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Effect of Ionospheric Attenuation on Radio Communication: A review

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Abstract: Many studies have reported the effect of ionospheric attenuation on propagation of radio waves. Literatures revealed that the higher the frequency of the radio signal, less it is effected by the ionosphere. The ionosphere has an important and special characteristic of bouncing back the radio signals transmitted from the earth. This property of ionosphere plays an important role in communication, navigation and broadcasting systems. Radio and GPS signals travel through this layer of atmosphere, or rely on bouncing back of the signals. The upper ionosphere, i.e., F region is used for radio communication and navigation as it reflects long, medium, as well as short waves. Any variation in the density of ionosphere can affect the entire radio communication system. This article critically reviews the effect of ionospheric attenuation in modern day communication, navigation and broadcasting.

Keywords: Ionosphere, Radio communication, Attenuation, Fading, Electron density, Plasma density, Navigation, Broadcasting.

I. INTRODUCTION

The Ionosphere is the ionized region in the Earth's atmosphere extending from about 50 km to roughly 2 000 km above the Earth's surface [1-4]. The sufficient ionization of ionosphere is mainly responsible for the propagation of radio waves. The ionosphere has three layers- D, E and F, which plays a significant role in propagation of radio waves. The D layer is the innermost layers whereas F region is the highest region of ionosphere, at altitude greater than 130 km. F layer is present during both day and night time, used for long distance propagation. E region extends generally from an altitude of 90 km to about 130 km. D region is the lowest ionospheric region, at an altitude of about 50km to 90 km.

The electron density of F layer is highest which makes it fittest for long distance HF radio communications. F region is classified into two layers- F1 and F2. During the day time there is a small layer F1 and over which there is highly ionized layer F2. In F_1 layer, ionization is caused due to photo ionization and it disappears through recombination with electrons [5-10]. In F2 layer chemical to diffusion transition occurs. At night time, the F1 and F2 layers becomes one at the level of F2. The waves with frequencies up to 35MHz are reflected by this region. However, in addition to the variation of the plasma density with altitude, the ionosphere also shows significant variation with longitude, latitude, solar activity, geomagnetic activity, and seasons along with time of the day. With the changes in the plasma density, the plasma temperature changes.

II. ANALYSIS AND RESULT

Absorption, reflection, refraction, scattering, polarization, group delay and fading/scintillation are different attenuation mechanisms of radio waves when it is propagating through ionosphere. Absorption, cloud and rain attenuation, attenuation due to snow, hail and fog are the causes of loss of energy of the radio waves in the regions other than ionosphere. The perturbation, outage or sometime total loss of signal due to attenuation in ionosphere is observed. Now a day, it becomes more area of concern due to our increased dependence on space-based system. All the modern communication systems like, Radar, Satellite, ionosondes, GPS and GNSS devices are affected due to the irregularities of the ionospheric levels. Above 10 GHz, the attenuation is due to rain. At high frequency, the attenuation of ionosphere is high due to the increased interaction of electrons, ions, and molecules present in the atmosphere with radio waves. The atmospheric gases are responsible for fading of radio waves at microwave and millimetric frequencies.

Some common types of attenuations seen during the propagation of radio waves due to change in the electron density are:

(i) Ionospheric Attenuation: Free-Space Loss/Attenuation
(ii) Attenuation due to Atmospheric Gases
(iii) Attenuation by Rain
(iv) Attenuation Due to Multipath

Some of the causes of attenuation of radio waves when it is passing through the ionosphere:

(a) Precipitation and clouds: The electromagnetic waves got attenuated due to the absorption and scattering process occurs due to rain. The fading of radio signals due to rainfall depends on various factors like - elevation angle, carrier frequency, height of earth station, latitude of earth station and rate of rain fall [11-12]. The radio signals having high frequency are attenuated to a greater extent in comparison to the signal with lower frequency due to rainfall. The raindrops behave as scattering centers for radio waves due to which when the raindrops come in the way of radio signals, they got scatter in different directions which results in the fading of the signal. A portion of the radio waves can absorb the radio waves leads to the attenuation of the signal. The extent of attenuation depends on the rate and intensity of rainfall. Heavier rainfalls result in more attenuation. The degree of attenuation also depends on the lenth of the path. Greater attenuation is seen for a longer path to be travelled by the radio waves.

(b) Atmospheric gases: The microwave signals at high frequency suffers fading due to absorption by atmospheric gases. The path attenuation due to atmospheric gases at lower frequencies (nearly below 3GHz) is small whereas oxygen and water vapour in the lower atmosphere can affect path attenuation at higher frequencies [1-2]. Different gases in the Earth's atmosphere can absorb radio waves at specific frequencies. For example, Oxygen molecules present in the atmosphere can absorb radio waves in the microwave and millimeter-wave regions of the electromagnetic spectrum. Carbon dioxide (CO2) can absorb radio waves in the infrared and far-infrared region of the spectrum. Absorption due to CO2 is significant at higher altitudes. Water vapor can absorb radio waves in the millimeter-wave and submillimeter-wave bands.

(c) Seasonal variation: There is a consistent seasonal absorption reported in the field strength of the radio waves propagating from the ionosphere. This is due to the change in relative positions of the Sun which effects the electron density of the ionosphere. Due to higher ionization level in day time and in summer months, the radio signals reflected off from the ionosphere easily. Seasonal variations can affect the skip distance also. During period of higher ionization as in daytime and in summer, the skip distances occurs higher. The signals may experience less fading during high ionization and converse is also true. During the polar winter, there can be a significant reduction in ionization levels and the maximum usuable frequency, making long-distance communication challenging.

(d)Interference fading due to movement of the ionosphere, and multipath changes: This type of fading is seen due to interference of two or more waves coming from different paths to the receiver. In this type of attenuation, the intensity of the resultant signal may vary over a wide range [13]. Interference fading which occurs due to multipath changes, results in reception of multiple copies of the same signal arriving at slightly different times and with different phases. These multiple copies can interfere with each other, leading to constructive or destructive interference.

(e) Variation with solar and magnetic activity: The propagation of electromagnetic wave is affected by solar activity to a lager extent. The waves with medium frequency is affected more. The night-time sky-wave field strengths of medium frequency signal decreases with solar activity. The deterioration of signal strength is observed higher at high latitude. The reason may be excess absorption associated with magnetic storm and post-storm effects [14-15].

(f) Scintillation effects: In scintillation effect a fluctuating signal in amplitude, phase, and apparent direction of arrival is received in place of the steady signal [16]. In the auroral region, the scintillation effect is observed due to geomagnetic storms due to large variation of electron density. The effect of scintillation is more dominant at higher frequencies. Higher-frequency radio signals are more susceptible to scintillation-induced fading and phase variations. For satellite communication systems operating in higher frequency bands, this effect is of great concern. The ionospheric scintillation depends on geographic location and time. It is generally observed at high latitudes, near the equator and during periods of increased solar activity. Regions near the equator are particularly prone to scintillation because of the equatorial anomaly, where irregularities in ionospheric electron density are prevalent.

(g)Faraday rotation: The rotation of plane of polarization in electromagnetic signal when it is passing through the ionosphere due to presence of the geomagnetic field and the anisotropy of the plasma medium is called Faraday rotation [17]. The magnitude of Faraday rotation is changing due to change in the electron density of the ionosphere. Actually, the magnitude of Faraday rotation depends on the frequency of the radio waves and the strength of the magnetic field in the ionosphere. The radio waves with higher frequency are more strongly affected by the Faraday's rotation.

(h) Sudden ionospheric Disturbance (SID's) associated with solar X-Ray events: Due to the X-Rays of SID's, the electron density of the most of the ionospheric layers increases [14, 18-19]. This increase in electron density can cause the total loss of signal in high frequency band whereas in VLF band the signal intensity may be enhanced.

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III. CONCLUSION

The ionosphere plays a vital role in modern day communication, broadcasting and navigation. The propagation of radio waves from low frequency to ultra-low frequency and above that depends on the ionospheric attenuation due to the change in its electron density. To minimize these effect, there must be high degree of prediction system for any type of change in electron density of the ionosphere due to any type of solar eruption, solar or geomagnetic storm. Also, the system should be equipped with such type of hardware or software which can minimize the effect of day and night, seasons, altitude, precipitation and atmospheric gases.

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