International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 3 Issue 02, February 2022

Multi-Satellite MIMO Communications Ku-Band Higher Data Rates Communication System

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Abstract: *The increased demand for high resolution satellite imagery for government, military, and commercial applications is driving the need for high data rate, millimeter-wave transmission systems to relay imagery information to a ground based end user. An important aspect of this system which interfaces digital information to the RF domain is the modulator driver. The current trend in miniaturization of electronics leaves systems more vulnerable to single-event radiation effects in space borne applications. In an effort to overcome this deficiency, a wideband, high data rate modulator driver circuit has been designed, built, and tested using only high reliability space rated electronic components.*

Keywords: *Satellite, Ku-band, Rainfall intensity, radiation effects.*

1. Introduction

Satellite communication in the Ku-band often suffers from rain attenuation causing link outage. This is an especially critical issue around the equatorial region where tropical weather conditions are characterized by common convective rain events and extremely high rainfall rates [1]. Rainfall intensity along terrestrial path is in-homogeneous in space and time and the raindrops have a non-spherical shape and thereby cause the attenuation on the horizontally polarized wave to be greater than the attenuation of the vertically polarized waves. The attenuation, due to these rain particles, is non-uniform and can only be statistically or experimentally determined from the rain rate measurements. Satellite communication system like other systems has some impairment for example, the transmitting and receiving equipment, polarization mismatch losses, di-pointing losses and free-space losses. The first three impairments can be improved and overcome their effects is not impossible, but the last one needs some technical and special methods to reduce not to overcome but to reduce its effects, free space losses in clear sky exists and affects the signal, and this loss increases in case of rain, snow, heavy clouds, specially, the regions with heavy rain suffering from the disconnecting the received signal during rains, in this paper is an attempt how to calculate the free space losses and then the received signal during rain and clear sky, comparing the two results to see the amount of losses, then how to compensate these losses, then, finally, giving the signal continuity without interruption of the received signal.

Today's communication satellites offer broad capacities in applications including information, voice, and video, with administrations gave to altered communicate versatile frameworks, individual correspondences, and private system clients. Around the world, there have been significant tests on Ka-band Satellites to take care of the issue of immersion of the accessible orbital spaces at C and Ku-band and to give new administrations to the data age. Ka-band framework is perceived as another era for correspondence satellites [2] [3] that includes various inventive advances, for example, on board handling (OBP) for sight and sound applications and changing to give two path administrations to and from little ground VSAT terminals [4]. To do this productively different pencil like spot pillars are utilized. This paper proposes 16 spot-shaft areas to cover Indian fundamental area. The on board preparing and exchanging (successfully the arrangement of what might as well be called an advanced phone switch board on a satellite) are now utilized in satellites giving versatile interchanges to handheld beneficiaries in some western piece of world.

A large portion of the new Ka-band satellites execute spot-pillar innovation to reuse the recurrence band over the coveted scope region. Instead of wide shafts that spread extensive regions (e.g. all of Europe), spot shafts cover much littler domains (1/50 – 1/100 of the vast region). Furthermore, due to the more extensive range accessible on Ka-band and the need to bolster numerous pillars, Ka-band satellites regularly execute wideband transponders (300MHz – 600MHz), around ten times contrasted with the run of the mill 27MHz with 54MHz Ku-band transponders. This kind of execution joined with cutting edge VSAT transmission innovation results in Ka-band satellites with 10-100 times the throughput that is accessible on the customary Ku-band satellites. It's no big surprise that the new era of Ka-band satellites are alluded to as High Throughput Satellites or HTS.

2. Satellite Communication

Satellite communication [4] service industry has grown more rapidly than was forecasted in 1992.This growth has been a global phenomenon as the economies of world have increased and improved a great extent requiring increased communication services for both business and consumer markets. With this increased demand and recent large, rapid expansion of business, consumer terrestrial mobile and internet communication services has opened new opportunities for satellite communication. Mobile and Internet transport access businesses have the demand for new multi- state satellite constellation to serve this market on both the national and international scale. Growth in above areas coupled with the global increase in TV viewer ship and high data rate transport have been responsible for the recent and future anticipated growth. There is also new demand for integrated satellite, terrestrial communications that will enable the transport of information seamlessly across these transport media. These large and rapidly growing satellite based business opportunities have attracted the attention of government and industrial interests of many countries and these nations are making significant investments of new capital to enable them to participate in this growth market. Many countries have allocated funds for satellite R&D projects to ensure their long term presence in the commercial satellite industry. The expansion of satellites into new applications and the increased global demand for satellite communications services have attracted the attention of investment community. This has resulted in the formation of new satellite service providers and stimulated mergers and acquisitions, the creation of new companies, the formation of global partnership and the privatization of formerly public satellite service organizations. The satellite communication industry has grown tremendously and number of professionals and range of activities have grown as well [35]. In the past, commercial communication satellite manufacturing and service provider organizations tended to be conservative and to be hesitant about inserting new technology into satellites.

This has changed in response to immediate need to serve customers burgeoning demand for entertainment programming TV, mobile communications and access to high bandwidth Internet data. Industry is inserting new technology into satellites at rapid pace. Recent examples includes onboard processing and switching, more efficient solar cell, higher power components, more efficient heat dissipation techniques, electric-based station keeping thrusters, inter satellite links, large antennas, phased array antennas, antennas with numerous spot beams and improved TWTAs. Increasingly, Satellite is no longer being viewed as a simple “bent pipe” but as an important component of a large global communications networking system, requiring interoperability between satellite and terrestrial communication components and thus compatible protocols and standards. This integration of satellites into the global network will require satellite industry to assume large software operations and develop new end user services.

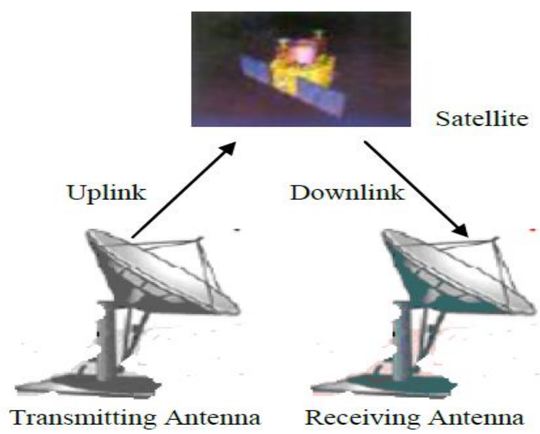

Fig.1 Basic Element of Satellite Communication

2.1 Element of Satellite Communication

Satellite itself is known as space segment and comprised of complex structure. It has some major subsystem like TTC system, Transponder, Fuel Tank called thrusters tank, Antenna system and Control system etc. Satellite transponder includes the receiving antenna to receive signals from ground stations, a broad band receiver, multiplexer and frequency converter which is used to reroute the received signals through high powered amplifier to downlink the ground stations. Satellite role is to trans ponds the received signal in other form of signal to be retransmitted to ground stations. For example of television broad cast where TV programs are up-linked to satellite, satellite transponder it and down linked over a wider region, so that it may be received by many different customers processing compatible equipment. Another use of satellite is observation wherein satellite is equipped with cameras, various sensors and it merely downlinks any information it picks up from its vantage point.

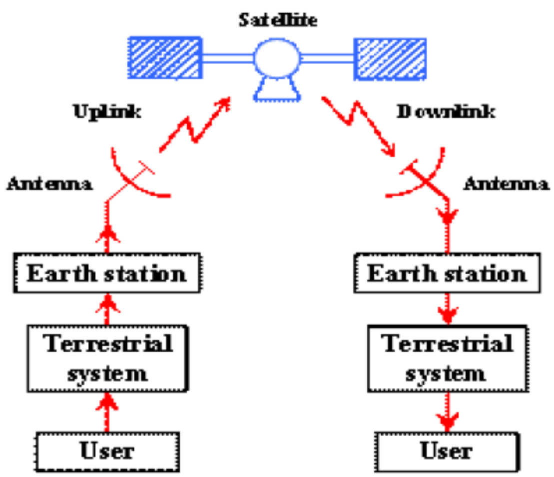

Fig.2 Satellite communication overview

2.2 The Ground segment

The earth stations are ground segment of satellite communication. Earth Station has two fold roles. In case of uplink or transmitting station terrestrial data in the form of base band signals is passed through a base band processor, an up converter, a high powered amplifier and through parabolic dish antenna up to an orbiting satellite. In case of down link or receiving station vice versa job performed and ultimately converting signals received through the parabolic antenna to base band signal.
Satellite manufacturing traditional pattern of highly specialized, customized, designed and built a few at a time is now changing. More emphasis is placed now on the use of common buses and use of matlab communication tools to customize the communications payloads. Mass produced system is adopted and many satellites are produced at once in an assembly line environment. Integration and testing is highly automated. The extent and nature of testing is reduced after prototyping and initial production is accomplished.

2.3 New High Powered Platform

One of the key technical trends in response to the deployment of LEO and MEO satellites has been the design of large aperture GEO system with very high power system. Earlier commercial satellite power generation was limited to 7 to 12 KW. But new generation designers have begun to discuss large flexible of floppy solar array generating 50-60 KW. Also intensive efforts are underway to improve solar cell performance by using gallium arsenide germanium, multi-junction cells with promise of solar cell efficiencies above 30%. There are parallel efforts to improve battery i.e. lithium ion and fuel cell technology in order to produce higher and higher powered satellites.

Critical Future Technologies

Critical technologies for future satellite communications are:

- Batteries
- Devices and structures for Phased
- Array and Multiple spot beam antennas on the ground and in space
- Fuels and combustion structures for launch vehicles
- High frequency (>20GHz) devices
- Materials for electronics devices
- Solar cell materials and structures
- Network technology for high data rate, integrated space and terrestrial systems
- Optical components and sub systems
- Radiation resistant device structures and circuits
- Strong and light-weight material
- Thermal dissipation materials

In addition experimental satellites are needed that can be used to test out new technology that cannot easily be tested on the ground. At the systems level, the future of satellites could also be impacted by high altitude, long endurance platforms which would operate from 65,000 to 1, 00,000 feet such as airships and loitering aircraft. Such systems could be used to substitute for satellite communication in regional applications or could be used in conjunction with satellites as a system capacity multiplier over populated areas.

2.4 Policies and Regulatory issues

In international satellite trade landing rights agreements, annual licensing fees for terminals, non-tariff barriers, allocation of frequencies and orbital slots, adequacy and effectiveness of intersystem coordination procedure, security and privacy of information being relayed on satellite system etc are some issues to be resolved. Most important of all is the need to develop protocols for seamless interconnection of satellite, wireless and terrestrial fibre networks. In the 21st century interconnection of satellite systems, particularly inter-satellite links will be a key challenge. Connecting them to low latency terrestrial network is truly a challenge.

Nowadays the satellite communication is used for various applications such as: Traditional Telecommunication, Atmospheric, oceanic and terrestrial observation using Satellites, Satellite based navigation and positioning, Space Science and Solar terrestrial applications, Satellite-based education and training, Military Application, Frequency reuses application, Use of Spot Beam Concept and its applications.

2.5 HDTV Spot Beams

High Definition TV Spot Beams with Ka band are often narrower in focus than the Ku/Ka band Spot Beams used for Standard Definition TV. If the user placed more than 50 miles from the signal center in a populated region, it is possible that one will not be able to receive the HDTV Spot Beams. It makes good business sense for them to maximize service in coverage area, but there are tradeoffs [4].

In low population density areas like north east beam, it makes sense to have the Spot Beams cover a 300-400Kms radius, because that enables more subscribers which results into more revenue. In metro cities it sometimes makes sense to focus the signal more narrowly for HDTV, and users are more densely packed together. However, due to different frequencies are used for adjacent Spot Beams, overlap usually can be managed.

2.6 Spot-Beam Satellites and Two-Way Communications

One advantage of Ka band is that it requires a smaller dish to offer very good performance. Ka band using Spot Beams is more efficient than a traditional C or Ku band satellites. The service is able to deliver significant improvements in performance. A Ka band satellite can provide as much as an 8X increase in capacity over Ku band satellites. The technology can provide upload speeds as fast as 16 Mbps and download speed as fast as 30 Mbps. Three Ka band satellites with Spot Beam technology are already in service in North America: Telesat Canada's Anik F2, WildBlue Communications Wildblue 1, and Hughes Network Systems SPACEWAY 3. According to Northern Sky Research, there are 15 million U.S.

3. Frequency Bands

Table 1 Frequency bands for satellite communication

Band	Frequency range	Total band-width	General application
L*	1 to 2 GHz	1GHz	MSS
S*	2 to 4 GHz	2GHz	MSS, NASA research
C	4 to 8 GHz	4GHz	FSS
X	8 to 12.5 GHz	4.5GHz	FSS Military
Ku	12.5 to 18 GHz	5.5GHz	FSS,BSS
K	18 to 26.5 GHz	8.5GHz	FSS,BSS
Ka	26.5 to 40 GHz	13.5GHz	FSS

The mobile satellite service (MSS) is allocated frequencies in the L and S-bands. In these bands, compared to higher frequencies, there is a greater degree of refraction and greater penetration of physical obstacles, such as foliage and non-metallic structures. These are desirable characteristics for mobile satellite service. Also the same bands are heavily being used for terrestrial applications. Therefore, there is intense competition among the various microwave services for L and S-band capacity.

For an allocation of frequency to a particular service, there is an allocation of a downlink band and uplink band. The uplink band is usually assigned a higher frequency because higher frequency suffers greater spreading, or free space loss, than its lower frequency counterpart. The earth station is capable of higher power, which helps to compensate for the poor performance at higher frequency.

4. Results

Presents Performance improvement in rain effect on ku band satellite communication system developed in MATLAB. In the simulation process, the goal was to reach. Commensurate with a more complicated generalized-selection-combining-based.

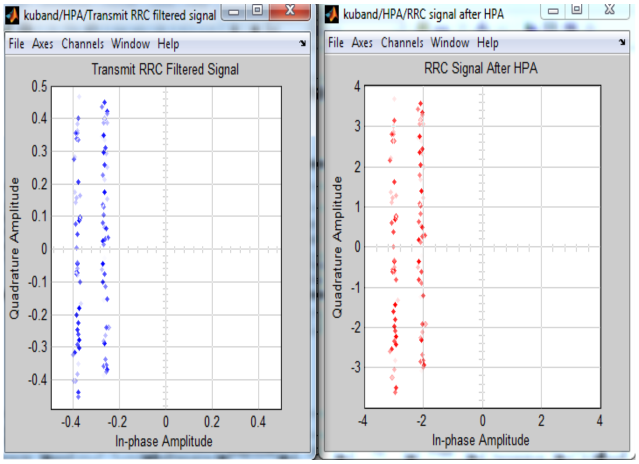

Fig.3 Simulation Block Diagram, Performance of the transmit RRC and After HPA signal

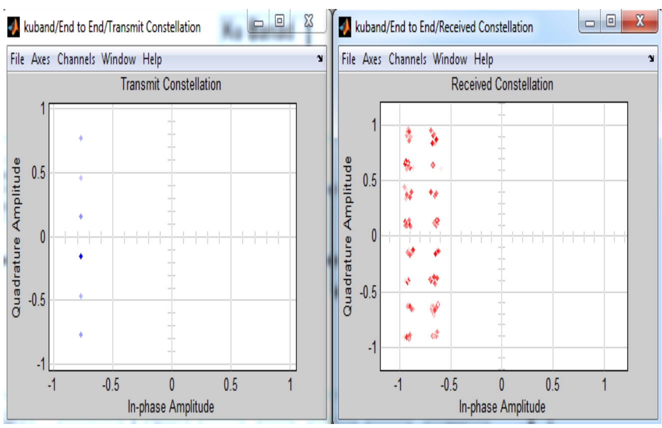

Fig.4 Simulation Block Diagram of the transmit Constellation and received Constellation signal

5. Conclusion and Future Work

The design, simulation, fabrication, and measurement of a wideband modulator driver for high data rate communications applications in a space environment have been presented. The uniqueness of this work lies in the requirements of the operating environment of the modulator driver and surrounding circuitry, namely that the active device is required to be able to operate reliably in a high radiation environment. Another factor driving the need for a discrete circuit design is the specific bandwidth restrictions required by the modulator system at the 2 GBPS data rate. A wideband modulator driver was successfully designed and built to meet the requirements for a 2 GBPS QPSK modulator operating in the Ku-Band of frequencies. When interfaced with the modulator, the EVM performance of the driver and modulator was 11.8% with associated phase and magnitude error of 6° and 5.5%, respectively. This performance is quite modest given the data rate and carrier frequency of the modulator system. The jitter performance of the modulator driver itself was a low 6.4 ps which is excellent. Overall, the wideband modulator driver delivers good performance relative to commercially available integrated circuit drivers and has the characteristics to operate with high reliability in a space environment. Cleared by DoD/OSR for public release under 10-S-2601.

Future Work

As previously discussed the modulator driver circuit while operating sufficiently for the given application, still has room for improvement and expanded functionality. Some areas for improvement would be in the phase and magnitude error performance of the modulator driver which directly affects the EVM performance. The jitter performance of the driver could be improved by using a low phase noise pHEMT that Microwave Technology, Incorporated manufactures and this could improve the phase error performance significantly. More effort could also be taken to improve the gain flatness over the bandwidth and specifically, the low frequency performance could be adjusted to produce flat pulses instead of sloped pulses. This would help improve the magnitude error performance of the driver circuit. The combination of these two areas of improvement could significantly increase the EVM performance of the modulation system used to exercise the performance of the modulator driver. Another area for future work could be to make this a DC coupled instead of AC coupled modulator driver.

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