Performance Analysis of Low Earth Orbit (LEO) Satellite Link in the presence of Elevation Angle, Fading, And Shadowing.

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By

Tanjila Farah

Student ID: 07110105

Prianka Roy

Student ID: 05310012

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DECLARATION

I hereby declare that this thesis is based on the results found by myself. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

Dr Satya Prashad Majumder   Prianka Roy   Tanjila Farah
Signature of   Signature of
Supervisor   Author

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Chapter one

Introduction

In 500 years, when humankind looks back at the dawn of space travel, Apollo's landing on the Moon in 1969 may be the only event remembered. At the same time, however, Lyndon B. Johnson, himself an avid promoter of the space program, felt that reconnaissance satellites alone justified every penny spent on space. Weather forecasting has undergone a revolution because of the availability of pictures from geostationary meteorological satellites--pictures we see every day on television. All of these are important aspects of the space age, but satellite communications has probably had more effect than any of the rest on the average person. Satellite communications is also the only truly commercial space technology- -generating billions of dollars annually in sales of products and services.

1.1 A brief history of satellite communication

In fall of 1945 an RAF electronics officer and member of the British Interplanetary Society, Arthur C. Clarke, wrote a short article in *Wireless World* that described the use of manned satellites in 24-hour orbits high above the world's land masses to distribute television programs. His article apparently had little lasting effect in spite of Clarke's repeating the story in his 1951/52 *The Exploration of Space* . Perhaps the first person to carefully evaluate the various technical options in satellite communications *and* evaluate the financial prospects was John R. Pierce of AT&T's Bell Telephone Laboratories who, in a 1954 speech and 1955 article, elaborated the utility of a communications "mirror" in space, a medium-orbit "repeater" and a 24-hour-orbit "repeater." In comparing the

communications capacity of a satellite, which he estimated at 1,000 simultaneous telephone calls, and the communications capacity of the first trans-atlantics telephone cable (TAT-1), which could carry 36 simultaneous telephone calls at a cost of 30-50 million dollars, Pierce wondered if a satellite would be worth a billion dollars.

After the 1957 launch of Sputnik I, many considered the benefits, profits, and prestige associated with satellite communications. Because of Congressional fears of "duplication," NASA confined itself to experiments with "mirrors" or "passive" communications satellites (ECHO), while the Department of Defense was responsible for "repeater" or "active" satellites which amplify the received signal at the satellite--providing much higher quality communications. In 1960 AT&T filed with the Federal Communications Commission (FCC) for permission to launch an experimental communications satellite with a view to rapidly implementing an operational system. The U.S. government reacted with surprise-- there was no policy in place to help execute the many decisions related to the AT&T proposal. By the middle of 1961, NASA had awarded a competitive contract to RCA to build a medium-orbit (4,000 miles high) active communication satellite (RELAY); AT&T was building its own medium-orbit satellite (TELSTAR) which NASA would launch on a cost-reimbursable basis; and NASA had awarded a sole- source contract to Hughes Aircraft Company to build a 24-hour (20,000 mile high) satellite (SYNCOM). The military program, ADVENT, was cancelled a year later due to complexity of the spacecraft, delay in launcher availability, and cost over-runs.

By 1964, two TELSTARs, two RELAYs, and two SYNCOMs had operated successfully in space. This timing was fortunate because the Communications Satellite Corporation (COMSAT), formed as a result of the Communications Satellite Act of 1962, was in the process of contracting for their first satellite. COMSAT's initial capitalization of 200 million dollars was considered sufficient to build a system of dozens of medium-orbit satellites. For a variety of reasons, including costs, COMSAT ultimately chose to reject the joint AT&T/RCA offer of a

medium-orbit satellite incorporating the best of TELSTAR and RELAY. They chose the 24-hour-orbit (geosynchronous) satellite offered by Hughes Aircraft Company for their first two systems and a TRW geosynchronous satellite for their third system. On April 6, 1965 COMSAT's first satellite, EARLY BIRD, was launched from Cape Canaveral. Global satellite communications had begun.

Some glimpses of the Global Village had already been provided during experiments with TELSTAR, RELAY, and SYNCOM. These had included televising parts of the 1964 Tokyo Olympics. Although COMSAT and the initial launch vehicles and satellites were American, other countries had been involved from the beginning. AT&T had initially negotiated with its European telephone cable "partners" to build earth stations for TELSTAR experimentation. NASA had expanded these negotiations to include RELAY and SYNCOM experimentation. By the time EARLY BIRD was launched, communications earth stations already existed in the United Kingdom, France, Germany, Italy, Brazil, and Japan. Further negotiations in 1963 and 1964 resulted in a new international organization, which would ultimately assume ownership of the satellites and responsibility for management of the global system. On August 20, 1964, agreements were signed which created the International Telecommunications Satellite Organization (INTELSAT).

By the end of 1965, EARLY BIRD had provided 150 telephone "half- circuits" and 80 hours of television service. The INTELSAT II series was a slightly more capable and longer-lived version of EARLY BIRD. Much of the early use of the COMSAT/INTELSAT system was to provide circuits for the NASA Communications Network (NASCOM). The INTELSAT III series was the first to provide Indian Ocean coverage to complete the global network. This coverage was completed just days before one half billion people watched APOLLO 11 land on the moon on July 20, 1969.

From a few hundred telephone circuits and a handful of members in 1965, INTELSAT has grown to a present-day system with more members than the

United Nations and the capability of providing hundreds of thousands of telephone circuits. Cost to carriers per circuit has gone from almost $100,000 to a few thousand dollars. Cost to consumers has gone from over $10 per minute to less than $1 per minute. If the effects of inflation are included, this is a tremendous decrease! INTELSAT provides services to the entire globe, not just the industrialized nations.

In 1965, ABC proposed a domestic satellite system to distribute television signals. The proposal sank into temporary oblivion, but in 1972 TELESAT CANADA launched the first domestic communications satellite, ANIK, to serve the vast Canadian continental area. RCA promptly leased circuits on the Canadian satellite until they could launch their own satellite. The first U.S. domestic communications satellite was Western Union's WESTAR I, launched on April 13, 1974. In December of the following year RCA launched their RCA SATCOM F- 1. In early 1976 AT&T and COMSAT launched the first of the COMSTAR series. These satellites were used for voice and data, but very quickly television became a major user. By the end of 1976 there were 120 transponders available over the U.S., each capable of providing 1500 telephone channels or one TV channel. Very quickly the "movie channels" and "super stations" were available to most Americans. The dramatic growth in cable TV would not have been possible without an inexpensive method of distributing video.

The ensuing two decades have seen some changes: Western Union is no more; Hughes is now a satellite operator as well as a manufacturer; AT&T is still a satellite operator, but no longer in partnership with COMSAT; GTE, originally teaming with Hughes in the early 1960s to build and operate a global system is now a major domestic satellite operator. Television still dominates domestic satellite communications, but data has grown tremendously with the advent of very small aperture terminals (VSATs). Small antennas, whether TV-Receive Only (TVRO) or VSAT are a commonplace sight all over the country.

A Selective Communications Satellite Chronology

- 1945 Arthur C. Clarke Article: "Extra-Terrestrial Relays"
- 1955 John R. Pierce Article: "Orbital Radio Relays"
- 1956 First Trans-Atlantic Telephone Cable: TAT-1
- 1957 Sputnik: Russia launches the first earth satellite.
- 1960 1st Successful DELTA Launch Vehicle
- 1960 AT&T applies to FCC for experimental satellite communications license
- 1961 Formal start of TELSTAR, RELAY, and SYNCOM Programs
- 1962 TELSTAR and RELAY launched
- 1962 Communications Satellite Act (U.S.)
- 1963 SYNCOM launched
- 1964 INTELSAT formed
- 1965 COMSAT's EARLY BIRD: 1st commercial communications satellite
- 1969 INTELSAT-III series provides global coverage
- 1972 ANIK: 1st Domestic Communications Satellite (Canada)
- 1974 WESTAR: 1st U.S. Domestic Communications Satellite
- 1975 INTELSAT-IVA: 1st use of dual-polarization
- 1975 RCA SATCOM: 1st operational body-stabilized comm. satellite
- 1976 MARISAT: 1st mobile communications satellite
- 1976 PALAPA: 3rd country (Indonesia) to launch domestic comm. satellite
- 1979 INMARSAT formed.
- 1988 TAT-8: 1st Fiber-Optic Trans-Atlantic telephone cable

1.1.2 Types of satellite applications

GEO

The first major geosynchronous satellite project was the Defense Department's ADVENT communications satellite. It was three-axis stabilized rather than spinning. It had an antenna that directed its radio energy at the earth. It was rather sophisticated and heavy. At 500-1000 pounds it could only be launched by the ATLAS- CENTAUR launch vehicle. ADVENT never flew, primarily because the CENTAUR stage was not fully reliable until 1968, but also because of problems with the satellite. When the program was canceled in 1962 it was seen as the death knell for geosynchronous satellites, three-axis stabilization, the ATLAS-CENTAUR, and complex communications satellites generally. Geosynchronous satellites became a reality in 1963, and became the only choice in 1965. The other ADVENT characteristics also became commonplace in the years to follow.

In the early 1960s, converted intercontinental ballistic missiles (ICBMs) and intermediate range ballistic missiles (IRBMs) were used as launch vehicles. These all had a common problem: they were designed to deliver an object to the earth's surface, not to place an object in orbit. Upper stages had to be designed to provide a delta-Vee (velocity change) at apogee to circularize the orbit. The DELTA launch vehicles, which placed all of the early communications satellites in orbit, were THOR IRBMs that used the VANGUARD upper stage to provide this delta-Vee. It was recognized that the DELTA was relatively small and a project to develop CENTAUR, a high-energy upper stage for the ATLAS ICBM, was begun. ATLAS-CENTAUR became reliable in 1968 and the fourth generation of INTELSAT satellites used this launch vehicle. The fifth generation used ATLAS-CENTAUR and a new launch-vehicle, the European ARIANE. Since that time other entries, including the Russian PROTON launch vehicle and the Chinese LONG MARCH have entered the market. All are capable of launching satellites almost thirty times the weight of EARLY BIRD.

In the mid-1970s several satellites were built using three-axis stabilization. They were more complex than the spinners, but they provided more despond surface to mount antennas and they made it possible to deploy very large solar arrays. The greater the mass and power, the greater the advantage of three-axis stabilization appears to be. Perhaps the surest indication of the success of this form of stabilization was the switch of Hughes, closely identified with spinning satellites, to this form of stabilization in the early 1990s. .

The latest products from the manufacturers of SYNCOM look quite similar to the discredited ADVENT design of the late 1950s.
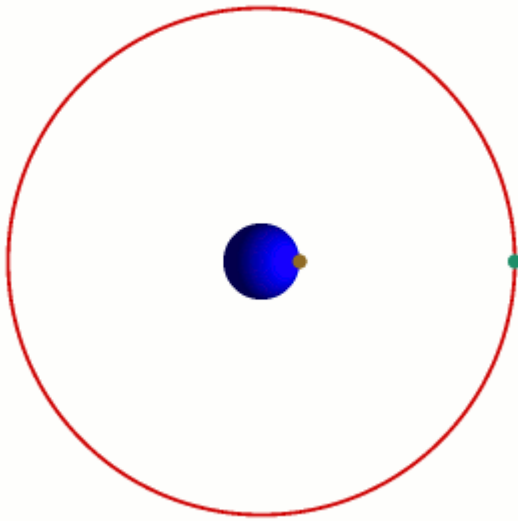
Fig: 1.1

A satellite in a geostationary orbit appears to be in a fixed position to an earth-based observer. A geostationary satellite revolves around the earth at a constant speed once per day over the equator.

The geostationary orbit is useful for communications applications because ground based antennas, which must be directed toward the satellite, can operate effectively without the need for expensive equipment to track the satellite's motion. Especially for applications that require a large number of ground antennas (such as direct TV distribution), the savings in ground equipment can

more than justify the extra cost and onboard complexity of lifting a satellite into the relatively high geostationary orbit.

1.1.3 LEO

In February of 1976 COMSAT launched a new kind of satellite, MARISAT, to provide mobile services to the United States Navy and other maritime customers. In the early 1980s the Europeans launched the MARECS series to provide the same services. In 1979 the UN International Maritime Organization sponsored the establishment of the International Maritime Satellite Organization (INMARSAT) in a manner similar to INTELSAT. INMARSAT initially leased the MARISAT and MARECS satellite transponders, but in October of 1990 it launched the first of its own satellites, INMARSAT II F-1. The third generation, INMARSAT III, has already been launched.

An aeronautical satellite was proposed in the mid-1970s. A contract was awarded to General Electric to build the satellite, but it was canceled-- INMARSAT now provides this service. Although INMARSAT was initially conceived as a method of providing telephone service and traffic-monitoring services on ships at sea, it has provided much more. The journalist with a briefcase phone has been ubiquitous for some time, but the Gulf War brought this technology to the public eye.

The United States and Canada discussed a North American Mobile Satellite for some time. In the next year the first MSAT satellite, in which AMSC (U.S.) and TMI (Canada) cooperate, will be launched providing mobile telephone service via satellite to all of North America.

In 1965, when EARLY BIRD was launched, the satellite provided almost 10 times the capacity of the submarine telephone cables for almost 1/10th the price. This price-differential was maintained until the laying of TAT-8 in the late 1980s. TAT-8 was the first fiber-optic cable laid across the Atlantic. Satellites are still

competitive with cable for point-to-point communications, but the future advantage may lie with fiber-optic cable. Satellites still maintain two advantages over cable: they are more reliable and they can be used point-to-multi-point (broadcasting).

Cellular telephone systems have risen as challenges to all other types of telephony. It is possible to place a cellular system in a developing country at a very reasonable price. Long-distance calls require some other technology, but this can be either satellites or fiber-optic cable.

Cellular telephony has brought us a new technological "system"-- the personal communications system (PCS). In the fully developed PCS, the individual would carry his telephone with him. This telephone could be used for voice or data and would be usable anywhere. Several companies have committed themselves to providing a version of this system using satellites in low earth orbits (LEO). These orbits are significantly lower than the TELSTAR/RELAY orbits of the early 1960s. The early "low-orbit" satellites were in elliptical orbits that took them through the lower van Allen radiation belt. The new systems will be in orbits at about 500 miles, below the belt.

The most ambitious of these LEO systems is Iridium, sponsored by Motorola. Iridium plans to launch 66 satellites into polar orbit at altitudes of about 400 miles. Each of six orbital planes, separated by 30 degrees around the equator, will contain eleven satellites. Iridium originally planned to have 77 satellites-- hence its name. Element 66 has the less pleasant name Dysprosium. Iridium expects to be providing communications services to hand- held telephones in 1998. The total cost of the Iridium system is well in excess of three billion dollars.

In addition to the "Big LEOS" such as Iridium and Globalstar, there are several "little LEOs." These companies plan to offer more limited services, typically data and radio determination. Typical of these is ORBCOM which has already

launched an experimental satellite and expects to offer limited service in the very near future.
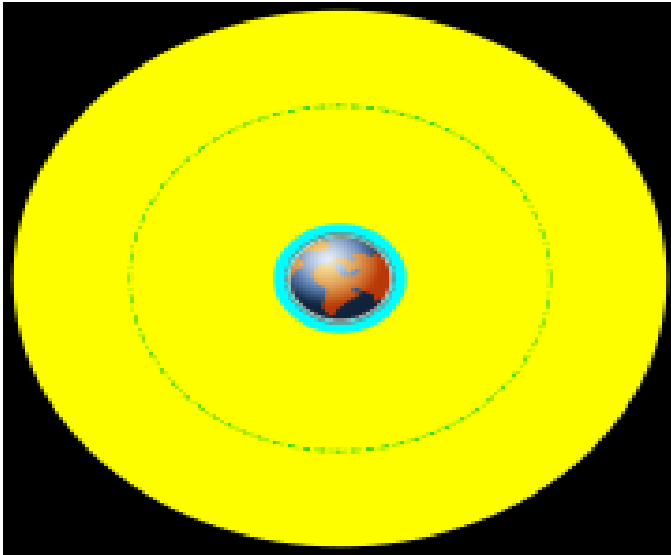

fig:1.2

A Low Earth Orbit (LEO) typically is a circular orbit about 400 kilometers above the earth's surface and, correspondingly, a period (time to revolve around the earth) of about 90 minutes. Because of their low altitude, these satellites are only visible from within a radius of roughly 1000 kilometers from the sub-satellite point. In addition, satellites in low earth orbit change their position relative to the ground position quickly. So even for local applications, a large number of satellites are needed if the mission requires uninterrupted connectivity.

Low earth orbiting satellites are less expensive to launch into orbit than geostationary satellites and, due to proximity to the ground, don't require as high signal strength (Recall that signal strength falls off as the square of the distance from the source, so the effect is dramatic). Thus there is a trade off between the number of satellites and their cost. In addition, there are important differences in the onboard and ground equipment needed to support the two types of missions.

A group of satellites working in concert is known as a satellite constellation. Two such constellations, intended to provide satellite phone services, primarily to remote areas, are the Iridium and Globalstar systems. The Iridium system has 66

satellites. Another LEO satellite constellation known as Teledesic, with backing from Microsoft entrepreneur Paul Allen, was to have over 840 satellites. This was later scaled back to 288 and ultimately ended up only launching one test satellite.

It is also possible to offer discontinuous coverage using a low Earth orbit satellite capable of storing data received while passing over one part of Earth and transmitting it later while passing over another part. This will be the case with the CASCADE system of Canada's CASSIOPE communications satellite. Another system using this store and forward method is Orbcomm.

1.1.4 MEO:

A medium earth orbit satellite (MEO) is a satellite that orbits the earth in between Low Earth Orbit Satellites (LEO), which orbit the earth at a distance from the earth of about 200-930 miles (321.87-1496.69 km) and those satellites which orbit the earth at geostationary orbit, about 22,300 miles (35,888.71 km) above earth. Each type of satellite can provide a different type of coverage for communications and wireless devices. Like LEOs, medium earth orbit satellites don't maintain a stationary distance from the earth. This is in contrast to the geostationary orbit, where satellites are always approximately 22,300 miles from the earth.

Any satellite that orbits the earth between about 1000-22,000 miles (1609.34-35,405.57 km) above earth is an MEO. Typically the orbit of a medium earth orbit satellite is about 10,000 miles (16,093.44 km) above earth. In various patterns, these satellites make the trip around earth in anywhere from 2-12 hours, which provides better coverage to wider areas than that provided by LEOs.

In 1962, the first communications satellite, Telstar, was launched. It was a medium earth orbit satellite designed to help facilitate high-speed telephone

signals, but scientists soon learned what some of the problematic aspects were of a single MEO in space. It only provided transatlantic telephone signals for 20 minutes of each approximately 2.5 hours orbit. It was apparent that multiple MEOs needed to be used in order to provide continuous coverage.

Since then numerous companies have launched both LEOs and MEOs. You need about two dozen LEOs to provide continuous coverage and fewer MEOs. However, LEOs typically orbit in a circular pattern around the equator. A medium earth orbit satellite may have a variety of different orbits, including elliptical ones and may provide better overall coverage of satellite communications, if enough of them are in place and the orbit is swift. The coverage of earth is called a footprint, and MEOs typically are able to create a larger footprint because of their different orbital patterns, and because they are higher than LEOs.

Today the medium earth orbit satellite is most commonly used in navigation systems around the world. These include Global Positioning System (GPS), and the Russian Glonass. A proposed MEO navigation system for the European Union called Galileo is expected to begin operations in 2013.

Orbital altitudes for satellite constellations

██ peak radiation bands of the Van Allen belts (high−energy protons)

orbits are not shown at actual inclination; this is a guide to altitude only

from Lloyd's satellite constellations http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/
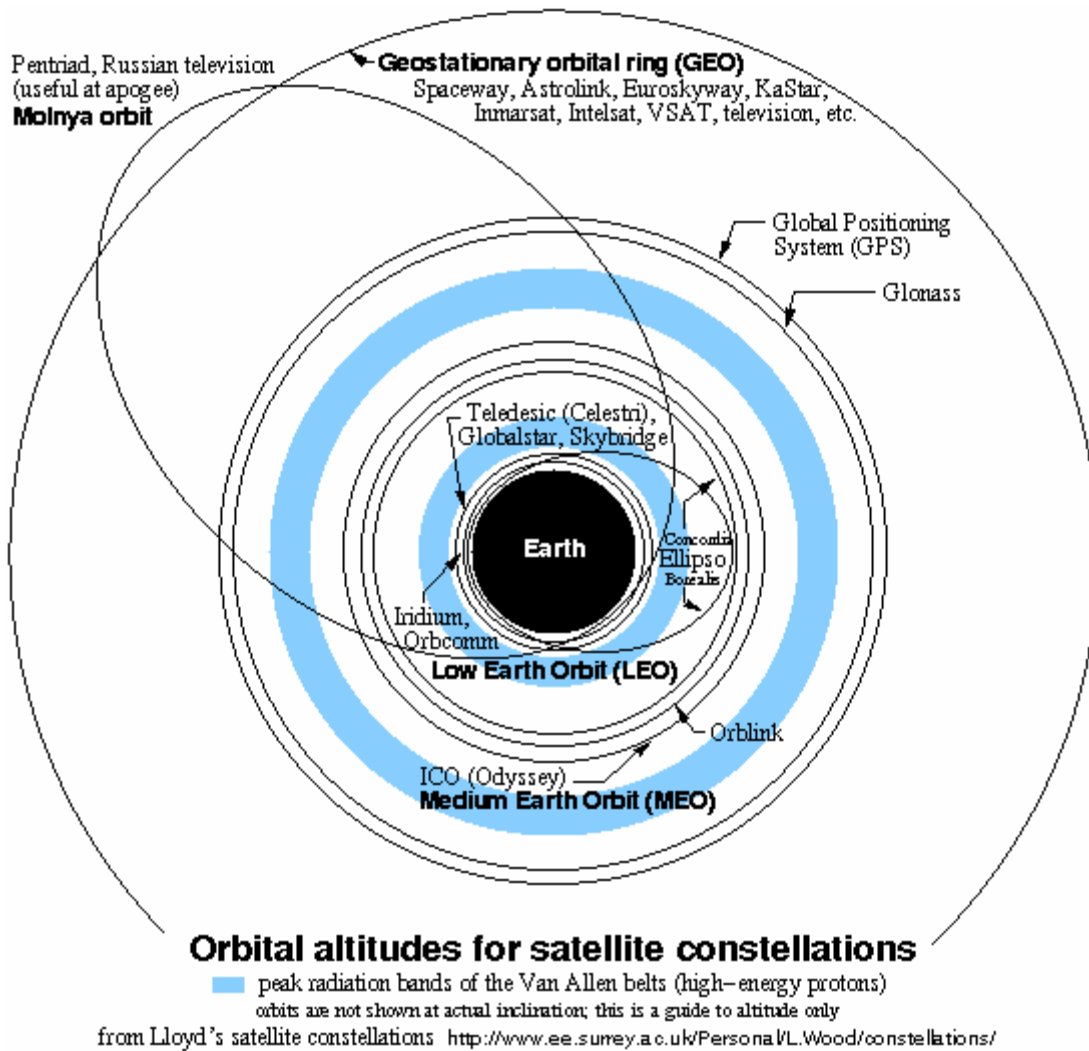
fig:1..3

1.2 LEO Satellite

A low Earth orbit is an orbit from roughly 100 to 1240 miles (160-2000km) above the Earth's surface. Nearly all human spaceflight has taken place in the low Earth orbit, with a few notable exceptions. A great number of satellites are also in a low Earth orbit, as is the International Space Station.

In fact, what many people think of as space from photographs is still well within a low Earth orbit. The low Earth orbit itself is roughly contained by the innermost Van Allen radiation belt, which is held in place by the Earth's geomagnetic field. There is some overlap between low Earth orbit and the Van Allen belt, with some satellites residing in the belt. The inner Van Allen radiation belt itself actually poses difficulties to satellite operation, because satellites have to be shielded against the high energy levels present. There is a proposal to drain the energy from this belt down substantially, reducing the amount of shielding that would be necessary, as well as the danger posed to human being by the energy levels.

There is a significant amount of drag exerted on objects within a low Earth orbit, depending on their altitude. Below about 310 miles (500km) objects reside within the thermosphere, while above this altitude they are within the exosphere. Various gasses are present in both, which exert drag on satellites, requiring them to expend some energy to remain in orbit. Because this drag increases as altitude diminishes, it is not common for objects to be placed at less than around 185 miles (300km) high.

A number of different human objects reside in low Earth orbit, from different time periods. The most notable of these is probably the International Space Station, which is situated around 200 miles (320km) above the Earth's surface, well within the thermosphere. The International Space Station is visited regularly by the Space Shuttle, the Soyuz spacecraft, the Automated Transfer Vehicle, and the Progress spacecraft, all of which engage only in low Earth orbit missions.

A large number of satellites also reside in low Earth orbit, traveling around the world in roughly 90 minutes, at a speed of about 5 miles per second (8km/s). Launching a satellite into low Earth orbit takes much less energy than launching it into space, and the equipment needed to send a signal back to Earth can be much less powerful. For these reasons, low Earth orbit satellites are still widely used, even though they cannot remain situated over one part of the planet in the way geostationary satellites in space can. Debris also clutters the low Earth orbit,

with some 8,500 objects larger than 10cm currently tracked. This debris poses a threat to satellites and missions, as even tiny objects traveling at that speed can cause enormous damage.

For all of the human activity in space, a surprisingly little amount of it has actually taken place outside of low Earth orbit. The amount of energy needed to bring a vehicle outside of this orbit is enormous, and returning can be tricky, making manned flights particularly daring. The Apollo program, which eventually sent men to the lunar surface, is probably the best known program to send humans outside of low Earth orbit, and since that time only a handful of other manned vehicles have passed the barrier.

Characteristics of LEO Systems

• "Anytime, Anywhere"

• Blends cellular and satellite technologies

Satellite

Terrestrial

Gateways

• 500 – 2000 km orbit

Below Van Allen Belts

• Fiber-like propagation delay

• Voice and data capabilities

• Hand-held multi-mode phones

2.1.1 Classes of LEOs

Little LEO Satellite Systems

In 1992, the ITU World Radio Administrative Conference (WARC) made new

allocations reflecting USA and Russian proposals in a number of bands below 1 GHz for the MSS (non-geostationary orbit types), shared with existing allocations to other services. Australia supported these allocations and adopted them through their inclusion in the Australia Radiofrequency Spectrum Plan [1].

The allocations were introduced to support a number of proposals for new LEO satellite systems providing low cost global data services such as:

❖ emergency alerting;

❖ data acquisition;

❖ paging;

❖ tracking and positioning; and

❖ message transfer.

These systems are often referred to as little LEO satellite systems (in contrast to the above 1 GHz LEO satellite systems which are known as big LEO satellite systems).

The allocations reflecting the USA proposals are of most interest to Australia, due to the expressed desire of companies wishing to provide low cost data services in Australia utilizing little LEO satellite systems based on those allocations. The allocations provide

1 Low earth orbiting (LEO) satellites are satellites with orbiting altitudes in the range of 200 – 2000 km, typically they circle the Earth every few hours.

2 For use of the bands 137 – 138 MHz and 400.15 – 401 MHz for downlinks, and the band 148 – 150.05 MHz for uplinks.

2.1 Typical Little LEO Satellite Systems and Characteristics

The configuration of a typical little LEO satellite system is shown in Figure 1. This figure shows LEO satellites and two types of earth stations – gateway stations (used by the system operator) and mobile terminals (used by subscribers to the system). As indicated in Figure 1, the communications paths between the various components are divided into forward and return links (sometimes termed outbound and inbound links).

Forward links describe the transmission of information from a gateway station to a mobile terminal and return links the transmission of information from a mobile terminal to a gateway station. As little LEO satellites typically circle the earth every few hours a gateway station or mobile terminal will only be visible to a satellite for a relatively small period of time. Consequently, store and forward techniques may need to be used to complete the communications path.
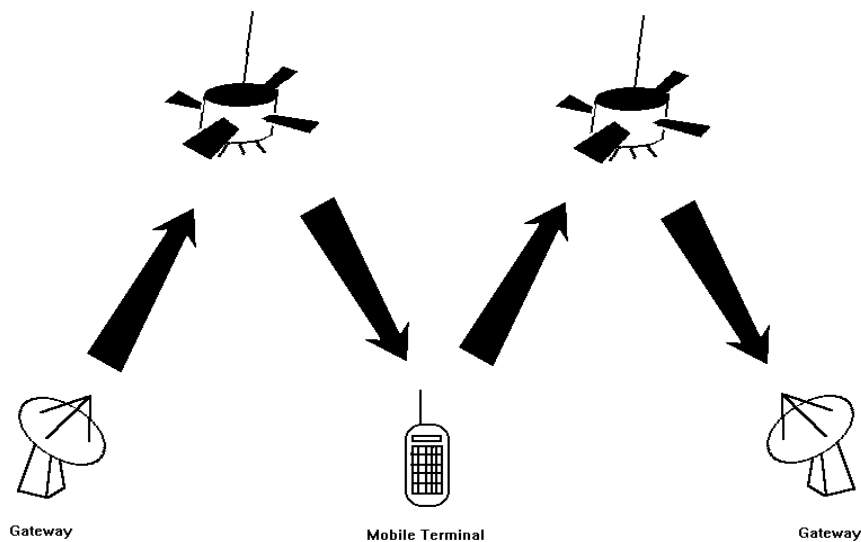

Gateway   Mobile Terminal   Gateway

fig:1.4

Different little LEO satellite systems use different downlink bands for forward and return links. By way of example, the Star sys system uses the 400.15 - 401 MHz downlink band for forward links to its mobile terminals and the 137 - 138 MHz downlink band for return links to its gateway stations, whereas the Orbcomm system uses the 137 - 138 MHz downlink band for both forward links to mobile terminals and return links to gateway stations.

Another difference between little LEO satellite systems is the type of modulation used. Spread spectrum and narrowband schemes are presently being used; sometimes both are used within a single system.

How Many Systems

The ITU has identified 9 proposed little LEO satellite systems planning to use the WARC 92 allocations, although it also notes that the currently allocated spectrum cannot support all of the proposed systems [2]. The Orbcomm and Starsys little LEO satellite systems appear to be the most advanced of these systems, particularly in terms of providing services in Australia. Indeed, a number of companies have already expressed interest in providing services using these systems in this country. As a consequence, this report, while making some general comments on the technical characteristics of little LEO satellite systems in the band 137 - 138 MHz, is primarily concerned with the analysis of interference potential to Orbcomm and Star says systems in this band.

2.3 Earth Station Receivers in the Band 137 - 138 MHz

From the available information, there could be four types of little LEO satellite earth

station receivers operating in the band 137 - 138 MHz. They are:

- ❖ gateway stations for systems with spread spectrum modulation schemes;
- ❖ gateway stations for systems with narrowband modulation schemes;
- ❖ mobile terminals for systems with spread spectrum modulation schemes; and
- ❖ mobile terminals for systems with narrowband modulation schemes.

As neither the Orbcomm nor Starsys systems use mobile terminals with spread spectrum modulation schemes in the band 137 - 138 MHz, this type of receiver is not considered further in this analysis. The general characteristics of the remaining types of receivers are discussed below.

Gateway Stations

Gateway stations typically use storable directional antennas with antenna gains between 15 - 20 dBi. Narrowband and spread spectrum modulation schemes are used with channel bandwidths varying from 50 kHz to 1000 kHz. Both Orbcomm and Starsys gateway stations operate in the 137 - 138 MHz band, and together can be considered representative of the type of gateways stations operating in this band.

Mobile Terminals

Mobile terminals typically use omni-directional antennas with a 0 dBi antenna gain.

Typically, narrowband modulation schemes are used with bandwidths varying from

15 - 30 kHz. Orbcomm mobile terminals operate in the 137 - 138 MHz band and can be considered representative of the type of mobile terminals used in this band.

Television Broadcasting Transmitters

The band 137 - 144 MHz has been used in Australia for television broadcasting purposes since circa 1950 and is known as TV channel 5A. Currently there are 19 channel 5A television transmitters in operation .

All but one of the 19 channel 5A transmitters are located in country areas away from capital cities. The exception is a 50 kW ERP_2 transmitter located near Newcastle that is approximately 110 km north of Sydney. The radiated power of channel 5A transmitters varies from 15 W to 100 kW ERP, and typically antennas with directional patterns are used.

The Australian Broadcasting Authority specifies a field strength of 50 dBuV/m as the level from a channel 5A transmitter at which a minimum level of service is achieved in an area of low ambient noise level (ie, typically rural areas) [4]. The area enclosed by a 50 dBuV/m contour is known as the coverage area. The distance to the outermost edge of this area from a channel 5A transmitter is estimated as varying between 16 km for a channel 5A ERP of 15 W, to 120 km for an ERP of 100 kW. A map showing the location of channel 5A transmitters, maps of coverage areas .

The broadcasting service allocation in the band 137 - 144 MHz is unique to Australia.No new assignments will be made for channel 5A stations and eventually these broadcasting requirements will be accommodated in other spectrum within ITU regional allocations for the broadcasting service; this objective is embodied in footnotes 207 and AUS26 of the Australian Radiofrequency Spectrum Plan

Interference Assessment

The potential for interference from channel 5A television transmitters to little LEO satellite systems' gateway and mobile stations is analyzed below.

Gateway Stations

Gateway stations can be expected to be planned in detail and the locations and emission characteristics of the 19 channel 5A television transmitters taken into account in that planning, in order to ensure that interference does not occur. Consequently they are not considered further in this report.

Mobile Terminals

Typically, little LEO satellite systems are such that mobile terminals could be used

anywhere in Australia. Thus the potential for interference to mobile terminals from

channel 5A television transmitters' needs to be analyzed further.

The interference potential of channel 5A transmitters is analyzed by modeling the television 5A signal as noise in the mobile terminal channel and comparing the received noise level with the typical received signal level from a LEO satellite. Such an analysis is contained in Attachment C. The procedure used in the analysis is outlined below.

1. Derive a piecewise linear representation of channel 5A emissions in the band 137 - 138 MHz from a plot of the emissions associated with the vision carrier of a television signal generated from typical program material.

2. Compare the piecewise representation with Orbcomm's satellite frequency plan for the band 137 - 138 MHz and identify a sub-band in which the interference potential to mobile terminals can be considered representative of the interference potential to the Orbcomm system as a whole.

3. Using the Hata land mobile propagation model or broadcasting propagation curves as appropriate, estimate(for the identified sub-band) distances from channel 5A transmitters at which the received noise level at a mobile terminal

from these transmitters *is the same as* the typical received signal level from a LEO satellite.

4. Compare the estimated distances with the coverage area of channel 5A transmitters and draw conclusions.

Using the above procedure leads to the conclusion that Orbcomm mobile terminals are not likely to operate satisfactorily until they are separated from channel 5A transmitters by distances varying from at least 31 km for a channel 5A ERP of 15 W, up to 177 km for an ERP of 100 kW. By way of comparison with channel 5A coverage areas, these distances are 15 to 57 km beyond the outermost 50 dBuV/m contour. It should be noted that the above analysis underestimates the separation distances within which the operation of little LEO terminals is not expected to be possible, because it assumes that terminal operation will not be possible when the received power at a mobile terminal from a channel 5A transmitter is approximately the same as that from a little LEO satellite (ie, -145 dBW). Proprietary data on a proposed satellite to mobile terminal link budget suggests that this is an optimistic premise. The above approach was taken,however, because insufficient information is currently available about the actual performance of a LEO terminal in the presence of PAL-B video sideband energy, that is,the analysis was based on a carrier to noise analysis (with a C/No of 0 dB presumed to be the critical threshold), because the reduction in BER performance of a narrowband little LEO terminal receiver in the presence of line spectra emissions that comprise the channel 5A signal is not yet characterized.

If it is assumed that a further 5 - 20 dB attenuation will need to be achieved (this estimate is deliberately broad, given the lack of relevant information as noted above),then estimates of separation distances vary between 43 to 213 km for an Eb/No of 5 dB, or 100 to 335 km for an Eb/No of 20 dB. For the longer distances in particular, terrain shielding from hills is likely to assist. To quantify the likely separation distances more accurately, laboratory testing would be required to characterize little LEO terminal BER degradation in the presence of a channel 5A

transmission. Field trials are also expected to contribute valuable understanding. To date no equipment has been able to be supplied by little LEO system developers for these purposes.

1.2.2 Big LEO Satellite Systems

Big LEO systems are designed to carry voice traffic as well as data. They are the technology behind "satellite phones" or "global mobile personal communications system" (GMPCS) services now being developed and launched.

Most Big LEO systems also will offer mobile data services and some system operators intend to offer semi-fixed voice and data services to areas that have little or no terrestrial telephony infrastructure. Smaller Big LEO constellations also are planned to serve limited regions of the globe. Examples of Big LEO systems include Iridium, Globalstar and the regional Constellation and ECO-8 systems.
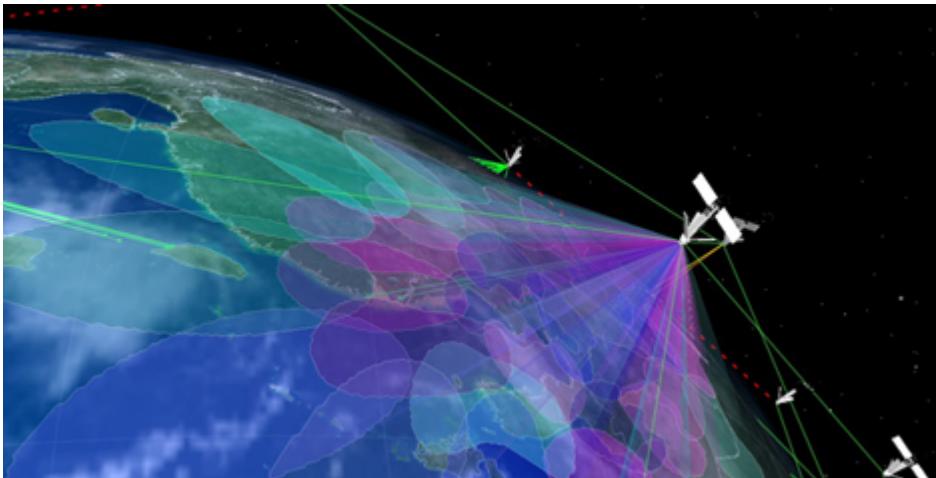
1.2.2.1 Iridium:

fig:1.5

The Iridium system is a satellite-based, wireless personal communications network providing a robust suite of voice and data features all over the globe. It is comprised of three principal components -- the satellite network, the ground

network and the Iridium subscriber products, including phones and data modems.

The design of the Iridium network allows voice and data messages to be routed anywhere in the world. Voice and data calls are relayed from one satellite to another until they reach the satellite above the Iridium handset or terminal and the signal is relayed back to Earth. When an Iridium customer places a call from a handset or terminal, it connects to whatever satellite happens to be overhead, and is relayed among satellites around the globe to whatever satellite is above the appropriate Earth gateway, which downlinks the call and transfers it to the global public voice network or Internet so that it reaches the recipient.

The satellites are in a near-polar orbit at an altitude of 485 miles (780 km). The 66 active satellites fly in formation in six orbital planes, evenly spaced around the planet, each with 11 satellites equally spaced apart from each other in that orbital plane.

A single satellite completely circles the Earth once every 100 minutes, traveling at a rate of 16,832 miles per hour, and traveling from horizon to horizon across the sky in about ten minutes. As a satellite moves out of reach, the call is seamlessly handed over to the next satellite coming into view.

Since Iridium is a LEO satellite system, voice delays are typically unnoticeable. Other mobile satellite systems use Geostationary Earth Orbits (GEOs), which, by comparison, are about 22,300 miles above the equator. As a result, latency can be quite high, causing speakers to have to wait for each other to finish. GEOs are also largely ineffective in more northern or southern latitudes. The curvature of the Earth disrupts message transmission when attempted at the edge of a GEO satellite's footprint.

Each Iridium satellite is cross-linked to four other satellites - two satellites in the same orbital plane and two in an adjacent plane. These links create a dynamic network in space - calls are routed among Iridium satellites without touching the

ground, creating a highly secure and reliable connection. Cross-links make Iridium particularly impervious to natural disasters - such as hurricanes, tsunamis and earthquakes - that can damage ground-based wireless towers since cross-links are space-based.

The Iridium ground network is comprised of the system control segment and telephony gateways used to connect into the terrestrial telephone system. With centralized management of the Iridium network, the system control segment supplies global operational support and control services for the satellite constellation, delivers satellite tracking data to the gateways, and controls the termination of Iridium messaging services.

The system control segment consists of three primary components -- four telemetry tracking and command/control (TTAC) stations, the operational support network, and the satellite network operation center (SNOC). Ku-Band feeder links and cross-links throughout the satellite constellation supply the connections among the system control segment, the satellites and the gateways.

Gateways are the ground-based antennas and electronics that provide voice and data services, messaging, prepaid and postpaid billing services, as well as other customer services. The gateways are responsible for the support and management of mobile subscribers and the interconnection of the Iridium network to the terrestrial phone system. Gateways also provide management functions for their own network elements and links.

1.2.2.2   Globalstar:

Globalstar uses Low Earth Orbit (LEO) Satellites in an orbit of 1,500 kilometers. There are advantages of LEO satellites over Geosynchronous (GEO) systems for delivery of mobile satellite services (MSSs). LEO satellite technology allows the use of a low power mobile handheld and vehicle mounted equipment that can be used while mobile. The omindirectional antennas used by Globalstar allows the user to be on the move without a disruption of service. In most of the GEO

satellite applications the terminal must be stationary to acquire a satellite signal. GEO satellite systems are normally 35,800 kilometers above the earth and are commonly used for television transmission, high-speed data, and other wideband services. Telephone users desire "telephone quality" transmissions. These users do not want time delay and echo which is inherent with GEO systems.

Current GEO satellite systems have limited capacity for mobile satellite services. The scare spectrum for MSSs communications requires a system that will provide services to users maximizing this spectrum and provide multiple satellites as well as ground stations sharing this spectrum. Globalstar's system accomplishes this with their 48 satellite constellation and ground station network. The GEO systems presently uses frequency division multiple access-frequency modulation (FDMA-FM). This technology has inefficient band segmentation to share the spectrum.

In the event one of the Globalstar satellites fail the system will provide capacity due to the rotation of its constellation. If a GEO satellite failed the service to an entire regions service would be disrupted.

Globalstar systems is able to accomplish this thorough its patented Path Diversity technology. Path Diversity is a method of signal reception that combines multiple signals over varying strengths into a single signal. The user can use a signal satellite or use between two to four satellites with this technology.

Using a rake receiver the user can use as many as four satellites simultaneously. These multiple signals are combined into one coherent static free signal. The Globalstar phone will alter its power levels to compensate for shadowing and interference. The average power output is between 50-300 mw.

As the satellites move in and out of view, they will seamlessly be added and moved from calls in progress. This reduces the number of dropped calls.

Globalstar uses IS-95 Code Division Multiple Access (CDMA) technology providing digitally crisp voice and data services. The CDMA technology assigns unique codes to each transmission and users share time and frequency allocations. The signals are separated at the receiver by a correlator that accepts only signal energy from the desired circuit. This CDMA technology allows a large number of users simultaneously to access a single frequency orthogonally reducing interference. This result in a manifold increase in capacity compared to an analog system.

Globalstar uses a combination of Frequency Division Multiple Access (FDMA) with CDMA and spread spectrum modulation. This supports multiple users simultaneously. Globalstar's path diversity combined with CDMA technology offered by multiple satellites give the customer high quality voice service with fewer dropped calls when calls are handed off between satellites.

Globalstar is the Most Popular Satellite Phone on the Planet because:

Affordability

Handsets are half the cost of the closest competitor. Voice and Data minutes are low as 14 cents per minute. Price plans start at $29.99 a month

Voice Clarity

Globalstar's use of CDMA (Code Division Multiple Access) technology gives secure and high quality clear calls.

Convenience

Globalstar provides the user with a standard North American phone number. No complicated country codes or special dialing is required.

No Voice Delay

Globalstar uses Low-Earth Orbiting (LEO) satellites which eliminates voice delay and echo found with other satellite voice services.

Superior Data Speeds

Globalstar offers the fastest satellite data speed of any handheld satellite phone in the industry.

The Globalstar phone is GlobalCom flagship product. GlobalCom sells of Globalstar satellite phones are five times more than their Iridium handheld phone.

Globalstar has over 200,000 activated satellite voice and data units. Globalstar offers satellite service in over 120 countries.

1.2.3 Broadband LEO Satellite system:

An emerging third category of LEO systems is the so-called "super LEOs" or "mega LEOs," which will handle broadband data. The proposed Teledesic and Skybridge systems are examples of essentially Big LEO systems optimized for packet-switched data rather than voice. These systems share the same advantages and drawbacks of other LEOs and intend to operate with inter-satellite links to minimize transmission times and avoid dropped signals.

1.2.3.1   Teledesic:

There is a significant worldwide demand for broadband communications capacity. Teledesic plans to meet this demand using a constellation of 924 low-Earth orbit (LEO) satellites operating in Ka-band (30/20 GHz). The Teledesic network will provide "fiber-like service quality, including low transmission delay, high data rates, and low bit error rates, to fixed and mobile users around the world starting in 2001.

Teledesic was founded in June 1990. Its principle shareholders are Craig McCaw, founder of McCaw Cellular Communications, the world's largest wireless

communications Company, and Bill Gates, founder of Microsoft, the world's largest computer software company.

Teledesic seeks to organize a broad, cooperative effort to bring affordable access to advanced information services to rural and remote parts of the world that would not be economic to serve thorough traditional wire line means.

Today, the cost to bring modern communications to poor and remote areas is so high that many of the world's people cannot participate in our global community. Forcing people to migrate into increasingly congested urban areas in search of opportunity is economically and environmentally unsound. All of the world can benefit from efforts to expand access to information technologies.

The solution is a satellite-based broadband network whose service cost in rural, remote areas is comparable to that of wire line networks in advanced urban areas. Such a network can provide a variety of services including multimedia conferencing, video conferencing, video telephony, distance learning, and voice. It will allow people to live and work in areas based on family, community, and quality of life.

The global scope of the Teledesic network embraces a wide range of service needs. Local partners will determine products and prices and provide sales and service in host countries. Teledesic will not market service directly to users. Rather, it will provide an open network for service provides in host countries. Teledesic will not manufacture satellites or terminals. Its goal is to provide the highest quality communications services at the lowest cost.

Wire line broadband (fiber) networks in advanced urban areas will drive demand for global access to broadband applications. Advanced information services are increasingly essential to education, health care, government, and economic development. Continued decrease in the price/performance ratio of microprocessors and computer memory will increase the demand for transmission of information. Video and high-resolution graphics require high data rates.

Most of the world's population will never get access to advanced digital applications through terrestrial means. The majority of the world does not even have access to basic voice service. Most areas that are not now wired never will be wired. Increasingly, wireless cellular will be the access technology of first choice in rural and remote areas. Cellular is limited to narrowband applications and most existing wire line networks will not support advanced digital applications.

Teledesic will provide seamless compatibility with terrestrial broadband (fiber) networks. Future broadband applications and data protocols will not be designed to accommodate the delays of geostationary satellites. Users will want one network for all application.

The Teledesic network will be complementary to terrestrial wireless networks. It will be a broadband overlay for narrowband cellular systems, backbone infrastructure for cell site interconnect, and backhaul for long distance and international connections. The aggregation of voice channels requires low-delay broadband capability.

Teledesic will provide a global wide-area network, a seamless, advanced, digital broadband network. It will fill in missing and problematic links everywhere, facilitating economic and social development in rural and remote areas.

Teledesic will supply instant infrastructure, providing rapid availability of advanced "fiber-like" services to almost 100% of the world's population. System capacity is not rigidly dedicated to particular end users or locations.

1.2.3.2 Skybridge:

SkyBridge is a satellite-based broadband access system, allowing services such as high-speed Internet access and video conferencing to take place anywhere in the world. The system targets urban, suburban and rural areas which are not yet connected to broadband terrestrial infrastructure, or which are uneconomical to cover with traditional infrastructure. This effectively positions SkyBridge as a broadband wireless local loop system.

The system is based on a constellation of 64 LEO satellites which link professional and residential users equipped with low-cost terminals to terrestrial gateways. User terminals are not specific to the system and the architecture of the receiving sites may be adapted to the following configurations: individual reception, community reception (a SkyBridge terminal is shared between several subscribers) and professional configuration where the SkyBridge terminal is connected to a LAN or a PBX
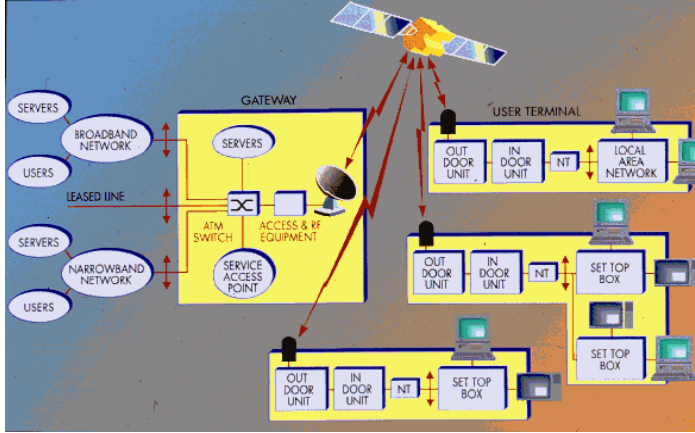
Each spot beam (350 km radius) covers a set of SkyBridge terminals connected to one or several user terminals and one or several

FIG:1.6

Sky Bridge gateways. A user is registered in a single gateway where the traffic to and from the user is concentrated. The system is open to a wide range of multimedia user terminals designed for terrestrial applications.

A satellite has a 3000 km radius coverage divided into fixed spot beams of 350 km radius. Each user is attached to one and only one SkyBridge gateway. The traffic to and from any of the SkyBridge users will always be concentrated on the gateway where the user is registered. Each gateway acts as an autonomous access network due to the transparent payload of the satellites.

Each satellite is in a circular orbit at an altitude of 1457 km above the Earth. The constellation is divided into two symmetrical Walker sub-constellations of 32 satellites each. The low-path delay (20 ms typically) of the LEO constellation chosen for SkyBridge is compatible with TCP/IP-like protocols used for terrestrial applications. Thus, communications over SkyBridge are not disrupted by handshaking protocols which drastically reduce the data rate over high-delay links. Moreover, the low delay of LEO satellites contributes to high service quality links similar to terrestrial networks ensuring seamless integration into terrestrial networks. The SkyBridge system is fully adapted to interactive applications with real-time constraints

The SkyBridge system is a global telecommunication system designed to provide business and residential users with interactive multimedia application as well as LAN interconnection or classical ISDN applications. It is aimed at fixed terminals including those which will allow user mobility and terminal portability. The system

accommodates highly interactive real-time applications aided by the low delay inherent to the system.

1.3   Limitations of Satellite channel

1.3.1 Ionosphere Effect:

Recently, with the escalating cost of large satellite missions, attention has turned to smaller satellites. Their advantages of low overall cost in construction and launch, and short time span between conception and launch has given a new impetus to the further study of the geosphere. By using a combination of space-based and ground-based receivers, it is possible to undertake new and exciting experiments directed towards furthering our knowledge of the ionosphere. Combinations of high earth orbit satellites, such as the Global Positioning System (GPS), and low earth orbit (LEO) micro satellites are providing the capability for satellite to satellite occultation experiments to reconstruct the vertical profile of the ionosphere. The topside ionospheric and plasmaspheric ionization content may also be explored with satellite to satellite experiments.

The ionised part of the atmosphere, the ionosphere, causes distorting effects or errors in satellite communications, navigation and altimetry. In order to understand these effects and improve our knowledge of the ionosphere, the various regions of the ionosphere have been monitored to different degrees on a long-term basis. Even instruments such as incoherent scatter radars, while providing profiles of both the topside and bottom side ionosphere, do not operate on a continuous basis and provide poor resolution for the lower ionosphere. The ground-based ionosondes provide non-homogeneous coverage of the bottom side ionosphere, as they are limited to observations from land. This is particularly true in the Southern Hemisphere where the oceans cover most of the Hemisphere. The topside ionosphere and the region above, the plasmasphere

are not easily monitored on a long-term basis. Only a few instruments such as incoherent scatter radars, topside sounders and in situ satellite-based diagnostics are able to provide details on the structure, composition and dynamics of the topside ionosphere. The properties of the plasmasphere are even less well known, and techniques to explore it are very limited. The advent of the Global Positioning System (GPS) with 24 satellites in 12 hour orbits at 20,000 kilometres, provides the opportunity to monitor on a global basis the variation of the ionisation content of the ionosphere and plasmasphere. For the GPS navigation and timing systems, the ionosphere produces the largest source of errors. These errors can be measured and utilised to improve models of the global distribution of ionisation, and hence be used to improve error corrections in future satellite applications. The GPS receiver networks on the ground, together with GPS receivers in orbit, provide the unique opportunity to perform this task. One of the payloads on the Australian scientific micro satellite, FedSat, planned for launch in November 2000, is a GPS receiver.

FedSat, the first Australian satellite to be launched in over 30 years, will be a microsatellite of around 58 kg launch mass. It is planned to launch into a sun synchronous polar orbit at a height of 800 km. FedSat's mission is basically a science and engineering one. The planned scientific payloads include a fluxgate magnetometer for monitoring the Earth's magnetic field and solar -terrestrial interactions as well as a dual frequency GPS receiver for ionospheric and atmospheric research. The aims of the program are to conduct basic research on the structure and dynamics of the ionosphere, plasmasphere and magnetosphere. The results will be applied to the forecasting of space weather. The space-qualified dual-frequency GPS receiver and patch antenna, supplied by NASA, are being built by Spectum Astro of Arizonia, USA. Using the two coherently connected frequencies f_1 = 1575.42 MHz and f_2 = 1227.60 MHz, high precision measurements will be made of the group and phase delay between the receiver on board of FedSat and the transmitters on the GPS satellites visible to FedSat. Two types of measurements are planned. In the occultation mode (Hajj

et al 1994), the ray path from the GPS satellites will pass horizontally through the ionosphere and hence provide scans through the ionosphere as FedSat rises and sets with respect to a GPS satellite (Hajj and Romans, 1998). The second type of measurement is for the overhead mode where the ray paths from the GPS satellites in a vertical cone above FedSat pass through the plasmasphere. Figure 1 illustrates the two modes. As the FedSat orbit is planned to be at 800 km, most of the ionisation measured by this technique is located in the plasmasphere and topside ionosphere. The following sections detail some of the proposed experiments to be carried out using the on board GPS receiver.
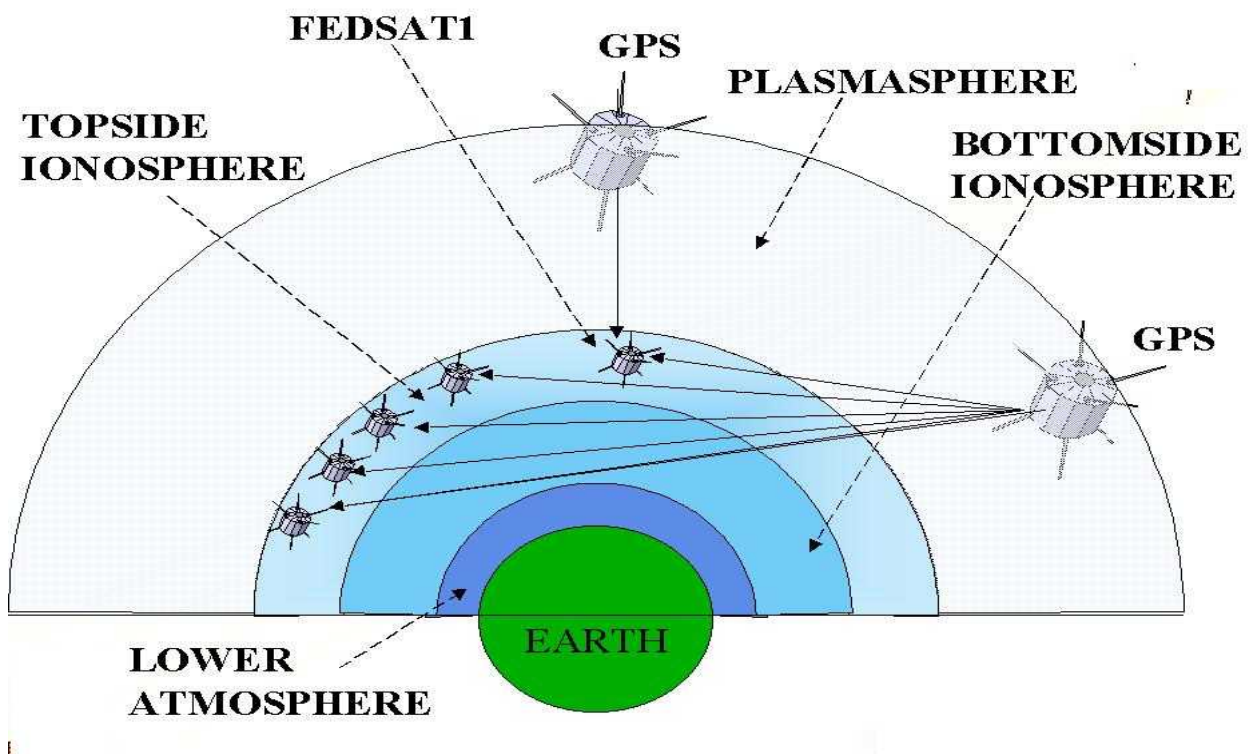

Figure 1.7: Model (not to scale) of the ray paths from the GPS satellites to the receiver on board FedSat. The occultation mode and the overhead mode are illustrated.

1.3.2

Fading:

In wireless communications, fading is deviation or the attenuation that a carrier-modulated telecommunication signal experiences over certain propagation media. The fading may vary with time, geographical position and/or radio frequency, and is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading

The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while traveling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal-to-noise ratio.

A common example of multipath fading is the experience of stopping at a traffic light and hearing an FM broadcast degenerate into static, while the signal is re-acquired if the vehicle moves only a fraction of a meter. The loss of the broadcast is caused by the vehicle stopping at a point where the signal experienced severe destructive interference. Cellular phones can also exhibit similar momentary fades.

Fading channel models are often used to model the effects of electromagnetic transmission of information over the air in cellular networks and broadcast communication. Fading channel models are also used in underwater acoustic communications to model the distortion caused by the water. Mathematically,

fading is usually modeled as a time-varying random change in the amplitude and phase of the transmitted signal.

Slow versus fast fading

The terms *slow* and *fast* fading refer to the rate at which the magnitude and phase change imposed by the channel on the signal changes. The coherence time is a measure of the minimum time required for the magnitude change of the channel to become decorrelated from its previous value.

Slow fading

arises when the coherence time of the channel is large relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. The amplitude change caused by shadowing is often modeled using a log-normal distribution with a standard deviation according to the log-distance path loss model.

Fast fading

Occurs when the coherence time of the channel is small relative to the delay constraint of the channel. In this regime, the amplitude and phase change imposed by the channel varies considerably over the period of use.

1.4 Objectives:

Study will be carried out on LEO satellites for high bit rate data communications for the purpose of GPS and navigational aids. Analysis will the carry out for uplink and downlink considering the effect of fading and shadowing both QPSK modulation coherent receiver. BER performance results will be evaluated in Matlab and the performance limitations due to above system imperfections will be determined at a given bit rate and BER.

CHAPTER 2

Analysis of LEO satellite Link

The bit error rate (BER) performance analysis for low earth orbiting (LEO) satellite based direct sequence-code division multiple access (DS-CDMA) communication systems, under various propagation channel models and communication scenarios, are almost well developed by many researchers. However, most of these works consider an assumed snapshot of communication scenario, for example, the worst case, to evaluate the BER performance under this scenario and without considering the occurrence probability of this scenario. This chapter extends the work by incor

(PDF) of elevation angles.

2.1 System Model:

The system model considered is shown

In fig: 2.1. Every satellite communication

System has two major

Parts.
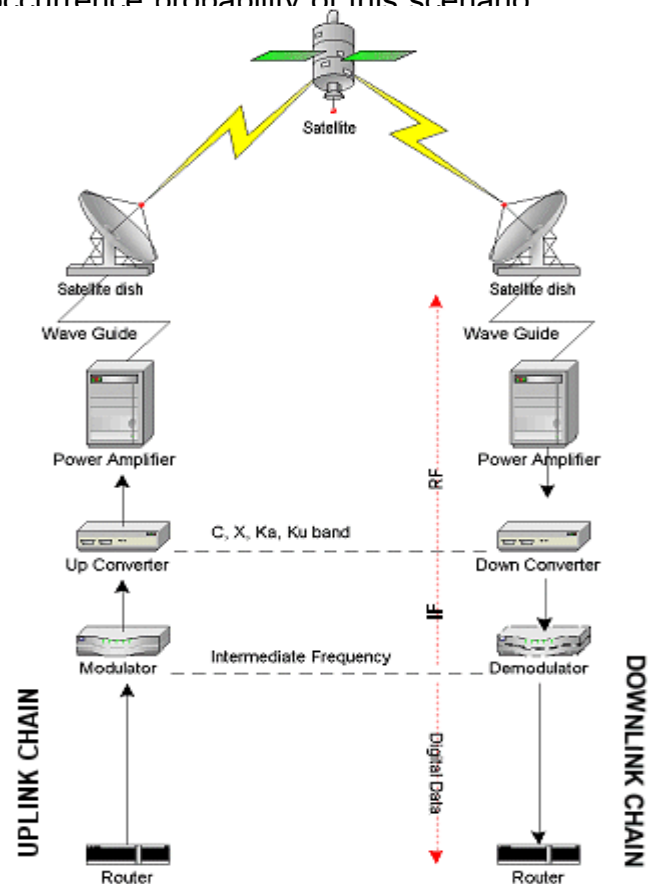
- The Satellite.
- Ground stations.

Fig:2.1

Ground Stations or Earth Stations mainly control the uplink & downlink chain. The term *uplink chain* is used to refer to the series of pieces of equipment that are used to produce a radio frequency signal for sending out data. The description provided here is imprecise as the exact configuration can vary widely. The *downlink chain* is built using nearly the same equipment in reverse order.

The drawing above shows the path of devices on the left hand side with all the up arrows.

Digital Satellite uplink Chain:

How it works:

I. Digital data is sent to the modulator which takes the data and converts it into a modulated signal in the *Intermediate Frequency* range (70-140 MHz). The modulators use standards such as *Digital Video Broadcast* to organize communication over the microwave link.

II. The *Intermediate Frequency* is piped to an "up converter" (usually via shielded coaxial cable) which mixes the *intermediate frequency* with a higher frequency to produce a final frequency which carries the modulated data.

III. Noise is removed from the signal via either a band pass filter or other means and then it is amplified in a *Klystron*, *Traveling Wave Tube* or *Solid State* amplifier.

IV. The final cleaned signal is transmitted down the wave guide to the dish.

V. The *feed horn* at the focal point of the dish emits the high frequency radio transmission, which the dish focuses into a directional transmission at the satellite.

Computer data is sent through a serial cable to a modulator. The modulator takes the data and produces a radio frequency from it. This frequency is usually in what is called the 'L-band' range (70-140 MHz). The modulator passes the information over coaxial cable to an 'up converter', which converts the radio frequency from

'L-band' up to microwave frequencies in the C, S, X, Ka, and Ku band ranges (frequencies above 1,000 MHz). Once the final signal has been produced, it's amplified to increase its total effective output power. The signal is then sent out a dish via the feed horn.

Downlink Chain:

How it works:

I. The satellite transmits a signal containing data
II. The signal is received at the satellite dish
III. The signal is amplified and fed to the Down Converter
IV. The Down Converter down mixes the signal to create an <u>intermediate frequency</u>
V. The intermediate frequency is fed to the demodulator and converted into a data signal
VI. The data stream is forwarded into the network via a router.

2.2 Analysis:

Signal To Noise Ration (SNR):

In <u>analog</u> and <u>digital</u> communications, signal-to-noise ratio, often written S/N or SNR, is a measure of <u>signal</u> strength relative to background <u>noise</u>. The ratio is usually measured in decibels (dB).

If the incoming signal strength in micro volts is V_s, and the noise level, also in micro volts, is V_n, then the signal-to-noise ratio, S/N, in decibels is given by the formula

$$S/N = 20 \log_{10}(V_s/V_n) \qquad (2.21)$$

If $V_s = V_n$, then S/N = 0. In this situation, the signal borders on unreadable, because the noise level severely competes with it. In digital communications, this will probably cause a reduction in data speed because of frequent errors that require the source (transmitting) computer or terminal to resend some packets of data. [wikipwdia]

Bit Error Rate (BER):

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10 to the minus 6, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent. [wikipwdia]

Probability Density Function/ Probability distribution function (PDF):

Probability Density or probability distribution identifies either the probability of each value of an unidentified random variable (when the variable is discrete), or the probability of the value falling within a particular interval (when the variable is continuous). The probability distribution describes the range of possible values that a random variable can attain and the probability that the value of the random variable is within any (measurable) subset of that range. .[wikipwdia]

Rice Factor:

Rice factor is the ration of direct signal power & faded signal power. Here we have denoted Rice factor By 'K'.

$$K = E_d / E_f \qquad (2.22)$$

Increasing the value of K means that direct power of the signal increasing.[farah]

Shadow fading/Shadowing:

Shadowing or shadow fading or large scale fading reveals it self as attenuation of average signal power. Shadow fading is induced by prominent terrain contours (hills, mountains) between transmitter & receiver. The receiver is said to be shadowed by this object. Shadow fading is described in terms of path loss & statistical variation about the mean. [14]

For our work we have denoted shadow fading as '**S'.**

Most of the research on satellite communications indicated that the elevation angle of the signal's transmission path influences the link quality. A few elevation-dependent channel models have been proposed to describe the fading statistics of the received signal at the specified elevation angles. However, for LEO satellite communications where the

elevation angle of the transmission path changes continuously, it is the distribution of elevation angles that has to be taken into account for obtaining the overall fading statistics. To obtain the specific BER performance result by incorporating our used PDF of elevation angles, the elevation-channel proposed by Corazza and Vatalaro [1] is employed. The original attempt for modeling the distribution of elevation angles for non-GEO satellite constellations is proposed by Corazza and Vatalaro The model assumes flat fading and has found very good matching with experimental data. It is suitable for all types of environment, such as rural, suburban and urban, simply by tuning the model parameters.

Elevation-angle-dependent PDF

The Rice PDF conditioned on a certain shadowing S is

$$p(r \mid S) = \frac{2r(1+K)}{S^2} e^{-K - \frac{(1+K)r^2}{S^2}} I_0\left(\frac{2r}{S}\sqrt{K(1+K)}\right), \quad r \geq 0$$

(2.23)

Here I_0 is the zero order modified Bessel function of the first kind, and K is the so called Rice factor. As the elevation angle of satellite link θ inferences the PDF of the received signal, the parameter K is modeled as functions of θ by data fitting to the measured data corrected by ESA at L-band in a rural tree-shadowed environment [2]. The resulting empirical formulas for θ in a range of $20° < \theta < 80°$ are expressed as:

$$K(\theta) = K_0 + K_1\theta + K_2\theta^2$$

<div align="right">(2.24)</div>

The coefficients for the specific example are reported in Table below and the resulting PDF of the received signal amplitude are shown in Fig.

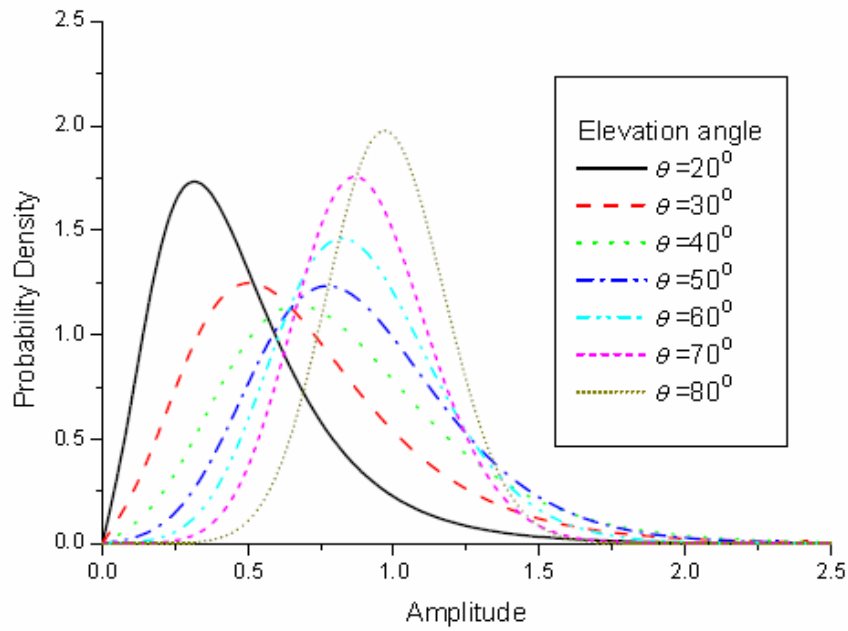| K |
| --- |
| $K_0 = 2.731$ |
| $K_1 = -1.074 \cdot 10^{-1}$ |
| $K_2 = 2.774 \cdot 10^{-3}$ |

Table 1

Figure 2.2 : The received signal amplitude PDF for Rice-lognormal channel at Different elevation angles.

2.3 Bit Error Rate Performance Analysis:

BER Performance Analysis

The BER performance for satellite based DS-CDMA is examined in this section by taking downlink link scenario as an example. Assume that a mobile user is in the #1 spot beam of the satellite's footprint and such a user experiences no interference from adjacent satellites. The received signal is given by

$$r(t) = A \sum_{j=1}^{J} \sum_{i=1}^{K} R_{ij} \beta_{ij} x_{ij}\left(t; \tau_{ij}; \varphi_{ij}\right) + n_w(t),$$

(2.25)

where A is the constant signal amplitude without fading, J and K represent the number of spotbeams and the number of simultaneously active users per spot beam, respectively, $n_w(t)$ is the AWGN with two-sided power spectral density $N_o/2, R_{ij}, \quad B_{ij}$ and $x_{ij}(t)$ are the fading amplitude, the antenna radiation pattern and the waveform for ith user in jth spot beam. Note that or simplicity, it is assumed that all users in the spot beam of interest are illuminated with a gain of unity, i.e., B_{ij} =1in the beam of interest. In eq 2.1 $x_{ij}(t)$ is given by

$$x_{ij}(t) = \sqrt{2 P_{ij}}\, b_{ij}\left(t - \tau_{ij}\right) c_{ij}\left(t - \tau_{ij}\right) \cos\left(2\pi f_c t + \varphi_{ij}\right)$$

(2.25)

where P_{ij} is the power of the transmitted signal, f_c is the common carrier frequency, $b_{ij}(t)$

and $c_{ij}(t)$ are the data and spreading signals respectively and the τ_{ij} and φ_{ij} represent

random delay and radio frequency phase uniformly distributed in [0,T] and [0,2π], respectively.

It is assume that in the beam of interest, $\tau_{i1} = 0$ and $\varphi_{i1} = 0$. The data signal $b_{ij}(t)$ is a

sequence of unit amplitude rectangular pulses of duration T_b. Each pulse represents an

information bit for user i. The spreading signal $c_{ij}(t)$ is a sequence of unit amplitude

rectangular pulses (chips) of duration T_c. There are L chips per bit and thus $L = T_b/T_c$ is the

 Processing gain for user i.

 A correlation receiver is typically used to filter the desired user's signal form all others users' signals which share the same bandwidth at the same time. For this

purpose the receivedsignal *r* (*t*) is mixed down to baseband, multiplied by the spreading sequence associated to the desired user and integrated over one bit period. This sequence of operations is called despreading. Thus, assuming that the receiver is delay and phase synchronized with the main multipath component of the signal of interest, the bit decision statistic for user #1 in #1 spot beam within the bit interval is given by-

$$g\left(T_b\right) = \int_0^{T_b} r\left(t\right) c_{11}\left(t - \tau_{11}\right) \cdot 2\cos\left(2\pi f_c t + \varphi_{11}\right) dt = \int_0^{T_b} r\left(t\right) c_{11}\left(t\right) \cdot 2\cos\left(2\pi f_c t\right) dt$$

$$= A_{11} R_{11} T_b b_0 + \sum_{j=2}^{J} \sum_{i=1}^{K} A_{ij} R_{ij} \beta_{ij} I_{ij}\left(T_b\right) \cos\varphi_{ij} + \upsilon$$

where

$$I_{ij}\left(T_b\right) = \int_0^{T_b} b_{ij}\left(t - \tau_{ij}\right) c_{ij}\left(t - \tau_{ij}\right) c_{11}\left(t\right) dt \;,$$

2.27

where $I_j, j = 1..J$ denotes the normalized MAI received by the users in *j*th spot beam, given by

$$I_u = \sum_{j=1, j\neq u}^{J} \sum_{i=1}^{K} \beta_{ij}^2$$

2.28

The signal to noise-plus-interference ratio is obtained by

$$SIR = \frac{A^2 R_{11}^2 T_b^2}{\left(\sigma_0^2 + \sigma_I^2\right)} = \frac{A^2 R_{11}^2 T_b^2}{N_0 T_b + \dfrac{A^2 T_b^2}{3L} E\{R_{ij}^2\}\displaystyle\sum_{j=2}^{J}\sum_{i=1}^{K}\beta_{ij}^2} = \frac{R_{11}^2}{\dfrac{N_0}{A^2 T_b} + \dfrac{1}{3L} E\{R_{ij}^2\}\displaystyle\sum_{j=2}^{J}\sum_{i=1}^{K}\beta_{ij}^2}$$

$$= \frac{R_{11}^2}{\dfrac{N_0}{2E_b} + \dfrac{1}{3L} E\{R_{ij}^2\}\displaystyle\sum_{j=2}^{J}\sum_{i=1}^{K}\beta_{ij}^2}$$

2.29

The BER conditioned on R_{11} is therefore

$$p\left(e \mid R_{11}\right) = Q\left(\sqrt{SIR}\right) = Q\left(\frac{R_{11}}{\sigma_{tot}}\right) = \frac{1}{2} erfc\left(\frac{R_{11}}{\sqrt{2\sigma_{tot}^2}}\right) = \frac{1}{2} erfc\left(R_{11}\sqrt{\rho}\right).$$

2.30

where $\rho = 1/2\sigma_{tot}^2$. The average BER is obtained by integrating (3.11) over the range of R_{11}.

Similar to the derivation process in [30], we have

$$P_e = \int_0^\infty p\left(e|R_{11}\right) p\left(R_{11}\right) dR_{11} = \int_0^\infty \frac{1}{2}\mathrm{erfc}\left(R_{11}\sqrt{\rho}\right) p\left(R_{11}\right) dR_{11}$$

2.31

Where,

$$p\left(R_{11}\right) = \frac{2r(1+K)}{S^2} e^{-K-\frac{(1+K)r^2}{S^2}} I_0\left(\frac{2r}{S}\sqrt{K(1+K)}\right), \quad r \geq 0$$

By employing this equation we get the average BER for our satellite system.

Chapter 3

Result & Discussion:

Following the analysis presented in chapter 2 we evaluate the bit error rate performance of LEO satellite link in the presence of fading shadowing and elevation angle. We used matlab to do this analysis.

In our simulation we have done the BER performance analysis of a single satellite LEO system of different elevation angle, different Rice factor & different shadowing effect.

From the graph we will see that the BER performance becomes decreasing with the increase of   signal to noise power ratio. Here in each graph for different angle, there is a series of Rice factor & for each fading, there is a decreasing line and when we increase fading effect the BER of the system improve (means the BER decreases).

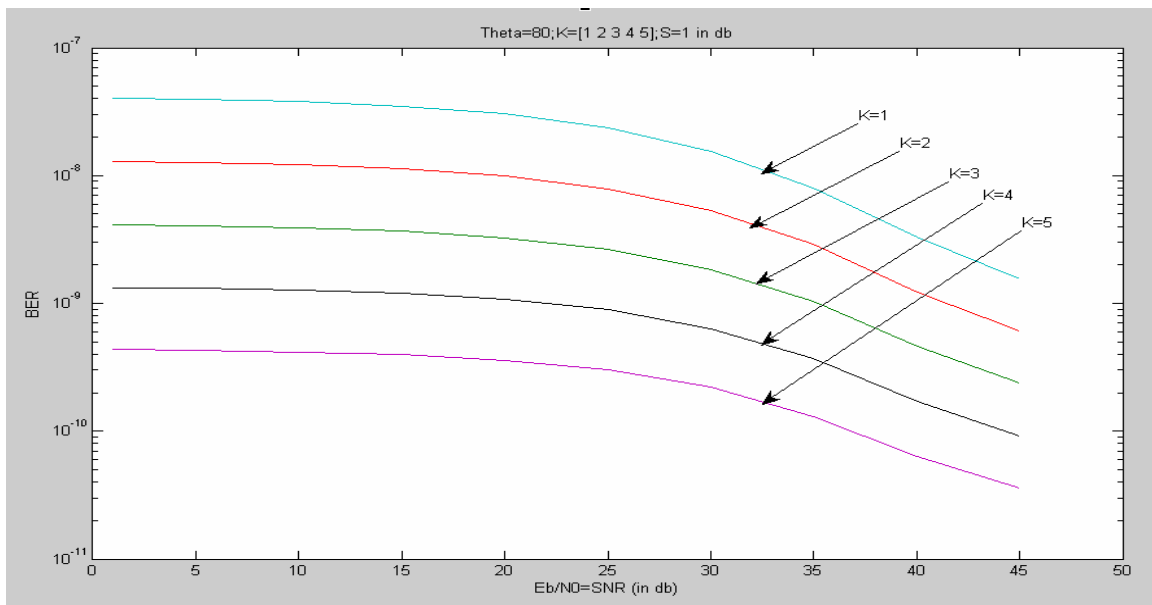The Graphs from the simulation is discussed bellow –

For Different angle (40^0, 60^0, 80^0) & for each angle Rice factor is 1, 2,3,4,5 in db.
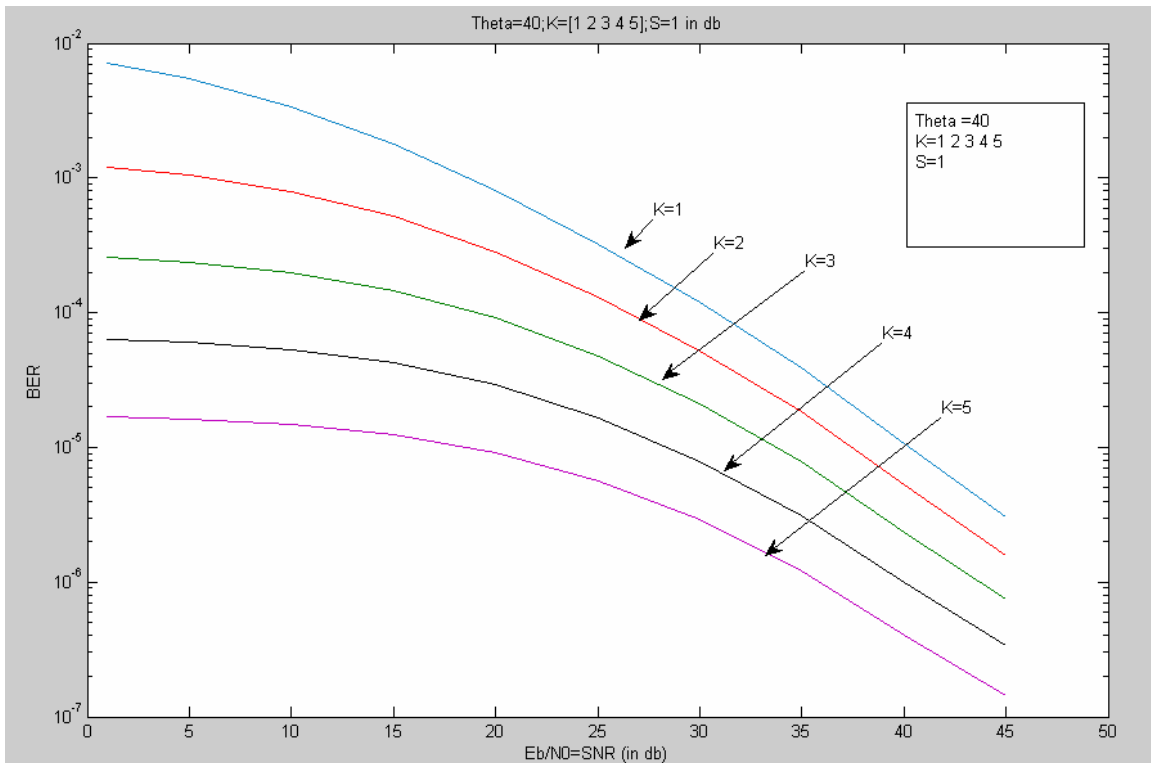
Graph 1: Angle 40^0; No Shadowing & Rice factor 1, 2,3,4,5

Graph 2: Angle 60^0; No Shadowing & Rice factor 1, 2,3,4,5
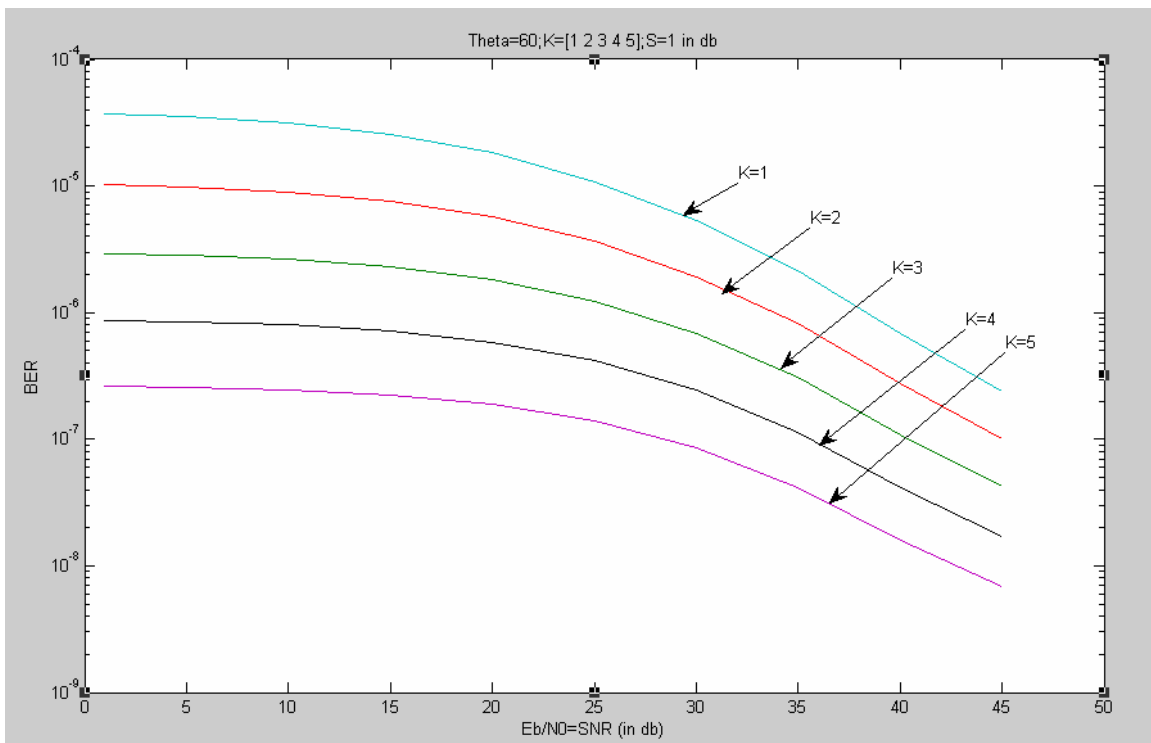
Graph 3: Angle 80^0; No Shadowing & Rice factor 1, 2,3,4,5

Angle (40,60,80) No shadowing Recian fading 1,2,3,4,5

K	Angle 40^0	Angle 60^0	Angle 80^0
1	$10^{-2.3}$	$10^{-4.5}$	$10^{-7.5}$
2	$10^{-2.9}$	10^{-5}	$10^{-7.9}$
3	$10^{-3.7}$	$10^{-5.5}$	$10^{-8.5}$
4	$10^{-4.3}$	$10^{-6.2}$	$10^{-8.8}$
5	$10^{-4.8}$	$10^{-6.7}$	$10^{-9.4}$

Table: 2

In above graphs 1 when angle is 40^0 bit error rate decrease from 10^{-2} to 10^{-5} with the increase of Rice factor. Which means Bit error rate situation is improving.

In above graphs 2 when angle is 60^0 bit error rate decrease from 10^{-4} to 10^{-6} with the increase of Rician factor. Which means Bit error rate situation is improving.

In above graphs 3 when angle is 80^0 bit error rate decrease from 10^{-7} to 10^{-9} with the increase of Rice factor. Which means Bit error rate situation is improving.

SO, with the increase of angle the bit error rate performance in improving . When the angle is high there is less obstacles which gives a better link performance to the satellite.

Now we induce shadow fading with this analysis, which we assumed to be not effective in the above graphs calculation.
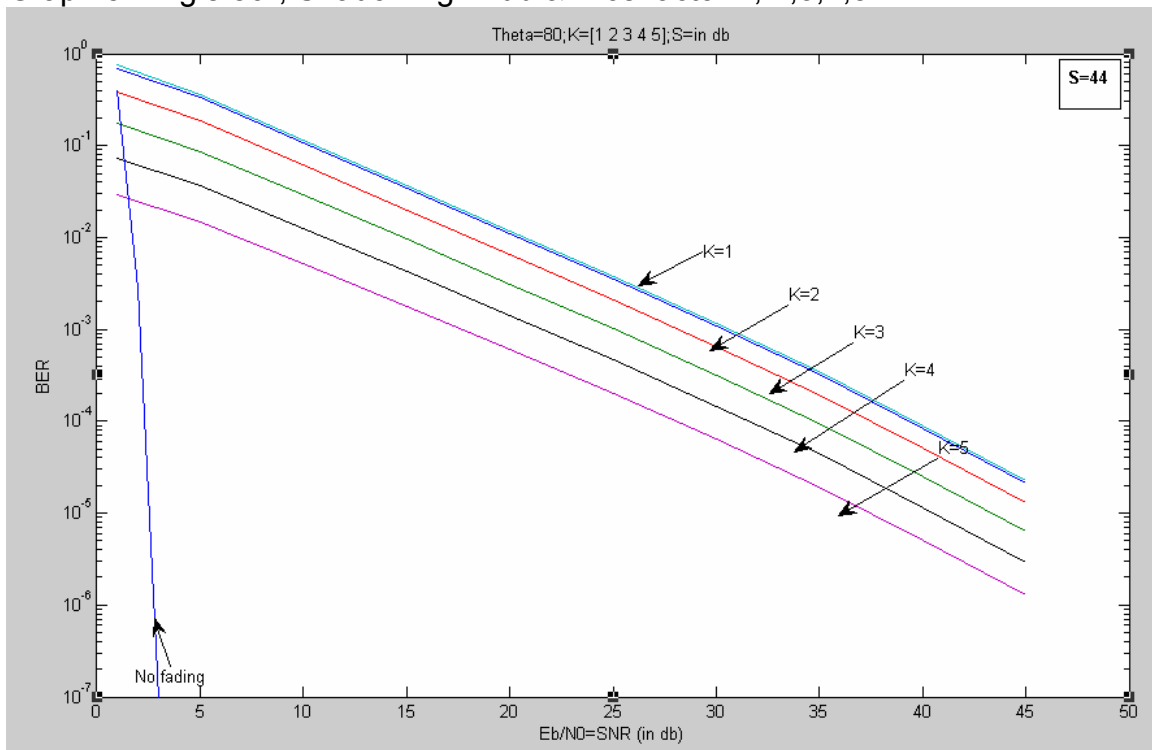
Because of the shadow fading the link performance will decrease & this difference is affected by angle of the satellite & Recian factor.
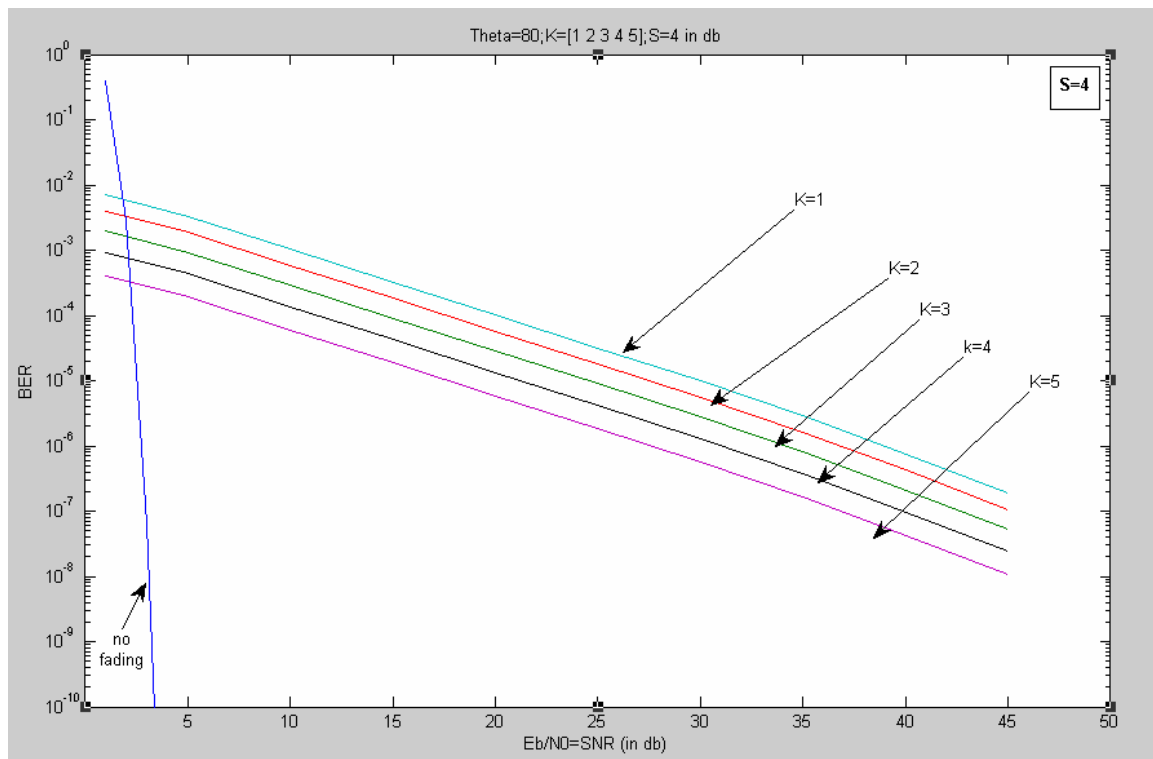
Graph 4: Angle 80^0; Shadowing 4db & Rice factor 1,2,3,4,5
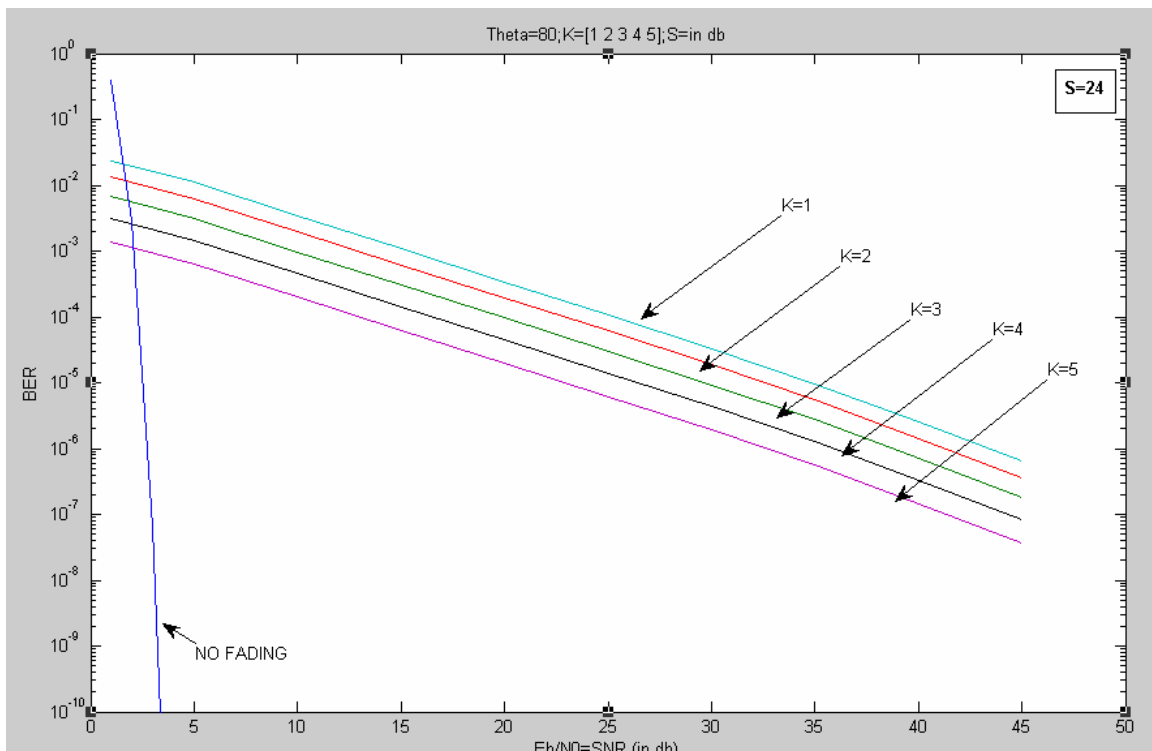
Graph 5: Angle 80^0; Shadowing 24db & Rice factor 1, 2,3,4,5

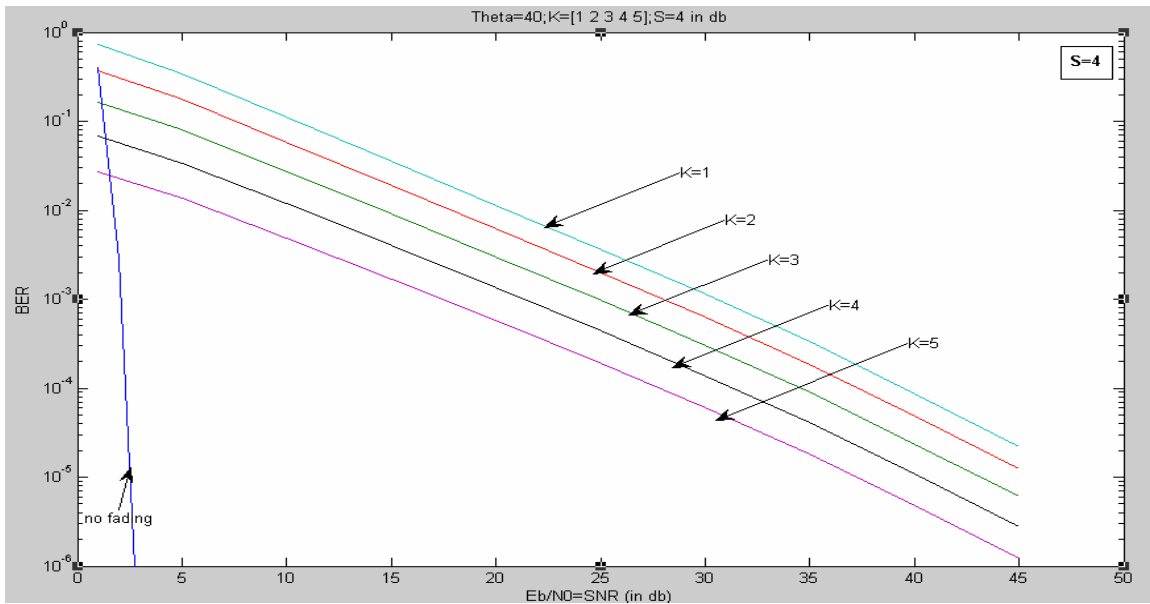Graph 6: Angle 80^0; Shadowing 44db & Rice factor 1, 2,3,4,5

Angle (80⁰), shadowing Recian 4db, 24db, 44db, fading 1, 2, 3, 4, 5

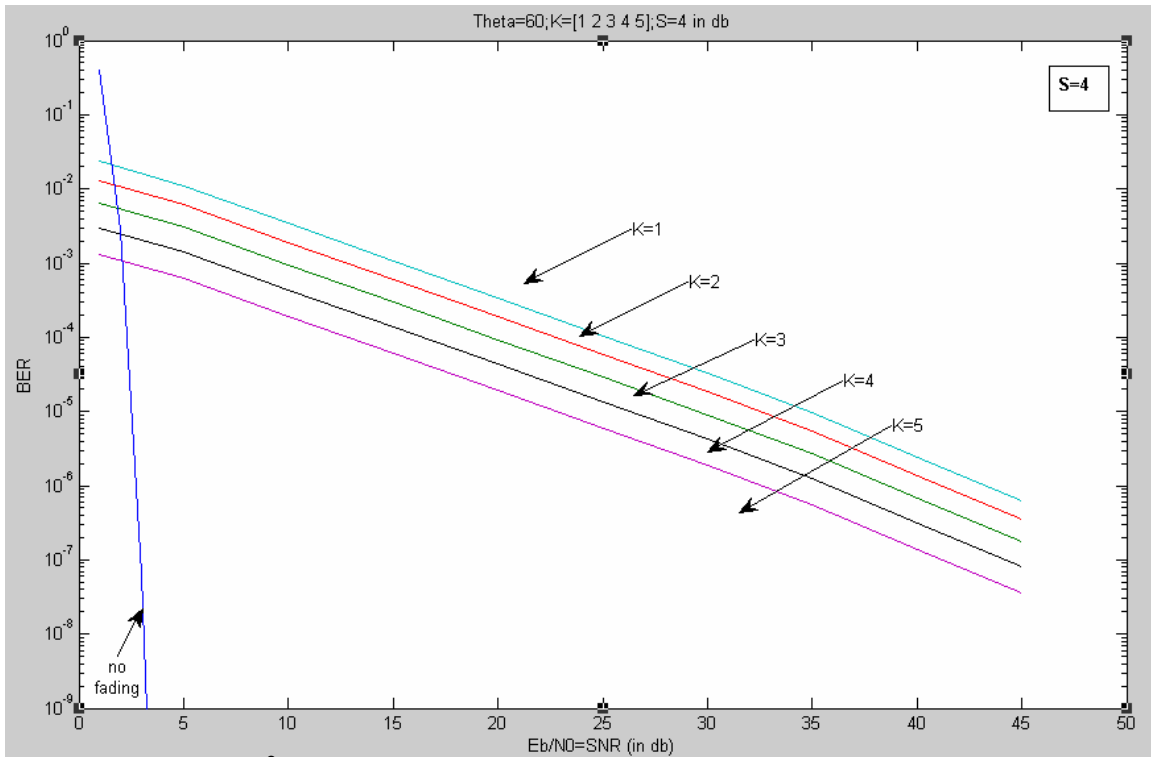| K	Shadowing 4db	Shadowing 24db	Shadowing 44db
1	$10^{-2.2}$	$10^{-1.7}$	$10^{-0.2}$
2	$10^{-2.4}$	$10^{-1.8}$	$10^{-0.4}$
3	$10^{-2.7}$	$10^{-1.3}$	$10^{-0.8}$
4	10^{-3}	$10^{-1.5}$	$10^{-1.3}$
5	$10^{-3.5}$	$10^{-2.9}$	$10^{-1.5}$

Table 3

From graph 4, 5, 6 we can see that at the same angle with the in increasing of shadow fading the BER performance of the link is decreasing. In these graphs angle of operation is $80^{0.}$ Now in graph 4 where the shadow fading is 4 db BER rang starts from $10^{-2.2}$, when shadow fading is 24 db BER rang starts from $10^{-1.8}$, when shadow fading is 44 db BER rang starts from $10^{0.4}$. So, The more the shadow fading is the more the BER performance as well as like quality decreases.
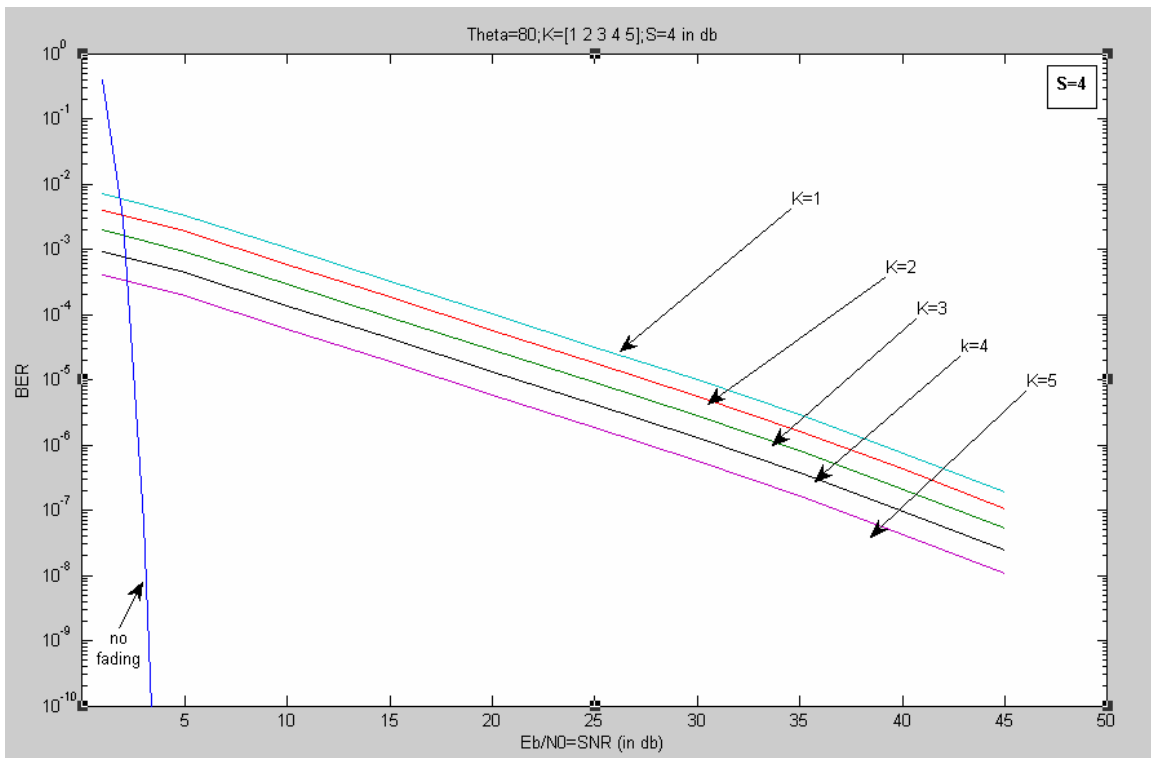
When Shadowing is 4db, for angle of $40^{0,}$ $60^{0,}$ 80^0 variance

Graph 7: Angle 40^0; Shadowing 4db & Rice factor 1, 2,3,4,5

Graph 8: Angle 60^0; Shadowing 4db & Rice factor 1, 2,3,4,5

Graph 9: Angle 80^0; Shadowing 4db & Rice factor 1, 2,3,4,5

Angle (40⁰ , 60⁰ ,80⁰); Shadowing 4db & Rice factor 1,2,3,4,5

| K	Angle40⁰	Angle60⁰	Angle80⁰
1	$10^{-0.1}$	$10^{-1.7}$	$10^{-2.2}$
2	$10^{-0.5}$	$10^{-1.9}$	$10^{-2.5}$
3	$10^{-0.8}$	$10^{-2.3}$	$10^{-2.7}$
4	$10^{-1.3}$	$10^{-2.6}$	10^{-3}
5	$10^{-1.7}$	$10^{-2.8}$	$10^{-3.5}$

Table : 4

If we compare graph 7, 8, 9 we can see that shadowing also dependent on angle of the satellite, as LEO satellite is always moving this effect is sever.

Now in graph 7 the angle was 40^0 & the BER started from $10^{0.4}$ where in graph 8 the angle was 60^0 & the BER started from $10^{-1.9}$ & in graph 9 the angle was 80^0 & the BER started from $10^{2.1}$ which shows the performance degradation of the system. In all this graphs our shadowing is fixed at 4 db.

 But LEO satellite is a constellation system so this angle based like quality degradation can be over come.

Power Penalty Graph:
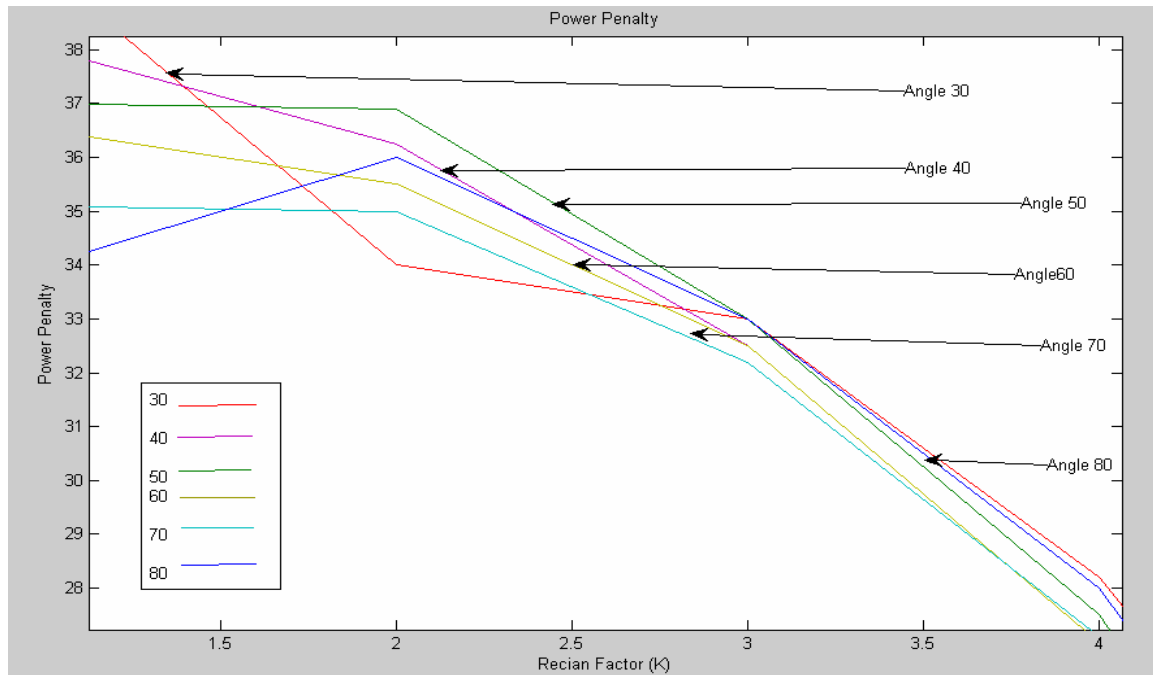
Graph 10: Power penalty vs. Rice factor

This power penalty graph shows the amount of power penalty due to the effect of Racian factor. At a given angle the power penalty can be reduced by increase the value of K.

Chapter 4

Conclusion

4.1 Summary

In examining the bit error rate (BER) performance analysis for the Low earth orbit (LEO) satellite communication system , this thesis has focused on the change in BER performance of the satellite link on the basis of elevation angle of the earth station antenna and the fading & shadowing turbulence. Here we have used a newly developed model of probability distribution function (PDF) in relation to elevation angle which gives us a more accurate analysis of the performance. Result shows that performance degradation can be substantial in times of lower elevation angle & also when fading & shadowing increases.

4.2   Achievements:

Thesis has analyzed the performance of the LEO satellite communication using a proposed elevation angle distribution. It has compared the results found in different elevation angle.

4.3   Future Work:

In an attempt to inject a degree of realism into this work, some works should further be made.

(1) We will be inducing some more turbulence link rain attenuation Atmospheric scintillation etc to analyze the performance degradation of the system & then try to find how to make it better.

(2) Performance can be improved using the diversity. A system for improving the performance using diversity will be developed.

(3) LEO satellite system is a constellation system. We will try to design a constellation for remote sensing.

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