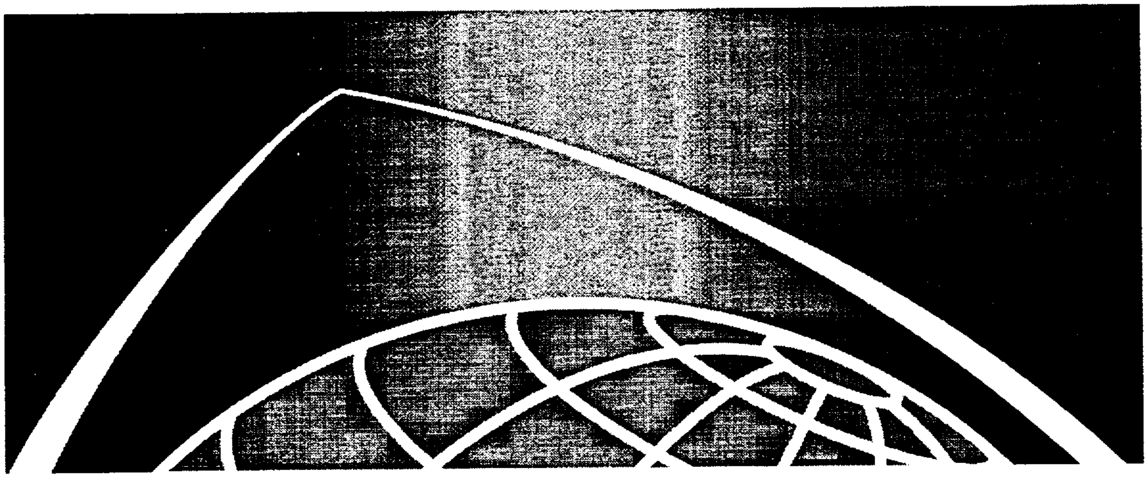
Globalstar



Description of the Globalstar System

February 24, 1997

DOCUMENT REVISION HISTORY

Revision	Date of Issue	Scope
A	6/3/94	Incorporated QUALCOMM Comments
B	12/20/94	Updated after SRR/PDR Reviews
C	8/10/95	Updated after the HLDR Reviews
D	2/24/97	Update to incorporate design changes

Abstract

This document is written to introduce new people to Globalstar. It attempts to provide a general overview of the system and to provide some information on the design of the system. It also attempts to define how Globalstar is envisioned to operate when the system is complete. As such, this is primarily tutorial in nature. In the interests of brevity, simplifications are made in the material herein. There is no attempt to be totally complete or comprehensive for all cases.

This document should not be interpreted as a binding specification. It does not contain requirements that should be interpreted as either complete or binding. Globalstar is an evolving system. This document will be updated as the design of the system progresses. When each revision is issued there is an attempt to represent the current thinking on the system.

For binding specifications and requirements please consult the released requirements documents and the released design information.

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2. SYSTEM SEGMENT DESCRIPTIONS

2.1 Globalstar System

The Globalstar system consists of a Space Segment, a User Segment, a Ground Segment, and a Terrestrial Network as shown in Figure 2-1.

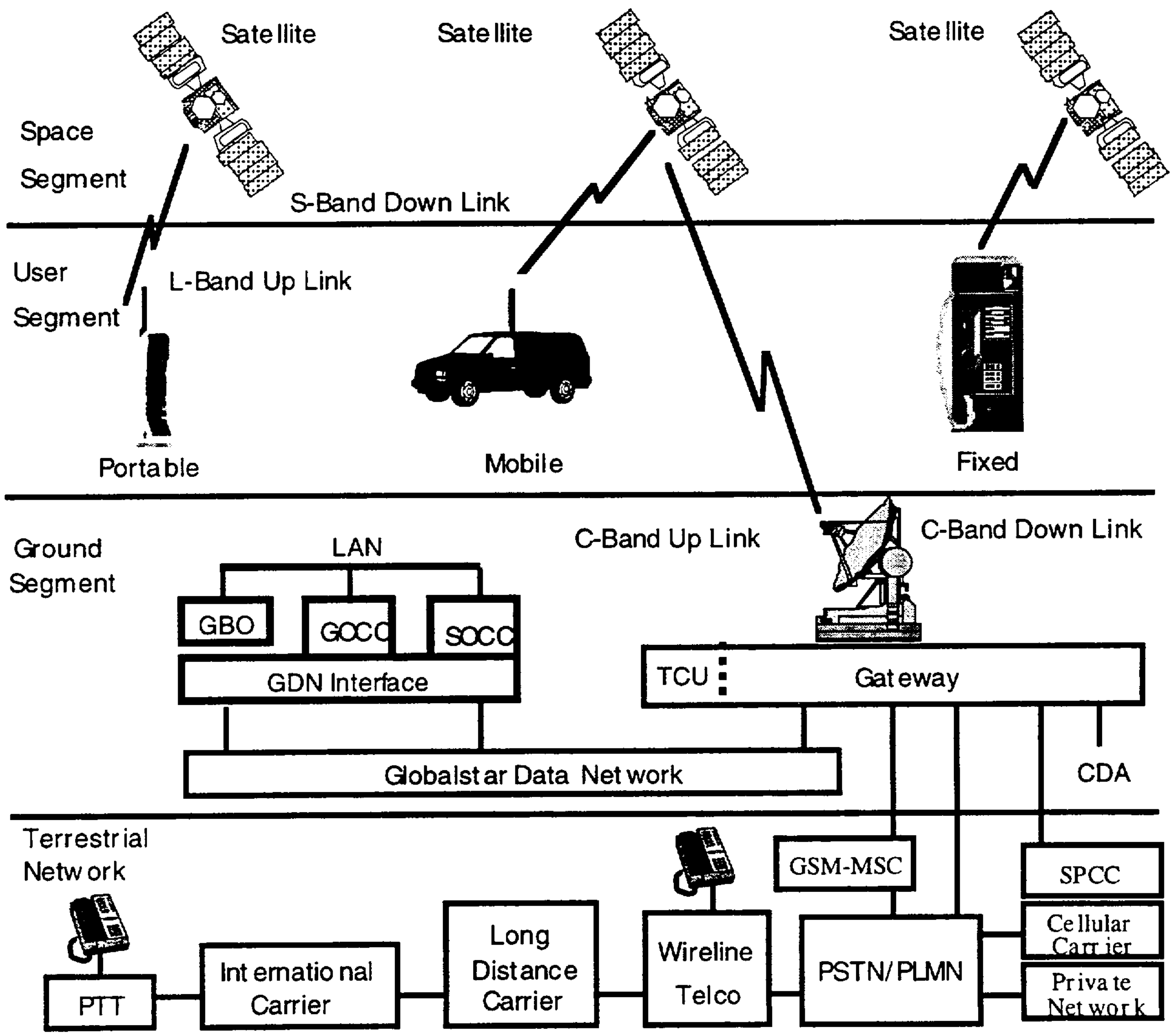


Figure 2-1 Globalstar System Integrates with Terrestrial Network

The Globalstar system provides communications from any point on the earth surface to any other point on the earth surface, exclusive of the polar regions. The satellite orbits are optimized to provide highest link availability in the area between 70 degrees south latitude and 70 degrees north latitude. Service is feasible in higher latitudes with decreased link availability.

The Globalstar space segment consists of 48 satellites in 1410 km Low Earth Orbits. The low orbits permit low power hand sets similar to cellular phones. These satellites are distributed in 8 orbital planes with 6 equally spaced satellites per orbital plane. Satellites complete an orbit every 114 minutes. User Terminals in a particular location on the surface of the earth are illuminated by a 16 beam satellite antenna as it passes over the earth as shown by the antenna footprints in Figure 2-2.

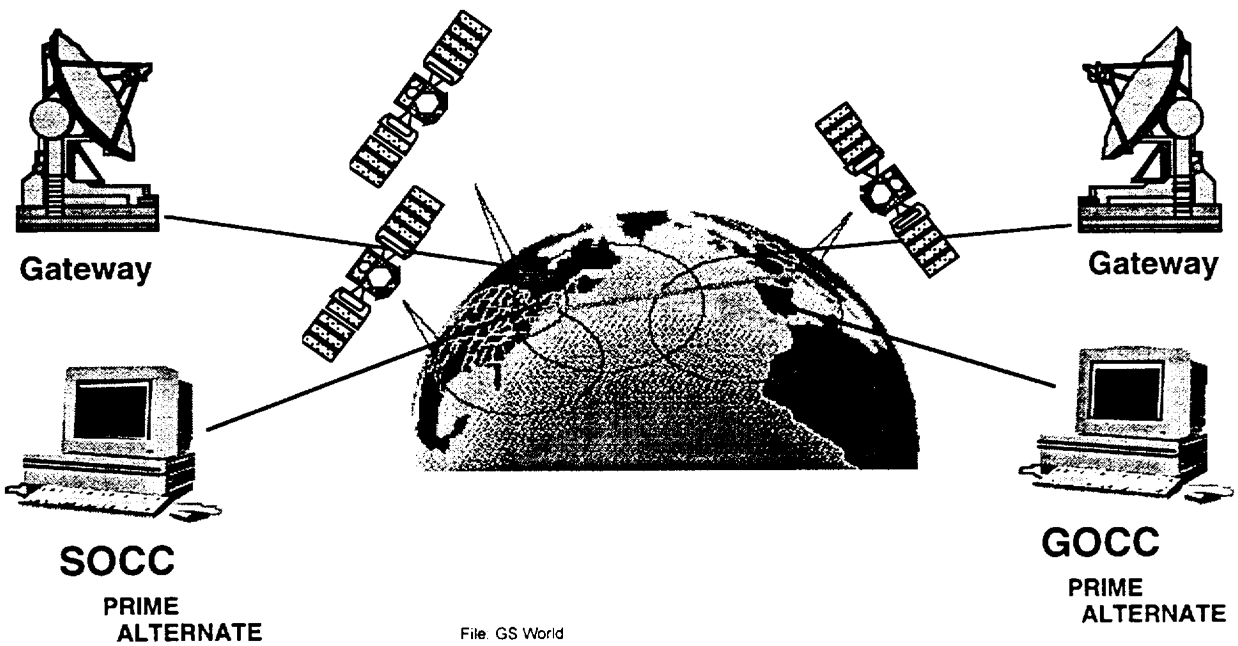


Figure 2-2 Ground Segment Accommodates Home Country Gateways

User Terminals can be served by a satellite 10 to 15 minutes out of each orbit. A smooth transfer process between beams within a satellite and between satellites provides unbroken communications for the users. The orbital planes are inclined at 52 degrees. Coverage is maximized in the temperate areas with at least two satellites in view, providing path diversity over most of the area. There is some small sacrifice in multiple satellite coverage at the equator and at latitudes above 60 degrees.

The Gateways to the terrestrial network are illuminated by an earth coverage beam. The Gateway connects the User Terminal to the terrestrial network via the Gateway. The terrestrial network is not a part of Globalstar.

2.2 User Terminal

The User Terminals come in several varieties. There are hand held units, mobile units and fixed station units. The candidate User Terminals are listed in Table 2-1

Table 2-1 Pre-Production User Terminals

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

Hand Held - A typical hand held unit is shown in Figure 2-3.

Figure 2-3 Typical Hand Held User Terminal

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. The area next to the head is not used for radiation. This meets the safety requirements.

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. This is part of the adapter kit. The improved transmitter and receiver are mounted in the base of the antenna.

Fixed - Fixed station terminals are normally Globalstar only. The fixed User Terminals have a performance equivalent to the mobile terminal except that the antenna gain and transmitter power may be even higher. Fixed terminals do not require path diversity to combat fading and blockage. Fixed Terminals must support seamless beam to beam and satellite to satellite hand off.

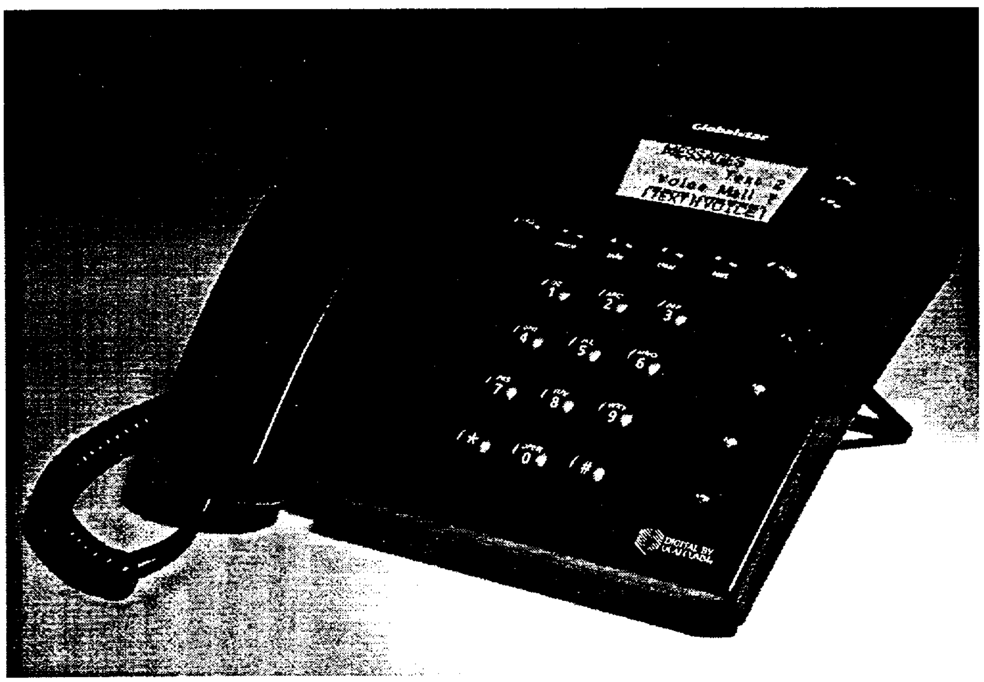


Figure 2-4 Typical Fixed Terminal Desk Set

Future User Terminals - Other User Terminals, such as Globalstar & TACS, will be developed based on market requirements.

SIM: All Hand held and Mobile User Terminals developed for Globalstar will support a Subscriber Identification Module (SIM).

Block Diagram - Figure 2-5 is a simplified block diagram of the Tri-Mode User Terminal which includes Globalstar/CDMA/AMPS.

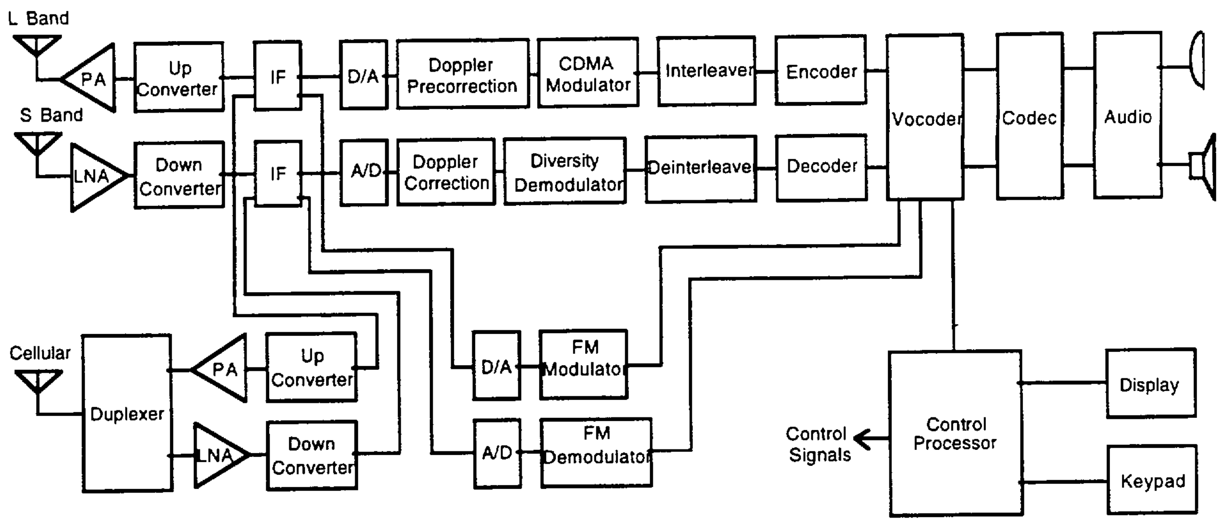


Figure 2-5 Tri-Mode User Terminal Block Diagram

Appearance : Hand held User Terminals look like a standard cellular telephone. These are multiple mode hand sets that operate with the local cellular system or Globalstar. Mobile User Terminals are functionally similar to the hand held units. A mobile consists of a hand set and a car kit. The car kit provides battery power, a higher RF power output and a higher gain antenna. There are indicators on the hand set that indicates the operational mode. Since there is no hand off between the local cellular system and Globalstar, if the user crosses a service boundary between the local cellular system and Globalstar, the call could be dropped and must be placed again. The indicators tell the operator that the mode has changed. Fixed installation User Terminals are Globalstar only. The fixed terminals are designed to serve areas that not served by cellular networks. They are fixed installations with a primary power source, higher RF power and a fixed high gain antenna.

Functions Performed : The start up functions of a User Terminal are programmable. As an example, when a dual-mode User Terminal first powers up it may attempt to log into the local cellular system. This addresses a scenario where the cellular system gets first priority to provide the service. If this fails the User Terminal then attempts to log onto the Globalstar system. Figure 2-6 illustrates a typical startup scenario within Globalstar.

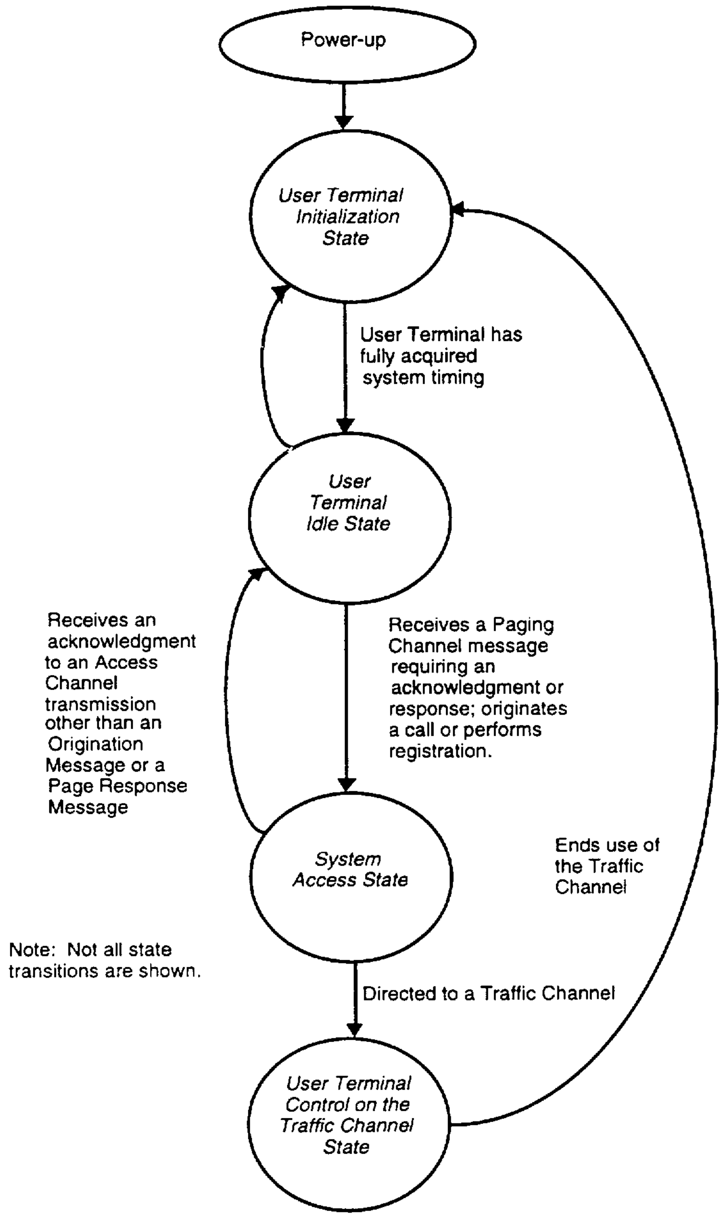


Figure 2-6 User Terminal Startup Scenario within Globalstar

The User Terminal looks for the best satellite pilot signal. When this is found it then switches to the sync channel and obtains the satellite database and other information. This database facilitates rapid acquisition of the pilot for any future calls. To place a call the user dials the number and presses "SEND". The User Terminal contacts the Gateway via the access channel. The Gateway and the User Terminal then work together to connect the call and support communications. Since the satellites are moving, the user is continuously being illuminated by different satellite beams or even different satellites. Diversity combining within the receivers supports a process of transferring traffic that is completely transparent to the user. The diversity combining process also provides better call reliability. The hand off process is accomplished without interruption to the call in process. 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.

Hand Off: The moving satellite constellation requires hand offs to different satellites and to different beams. In general, hand off is transparent to the user. Hand off on the forward link does not imply hand off on the return link.

Forward Link: In the forward link direction (from the Gateway to the User Terminal), hand off is totally under control of the Gateway. The User Terminal finds pilots and reports quality to the Gateway. When a second pilot is seen, the quality is reported to the Gateway. If the Gateway determines that it is advisable, the Gateway will instruct the User Terminal to incorporate the signal into the diversity combiner. At all times the user terminal is using a fast algorithm to search for other pilots. Once a suspected pilot is detected, it is turned over to one of the fingers used as a clincher. So at one point in time, the User Terminal may have 3 fingers active. One is the traffic finger, one is used for diversity combing and the third finger is used as the clincher. In the forward direction the role of the User Terminal can be summed up as the proposer. The Gateway can be viewed as the disposer. The User Terminal suggests which pilots should be used. The Gateway decides.

Return Link: In the Return Link direction, the Gateway uses up to 6 fingers. Eb/No is measured. If the Eb/No is above a usable threshold it is added into the diversity combiner multiplex. New signals are added in until the Gateway runs out of fingers. A stronger signal will not cause the Gateway to take a weaker signal out of the diversity combining process as long as it is above the threshold. Once a signal drops below the acceptable threshold, it will be taken out of the diversity combining process and the finger released for assignment to other incoming User Terminal signals.

Soft Hand Off: In soft hand-off, two or more received signals through different links are simultaneously demodulated, combined, and decoded by the same entity. It is characterized by commencing communications using a new pilot on the same CDMA frequency before terminating communications with the old pilot. This is a hand off occurring while the user terminal is operating on the Traffic Channel.

Hard Hand Off: In hard hand off, the receiving entity stops demodulating and decoding information transmitted on one link and starts demodulating and decoding information transmitted on another link with possible loss of information. A hard hand off is characterized by a temporary disconnection of the Traffic Channel. Hard hand offs occur when the user terminal changes frequency or frame offsets.

3. FREQUENCIES AND COVERAGE ANALYSIS

3.1 Frequency Plans

Globalstar uses C-Band between the Gateway and the Satellites as shown in Figure 3-1.

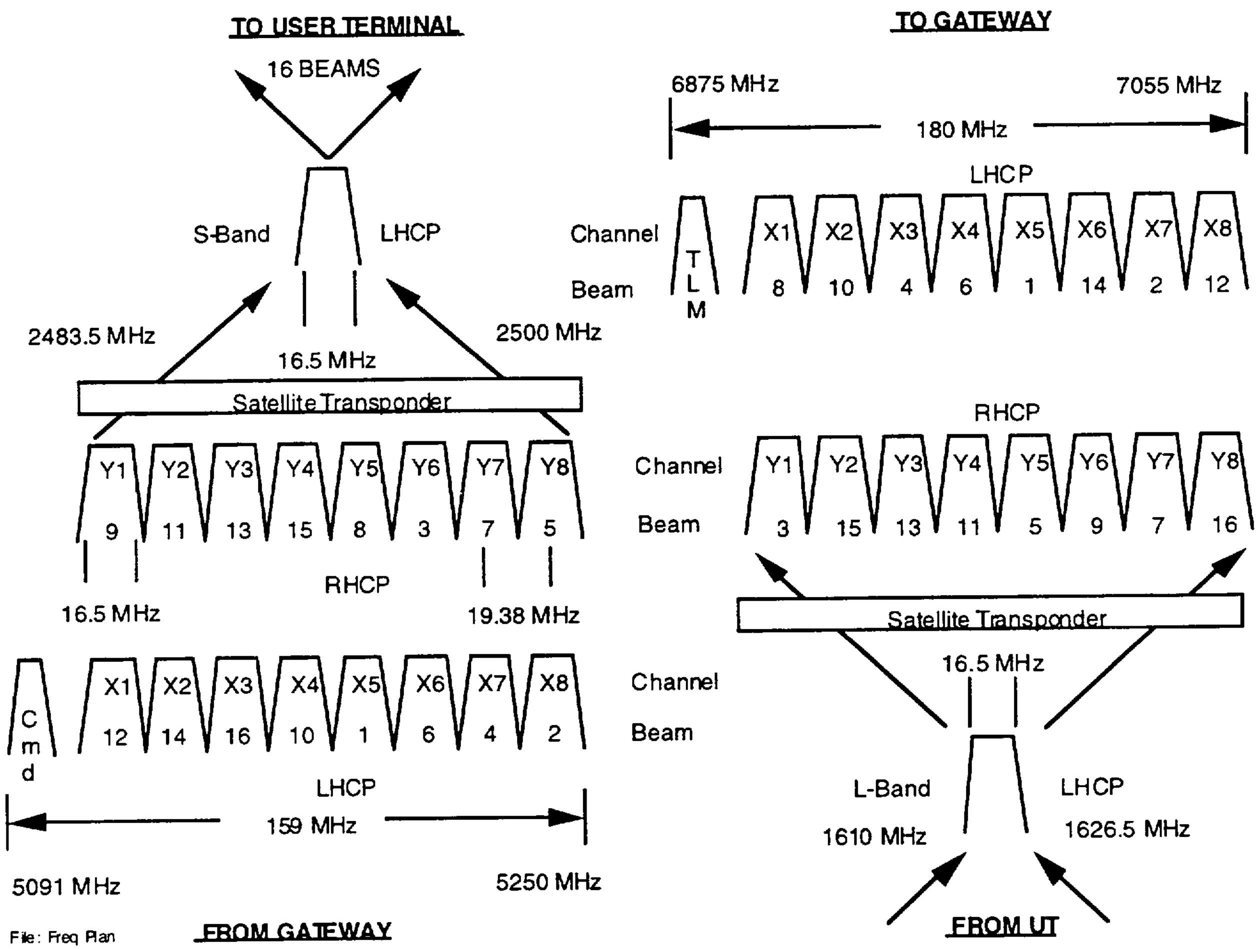


Figure 3-1 Frequency Plan - Emphasizes Conservation of Spectrum

The C-Band antennas on the satellite use an earth coverage beam. The Gateways use a parabolic antenna and program track the satellites. Program tracking uses the orbital data provided by the Satellite Operation Control Center to position the Gateway antenna.

Efficient Spectrum Utilization - The spectrum is used efficiently by incorporating frequency reuse and spread spectrum into the design. Both Right Hand Circular Polarization (RHCP) and Left Hand Circular Polarization (LHCP) are used for C-Band. This allows 8 frequencies to connect to 16 beams on the satellite. The beam numbers shown in Figure 3-1 map to the S-Band beams shown in Figure 3-2 and the L-Band beams in Figure 3-3 which follows. The alpha characters used within the spectrum blocks and on the following diagram indicate polarization.

X= Left Hand Circular Polarization

Y= Right Hand Circular Polarization

3.2 Satellite Antenna Beam Configuration

The S-Band antennas on the satellite are configured to produce 16 beams as shown in Figure 3-2.

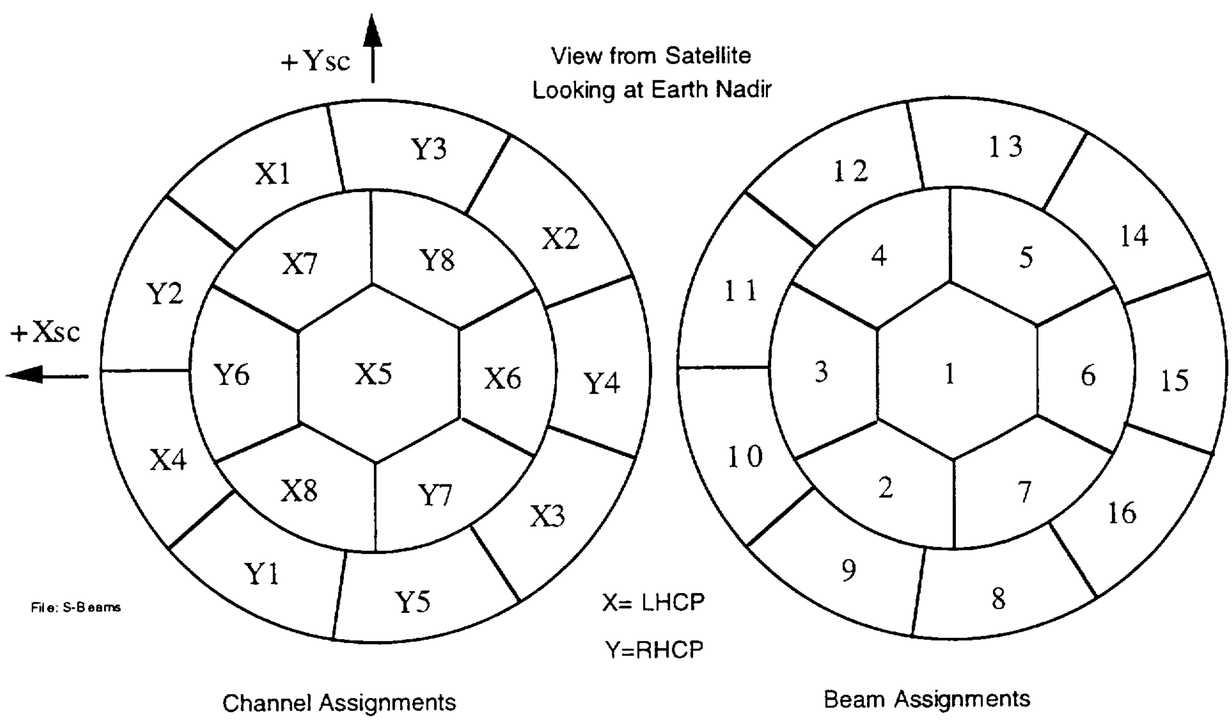
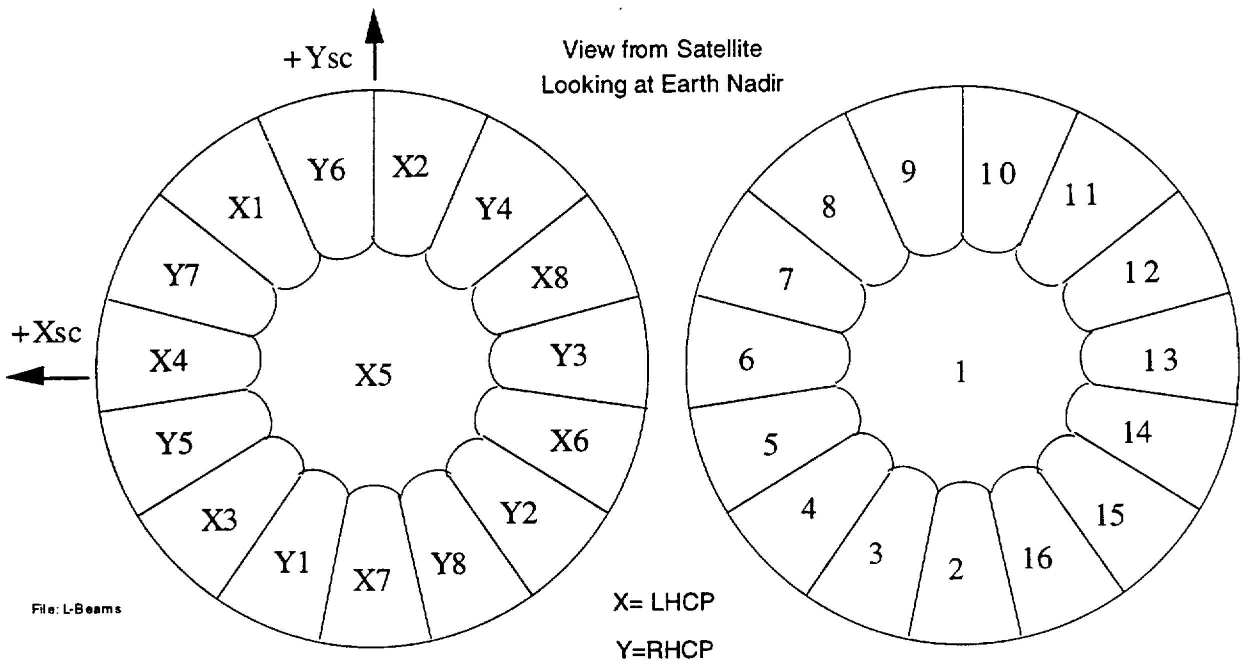


Figure 3-2 S - Band Beams

The antennas are multiple beam antennas designed to provide an isoflux pattern on the earth in the service region. The isoflux pattern is obtained by shaping the beam so that the gain at the edge of coverage is higher than at the beam center. This compensates for the difference in losses due to the longer slant range at the beam edges.

L-Band Pattern: The L-Band pattern consists of 16 beams. Beam 1 is in the center. The remaining 15 beams are arranged in an annular ring around the center beam as shown in Figure 3-3.



Channel Assignments Beam Assignments

Figure 3-3 L- Band Beams

This configuration provides better coverage on the earth to reduce the power requirements on the L-Band transmitters in the User Terminals.

Efficient Spectrum Utilization - As shown in Figure 3-4 and Figure 3-5, only 16.5 MHz of L-Band and S-Band spectrum are used. The same set of frequencies are reused in each of the 16 beams. Note that C-Band frequencies are assigned to beams to minimize interference. The Globalstar approach is very efficient in its use of the valuable L-Band and S-Band spectrum. L-Band is used to communicate from the User Terminal to the satellite and S-Band is used to communicate from the Satellite to the User Terminal. Within each of the beams, there are 13 FDM channels.

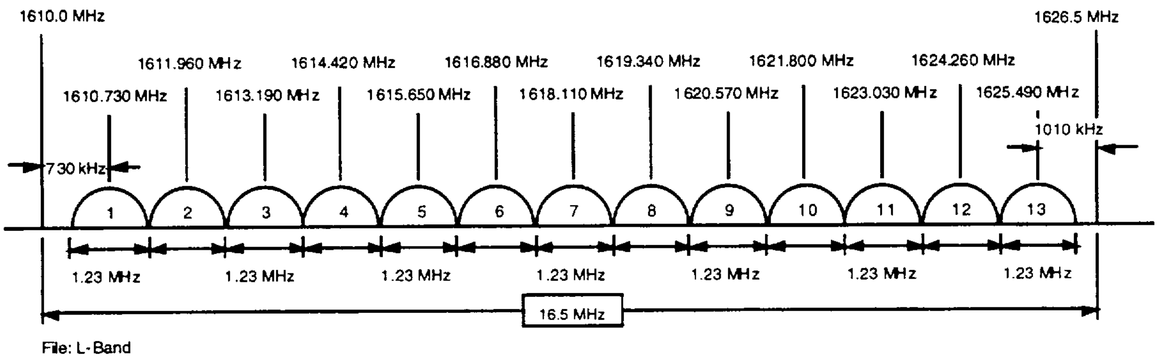


Figure 3-4 L - Band Channel Frequencies

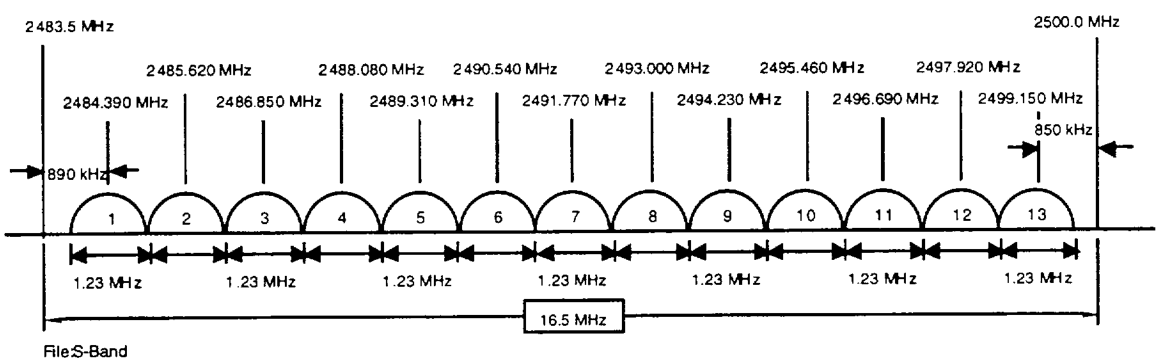


Figure 3-5 S - Band Channel Frequencies

Spectrum Sharing - Within a channel, spread spectrum is used to convey the voice or data intelligence. Multiple voice or data circuits may be carried within a single 1.23 MHz FDM channel. The circuit data is separated by unique PN spreading sequences. This allows the same spectrum to be shared by other CDMA users.

3.5 Channel Characteristics

Figure 3-9 illustrates the orientation of a User Terminal in a typical temperate climate scenario with multiple satellite coverage.

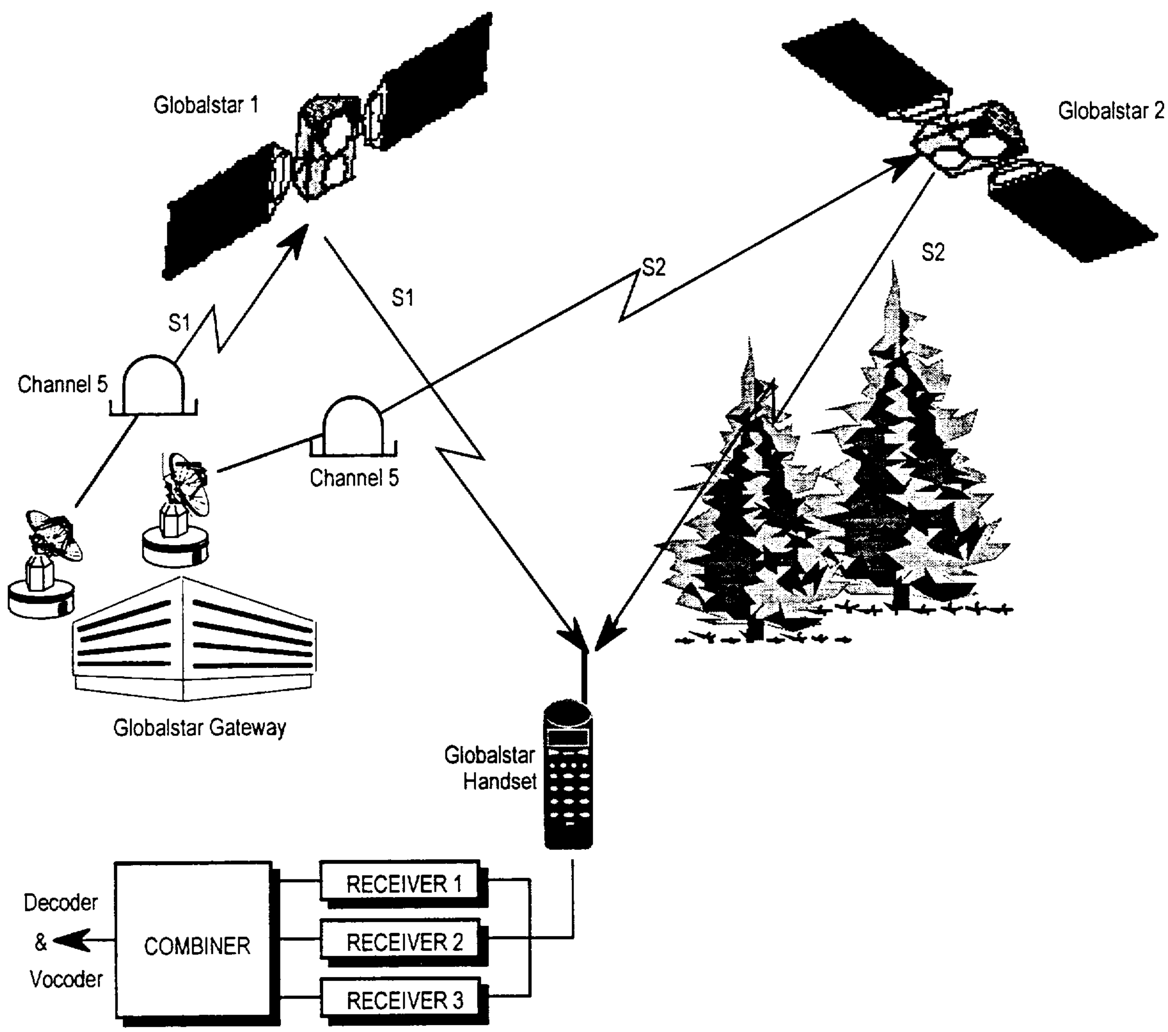


Figure 3-9 Channel Characteristics Considerations

Line of Sight: For the Globalstar system, many of the obstructions in the direct line of sight do not completely block the line of sight, but rather simply attenuate the signal. 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.

Specular Reflection: The specular reflection component is the signal reflected off the surface of the earth. The magnitude of the reflected signal can be large if the surface is relatively smooth and flat at the point of reflection. The specular component will prove to be an insidious problem for the hand held antennas. It can either add to or subtract from the signal received from the direct line of sight. This problem can be managed effectively for the mobile and the fixed station antennas.

Diffuse Reflection: The diffuse component is composed of a sum of a large number of individual terrain scatter from outside the first Fresnel zone. This diffuse component is characterized by phase incoherent multi-path with a uniform phase distribution and a Rayleigh amplitude distribution. The signal fading associated with the diffuse component combining with the direct component produces the fast-fading characteristics of the propagation channel.

Building Penetration: Globalstar has limited ability to penetrate buildings. Operation is possible in wood frame buildings or near windows with a wide angle view of the sky. The best locations within building results in 6 to 13 dB added insertion loss. There is a high degree of sensitivity to antenna location within the building. A change in lateral position of 20 to 30 centimeters can produce a 30-dB variation in signal power.

In Pocket: With the antenna extended, operation depends on orientation. Body blockage can insert attenuation in excess of 15 dB. If the antenna is stowed, operation is not considered feasible.

Interference: User Terminal receivers may experience interference when operating in close proximity to microwave ovens, plywood plants or hospitals. The transmitters are frequency coordinated for operation with Radio Astronomy sites, for operation with GPS, and with GLONASS. The Gateway site locations are selected to avoid interference with the Microwave Landing Systems (MLS) associated with airports.

Conclusions: Several Conclusions can be drawn for Globalstar operations.

1. Operation at higher elevation angles is preferred.

2. Mobile will suffer less from specular. Power control may be less effective at some operating speeds.

3. Fixed terminals will suffer less degradation from all sources.

4. Forward and Return link behavior are not correlated. Conclusions from one direction cannot be used to derive control information for the other direction.

4. CODE DIVISION MULTIPLE ACCESS (CDMA)

4.1 Introduction

The Globalstar Air Interface uses a modified form of IS-95 to support Code Division Multiple Access. CDMA was selected for Globalstar because it represents a proven technology that can provide a bandwidth efficient modulation scheme for satellite communications. It is relatively interference tolerant, both from the standpoint of generation of interference to other services and tolerating outside interference. As a bonus, there is a level of security inherent in the modulation scheme. It is difficult to listen into conversations or to pirate services from the system. CDMA is able to provide good voice quality while operating at relatively low RF power levels. The Globalstar CDMA is based on the existing QUALCOMM CDMA product line used for terrestrial cellular communications.

Path Diversity combats fades and blockage - Probably one of the most important aspects of CDMA is associated with the way Globalstar uses CDMA. Diversity combining is used to provide continuous communications even under conditions where a path to one satellite is totally blocked. The Globalstar system can operate with relatively low link margins and still provide a high link availability.

CDMA supports spectrum sharing - There are other useful and interesting aspects of CDMA. In CDMA two or more systems can occupy the same frequency-power space. Separation of the intelligence is accomplished by demodulating the PN spreading sequence. This supports band sharing by more than one system.

Soft Capacity Limit: There is another useful aspect of CDMA. Since CDMA is basically a system whose capacity is limited by self generated interference, the limit is a soft limit. Unlike bandwidth limited systems like Time Division Multiple Access (TDMA) or Frequency Division Multiple Access (FDMA), CDMA allows the predicted capacity limit to be exceeded with soft degradation occurring.

4.2 Diversity Combining

Diversity combining is used to mitigate the effects of link phenomena. In a simple form, diversity combining uses the signal with the best signal to noise ratio. Rake receivers are used to receive and combine the signals from multiple sources. As an example, the User Terminal will provide diversity combining for the forward link signals received through up to two different links simultaneously.

Diversity increases Availability - The performance in the diversity mode will always exceed the performance that would be achieved with communications via a single string link. Diversity combining is continuous. There is no break in service if one or more of the diversity links is lost.

Multiple Satellite - Forward Link: In the forward direction, the use of diversity brings substantial gain if one of the satellites is obstructed and is break even for unobstructed operation without multi-path. With multi-path fading (typically with high values of Ricean k) the diversity also provides benefit.

Multiple Satellite - Return Link: In the reverse direction, there is a clear advantage because gain results even with no obstruction. Because this is non coherent diversity combining, the gain is not quite as much as with coherent operation.

Multiple Beam - Forward Link: There is no diversity advantage for using multiple beams. All beams come from precisely the same point in the sky and are at the same sub-channel frequency. Whatever shadowing or multi-path occurs for one beam occurs for the other.

Multiple Beam - Return Link: On the Return Channel the signals the gateway sees through the different beams are, of course, the same; they fade in exactly the same way. But the noise backgrounds in which they are received are essentially independent. There is some advantage to using diversity.

4.3 Fade Mitigation

The Gateway will support power control to address slow fades and interleaving to address medium to fast fades. Power control is implemented on both the forward and return links.

Power Control: To support forward link power control, the user terminal reports pilot quality statistics to the gateway. For return link power control, the Gateway measures frame error rate. The response time of the power control is adjusted to accommodate the satellite round trip time delays. Average round trip delay is on the order of 30 ms.

> **Forward Link**: Forward link power control is closed loop under control of the Gateway. The dynamic range of the forward link power control is at least 20 dB.

> **Return Link**: The return link is operated open loop when a fade is first sensed, then closed loop under control of the Gateway. The dynamic range of the return link power

control is a maximum of 20 dB with a 0.5 dB step size. The User Terminal will limit the integrated transmitted power to conform with regulatory requirements.

Interleaver: The Interleavers will operate over a 20 ms vocoder packet frame which will effectively address medium and fast fades.

4.4 Acquisition

Search to Acquire: When a Globalstar phone hunts for a pilot channel it must search through a multi-dimensional space. Three of the more obvious dimensions are illustrated in Figure 4-1.

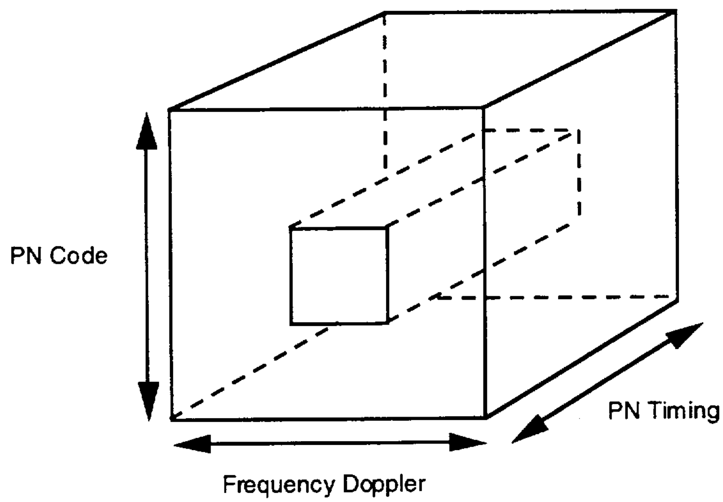


Figure 4-1 Acquisition Search Space

The goal is to reduce the search volumes by all means practical. Given that the search volume is decreased; then parallel processing can be used to speed the search process without compromise to the probability of a correct acquisition.

Latitude Dependence: The acquisition time is also a function of other variables such as latitude as shown in Figure 4-2.

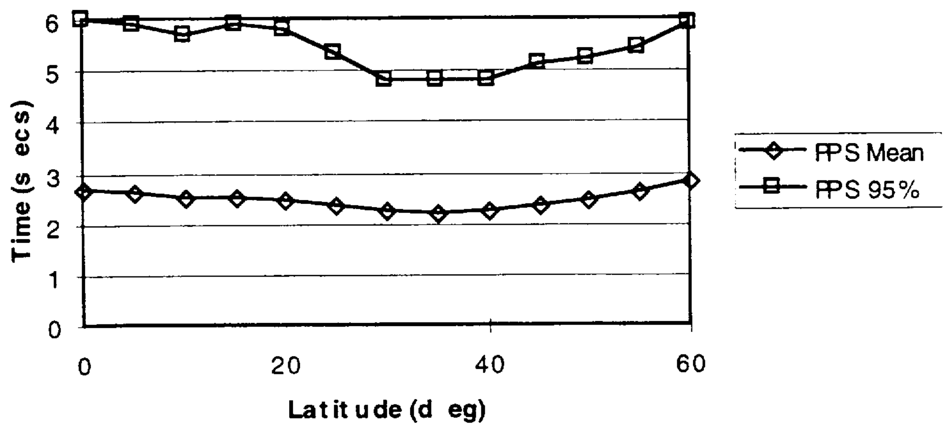


Figure 4-2 Acquisition Time as a function of Latitude

The Search is latitude dependent due to the orbital geometry. Less satellites are visible at high latitudes.

Several approaches are used to attain this apparent rapid response. Parallel searching speeds the search process materially. The Ground Operations Control Center (GOCC) is also involved in speed up of the search process. The search times shown in Figure 4-2 apply if the pilot frequency is known. The GOCC can help by assigning the pilot frequencies near the center of the band in a given geographical area. This basically collapses the search frequency dimension shown in Figure 4-1 to the uncertainty due to Doppler.

Summary: This means that if the User Terminal stays in its home gateway area the acquisition process can be very quick. If the pilot frequency is unknown due either to poor assignment by the GOCC or due to the User Terminal roaming to another gateway area, the search time can extend. Basically the maximum search time is the number of pilots that must be searched times the time to acquire as shown in Figure 4-2. The mean time to acquire is roughly half of the maximum time to acquire.

4.5 Forward CDMA Channel

An example assignment of the code channels transmitted by a gateway is shown in Figure 4-3. Out of the 128 code channels available for use, the example depicts the Pilot Channel (always required), one Sync Channel, seven Paging Channels (the maximum number allowed), and 119 Traffic Channels of Rate Set 1. Another possible configuration could replace all the Paging Channels and the Sync Channel one for one with Traffic Channels of Rate Set 1, for a maximum of one Pilot Channel, zero Paging Channels, zero Sync Channels, and 127 Traffic Channels of Rate Set 1.

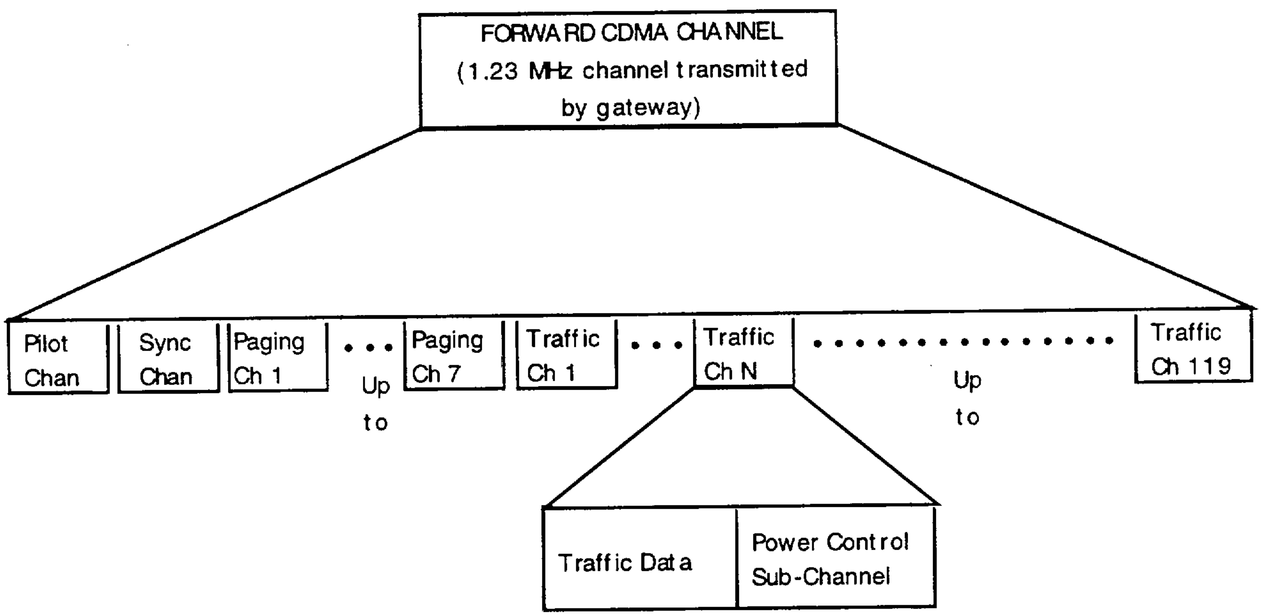


Figure 4-3 Forward CDMA Channel Transmitted by a Gateway

The forward CDMA channel consists of the Pilot Channel, one Sync Channel, up to seven Paging Channels, and a number of Forward Traffic Channels. Multiple Forward Channels are used in a Gateway by placing each Forward Channel on a different frequency.

The forward link Pilot, Sync and Paging Channel is generated as shown in Figure 4-4.

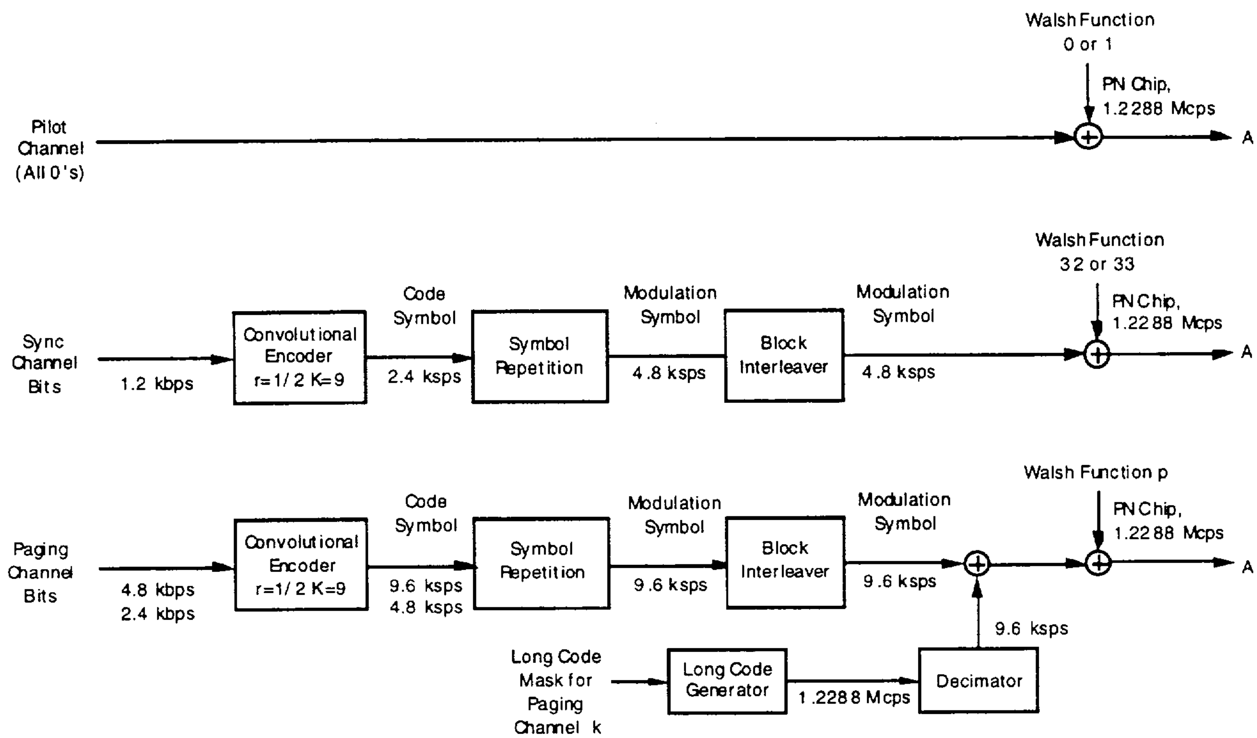


Figure 4-4 Forward Link Pilot, Sync and Paging Channel

The forward link is modulated as follows.

Pilot Channel: The Pilot Channel is transmitted continuously by the Gateway and is utilized by the User Terminals operating within the coverage area of the Gateway to acquire timing on the forward channel, to provide a phase reference for coherent demodulation and to provide signal strength comparisons that govern when to do hand offs. The Pilot channel will generate an all zeros Walsh Code. This is combined with the short code used to separate signals from different Gateways and different satellites. The pilot channel is modulo 2 added to the 1.2288 Mc/s short code and is then QPSK spread across the 1.23 MHz CDMA bandwidth. The User Terminal monitors the pilot channel and assesses its signal strength at all times except when it is operating in the slotted mode.

Sync channel: The Sync Channel is an encoded, interleaved, spread and modulated spread spectrum signal that is used by the User Terminals operating within the gateway coverage area to acquire initial time synchronization. The Sync channel will generate a 1200 b/s data stream that includes (1) time, (2) transmitting Gateway identification, (3) assigned paging channel. This is convolutionally encoded and Block Interleaved to combat fast fades. The resulting 4800 symbols per second data stream is modulo two added to the sync Walsh code at 1.2288 Mc/s and the short code. It is then QPSK spread across the 1.23 MHz CDMA bandwidth.

Paging Channel: The Paging Channel is used for transmission of control information and pages from a gateway to a user terminal. The paging channel is convolutionally encoded at Rate = 1/2, Constraint length K = 9 and block interleaved. The resulting symbol rate is combined with the long code. The paging channel and the long code are modulo two added and provided to the symbol cover where the resulting signal is modulo two added to the 1.2288 Mc/s Walsh Code and the short code. The results are then QPSK spread across the 1.23 MHz CDMA bandwidth.

Forward Traffic Channel: The Forward Link Traffic Channel - Rate Set 1 is generated as shown in Figure 4-5.

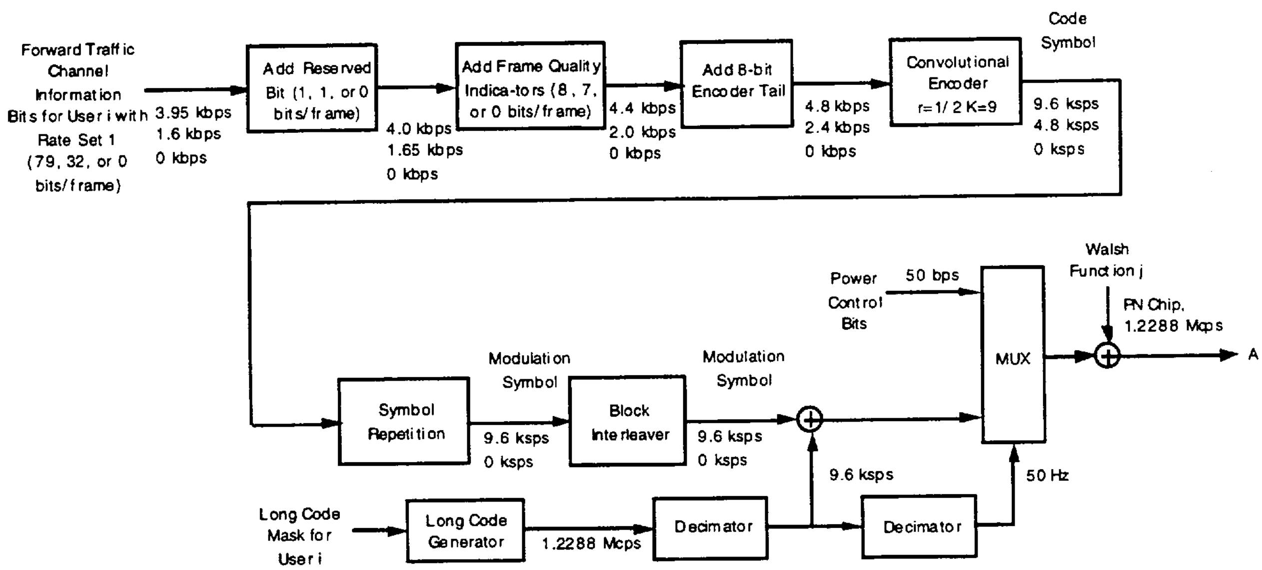


Figure 4-5 Forward Link Traffic Channel - Rate Set 1

The Forward Link Traffic Channel - Rate Set 2 is generated as shown in Figure 4-6.

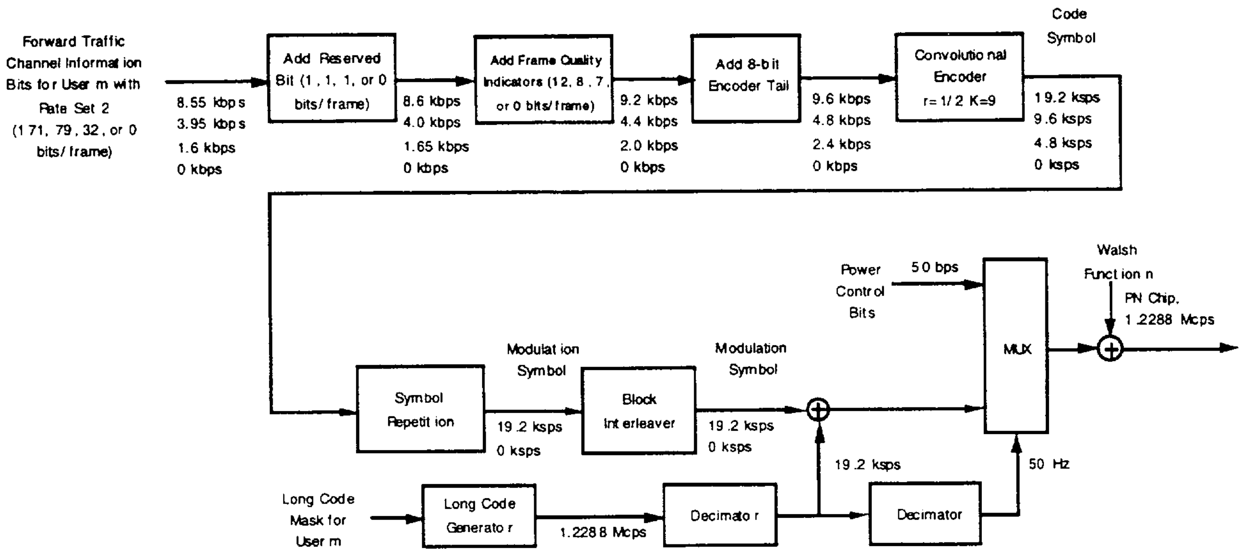


Figure 4-6 Forward Link Traffic Channel - Rate Set 2

The Vocoder encodes the voice into a PCM data stream. The data stream is the processed as shown in Figure 4-5. The resulting data stream is then power controlled and modulo two added to the 1.2288 Mc/s Walsh code and the short code. The results is then QPSK Spread across the 1.23 MHz CDMA communication channel bandwidth. The Globalstar Air Interface will support two different rate sets from the Gateway. Within a rate set, the Globalstar Air Interface (GAI) will support variable data rate operation. When the high rate shown in Figure 4-5 is used, two Walsh codes are required.

Modulation and Spreading: Modulation and spreading is applied as shown in Figure 4-7.

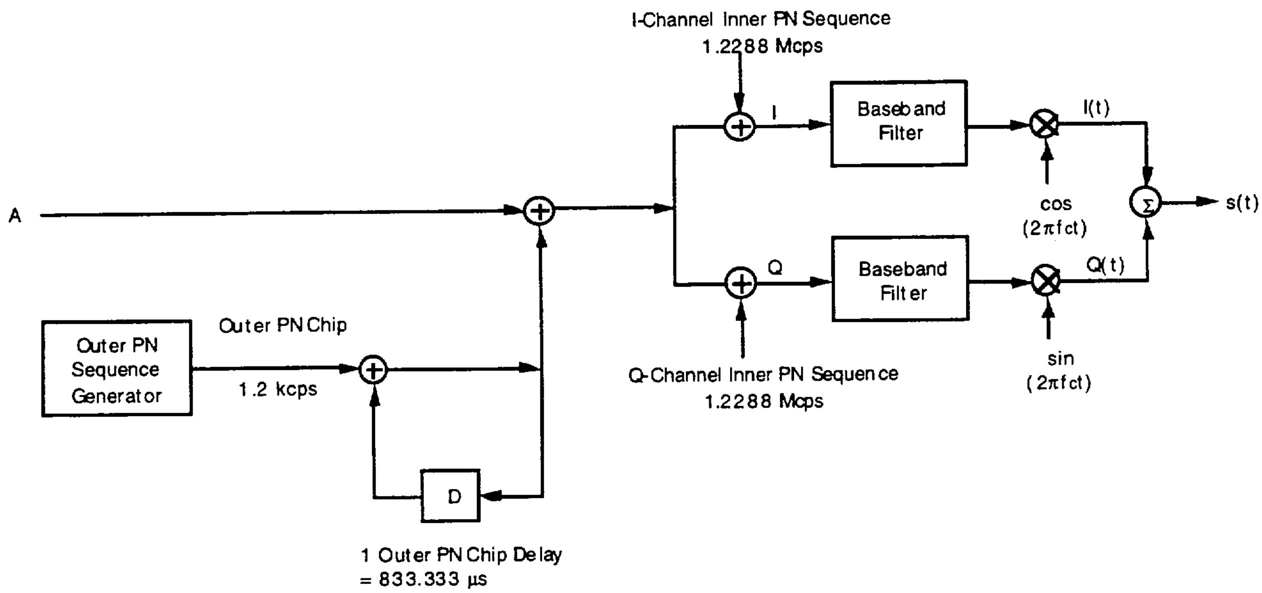


Figure 4-7 Forward Link Modulation and Spreading

The spreading sequence structure for a given Globalstar CDMA channel is comprised of an inner PN sequence pair and a single outer PN sequence. The inner PN sequence has a chip rate of 1.2288 Mcps and a length of 1024, while the outer PN sequence has an outer chip rate of 1200 outer chips per second and a length of 288; the outer PN sequence modulates the inner PN sequence to produce the actual spreading sequence, lasting exactly 240 msec. Exactly one inner PN period is contained within a single outer PN chip. The spreading and modulation process applies to all forward link channels.

Path Identification: It is necessary to know the path that a signal has taken in order to facilitate gateway sharing of a forward CDMA channel and to support diversity combining. Path information is derived from the pilot signal.

> **Gateway:** Two gateways can share a forward CDMA channel. Pilot channel 0 is assigned to the first gateway can be allocated more power and serve as a beacon pilot within the beam to increase acquisition speed of the User Terminals in the beam.

> **Orbital Plane:** The inner PN sequence is used to identify the orbital plane. The length of the sequence is 2^{10} chips at a chip rate of 1.2288 mcps. there are 24 repetitions every 20 ms.

> **Satellite:** Each satellite is identified by a pilot PN sequence.

> **Beam:** Each Satellite Beam has a unique outer PN sequence offset.

Beam Juxtaposition: Each Adjacent beam within a satellite is identified by a unique inner PN sequence offset. Inner PN offsets are reused among non adjacent beams of a satellite.

Sharing of Forward CDMA Channel: It is also possible for two gateways to share a single subbeam. This mode is used when a gateway's traffic needs only a fraction of a subbeam and each gateway must supply a separate pilot. In particular, this mode is useful when a satellite beam is moving from gateway service area A to gateway service area B. Gateways A and B can then share a subbeam as the traffic from A is ramping down and the traffic from B is ramping up. When sharing the first gateway will use all even-numbered code channels, and the second gateway will use all odd-numbered code channels.

The Pilot Channel of the first gateway is transmitted on code channel 0. The Sync Channel associated with this Pilot Channel, if it exists, is transmitted on code channel 32. The Primary Paging Channel (Paging Channel number 1) of the first gateway, if it exists, is transmitted on code channel 64. Paging Channel numbers 2, 3, 4, 5, 6, and 7, if they exist, are transmitted on code channels 2, 66, 4, 68, 6, and 70, respectively.

The Pilot Channel of the second gateway is transmitted on code channel 1. The Sync Channel associated with this Pilot Channel, if it exists, is transmitted on code channel 33. The Primary Paging Channel (Paging Channel number 1) of the second gateway, if it exists, is transmitted on code channel 65. Paging Channel numbers 2, 3, 4, 5, 6, and 7, if they exist, are transmitted on code channels 3, 67, 5, 69, 7, and 71, respectively.

4.6 Return Link CDMA Channel

The Reverse CDMA Channel is composed of Access Channels and Reverse Traffic Channels as shown in Figure 4-8.

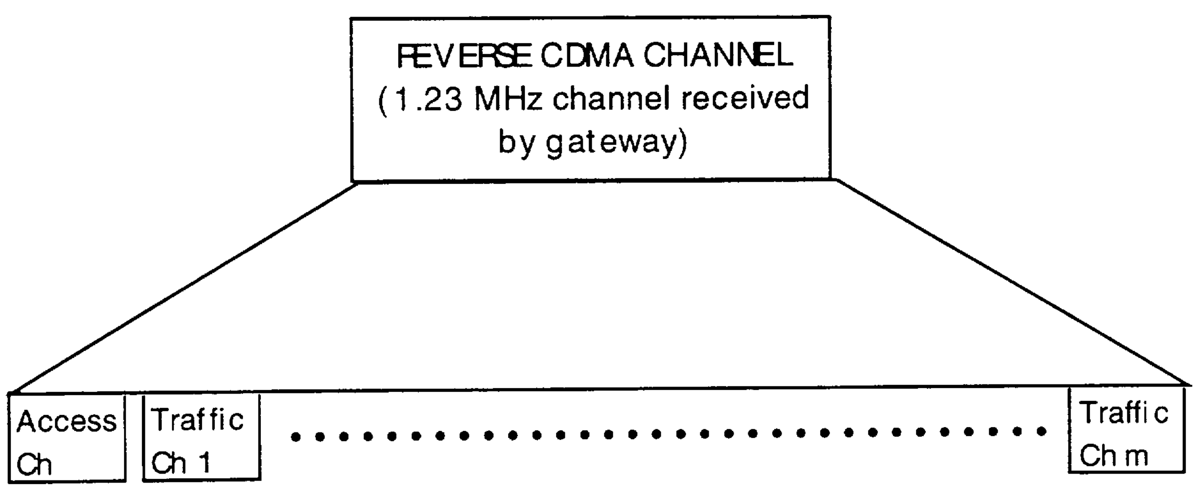


Figure 4-8. Reverse CDMA Channels Received at a Gateway

Figure 4-8 shows an example of all of the signals received by a gateway on the Reverse CDMA Channel. These channels share the same CDMA frequency assignment using direct-sequence CDMA. Each Traffic Channel is identified by a distinct user long code sequence. Each Access Channel is identified by its quadrature spreading codes and the gateway identification in the long code mask. Multiple Reverse CDMA Channels on different frequencies may be used by a gateway.

The Reverse CDMA Channel has the overall structure shown in Figure 4-9 and Figure 4-10. Data transmitted on the Reverse CDMA Channel is grouped into 20 ms frames. All data transmitted on the Reverse CDMA Channel is convolutionally encoded, block interleaved, modulated by the 64-ary orthogonal modulation, and direct-sequence spread prior to transmission.

Access Channel: The Access Channel is used by the User Terminal for communicating to the Gateway. It is used for short signaling message exchanges such as call origination, response to pages, and registrations. The Access channel is a slotted random access channel. Each Access Channel, as shown in Figure 4-9, is identified by a distinct Access Channel long code sequence.

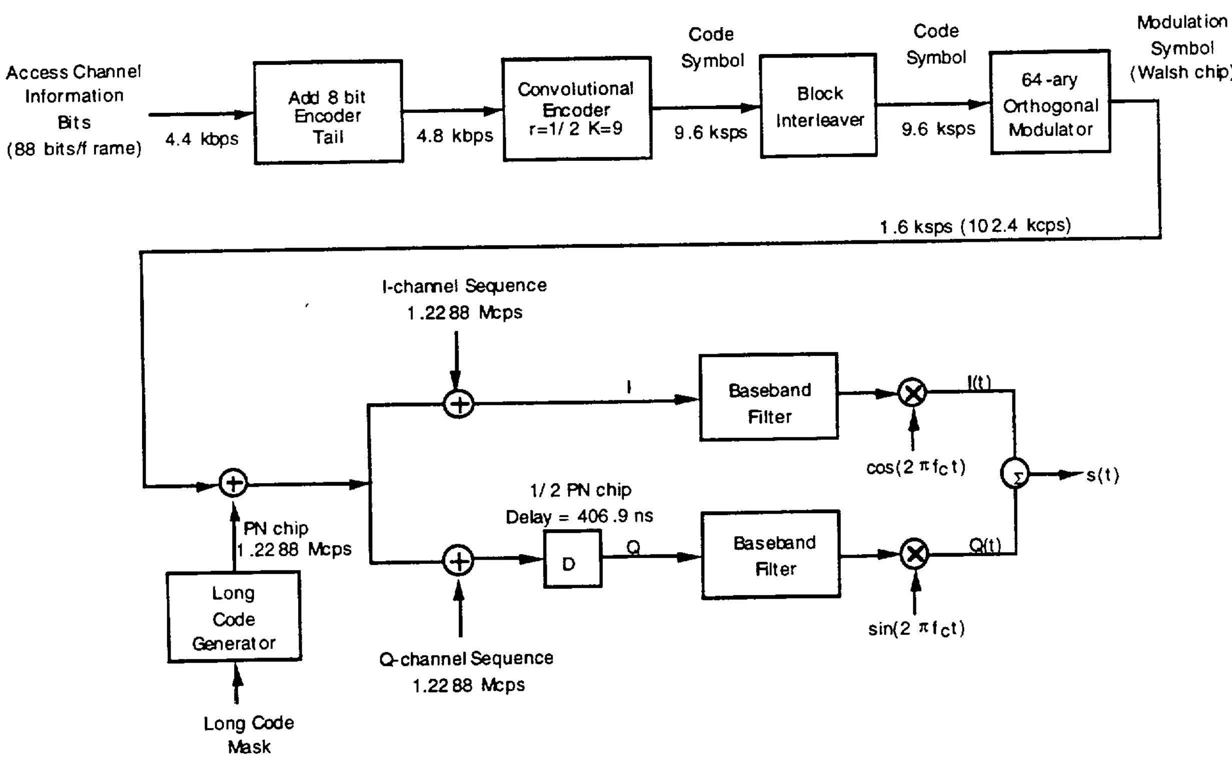


Figure 4-9 Return Link Access Channel

Return Link Traffic Channel: Each Traffic Channel is identified by a distinct user long code sequence as shown in Figure 4-10.

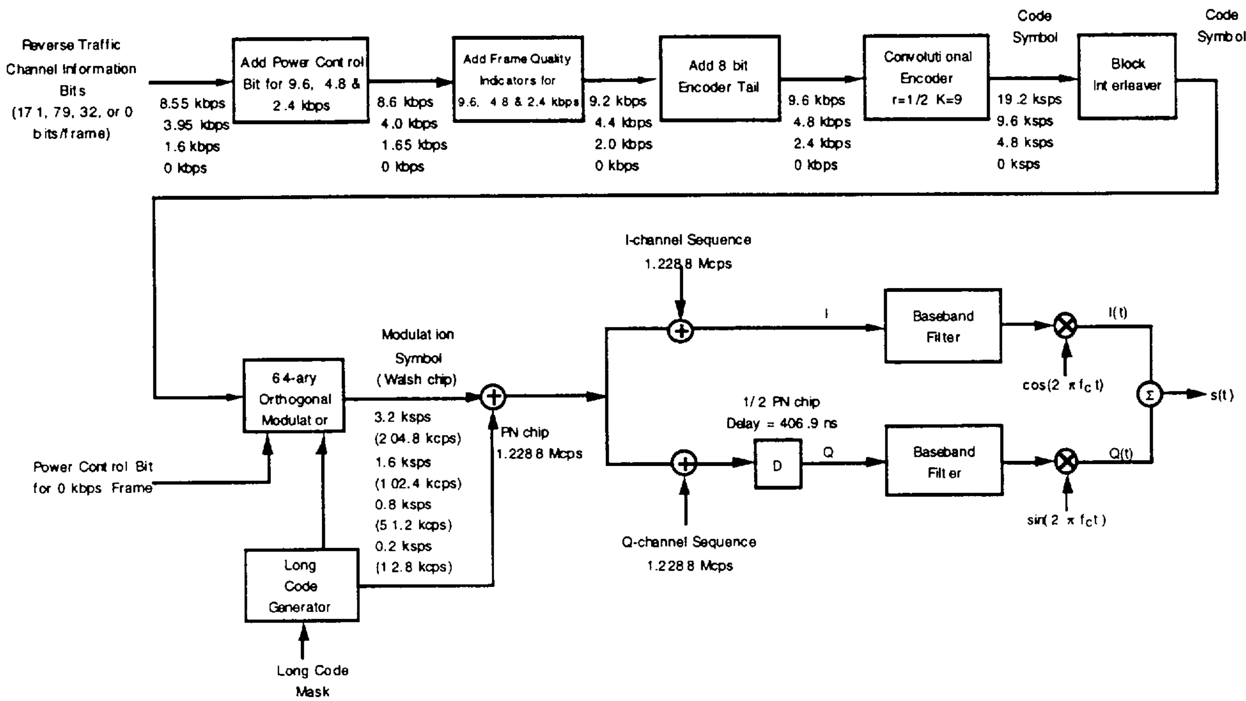


Figure 4-10 Return Link Traffic Channel

The rate 1/2 code used for the Globalstar return link takes advantage of longer coherence times for the channel and will perform better in the Additive White Gaussian Noise (AWGN) channel typical of Globalstar. The rate 1/3 code, typically used in terrestrial CDMA, performs better in a Rayleigh channel because it offers greater diversity. The return link does not use the randomizer used in cellular CDMA. It uses a continuous transmission with code symbol repetition to maintain the same rate.

4.7 CDMA End to End Performance

There are a number of other CDMA topics that span both the forward and return links.

Time: All gateway digital transmissions are referenced to a common CDMA system-wide time scale that uses the Global Positioning System (GPS) time scale, which is traceable to and synchronous with Universal Coordinated Time (UTC). GPS and UTC differ by an integer number of seconds, specifically the number of leap second corrections added to UTC since January 6, 1980. The start of CDMA System Time is January 6, 1980 00:00:00 UTC, which coincides with the start of GPS time. System Time keeps track of leap second corrections to UTC but does not use these corrections for physical adjustments to the System Time clocks.

When receiving the paging channel, the User Terminal is within 1.0 microseconds of the earliest arriving signal used for demodulation.

Link Delay: Delay through a link is an important end to end parameter. It becomes particularly important in conversations when one party attempts to interrupt the other. The LEO orbit satellites will provide a much more benign delay than the more common synchronous orbit satellites. Delay is held to 150 ms in each direction. There is a design margin, of course. Figure 4-11 summarizes the delay for the forward link.

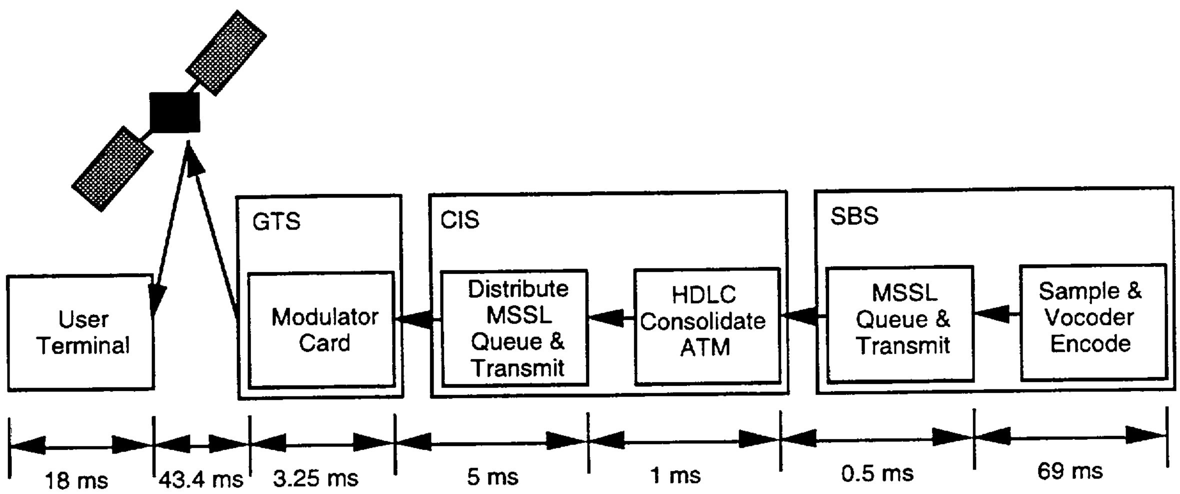


Figure 4-11 Forward Link Delay Budget

Figure 4-12 illustrates the delay budget for the return link.

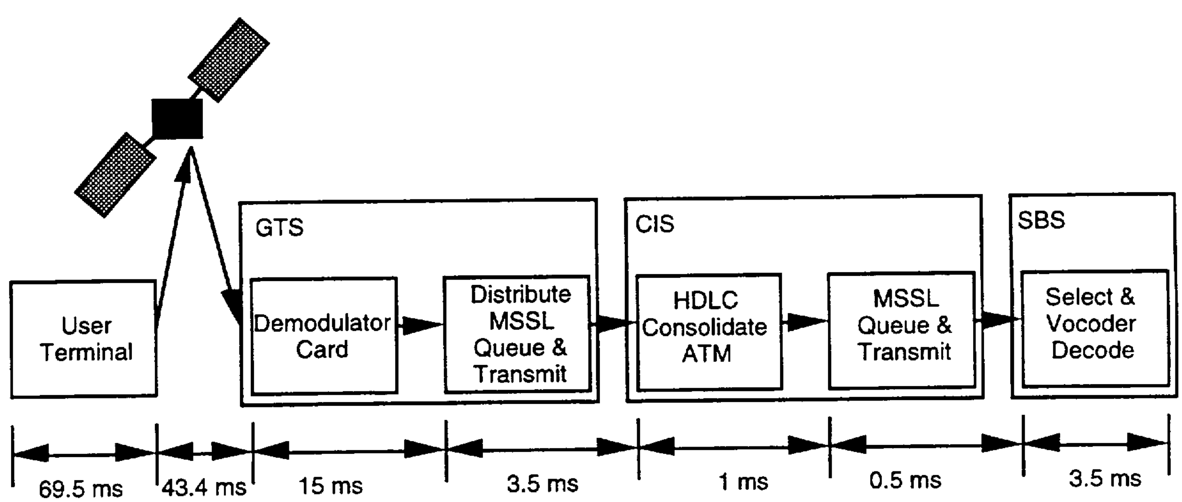


Figure 4-12 Reverse Link Delay Budget

Tradeoffs are possible to improve voice quality, improve capacity or other system level parameters at the expense of end to end delay.

Vocoder: The Globalstar vocoder is uses a Code Excited Linear Prediction (CELP) algorithm with a structure similar to that used by the IS-96 coder but with several improvements. The percentage of time between rates of 0 b/s and 8,550 can be adjusted. Voice quality can be traded for capacity. Voice quality can also be traded for signal delay. The Globalstar design will operate with high voice quality when the capacity is not stressed and when the links can be closed. If the links cannot be closed or if the capacity is being stressed, voice quality can be sacrificed. Vocoder rates and resulting channel rates are shown in Table 4-1.

Table 4-1 Vocoder and Channel Rates

Configuration	Vocoder Rate	Channel Rate	Purposes
Rate 1	8,550	9,600	High Quality Option
Rate 1/2	3,950	4,800	Baseline Voiced
Rate 1/4	1,750	2,400	Baseline Unvoiced
Rate 1/8	800	1,200	Baseline Pauses/Background

Some improvements are envisioned that may increase capacity. In the forward direction, a zero rate can be used. Since this is the coherent direction, the User Terminals can stay locked on by using the pilot. This is the direction that constrains capacity. In the return direction, some energy must be transmitted to keep the receiver locked since the return direction is not coherent.

Power Control: The objective of power control is to transmit the minimum power necessary in order to achieve a given quality of service. Quality of service could be specified in terms of the Frame Error Rate (FER) and the probability of outage. Accurate power control reduces the transmit power needed to achieve a given quality of service objective, thereby prolonging battery life of portable phones. In addition, it also enhances capacity. Figure 4-13 is a simplified end to end diagram to support the description of power control.

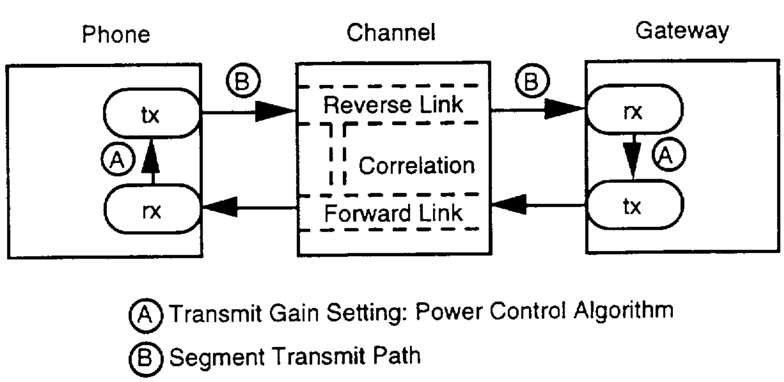


Figure 4-13 Power Control Simplified Diagram

Power Control and time to acquire are intimately related as shown in Figure 4-14.

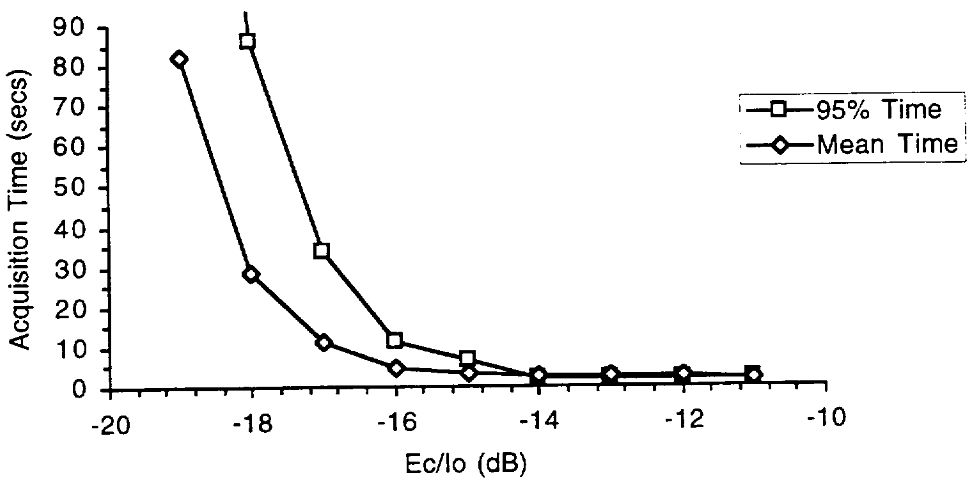


Figure 4-14 Acquisition Time as a function of Eb/No

Once the target for Eb/No is established, the task of power control is to maintain the desired Eb/No. Acquisition time will extend if the Eb/No is not well established correctly or controlled to the desired value. In order to achieve the power control there are two loops.

Inner Loop: The inner loop controls to the target Eb/No on a one bit per frame basis.

Outer Loop: The outer loop adjusts the target Eb/No based on the measured Frame Error Rate.