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Solar Storm Impacts on Wireless Networks

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ABSTRACT

Satellite communications, navigation systems and electrical transmission equipment all rely heavily on Wireless Technologies. Solar storms are predicted in the near future and this could have "devastating effects" on human technology as they can release particles that subsequently disable or permanently destroy computer circuits. Solar storms can vary in size and as a result can have different effects such as satellite disorientation, spacecraft electronics damage, spacecraft solar panel degradation, extreme radiation hazard to astronauts, launch payload failure, high altitude aircraft radiation, shortwave radio fades and disruption in polar regions, ozone layer depletion, cardiac arrest, dementia and cancer. This paper explores the possible impact of a solar storm on daily living by giving an overview of predicted outcomes as well as summarizing the results of past flares.

Keywords: *Solar Storm, Ionosphere, Multimedia, Communications*

I. INTRODUCTION

Satellite communications, navigation systems and electrical transmission equipment all rely heavily on Wireless Technologies. With pending Solar storms, this could have "devastating effects" on human technology when they hit a peak in 2013, according to the US National Oceanic and Atmospheric Administration assistant secretary Kathryn Sullivan [1]. These solar storms can release particles that subsequently disable or permanently destroy computer circuits. The Wireless network utilises the ionosphere which is a layer around the Earth about 50-100km up. The layer contains ionised electrons which satellite communications rely heavily upon. Cosmic and terrestrial radiation may contribute energy to the ionization process. A geo perspective of the resonant energy available includes more than just a local vertically reflecting ionosphere and antenna system. The two conducting spheres, the earth-sphere and the ionosphere, must be involved, acting as a resonant waveguide with the atmosphere as an insulating medium. It is not yet known what factors may limit the usable energy available from this process, other than radio interference, aviation safety and public safety [2].

Solar storms can vary in size and as a result can have different effects on the Earth. One of the largest solar storms in the past 450 years occurred in September 1859. Civilization has evolved today into a society that relies heavily upon technology and therefore a solar storm of a similar magnitude today could produce a catastrophic global situation [3]. Solar proton events produce satellite disorientation, spacecraft electronics damage, spacecraft solar panel degradation, extreme radiation hazard to astronauts, launch payload failure, high altitude aircraft radiation, shortwave radio fades and disruption in polar regions, ozone layer depletion, cardiac arrest, dementia and cancer [3]. Marconi showed the viability of global wireless communications with successful transmissions from Poldhu Station, Cornwall, to St. John's, Newfoundland, in December 1901. This feat was only possible due to the high altitude reflecting layer, the ionosphere, which reflected the wireless signals [4]. It is the ionosphere's electrical currents that could produce unprompted electrical currents within the Earth (and thus within the wires of the electrical telegraph) which could also affect the reception and dependability of the transmitted long-distance wireless signals [4]. The association of this disturbed long wavelength radio transmissions and individual incidents of solar activity were first identified in 1923 [5].

The 802.11 standard contains a number of problems, ranging from interference, co-existence issues, exposed terminal problems and regulations to security. Despite all of these it has become a widely deployed technology as an extension of companies' networks to provide mobility. A serious vulnerability which exists for Wireless Local Area Networks (WLAN) is Denial of Service (DOS) attacks [10]. This is because the management and control frames of 802.11b are not protected. For example an attacker can forge the De-authentication or Disassociation messages, which will remove a client off a WLAN. In addition, an influx of association requests may be sent to an Access Point (AP), preventing any other client from connecting to the AP [10]. Due to increased popularity, wireless related technologies have evolved at a rapid rate the past couple of years which eventually lead to the development of a mature security solution, 802.11i [10]. Tracking any factors that may impact these technologies is crucial in order to safeguard against any situations that may put human life at risk.

GIS systems can be used in a wide variety of applications in diverse fields such as agriculture, geology, military and urban planning. Applications that run on portable devices will need access to Geographic Information Systems (GIS) information. WWANS, or commonly named mobile telephone networks, are cellular networks that primarily appeared as voice networks and, subsequently, due to the collective requirement of data transmission have been modified to transmit any kind of data. These networks have evolved and according to their capabilities are classified accordingly [12]. Today the requirement for accurate position and navigation aids in many commercial sectors are becoming increasingly apparent and the precision of absolute GPS is not enough [12]. Any impact on this technology could have serious consequences for many organisations.

2. IONOSPHERE

The dispersive effect of ionosphere, which demonstrates dynamic spatial and temporal variations, remains the largest error contributor in Global Positioning Systems. Dispersive network residuals are anticipated to increase towards Solar Cycle 24 [7]. High Frequency (HF) radio operates at carrier frequencies that potentially propagate to any point in the world via one or more “reflections” from the ionosphere. It should be noted though that such “skywave” links are subject to complex exchanges among the solar and terrestrial environments, therefore as a result, the ability to communicate directly between random pairs of points via HF may not be reliable under all conditions [8].

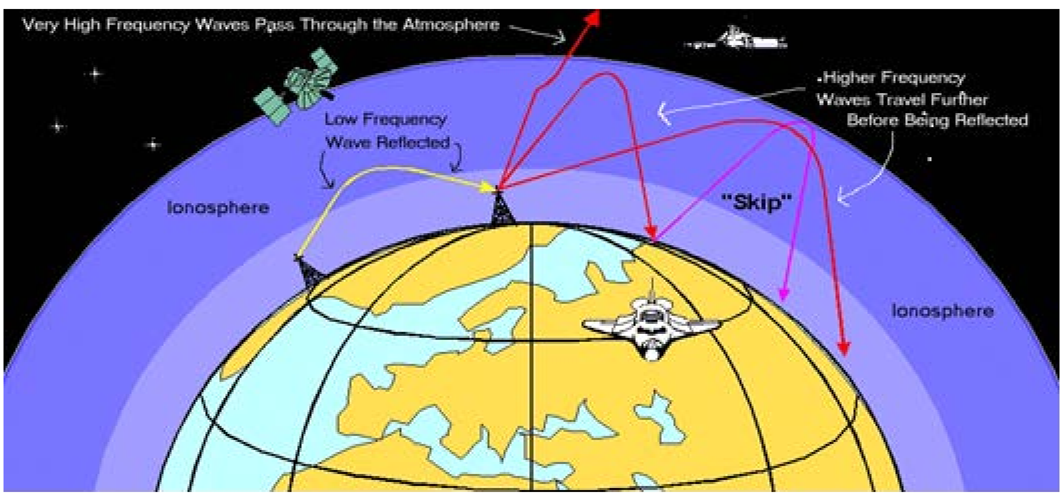

Figure 1: The Ionosphere [6]

The rapid development of Global Positioning Systems (GPS) based location based services (LBS) has opened new avenues for ubiquitous positioning and can potentially transform almost all geospatial practice, such as surveying, mapping, geographical information systems, photo-grammetry, risk management and emergency response, vehicle and asset tracking, machine control, workforce management and logistics [9]. The key background facility of the LBS is a backbone ground-based GPS infrastructure. The atmospheric effects, especially the ionosphere, are the key restrictive factors for real-time high accuracy positioning [9]. Therefore monitoring of the ionosphere is imperative. Any fluctuations in this layer can have significant knock-on effects.

Impacts of solar storms on terrestrial processes on communications include Ionosphere variations. Effects here include induction of electrical currents in long communications cables, Wireless signal reflection, propagation, attenuation affecting commercial radio/TV, local and national safety and security entities, communication satellite signal interference and aircraft communications. Magnetic Field Variations *a*ffect altitude control of communications spacecraft. Solar Radio Bursts produce excess noise in wireless communications systems and Interfere with radar and radio receivers. Charged Particle Radiation causes solar cell damage, semiconductor device damage and failure and faulty operation of semiconductor devices. Micrometeoroids and Artificial Space Debris cause solar cell damage to spacecraft and damage to surfaces, materials, complete vehicles.

It is evident that any impact on our ionosphere can have a significant impact on our "wireless" environment.

Table 1: Space Weather Impact October-November 2003 [4]

Spacecraft Mission	Change in Operation	Status Electronic Errors	Noisy Housekeeping Data	Solar Array Degradation	Change in Orbit Dynamics	High Levels Accumulated Radiation
Aqua	None	x				
Chandra	Instrument safed					x
CHIPS	Control loss	x				
Cluster	None			x		
Genesis	Auto safed	x				
GOES 9,10	None		x			
ICESat	None	x				
INTEGRAL	Command safe					
Landsat 7	Instrument safed					
RHESSI	Abs. ime seq. stop	x				
SOHO	Instrument safed			x		
Stardust	Auto safed	x				
TDRSS	None	x				
TRMM	Added delta V				x	
WIND	None			x		

Table 1 above depicts the impact of space weather on spacecraft. Interestingly RHSSI studies the basic physics of particle acceleration and explosive energy release in solar flares. Telecommunications cable systems use the Earth itself as a ground return for their circuits, and as a result these cables provide highly conducting paths for concentrating the electrical currents that flow between these newly established, but temporary, Earth "batteries" [5]. Any 'interference' to this current could have a significant impact. On February 10, 1958 a flare was noted with the following appearing in the New Yorker newspaper a few days later: "At almost the exact moment when the magnetograph traces leaped and the aurora flared up, huge currents in the earth, induced by the heavenly turbulence, manifested themselves not only in power lines in Canada but in cables under the north Atlantic." Voltage on the first transatlantic telephone cable "…Circuit breakers began tripping out in Ontario transformer stations, plunging the Toronto area into a temporary darkness broken only by the strange light of the aurora overhead" [13]. More recent investigations have shown that there has even been speculation about the possible ionospheric perturbations associated with the 2010 Haiti earthquake, as based on medium-distance subionospheric VLF propagation data [14].

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3. CONCLUSION

Solar storms frequently impact the Earth's upper atmosphere, the ionosphere. The region of free electrons and ionized atoms vary with solar activity. Under severe conditions, this activity has interrupted communications and electrical power over wide areas. These storms also cause error in basic GPS receivers. The properties of the ionosphere alter with the time of day, the season, and with the level of solar activity. In the case of solar activity, solar flares can cause radio signal 'fade outs' which are well-known to amateur radio operators [11]. As a result, the impact of future Solar Storms cannot be underestimated, as we as a society become more and more reliant on technology.

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