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Propagation Issues in the Globalstar System

Toby Prescott - Qualcomm, Inc.

Introduction

The purpose of the Globalstar system is to provide reliable, timely space based telecommunications services for fixed, handheld and mobile user telephones throughout the world. The system supports communication services for voice and data as well as low rate data services such as paging. The Globalstar system can also support user position determination. The purpose of this paper is to provide a brief introduction to the Globalstar system followed by a discussion of the propagation issues in the Globalstar system design.

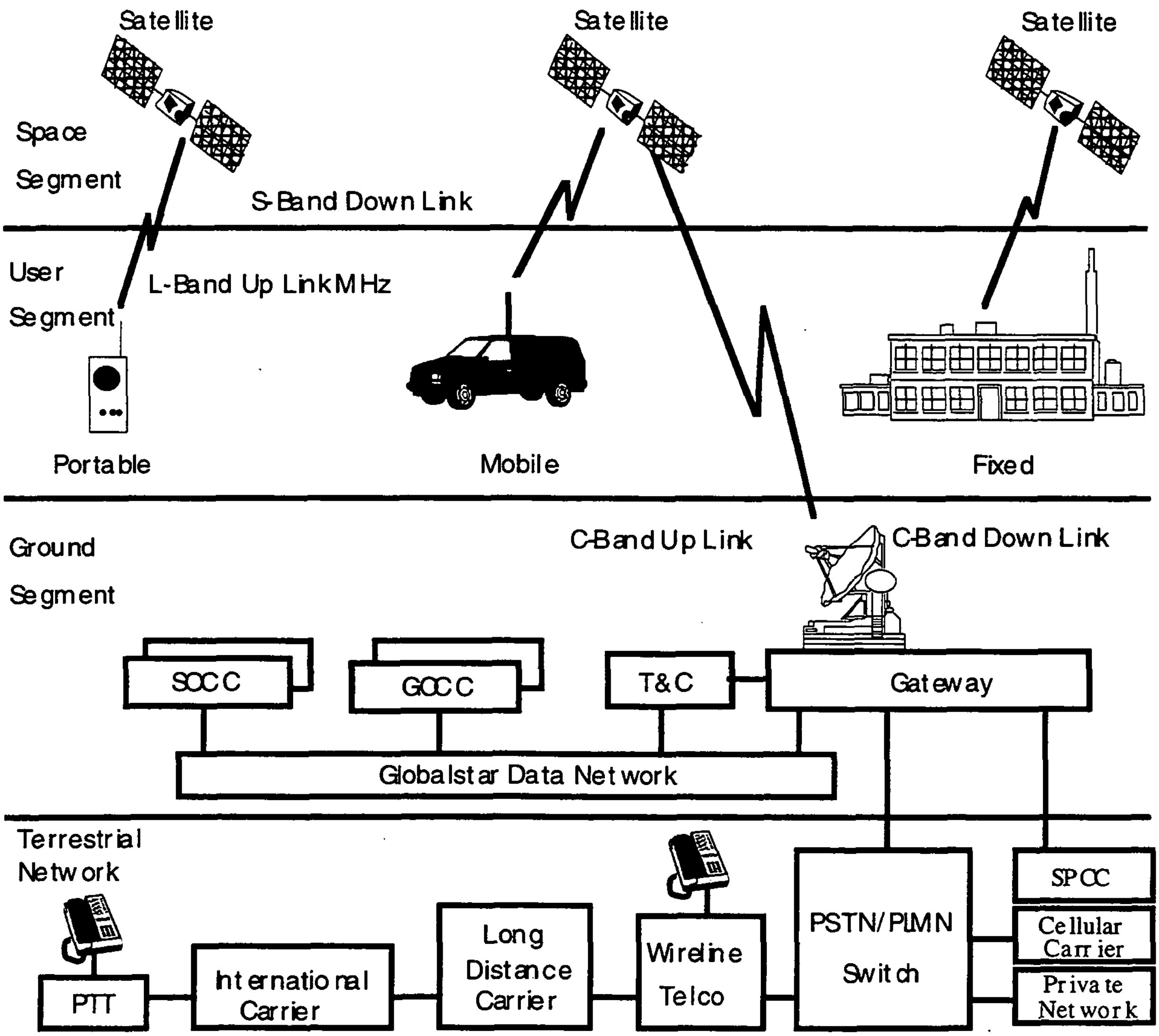

Figure 1 Globalstar System Integrates with Terrestrial Network

Globalstar System Overview

The Globalstar system consists of a space segment, a user segment, a ground segment, and a terrestrial network as shown in figure 1.

The Globalstar system provides communications from any point on the earth's surface to any other point on the earth's surface, exclusive of the polar regions. The Globalstar space segment consists of 48 satellites in 1410 km Low Earth Orbits. The low earth orbits permit low power handheld telephones to be used similar to the cellular telephones. These satellites are distributed in 8 orbital planes with 6 equally spaced satellites per orbital plane. User telephones are illuminated by the satellite antenna as it passes over the earth as shown by the antenna footprints in figure 2.

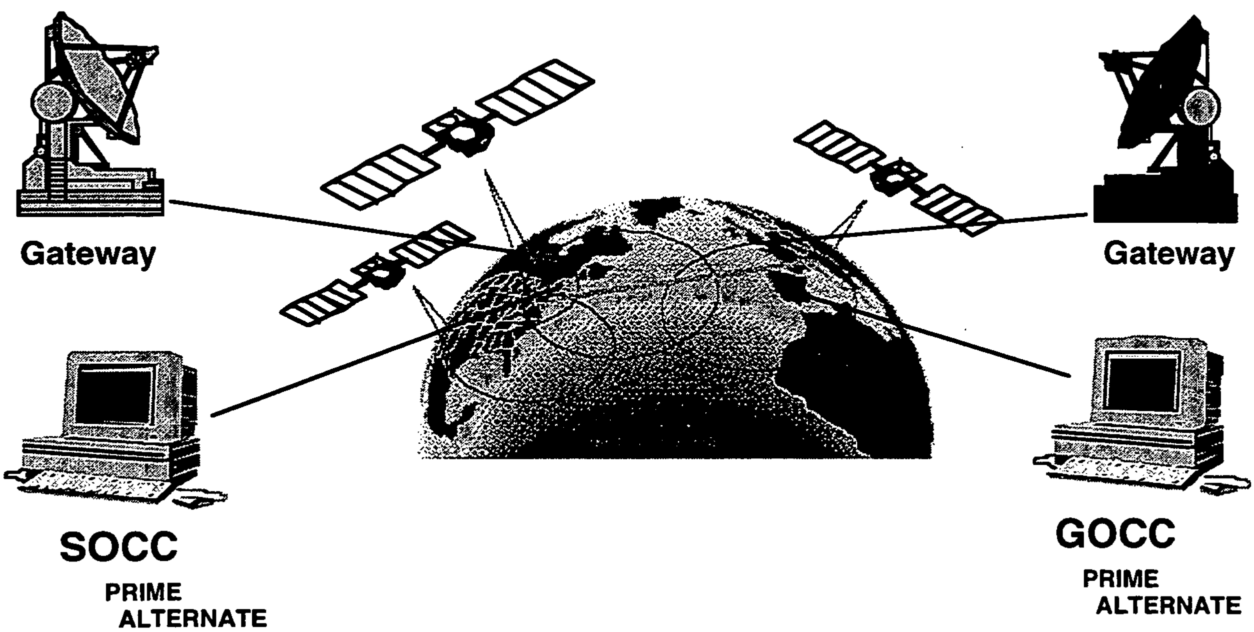

Figure 2 Ground Segment Accommodates Home Country Gateways

User telephones can be served by a satellite for up to 15 minutes per orbit. The inclined orbital planes provide full earth coverage with multiple satellites in view, providing space diversity, for a large percentage of time. Since the satellites are moving, the user is continuously being illuminated by different satellite beams and different satellites. Diversity combining within the receivers and Gateways supports a process of transferring traffic that is completely transparent to the user. The diversity combining process also provides better call reliability. Normally a user is covered by more than one satellite. If the user moves into an area that shadows or blocks access to one satellite, the space diversity link through a satellite that is not blocked maintains uninterrupted user communications.

Gateways are illuminated by an earth coverage beam. The Gateway connects the user telephone to the terrestrial network through an earth terminal that acts as the gateway between the Globalstar system and the terrestrial network.

User Telephone Equipment

The user telephones come in several varieties - hand held units, mobile units and fixed station units. The candidate user telephones are listed in table 1.

Hand Held. The radiating element of the antenna is positioned above the head of the user. The antenna is positioned vertically to effectively utilize the symmetrical radiation pattern of the hand held antenna.

Mobile. The mobile units consist of a hand held unit inserted in an adapter in the vehicle. The mobile units typically have a higher gain antenna, a lower noise receiver, and a higher RF power output that is provided by the adapter kit.

Fixed. Fixed station terminals are Globalstar only. The fixed user terminals have multiple antennas pointed at different portions of the sky. Each antenna element has higher gain than mobile or hand held units and one antenna is used at a time. This permits lower satellite power in the forward direction and lower interference in the reverse direction.

Table 1 Pre-Production User Telephones

Fixed Terminal	Mobile and Hand Held
Globalstar Only	Globalstar Only
	Dual Mode Globalstar & GSM
	Tri Mode Globalstar & Terrestrial CDMA & AMPS

Gateway

The Gateways are geographically distributed by the service providers to serve their customer base. Gateways are designed for unmanned operation. The Gateway consists of up to four identical parabolic dish antennas, drive mechanisms for positioning the antenna, the Code Division Multiple Access (CDMA) equipment, PSTN interface equipment that interfaces with the terrestrial telephone network and computer equipment to operate the Gateway and collect status and performance data.

The Gateway connects the Globalstar space segment to terrestrial switching equipment. The Gateway receives telephone calls from the terrestrial switching equipment and generates Code Division Multiple Access (CDMA) carriers to transmit through the satellite. The satellite then re-transmits the signal to the user telephones. These user telephones may be either hand held, fixed or mobile and located anywhere within the satellite antenna footprint.

In the return direction, the Gateway receives transmissions from any user telephone and connects the call to terrestrial switching equipment that can then connect to any subscriber using the standard telephone system. Connections can also be made to terrestrial cellular subscribers or to other Globalstar user telephones.

Globalstar Satellite

The Globalstar satellite is a simple low cost satellite designed to minimize both satellite costs and launch costs. A pictorial of the satellite and some of the major characteristics are shown in figure 3.

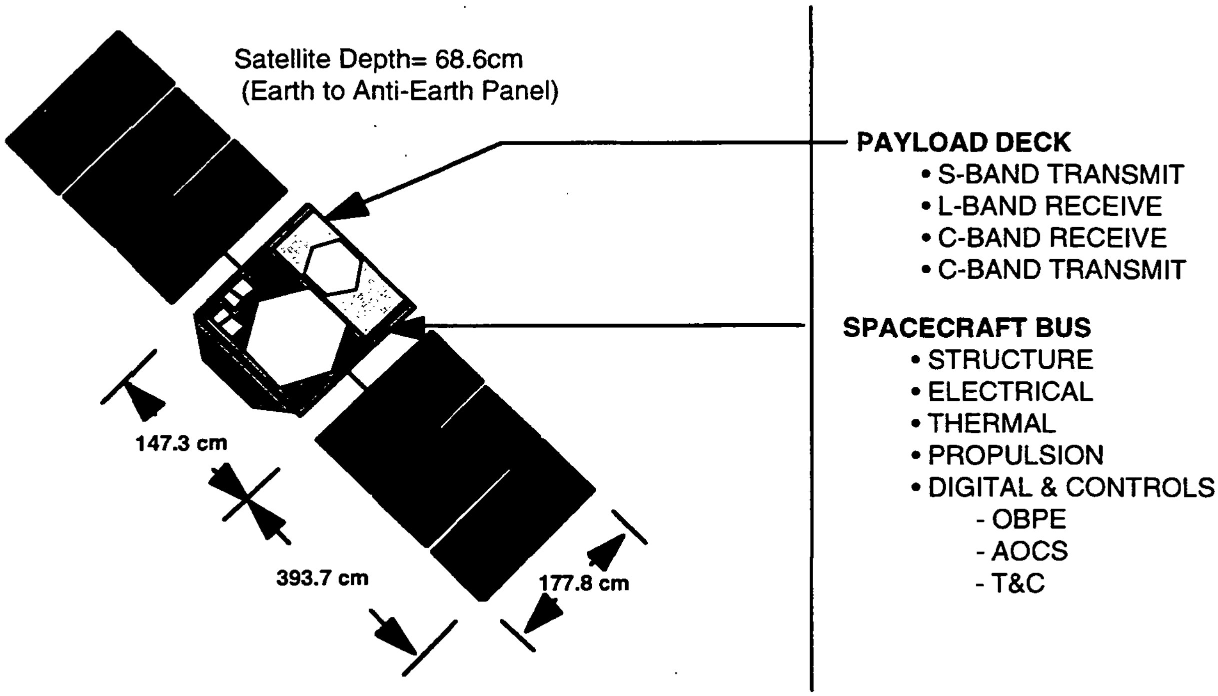

Figure 3 Globalstar Satellite Pictorial - Simple Satellite

A user telephone transmits to the satellite by L-Band. The signal enters the satellite through the L-Band low noise amplifier. It is amplified and then converted into a C-Band signal. This is radiated to the Gateway. The Gateway receives the signal and downconverts to an intermediate frequency. The communications traffic is presented to the CDMA equipment for demodulation.

In the transmit direction, the Gateway combines the up link CDMA signals with the signal from the command transmitter and radiates it at C-Band up to the satellite. The satellite then downconverts the signal and radiates an S-Band down link signal to the user telephones.

Ground Operations Control Center/Satellite Operations Control Center

Ground Operations Control Center is responsible for planning and management of the communications resources of the Globalstar satellite constellation. This is coordinated with the Satellite Operations Control Center that manages the satellites, controls the orbits and provides Telemetry and Command services for the satellite constellation.

Channel Propagation Considerations

The channel propagation modeling is of paramount importance in developing a communication system for both performance prediction and system design. For the terrestrial cellular telephone system, the propagation channel has been well studied. However, in the Globalstar environment further work is required to develop a comprehensive model. For the terrestrial system, typically the user equipment does not receive a direct line of sight signal component. Instead, the signal is composed of the reflections from many diffuse scatterers. In terrestrial CDMA, we employ a Rake receiver design to combine energies from different paths to offset some of the signal fading. For the Globalstar system, the typical scenario will enable the user telephone to maintain a direct line of sight component with the satellites in view. For the Globalstar system located in rural locations, most of the obstructions of the direct line of sight component will be due to vegetative shadowing that does not completely block the direct line of sight component, but rather simply attenuates it. Therefore, the Globalstar channel is significantly better than the terrestrial channel from a signal fading perspective.

Significant improvement in channel propagation comes from the use of continuous multiple satellite diversity employed in the design of the Globalstar system. The use of satellite diversity will help mitigate signal fading and greatly reduce the power requirements to originate and maintain calls relative to operations with a single satellite. Given two satellites in view at the same time, the probability of signal blockage or shadowing to both satellites is significantly less than the probability of blockage to a single satellite.

Another difference with terrestrial system is vastly different forward and reverse link frequencies. The correlation between signal fades on the forward and reverse link frequencies will be used in developing strategies for power control. One of the major problems associated with the land mobile satellite channel is the long delays associated with the transit times to and from the Gateways through the satellite. This satellite link delay is tens of milliseconds long compared to less than a couple of milliseconds in the terrestrial case.

Signal Components

The signal received at a user phone is composed of three components: direct line-of-sight, specular reflection and diffuse reflection. The diffuse component is composed of a sum of a large number of individual terrain scatterers from outside the first Fresnel zone of the vehicle. This diffuse component is characterized by phase incoherent multipath with a uniform phase distribution and a Rayleigh amplitude distribution (hence known as Rayleigh fading). The signal fading associated with the diffuse component combining with the direct component produces the fast-fading characteristics of the propagation channel.

The direct signal component is subject to shadowing by obstacles in the local environment such as trees and buildings. This form of fading has fade rates that are significantly less than the Rayleigh component and is primarily due to the motion of the mobile unit with respect to the geometry of the object causing the shadowing. In the presence of vegetative shadowing, a direct line-of-sight signal is subject to attenuation by the surrounding vegetation. The direct line-of-sight signal has an amplitude characteristic that can best be described as being log-normally distributed [2]. This direct line-of-sight signal combined with the Rayleigh distributed multipath signal from the diffuse scatterers provides a composite Rician distribution with a line of sight signal amplitude variability defined by the log normal distribution.

In the case of travel through a city, the most significant characterization is the percentage of time the direct signal path is blocked due to the geometry of the local buildings with respect to the signal line-of-sight. It has been found that the description of the distribution function during times of direct line-of-sight signal blockage is best described by a Rayleigh distribution whose mean received power is described by a log-normal distributed variable. In instances where there is no signal blockage, the distribution is best described by a Rician distribution.

Channel Modeling

Given the limited satellite resources, estimation of system performance is critically dependent upon the signal propagation losses. The purpose of the channel modeling activity is to accurately characterize the signal propagation from (or to) the satellite when communicating with a GS telephone user. Signal propagation characteristics are strongly dependent on the environment surrounding the user telephone such as the height and density of vegetation, the location of man made structures, nearby hills, etc. Therefore, the signal characterization must account for the type of terrain one expects to encounter and the location of objects in the environment that impede the direct line of sight between the satellite and user telephone.

At different locations and terrain types, we are concerned with determining the following signal characterizations for each of the states identified above:

1. The signal fade power probability distribution functions,
2. Characterization of the modeling parameters of the magnitude function for the direct line of sight component and the diffuse component
3. Temporal characterization of the diffuse signal component
4. Average fade and non-fade durations
5. Probability distributions of fade (and non fade) durations below (above) a series of signal thresholds
6. Time delay spread
7. Cross correlation of signal magnitude functions between L-band and S-band signals

This signal characterization at each location is dependent upon the geometry between the satellite and the user telephone (primarily satellite elevation angle and the line of sight vector between the satellite and the user telephone), motion of the user telephone, and the user telephone antenna characteristics.

Characterization of the environments to be encountered is also a big factor to be considered. This characterization involves determining the percentage of time one would anticipate encountering the various terrain types in a given locale.

System Design Considerations

The sections below provide an overview of some of the design issues in the Globalstar system with channel propagation considerations.

Power Control

To achieve the high capacity, quality and other benefits inherent in the CDMA waveform design, the Globalstar system will employ power control on both the forward link (Gateway to user telephone) and reverse link (user telephone to Gateway) communications. On the reverse link, the objective of the power control process is to produce the same nominal received signal power from each transmitting user telephone. On the forward link, the objective of the power control process is to provide a minimum power at each user telephone adequate to achieve the desired quality of service for each user telephone.

The principal problem facing the designer of the Globalstar power control is the large round trip propagation delay that reduces the tracking capability of closed loop power control. Fortunately, the satellite channel is inherently Rician due to the strong line-of-sight component, as opposed to the Rayleigh channel prevalent in terrestrial cellular systems. This has the implication of reducing the tracking requirement for power control, which now has to contend only with the effects of shadowing and/or blocking by trees and buildings. These effects have different dynamics than diffuse multipath fading effects. The Globalstar system design also provides for multiple satellite diversity for most users. This has the effect of reducing the fluctuations in signal level. Due to the large round trip delay, the bandwidth of the fading processes that can be compensated for with power control is limited and must be compensated using a combination of interleaving, coding and open loop power control.

To compensate for the sluggishness in the closed loop power control, investigations of open loop power control strategies are being considered. In the open loop power control, the user telephone (or Gateway) measures the received forward (or reverse) link signal and adjusts the power of his transmit reverse (or forward) link signal. The open loop power control can be operated at higher operational bandwidths and can therefore react more quickly to its environment. Essential to the development of closed loop power control strategies is a better understanding of the cross correlation between L-band and S-band signaling.

System Capacity

Computation of the capacity of the Globalstar system is a complex problem. However, one of the overriding factors in the computation of the channel capacity is the inclusion of channel propagation characteristics. Satellite resources are finite and must be carefully controlled. The channel propagation characteristics coupled with the power control process dictates the amount of diversity gain to be achieved by employing multiple satellites, the peak power required by a satellite and the total power consumed by the satellite. Of paramount interest is the determination of propagation state probabilities as a function of satellite to user telephone geometry in a variety of different locations.

Low Level Design

The low level design of the Globalstar system is dependent upon the characteristics of the received signal after the application of the power control process. The residual channel characteristics are used for the design of plethora of different issues. In our application, the channel characteristics are primarily superior to those encountered in the cellular system.

Summary

In this paper, an overview of the Globalstar system was provided with emphasis on design issues associated with the channel propagation characteristics of the land mobile satellite channel. Based upon a comparison of the terrestrial cellular propagation channel, the land mobile satellite channel provides many advantages. However, further work is required to completely define the propagation channel for the Globalstar development effort.