Globalstar for the Military

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ABSTRACT

Globalstar, a new satellite-based mobile voice/data telephone service, is being planned by LQSS for operation in 1998. It will let military personnel, using handheld, ship-board, or vehicular mobile terminals in even the most remote areas of the world, to stay in contact with each other and with personnel who are on established communication networks. A constellation of 48 low-earth orbiting (LEO) satellites and an advanced method of digital signal formatting will provide low-cost and reliable voice, data, fax and position-locating services to military personnel in most areas of the world. Globalstar will interoperate with existing local (domestic or foreign), long-distance, public, private, terrestrial-cellular, DoD, and specialized telecommunications networks. The system will permit the military, for its general purpose communications, to share with commercial MSS (Mobile Satellite Services) at low cost.

This paper includes an overview of the Globalstar system and describes possible DoD applications.

1. INTRODUCTION

DoD has established highly survivable communications systems for serving the needs of the U.S. Armed Forces in war fighting conditions. However, most DoD communication takes place during times of peace and outside of regions of conflict. For that reason, the DoD places a significant volume of traffic over commercial telecommunications networks. Geosynchronous satellites and under-sea cables have extended these networks world-wide between regions served by wireline telephone companies. Terrestrial cellular radio has expanded the scope of these networks to mobile users, typically in populated urban centers.

With Globalstar, DoD will have the opportunity to extend the reach of its telecommunications networks to the most remote regions of the world, without being constrained to telephones connected directly to the wire-line networks. Communications equivalent to terrestrial cellular radio will be available over areas vastly greater than those served by terrestrial cell sites. While not intended for war fighting applications, the Globalstar satellite system will serve as a backup and supplement to military communications systems.

2. SYSTEM DESCRIPTION

In the Globalstar world, from handheld, ship-board, and vehicular terminals, military and other DoD personnel will be able to place telephone calls from distant lands and seas to any telephone on existing telecommunications networks. (See Figure 1.) Personnel can be located and called, or can call any other handset or telephone in the world. One telephone number can be assigned to an individual, not a place. Digital signal formatting with spread-spectrum modulation will allow the ready application of DoD security measures such as STU-III telephones to an already private system.

The low altitude of the Globalstar LEO satellites permits the use of low-power handsets. Globalstar provides multiple-satellite coverage to allow true "space"

diversity to mitigate against blocking and shadowing, to enhance traffic call capacity, and to provide fail-safe operation. Globalstar takes advantage of CDMA (Code-Division Multiple Access) call transmission format to increase spectrum usage. Globalstar includes a simple satellite design, which does not rely upon expensive, less flexible, and potentially less reliable satellite-to-satellite call transfers. The Globalstar ground segment can be either shared commercial, or dedicated military, fixed-site gateways, or be transportable gateways to serve special contingency operations anywhere on earth. Gateways will serve mobile stations within a range of many hundreds of kilometers and will provide access to terrestrial networks either directly or by way of a fixed satellite service link.

2.1 Mobile Terminals

Three basic categories of Globalstar mobile terminals will be handheld, vehicular, and fixed. All Globalstar mobile terminals will share essentially the same signal processing and RF characteristics, so that they will appear to the Globalstar LEO satellites and gateways as equivalent terminals, although type identification can be associated with the terminal identification in network control.

Mobile terminals can be built with dual-mode – and even multi-mode – operation for compatibility with any terrestrial radio network, including existing analog cellular radio in the USA and other parts of the world.

Handheld Terminals

Handheld terminals will be in appearance and operation much like terrestrial cellular radio handsets, with a few notable differences. A low-power transmitter of approximately 0.2 watt average power will maximize both battery life and safety. A patch antenna will provide dual-frequency-band operation: L-band for the up-link and S-band for the down-link. It will have a horizontal omni-directional and vertical hemispherical pattern for communicating with the LEO satellites as they pass overhead. The antenna will be capable of being extended to avoid propagation blockage by the user's head and to minimize radiation effects, and it will be collapsible for stowing.

Platform-Mounted Terminals

Globalstar mobile terminals will be equally applicable for vehicle operation, for shipboard operation, or for aircraft operation. The primary differences between handsets and platform-mounted mobile terminals will be in the packaging and the power supply. Packaging will separate the antenna from the transceiver to mount the antenna external to the platform envelope. Antennas could be mounted to the top of masts to clear local trees or superstructure obstacles. Aircraft antennas would have to be integrated with the airframe, but the small-sized, patch antennas will allow for flush, surface mounting. Terminal power will be obtained from the vehicle battery and/or power system.

Fixed Terminals

Globalstar fixed terminals will be those intended for permanent installations in remote regions having no access to terrestrial telecommunications networks. Power could be derived from solar panels or other local power source. The antenna, the solar panel, and terminal would be packaged for pole mounting, with the antenna high enough to clear the adjacent trees.

2.2 Satellites

Constellation

The Globalstar LEO satellite constellation will be comprised of 48 satellites arranged in 8 orbital planes. (See Figure 2.) The circular orbital planes will be inclined 52° from equatorial. The constellations are designed to provide at least one satellite in view above 10° elevation angle for all latitudes up to 70°. Multiple satellite coverage will be nearly always available. The circular orbit altitude will be approximately 1400 kilometers (756 nautical miles) with a period of 114 minutes.

Satellite Communications Payload

The Globalstar LEO satellites will be small in size and uncomplicated. The communications payload is designed to relay signals between the user terminals and the gateway earth stations through linear "bent-pipe" transponders. Communications with the Globalstar gateway earth stations will be by way of separate C-band frequencies for both the up and down-links.

For communication with mobile user terminals, a satellite will have multiple antenna beams, formed by flat arrays of active and passive antenna elements, which will produce multiple footprints on the surface of the earth. Each footprint will provide L-band up-link and S-band down-link communication. The ensemble of a single satellite's footprints will cover an area on the surface of the earth of approximately 26×10^6 km^2 (10×10^6 mi^2), where a user at a range of 2900 km (1800 mi) will still view the satellite at minimum of 10^o elevation angle.

Satellite Operational Control

Two Globalstar Satellite Operations Control Centers, to be located on the east and west coasts of CONUS, will provide for constellation management, with 1) ephemeris determination, 2) planning and scheduling operations for active, retired, and spare satellites in orbit, and 3) in-orbit testing. T&C (Telemetry & Command) stations, collocated with selected gateways to provide worldwide coverage, will accomplish the control of the satellites during launch and movement to their assigned orbits, and continue to provide C&S (Control & Status) communication during operation.

2.3 Gateway Earth Stations

Globalstar gateway earth stations will provide access between the Globalstar system and other telecommunication systems, such as PSTN (Public Switched Telephone Networks), PTT (Postal Telephone and Telegraph networks in foreign countries), PCN (Personal Communications Networks), FTS-2000, DISN (Defense Information System Network), and FSS (Fixed Satellite Services). Globalstar gateways will serve as Globalstar network nodes for routing signals through satellites and beams to the designated user terminals.

Commercial gateways will be owned and operated by the providers of MSS (Mobile Satellite Services) for geographically-defined service areas. With the diversity inherent in the Globalstar system, more than one service provider can operate in the same or overlapping service areas. DoD and other agencies could own and operate their own gateways, typically at bases in remote regions of the world, or they could share gateway functions with friendly foreign and domestic commercial operators. Transportable gateways could provide autonomous in-theater service to rapidly-deployed forces anywhere on earth (useful up to 70^o latitude).

RF Subsystem

Three 2.4-meter antennas at each gateway site will track three satellites in view at any one time. An RF subsystem will consist of LNA's and HPA's mounted on an antenna assembly and, within the gateway equipment shelter, frequency synthesizers will provide the frequency division multiplexing for the feeder-link signals while modems will be provided for every active satellite beam.

Routing Matrix for Handoff

Routing traffic to and from mobile terminals through the several satellites in view and through selected active beams on each satellite will be accomplished by a baseband routing matrix, connecting modems to traffic circuit units.

Gateway traffic circuit units, one for each data or voice conversation, will provide for handoffs from satellite to satellite and from beam to beam, will encode/decode the CDMA waveform at baseband to/from analog voice or to/from data, and will provide the I/O to the external world. Incorporating

"make-before-break" combining (rather "break-before-make" switching), Globalstar handoffs will be seamless to data communications, without the switching disruptions currently experienced with data communication in analog terrestrial cellular radio operation.

RDSS

Globalstar Gateways will provide for Radio Determination Satellite Service (RDSS) to locate user terminals on the surface of the earth. From two successive round-trip time delay measurements of a gateway-user-gateway signal, the user location may be calculated by triangulation. Location accuracy of less than 1 km will be possible.

2.4 CDMA, Frequency Division, and System Capacity

The multiple access scheme to be employed by Globalstar is CDMA (Code Division Multiple Access) which will be used in combination with frequency division. The filtering and signal processing technique will allow the different signals from many simultaneous users that want to use the same electromagnetic spectrum to have their signals separately received and demodulated without crosstalk. The scheme includes directive antennas on the satellites and at the gateways so that signals propagate to the intended user terminals but not to (very many) unintended user terminals.

Voice conversations to be transmitted are first analog-to-digital converted by a variable-rate vocoders to reduce the required transmission bandwidth for purposes of traffic capacity expansion and to enhance the signal-to-noise ratio quality and reduce the transmitter power required for each conversation.

CDMA

CDMA is the best technique for providing spectrum-efficient, economical, and quality digital Mobile Satellite Service. CDMA is a modulation and multiple-access spread-spectrum communication scheme, a well-established technology for military communications that has been applied only recently to digital cellular radio communications and other advanced wireless technologies.

Each digital signal to be placed into a frequency channel will be coded with a different higher-data-rate pseudorandom binary sequence during the modulation process, which will spread the signal spectrum over a wider bandwidth. In a frequency channel carrying multiple CDMA signals, interference will be accepted but controlled with the goal of increasing system capacity. CDMA does this effectively because it is inherently an excellent anti-interference waveform.

The CDMA signal format and network interfacing for Globalstar is derived from the latest, tested and demonstrated Qualcomm, Inc., terrestrial-cellular-radio technology, which places Globalstar in a significantly advanced state of development.

Frequency Division

In the Globalstar system, the frequency band available to MSS for user-satellite communication will be divided into smaller frequency channels, where each channel carries the combination of multiple distinctly different conversations, each of which can be distinguished by means of CDMA. (See Figure 3.) The CDMA codes can be reused in adjacent frequency channels, which provides for interference coordination and avoidance.

The gateway-to-satellite feeder links use another level of frequency diversity to carry the many frequency channels, each with multiple summed CDMA signals, to and from the plurality of satellite beams of the several satellites. Polarization diversity is employed on the feeder links to reduce the required bandwidth by half.

System Capacity

The capacity of the Globalstar system will be the capacity that can be carried by the sum

total of all the Globalstar satellites at one time. Predicting traffic loading is a statistical exercise, because some of these satellites will be over minimal traffic regions and some over heavy traffic areas, where heavy traffic areas will only present a maximum load on a satellite at specific times of day (e.g., rush hours) or possibly during specific events (e.g., military contingencies). The capacity of Globalstar in CONUS will be 6500 duplex circuits available 100 percent of the time and more than 100,000 circuits world-wide.

2.6 Propagation Issues and Diversity

The Globalstar system is designed to have several satellites in view of one mobile terminal at one time, to provide the user the opportunity to transmit and receive by way of the satellite with the best available signal, or to combine all available signals to produce an even better signal. In situations where a particular user-satellite path may be blocked by a structure or shadowed by trees (See Figure 4.), Globalstar satellite diversity will provide the user access to a second or third satellite in view. This diversity scheme will achieve a high degree of circuit availability and will allow each mobile user terminal to operate at a lower power level and with longer battery life than would be possible in order to achieve the same high availability with more powerful transmitted signal levels. In fact, building blockage could preclude communications without Globalstar's satellite diversity at almost any reasonable and safe power level.

Both the Globalstar Gateway and the user terminal will be designed to accommodate doppler shifts due to satellite motion, both in the frequency and in the data rate. Doppler effects associated with the feeder links can be pre-corrected. The LEO satellite two-hop latency delay of less than 25 milliseconds, considerably less than the 250 milliseconds of a geosynchronous satellite link, will be imperceptible during voice conversations.

2.7 Network Management

It is in the realm of network management that DoD requirements may be most distinguished from commercial requirements. DoD will operate in a manner similar to a private sub-network within the overall Globalstar system. Capabilities will be added for special DoD handling of user access, call processing, and call management, as required for control of the telecommunications resources and for security considerations. Secure DoD controlled user access to the DoD sub-network will be achieved by dedicated DoD data bases, centrally maintained by a DoD Network Access Control Center. Domestic and foreign commercial Globalstar operators throughout the world will maintain a network control system that will ensure that service will be available to the DoD sub-network.

This management function also includes C&S (Control & Status), performance monitoring (of traffic call completion and quality), and accounting (billing) functions. Much of this management will be accomplished in software by means of hardware storage media for automatic processing but with display to operators of the Globalstar system.

Network Control Center

Globalstar Network Control Centers will be owned and operated by Globalstar, to provide for a centrallized management of the telecommunications assets of the Globalstar system. These centers will balance the overall traffic requirements or a large geographical and/or political region by assigning frequencies and codes to Network Coordination Gateways.

Network Coordinating Gateway

Distributed network control functions, in addition to those performed by centralized Globalstar Network Control Centers, will also be performed at certain operator-owned Globalstar Gateways, in which case they will be identified as Globalstar Network

Coordination Gateways. For the operator's service area, this will include the control of internal network access by Globalstar mobile terminals, and control of external access at the interfaces with other telecommunications networks.

Internal access by Globalstar mobile terminals assigned to DoD operations and control of external access of DoD networks may be placed under the direct control of DoD personnel. The DoD network control hardware and software need not be collocated with a commercial Globalstar Network Coordination Gateways but may be located within the physical confines of a secure DoD facility, with interconnection with a commercial Globalstar Network Coordination Gateways or the Network Control Center by way of secure terrestrial or FSS (Fixed Satellite Service) data communications media.

Terminal Control

Terminal control includes the assignment of mobile terminals to DoD users and the operational procedures that apply to classes users. One terminal may be assigned to one user or to a group of users.

The internal access by Globalstar mobile terminals may be managed at a Network Coordinating Gateway by means of two data bases much in the same manner as is accomplished in a terrestrial cellular radio system. Two identifications, one communicated by the DoD mobile terminal itself and a second being the DoD user password, would be verified in the Home Location Register (directory data base) in a DoD Network Access Control Center. The Home Location Register maintains records of all legitimate users within the operator's local service area. Authorization to use the Globalstar network will be returned to the user terminal during call setup. Call priority and precedence as well as call restrictions could be associated with the user's password.

A second register will be identified as the Visitor Location Register, also typical of terrestrial cellular radio systems where it provides for the user "roaming" function. Upon entering a service area which is not the user's home service area, an extended call setup procedure must be completed for the initial call in the new service area, whereby the local Globalstar gateway must query the user's Home Location Register to authenticate the user. Thereafter, for the approved duration, visitor access will be authorized by means of the local Visitor Location Register.

Security

Globalstar will be inherently more secure than a typical communications system. The CDMA signal is spread by means of a pseudorandom code of noise-like nature over a bandwidth much wider than the bandwidth of a typical VHF or UHF radio. Each conversation will be encoded and must be decoded by a unique code phase of the long pseudorandom sequence. The relatively high LEO satellite doppler frequency and timing offsets will make it difficult to casually intercept a Globalstar conversation. Call authentication procedures will make it more difficult to place an unauthorized call.

Globalstar data communications rate of 2.4 kbps or more will support a digital STU-III telephone conversation.

3. MILITARY APPLICATIONS

Plain Old Telephone Service Extension

DoD is a major customer of POTS (Plain Old Telephone Service) for its day-to-day operations, using these ready means of communications to provide administrative, logistics, financial, and morale-boosting personal communications. These calls are predominately dial-up person-to-person rather than conference or party-line calls. Data communications traffic is increasing as the result of inexpensive FAX messaging and personal computer networking. The primary use of Globalstar will be to extend voice and data POTS to remote areas not served by terrestrial wire-line telephones or

by terrestrial cellular radio systems. As such Globalstar can extend the coverage of networks such as DISN to users overseas and to areas not adequately served by other terrestrial telecommunications systems.

U.S. Navy Application

It can be anticipated that a great demand for Globalstar services will be for U.S. Navy ship-to-shore and ship-to-ship communication. Globalstar will permit personnel aboard a ship (within range of a commercial or dedicated Globalstar Gateway) to place authorized calls to any telephone in the world simply by dialing a phone number on a Globalstar mobile terminal, which itself could be accessed through the ship's PBX. Likewise, a telephone call placed anywhere in the world can be placed to a mobile terminal aboard ship. Sailors on deck could use handheld terminals for ship-to-ship communications during maneuvers. Navy terminals could be used for communication with foreign ships which do not share a common military communications system with the U.S. Navy but which are equipped with commercial Globalstar handheld or ship-board terminals.

Gateways serving ocean regions could be those owned and operated by foreign PTT's in neighboring maritime countries, or those owned and operated by DoD which may be located at selected Navy bases, or ones that are installed aboard a (communications) ship serving a fleet at sea.

Transportable Gateway

A possibly more imaginative application would be in a contingency operation, where U.S. Armed Forces might be deployed to a remote region of the world where the local telecommunications network could not be relied upon. Globalstar mobile terminals could provide for logistics communications to back up rapidly moving Forces, where systems such as MSE have yet to be deployed. A single transportable Globalstar gateway could be deployed to serve the entire theater of operation. Such a gateway could be contained in a vehicular transportable shelter which, with the gateway antennas, could be brought to site aboard a military transport aircraft and be set up within hours. U.S. Armed Forces could be issued Globalstar handheld units prior to transfer and deployment in theater for use during amphibious landings or during the establishment of an airstrip. While the majority of the communications might be local to the operation, handheld terminals could be allowed access to any other telephone network in the world through a Globalstar transportable gateway by way of a collocated transportable VSAT FSS link.

Special Operations

In countries where the local PTT has established a Globalstar service area, or at least may be served by an adjacent country's Globalstar gateway, service to special operations and intelligence missions can be supported. These missions would utilize the ability of Globalstar to support clandestine, rapidly-moving, widely-separated units. Undoubtedly the secure digital communications capabilities of Globalstar would be utilized in these operations.

Disaster Relief Coordination

Of course, with portable communications capability, disaster relief coordination will be an obvious application. Operating by way of fixed Globalstar gateways remote from the disaster area, or by means of transportable Globalstar gateways flown in for the purpose, means can be provided for rapidly establishing emergency communication. Disaster relief teams within the disaster-affected area can report back to an unharmed area to convey accurate damage assessment followed by requests for food, shelter, and medical personnel and supplies. With ready access through Globalstar to the PSTN, victims of the disaster can make contact with worried relatives.

4. SUMMARY

Globalstar will extend voice and data telecommunications services to and from handheld, vehicular, and fixed user terminals. Globalstar will be an extension of the telephone network, a complementary service to terrestrial cellular radio, and will provide affordable and reliable voice, data, FAX, and position location to U.S. Armed Forces, other DoD, and Government personnel worldwide. This communication service will be extended over vast areas of the earth by way of a constellation of 48 Low Earth Orbiting (LEO) satellites. Gateway earth stations will provide interconnection between the LEO satellites and other networks, such as terrestrial telephone, radio, or satellite systems. Communication network control & status will be accomplished by means of a hierarchy of Network Control Centers and Network Coordinating Gateways, while satellite control & status will be provided by Globalstar for all system operators. Globalstar will provide an inexpensive way to break through geographical barriers of personal communications.

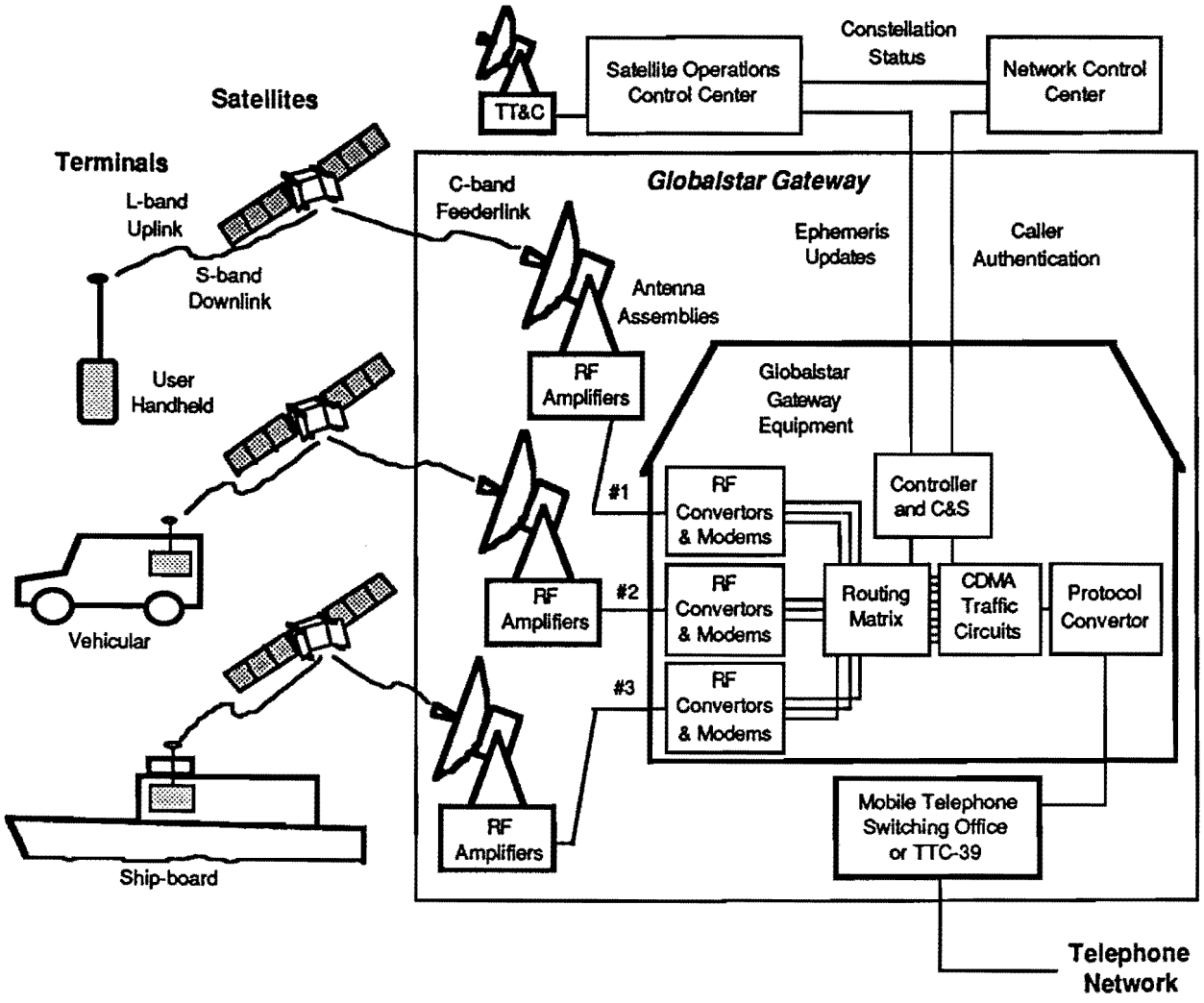

Figure 1 Globalstar Network Elements

Computer generated
view from
45° West longitude
20° North latitude

- 48 satellites in 8 orbital planes at 1,390 km altitude and 52° inclination
- High capacity, multiple satellite worldwide coverage between ±70° latitude
- Single-Satellite coverage area diameter 5,700 km (10° elevation angle)

Figure 2 Globalstar 48 Satellite Constellation

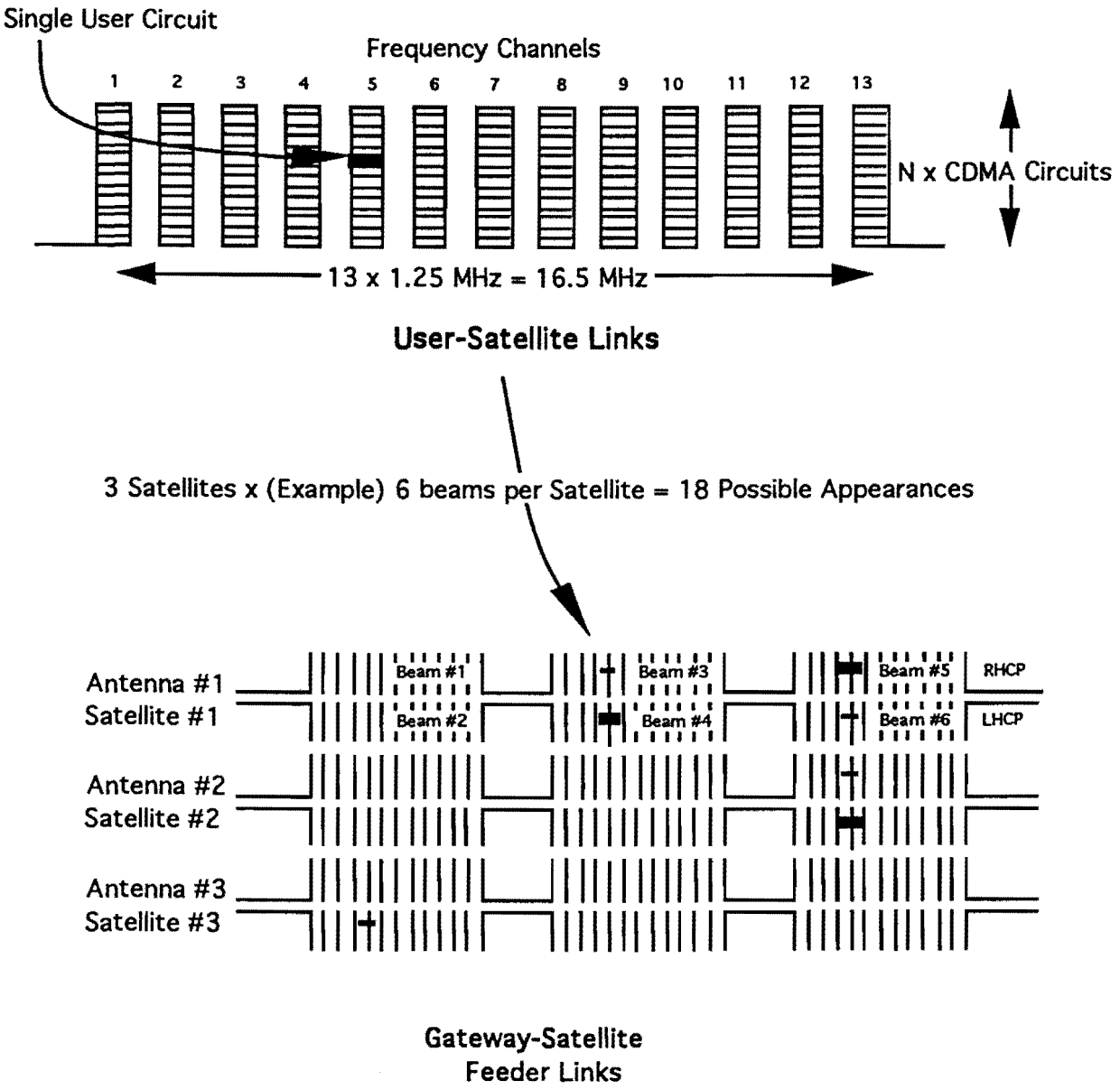

Figure 3 Globalstar Frequency Plan

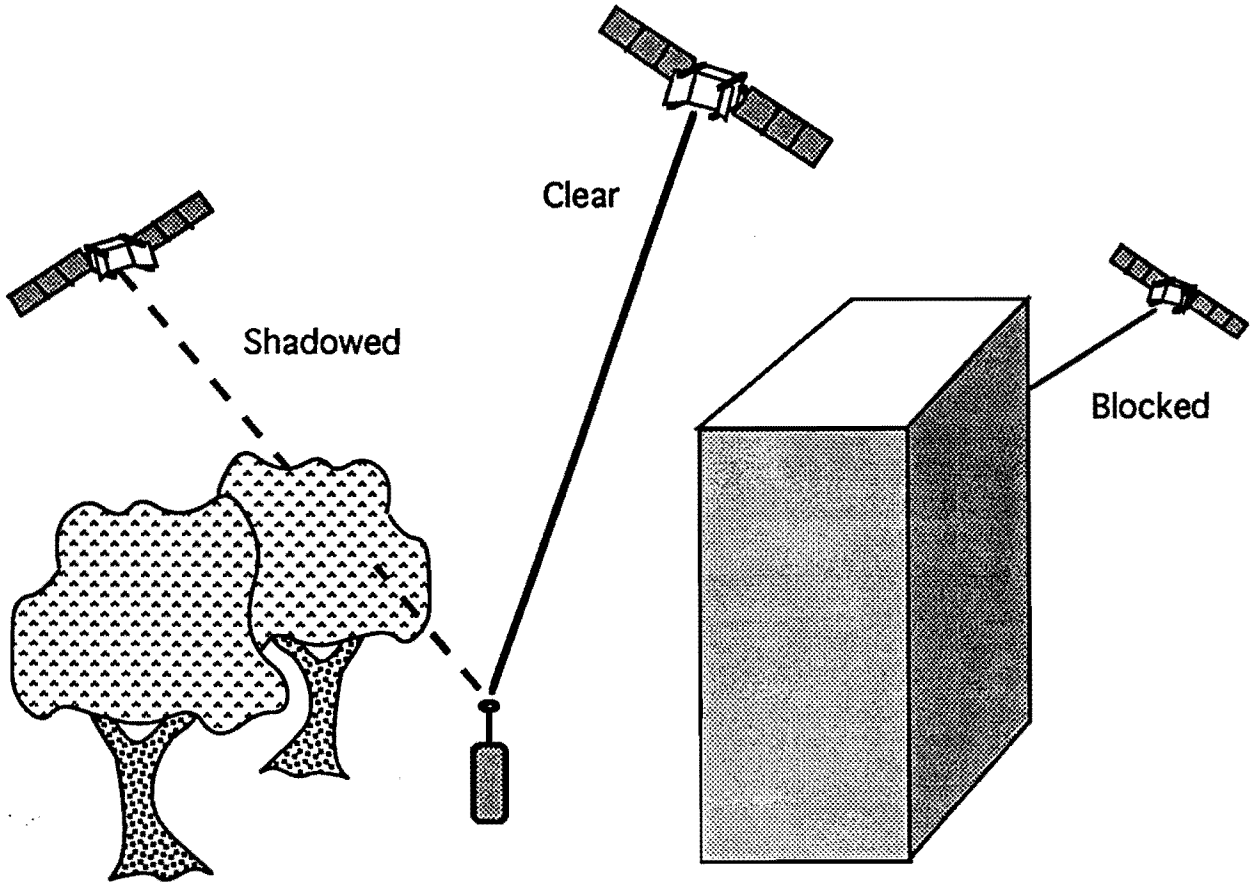

Figure 4 Globalstar Propagation Satellite Diversity