Communication Satellites:
Frequency Band limitations Versus Implementations

Written By: Kirubel Z. Seifu

Mentor: Dr. Chiu Tai Law

Abstract

The role of communications satellites in the national and global information infrastructure is diverse. Communications satellites utilize electromagnetic spectrum to transmit information. The material in this project is involved in studying the application of telecommunication devices for various frequency ranges, such as L-band, C-band, Ku-band, Ka-band, etc. in implementing the emerging frequency band of Ka-band, a broadband with approximate width of 18 – 40 Giga hertz. This broadband is now becoming a big issue because the lower frequency bandwidth between 12-18 Giga hertz named Ku-band will be occupied by larger telecommunication service providers filling up the band while various factors such as rain attenuation, antenna wetting, depolarization due to rain and ice, cloud attenuation etc. still affect significantly high frequency propagation. As the traffic of the Ku-band and other lower band spectra are highly congested, regulatory organizations encounter problems in reallocating services to other frequencies. If reallocations of frequency are to be sought to certain bandwidth, it would result a loss of billions of dollars per year to previously mounted communications satellites which transport various signals. Hence, this paper shall explore the new technologies and concepts in implementing wireless devices that have potential in alleviating traffic congestion of communication satellites.

I. Introduction

A communication satellite system, distinguished by its global coverage, emerged by the end of World War II. Satellites have made our global world interconnected and interdependent[1]. Today, there are approximately 150 communication satellites in orbit which are responsible for various satellite services such as GPS (Global Positioning System) satellites, satellites phones, TV network, weather satellites, military satellites, etc which continue to alter the patterns of our society. Communication between two locations separating by long distance is only achievable when signals or messages are encoded on the top of high frequency electromagnetic wave. “Frequency is simply the number of times that an electrical signal ‘wiggles’ in one second,” and is measured in Hertz (Hz)[2]. By adopting appropriate frequency bands of EM wave that acts as “carrier” of signals, we exploit their low losses and distortion in maximizing communication speed and distance.

This publication shall overview the works of various researchers such as Schellenberg [4], J. M., Chandler [10], C. W, Castanet [7], L. , etc in the field of Electrical Engineering. I keenly anticipate that I would acquire an all rounded knowledge from their publications in satellite communications. These authors have come out with new findings and concepts which could be deployed to various applications of communications satellites. Hence, in this paper we shall be providing case studies between the most commonly used satellite bands; and also discuss the new interference and fade mitigation techniques scientists use to overcome technological challenges.

Literature Review

II. Segments of Communication Satellites

A satellite system consists of a space segment and a ground segment both constituting: transmitters, antenna, amplifier, and power generators. The space segment is composed of satellites, which may be classified into geostationary orbit (GSO) and low earth orbit (LEO) satellites. The GSO is 35,786 km above the equator, and its revolution is synchronized with the Earth’s rotation while LEO satellites are located 3000 km above the surface of the earth.

Nowadays, the majority of communication satellites are placed in GSO orbit. One of the biggest differences between a LEO satellite and GSO satellite is in their antennas [2]. GSO satellites have wider antennas and higher transmission power than LEO’s. This allows the GEO satellites to broadcast to everyone in a large area. The first and foremost limitation of GEO satellites is round trip latency which is a measure of the time it takes for a signal to reach the satellite, be turned around and sent, and propagate to the receiver [9]. The following illustration shows the least components that satellites should have.

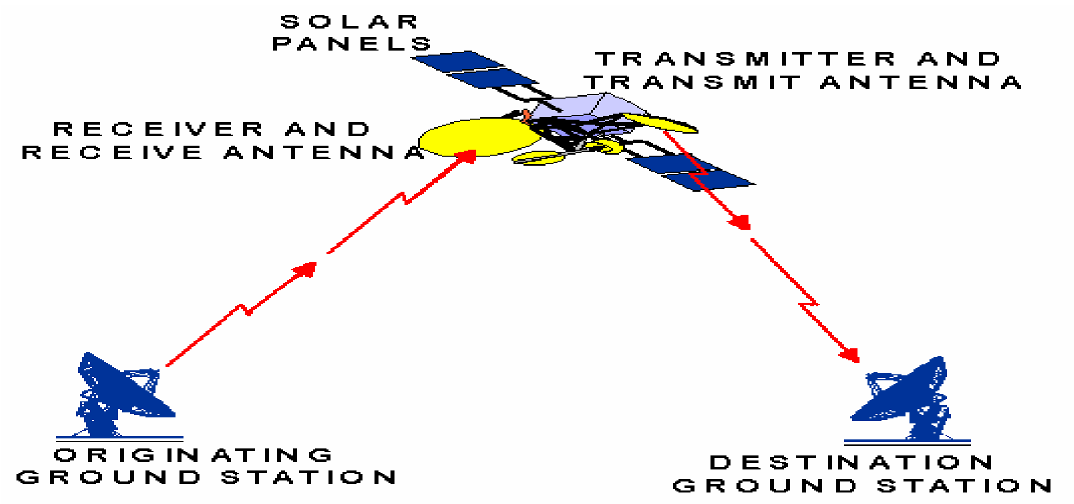

Figure 1. Basic Components of Communication Satellites [2]

III. Frequency Bands for Communication Satellites

The frequency range available for satellite communications services is limited, and regulated by international agreements[11]. For this reason, the spectrum has to be used in a highly efficient manner. Frequency assignment for different wireless services is regulated by the International Telecommunications Union (ITU), a sub-organization of the United Nations[3].The following are the frequency ranges or frequency bands used in communication satellites:

A. L-band (1 -2 Giga Hz)

Applications: GPS satellites, satellite phones, WorldSpace satellite radio

Figure 2. L-Band Satellite Antenna [12]

This bandwidth has broad applications in digital audio broadcasting, Telecommunications use, and military use.

B. C-band 4-8 Giga Hz)

Applications : Cable TV distribution, Satellite TV (large 7-10 ft. steerable dishes),

Figure 3. C-Band Satellite Antenna [13]

By the late 1960's, the world's first commercial satellite systems used C-band frequency range of 3-7 Giga Hz (GHz). Today, as there are several TV broadcast stations and telecommunication service providers, scientist are facing high technical challenges with in the congested wireless communication channel of C-band. Since frequency ranges greater than 10 GHz have major drawbacks during broadcast, scientists have not been able to shift to the wider frequency bands than C-band. At higher frequencies, the size of falling droplets, rain-filled clouds, or even snow play a significant role in reducing the intensity of incoming signals from antennas mounted on satellites.

C. Ku-band (12-18 Giga Hz)

Applications: TV network satellite distribution, Satellite TV

Figure 4. Ku-Band Satellite 39'' Ku-Band Antenna[14]

This bandwidth has high transmitting signal level as compared to C-band satellites. Ku-band satellites have a reduced size in approximately 30cm. This significant reduction in antenna size lowers the cost of the equipment and simplifies the system installation. In places where torrential downpour occurs, the level of incoming Ku-band satellites signal lowers severely, degrading the quality of signals or even interrupt the reception entirely.

Hence, in order to counter act the rain fade problem, Ku-band designers use larger aperture antennas which could at least to lower the risk of losing signal or reception [7].

D. Ka-band (18-40 Giga Hz)

Applications: misc commsats, satellite phone backhaul

Figure 5. Ka-Band Satellite 26'' Antenna [15]

This band is the one of the higher frequency band expected to be in use dramatically for the next couple of years. Because of a radio spectrum shortage below about 17 GHz, frequencies in Ka and higher spectral bands are seen as good candidates for Earth-space communications in the future [6].

IV. Frequency Bands Limitations Versus Implementations

The higher frequency Ka-band was virtually unused while most communication satellites operate in the lower frequency C- and Ku-bands. The Ka-band has a greater bandwidth (in other words, it has a higher capacity for data transfer) and allows smaller spacecraft and ground stations. Ka-band frequency is capable of carrying simultaneously a multiple mix of voice, high-speed data, and teleconferencing transmissions. High frequency means short wavelengths, though. And the millimeter wavelength Ka-band signals are easily degraded by rain, a problem known as rain fade. [6] "Radio wave propagation at frequencies above 17 *GHz* is plagued with rain-induced signal attenuation, a factor that for small probability levels can be very large. Therefore, services that require a low to moderate degree of link availability are likely to be attracted to frequencies above 17 GHz sooner than those demanding a very small probability of outage. The aeronautical mobile satellite service can use the Ka-band to its advantage considering that the cruising altitudes of most flights are high enough to either eliminate or considerably reduce the rain attenuation problem. Links in parts of the world with a low annual rainfall can use frequencies above about 17 GHz without significantly compromising link availability.” [6]

Propagation factors that affect Ka-band satellite links include [5]:

- rain attenuation
- depolarization due to rain and ice
- cloud attenuation
- troposphere scintillation

Rain attenuation is the dominant propagation impairment at Ka-band frequencies. Rain attenuation is a function of frequency, elevation angle, polarization angle, rain intensity, rain drop size distribution and rain drop temperature [5]. Satellite path signals are depolarized by clouds of ice crystals in the upper atmosphere and by the ice particles which are present at the top of rain clouds. Rain also depolarizes satellite signals, converting energy from one polarization to another, and causes interference between channels. The clear cloudless atmosphere also absorbs radio signals. Scintillation are caused by atmospheric turbulence which are experienced in a clear atmosphere [10]. TRW Space & Electronics, Engineering has come out with Gen*Star, a new satellite communications system for the emerging Ka-band market. The Gen*Star antenna design is based on design and development efforts that began in 1995. Gen*Star , for example, provides a full-Earth field of view (FOV) from a single satellite in GSO. Gen*Star is designed to operate in space for years with multiple-beam antenna (MBA) system. The Gen*Star antenna uniqueness stems from the capability to cover the entire Earth FOV from geosynchronous orbit with the same performance that previous systems covered—a regional area in an antenna that stows for launch into a very compact space. The Gen*Star antenna architecture has a high degree of flexibility. The configuration can be easily customized for a specific mission requirement. The foremost enablers of this flexibility are:

- Standardized components
- Capability to use any polarization or combination of polarizations
- Frequency insensitivity enables other frequency bands to be integrated
- Compact design enables many packaging options

In bringing effective and optimized scheme for the global telecommunication, Fitch M. from BT Exact also introduces a technical incentive of the automatic device called transponder. Transponder is a broadcast translator that amplifies, translates, receives and retransmits a signal on a different frequency. The modulation scheme is multi-level Gaussian frequency-shift keying (MGFSK). It is a narrow-band FM scheme and as such it has a constant envelope and is therefore suited (a) to low-cost transmitters where the output amplifier can be saturated and (b) to satellite channels where the satellite transponder can be saturated. While MGFSK of itself is not new, it has not been applied to commercial satellite communications before. The ability of the proposed modulation scheme to provide 2-3 times increased capacity would significantly enhance the quality of news broadcasts from remote regions [10]. The proposed modulation scheme would enable more efficient use of satellite transponders for this growing communications demand. Given that the typical market rate for leasing a Ku band transponder is $1.6M to $2M per year, there is significant incentive for service providers to use transponders very efficiently[10]. The key application areas for the proposed scheme is in military applications and rolling satellites news such as CNN, Sky News, etc.. These are the most suitable applications because large dish antenna receivers can be used and it is feasible to upgrade the systems because of their relatively small installed base [15].

V. Conclusion

Although Ka is attractive from the point of view of the amount of frequency bandwidth that the satellite can potentially use, some important limitation could moderate the enthusiasm of using them if specific techniques were not implemented in the satellite system to guarantee the capacity, the availability and the quality of service. The major limitation is the effect of radio-wave propagation through the lowest layers of the atmosphere. As the operating frequency is increased, the attenuation and scintillation effects of atmospheric gas, clouds and rain become more severe [7]. Hence communications satellites with wide-coverage, wide-bandwidth, and low-noise communication systems with high effective isotropic radiation power such as multi-level

Gaussian frequency-shift keying (MGFSK) transponder and Gen*Star multiple-beam antenna (MBA) system should be implemented in order to breakthrough the limitations of frequency bands into high-traffic areas.

References

1. Pelton, J. N. (2004). *Communications Satellites*. Mahwah,NJ: Lawrence Erlbaum Associates. (Ch.1,P.3)
2. Leonard, D. . Satellite Communications - A Short Course. *Research & Technology*. From http://ctd.grc.nasa.gov/rleonard/regcontents.html
3. Kim, W. S. (1996). Role of Communications Satellites in the National and Global Information Infrastructure. *Research & Technology*. From http://www.grc.nasa.gov/WWW/RT/RT1995/5000/5610b.htm
4. Schellenberg, J. M. (1995). Highly Efficient Amplifier for Ka-Band Communications. *Technical Digest 1995*, 284-287. From http://www.grc.nasa.gov/WWW/RT/RT1995/5000/5620h.htm
5. Acosta, R. J. (1997). RAIN FADE COMPENSATION ALTERNATIVES FOR KA BAND COMMUNICATION SATELLITES. *Third Ka Band Utilization Conference*. From http://gltrs.grc.nasa.gov/reports/1997/TM-107534.pdf
6. Davarian, F. (1994). Earth-satellite propagation research. *Communications Magazine, IEEE, 32*(4), 74-79. From:http://ieeexplore.ieee.org/xpls/abs_all.jsp?isnumber=6820&arnumber=275338&count=8&index=5
7. CASTANET, L. . INTERFERENCE AND FADE MITIGATION TECHNIQUES FOR KA AND Q/V BAND SATELLITE COMMUNICATION SYSTEMS From: http://www.cost280.rl.ac.uk/documents/WS2%20Proceedings/documents/pm-5-002.pdf
8. Chandler, C. W. (2002). Advanced Antenna Technology for a Broadband Ka-Band Communication Satellite. *Technology Review Journal*. From: http://www.ms.northropgrumman.com/PDFs/TRJ/TRJ-2002/SS/02SS_Chandler.pdf
9. Kopp, C. (2005). Mobile Satellite Communications - Part 1. *Air Power Australia*. From: http://www.ausairpower.net/OSR-0397.html
10. Fitch, M. (2004). Gaussian multi-level FM for high-bandwidth satellite communications. *BT Exact*. From: http://keithbriggs.info/documents/MGFSK_paper1_IB2_mrf-feb27.pdf
11. Molisch, , A. F. (2005). *Wireless communications* . Chichester, England ; Hoboken,: John Wiley & Sons. (Ch. 2, P. 30)
12. www.qcom.com/images/tact_bg.jpg
13. http://images.google.com/imgres?imgurl=http://upload.wikimedia.org/wikipedia/commons/thumb/4/43/C-band_Radar-dish_Antenna.jpg/398px-C-band_Radar-dish_Antenna.jpg&imgrefurl=http://commons.wikimedia.org/wiki/Image:C-band_Radar-dish_Antenna.jpg&h=598&w=398&sz=33&hl=en&start=1&tbnid=b8bu7oJCMGEyCM:&tbnh=135&tbnw=90&prev=/images%3Fq%3DC-Band%26gbv%3D2%26hl%3Den%26sa%3DG
14. http://www.servsat.com/images/andrew%202.4m%20Ku%20Band.gif
15. www.satsig.net/tooway/tooway-ka-band-terminal.jpg