IMF turnes its polarity to southward which causes more field lines to be broken and pushed back. As a consequence, the magnetic pressure presses some of the magnetic field lines and force them to reconnect at the sun-away side. The reconnecting magnetic field lines forms a plasmoid which is then translated over the magnetic field lines to the polar caps. During magnetospheric storms and substorm, large amount of energy is transferred to the magnetospheric system.

1.3 Ionosphere

Ionized component of the upper atmosphere is named as the Ionosphere. Ionosphere has important consequences like enabling the flow of currents, effecting the upper atmosphere either by producing or slowing down thermopsheric winds. More important is that Ionosphere

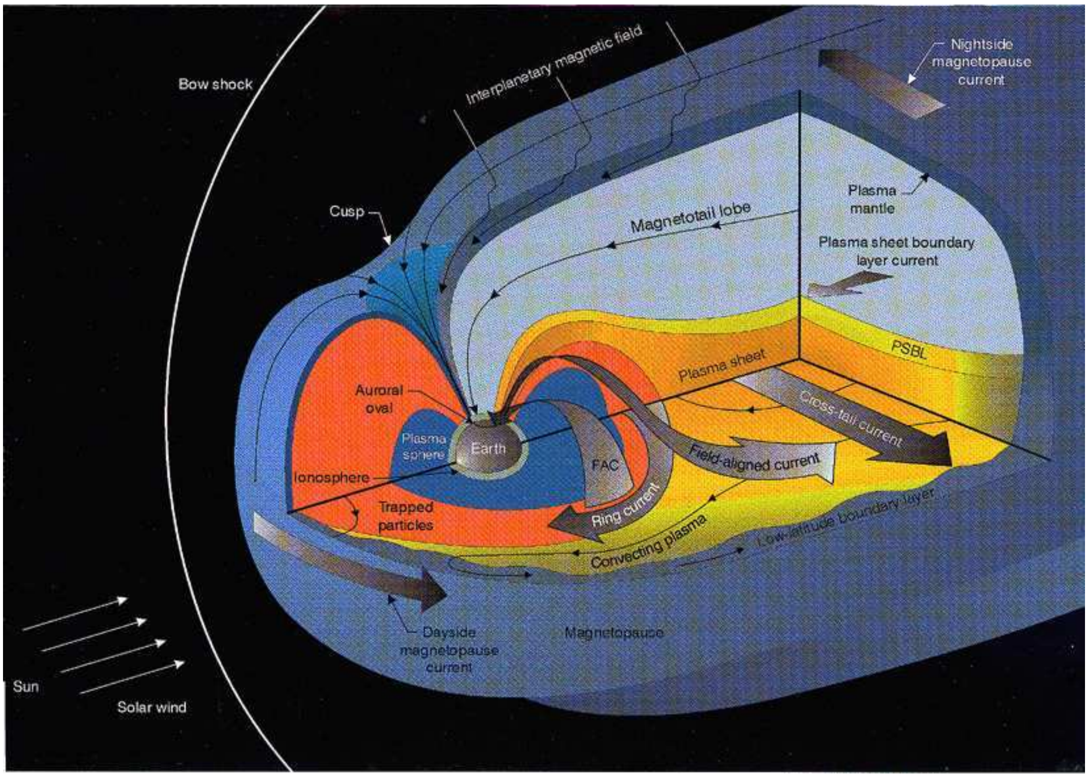

Figure 1.1: The Structure of the Magnetosphere

plays an important role on the modification of the electromagnetic waves[8].

Ionosphere is composed of 3 layers, which are;

- D Layer
- E Layer
- F Layer

These layers are categorized by the chemical reactions taking place, chemical composition and dynamical processes. For more detailed information, the reader is refered to [8] and [14].

From the telecommunication point of view, the most important layer amongst these layers is the F layer since it is the last layer for reflecting the high frequency electromagnetic waves. The maximum frequency which can be reflected from a certain layer of Ionosphere is named as *critical frequency*. Ionospheric F layer critical frequency, f_0F2, which is the maximum frequency of a wave that can reflect from the F Layer, specifies the maximum usable frequency by the relation:

$$f_{usable} = \frac{f_0 F2}{sin(\Delta\Lambda)} \tag{1.1}$$

where $\Delta\Lambda$ is the latitude difference between the measurement site of f_0F2 and the position where f_{usable} is calculated. Higher the value of f_0F2 is, higher the f_{usable} is.

At a given time of year and phase in the solar cycle, ionosphere exhibits regular diurnal variations at mid-latitudes as the plasma co-rotates with the Earth. The daily variation of the F region electron density distribution greatly affects the propogation of radio waves in the frequency range from 3 kHz (Very Low Frequencies) to 30 MHz (High Frequency). Of particular importance is the maximum plasma density of the F layer. Since f_0F2 is the important parameter which is (in Hz) numerically equal to about nine times the square root of the maximum electron density (in m^{-3}), unless stated otherwise, the ionospheric variablity was quantified by refering to the f_0F2 values [16]. Thus it is an important and crucial information to know, understand and forecast the value of f_0F2.

1.4 Interaction of Magnetosphere and Ionosphere

Two layers of the Earth, Magnetosphere and Ionosphere are not independent of each other. Processes affecting one of them also effects the other via several mechanisms. Some of the best examples are the Aurora Borealis, Nothern Lights and Aurora Australis, Southern Lights.

Magnetic reconnection at the magnetospheric boundaries in regions where interplanetary magnetic fields are antiparallel and viscous interactions along the boundary makes the energy, momentum and plasma enter the magnetosphere[1]. The Sun's solar energy that is carried by the Solar Wind influences the Ionosphere and Magnetosphere via particles, currents and fields. For more detailed information about the current systems and the connection, reader is refered to [20].

1.5 Literature Survey

The variability greatly limits the efficiency of systems using HF frequencies such as communications, radars and navigation [24, 10]. The possibility that there may be an observable link between the IMF and the behaviour of the mid-latitude ionosphere has led to several investigations [12] and the possible effects of the orientation of the Interplanetary Magnetic Field on Atmospheric, Ionospheric and Magnetospheric phenomena was investigated by many scientists. In [21], the IMF data have been sorted according to the polarity of IMF B_z and studied the effects of the IMF B_z southward turnings on the mid-latitude ionosphere. Following [19], a reversal of the polarity of the IMF B_z component between hourly data points was named as an **event type 1** (with start time t_1 and end time t_2=t_1+1h.) provided that change in magnitude, δB_z, is at least 2 nT. It was required further that the IMF B_z polarity was the same for both 4 h. before and 4 h. after turnings. In total, there were continuous IMF B_z data over an 8 hour period and this condition was met. In order to study the day-to-day variability of the f_0F2 about the regular diurnal variations, each hourly value of f_0F2 *quiet* soundings when simultaneous magnetic Kp index was less than 2+ was identified with 15 days of the sounding in question. Then, the mean quiet-time value at the same Universal Time (UT), the quiet time control value, was subtracted from the actual observed value. The resulting value is then termed as δf_0F2. In [17], [21], it has been pursued the Superposed Epoch (SPE) studies of the f_0F2 values from Uppsala, Lannion, Dourbes, Kalin, Potier, Slough Vertical Ionosondes and it was revealed that much of the day-to-day variability of the mid-latitude ionosphere may be related to the orientation of the southward IMF B_z. In particular, significant depression of over 1 MHz was found in the average critical frequencies following a southward turning of the IMF B_z.

In [16], the associated geomagnetic response of polarity reversals of IMF B_z by using the SPE method has been investigated since the ionospheric effect is well correlated with geomagnetic disturbance, as seen in a variety of magnetic indices like Kp, AE and Dst when the IMF B_z polarity turned from north to south [16]. It has been confirmed that the energy deposited at high latitudes, which leads to the geomagnetic and high ionospheric disturbances following a southward turning of the IMF, increases with energy density (dynamic pressure) of the solar wind flow[16]. The magnitude of all responses were shown to depend on δB_z

Although, in [25], it has been mentioned that IMF B_y has no significant role on the substorms in their work, many researchers have tried to find a clue of the dependence of IMF B_y on geospace variability. One of the results in [18] proposed a possible relation between the IMF B_y and magnetospheric convection electric field. Moreover, in [13], it has been shown that turnings of IMF B_y during quasi-steady IMF B_z can be linked to the substorm activities. In addition, dependence of auroral activity on IMF B_y and B_x components have been shown by [15]. A more striking and recent result by [5] was that average power flux for both hemispheres was found to be greater for negative values of IMF B_y where power flux in responsible for the photoionization and photodissociation in the Ionosphere. Although, IMF B_z turnings have a crucial effect on the magnetospheric system, it has been shown by [3] that events for which IMF B_z is northward for at least 2 hours before and at least 3 hours after a IMF B_y sign change caused aurora formation in both hemispheres which showed the link between IMF B_y and Ionosphere. Another important effect of IMF B_y is that it modulate the flow pattern of convection via the action of the neutral thermosphere [17].

1.6 Summary

In the space era, the impact of the solar activity on our lives, on the technology, on our past, present and future has to be qualified and quantified. However, processes effecting our system are mostly non-linear and time-varying processes. In complying with such a must, one need to experiment, monitor, build up Solar and Terrestrial data archieves and do modeling by using the experiences and data available in order to forecast or predict the future for system designers, operators and users.

Therefore, revisiting the problem and including the IMF B_y polarity in the definition of the event, the effects of southward turnings of the IMF B_z were investigated by using Superposed Epoch (SPE) Method. Then the effects of polarity reversals of IMF B_y and IMF B_z components on the f_0F2 for a single vertical ionosonde station were attempted to be modeled by using Genetic Programming Method. It is interesting to note that the SPE has been one of the oldest techniques whereas GP is one of the recent techniques.