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The Iridium™ System
Personal Communications Anytime, Anyplace

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ABSTRACT

The Iridium system is designed to provide handheld personal communications between diverse locations around the world at any time and without prior knowledge of the location of the personal units. This paper will provide an overview of the system, the services it provides, its operation, and an overview of the commercial practices and relatively high volume satellite production techniques which will make the system cost effective.

A constellation of 66 satellites will provide an orbiting, spherical-shell, infrastructure for this global calling capability. The satellites act as tall cellular towers and allow convenient operation for portable handheld telephones.[1] The system will provide a full range of services including voice, paging, data, geolocation, and fax capabilities.

Motorola is a world leader in the production of high volume, high quality, reliable, telecommunications hardware.[2] One of Iridium's goals is to apply these production techniques to high reliability space hardware. Concurrent engineering, high performance work teams, advanced manufacturing technologies, and improved assembly and test methods are some of the techniques that will keep the Iridium system cost effective.

Mobile, global, flexible personal communications are coming that will allow anyone to call or receive a call from/to anyplace at anytime. The Iridium system will provide communications where none exist today. This connectivity will allow increased information transfer, open new markets for various business endeavors, and in general increase productivity and development.

OVERVIEW

Motorola is leveraging its expertise as the leading U.S. manufacturer of cellular equipment and a leading world manufacturer of mobile communications radios in the design of the Iridium system. The system will provide a digitally switched telephone network and a global dial tone allowing the user to place a call to or be called by any other telephone in the world. A user will have the convenience to call a portable telephone number and talk directly to an individual--global roaming is designed into the system and you call the handheld phone of a person, not just the place where a fixed phone is located.[3]

A key feature of the system is the use of a constellation of low altitude satellites which will not have annoying voice delay. The low altitude satellites allow the use of low power, handheld telephones in this personal communication system. Earth gateways provide the interface to the public switched telephone networks and determine the routing as a call is placed. The system will have its own operational control system for command and control of the communications system and the constellation of satellites.

The Iridium system will provide the full range of communication services that are expected in a modern system. High quality voice using a pocketable handheld telephone is the driving requirement. The system will also have provisions for paging, data, messaging, fax, and geolocation.

System operation is similar to existing ground-based cellular. In fact the dual mode handset will have the capability to operate on both cellular and Iridium frequencies and with both communication architectures. When a call is dialed and sent, the system will first try to use a cellular channel from the local terrestrial system. Iridium will transmit to a satellite on an Iridium channel only if ground-based cellular is not available. The gateways will route the calls through the constellation in the most economical fashion and will use existing terrestrial infrastructure when necessary. As such the Iridium system will complement existing systems, not replace them.

SYSTEM DESCRIPTION

The Iridium system provides global, handheld personal communications. It is based on a cellular telephone concept and will use pocketable telephones for communications to or from anyplace at anytime without prior knowledge of the portable telephone's location. The three major system elements are the pocket size handset, the constellation of 66 spacecraft, and the ground infrastructure--the gateways and the system control facility, see Figure 1. The following sections provide additional detail.

Handset

The pocket size handset, see Figure 2, is designed with a dual mode capability--both ground-based cellular and Iridium calls can be placed. The user will specify when the phone is purchased which terrestrial capability is desired. The phone will have both modes built in and will attempt a call through ground-based cellular first. If a cellular circuit is available, it will be used. When cellular is not available, the call is routed through the satellites.

In addition to this voice capability, the handset will also be capable of sending or receiving paging, fax, and data messages. A standard port on the side of the unit will provide the data interface to a fax, printer, or other data unit. In addition, the system will continuously monitor the location and status of all subscriber units.

Not all users require a handheld unit. Other subscriber units will be available including solar powered telephone kiosks and pager-only units. The advantage of the solar powered kiosk is use in lesser developed areas without a hardwired telephone or power grid. The phone booth can connect anywhere, anytime even without terrestrial telephone or power lines. A basic level of telephone service could be provided in this fashion where service had never before been available or for emergency restoration of service after a disaster.

Spacecraft

Iridium spacecraft are another key element in the system's ability to provide handheld personal communications. They will create beams of coverage similar to the cells of a ground-based cellular system. In ground-based cellular, the ground antennas are at fixed locations and create fixed cells of coverage that a mobile user randomly moves through. The Iridium satellites act as antenna towers several hundred miles tall and create cells of coverage that move as a result of the orbital satellite's motion. Even a mobile Iridium user is relatively fixed with respect to satellite motion and cell to cell handoff of a user is deterministic based on the uniform motion of the satellites in their low earth orbits.

The satellites will also have cross links to route calls between satellites. Each satellite will support

up to four simultaneous cross links--one to each of the satellites immediately ahead of or behind it in its own orbital plane and also one to satellites to the left or right in adjacent orbital planes.

Ground Infrastructure

The ground infrastructure for the Iridium system include gateways and the system control facility. Gateways are in key locations worldwide as they contain the Iridium databases for billing purposes and will be used as the interconnect point into the public switched telephone network.

Since each satellite has crosslinks, a gateway does not have to be in view of every satellite. Yet, gateways will be involved in every call. They will first determine if the user of an Iridium handset is a valid user. Given that a valid user is attempting to make a call, gateways will also have the databases to determine the location of the called telephone. The gateway will then determine the call routing and will format a header with the information needed by the satellite switch to route the call. After the completion of the call, the gateway will develop billing information.

The system control facility will control the communication system and will also command and control the spacecraft. The configuration of the constellation of satellites will be controlled to provide the most efficient full-earth coverage. The system control facility will also read the state of health and configuration of the satellites and associated systems and subsystems. Anomalies will be detected and resolved in the control facility.

SERVICES

The Iridium system is designed to provide a quality personal communications service to users anywhere in the world. Digital transmissions will provide a full range of communication services including voice, paging, data, facsimile, and geolocation.

Voice

Ubiquitous, handheld, personal voice communications are the hallmark of the system. A user anywhere on the surface of the earth is assured that at least one satellite will always be in view and will be available to provide high quality voice service. Iridium satellites in low earth orbit are designed to allow high quality transmissions without the time delay of geosynchronous communication satellites. The system is designed with 16 dB link margin which allows communication in a variety of routine fading situations including from inside a vehicle and through foliage. [4]

Paging

Global paging is another quality service offered by the Iridium system. The handheld telephone can receive a page and separate pager-only units will be available for those users needing just paging.

Data

Transparent data service (at 2400 bits per second) is offered in the Iridium system. Different length messages are possible with one option being a short message to provide location and user status.

Fax

The system will communicate facsimile messages. The pocket size handset will have a data port built into it that will provide the interface to an external fax unit. The handset will be able to receive and store faxes in memory. The user can review the fax by scrolling through the information using a display screen on the handset. A hard copy of a fax can be printed by using the data port to connect to a fax or printer.

Geolocation

For the Iridium system to work, it must locate the user unit. The geometry of the system can provide location during routine standby operation. A Global Positioning System (GPS) chip can be built into special user units if more precise location is required.

OPERATION

The users of this system want a system that operates efficiently and provides high quality, reliable, personal communications. The Iridium

system is designed to provide just that--quality personal communications at anytime, anywhere in the world, with the system not needing prior knowledge of the user's location. The system has a robust design with global coverage that provides the convenience and capability that users demand.

Coverage

A global personal communication system requires continuous worldwide coverage. The Iridium system, with its constellation of 66 low altitude satellites, uses circular polar orbits of 420 nautical miles altitude. There will be six orbital planes with 11 satellites per plane. The constellation is designed to have at least one satellite in view of all locations on the surface of the earth at all times.

The system control facility will schedule cells to turn off as the satellites move through the northern and southern latitudes where the greatest overlap occurs. Each of the 66 satellites project a pattern of 48 cells--or a system total of 3168 cells. Only 2150 active cells are needed to cover the earth so at any given time about 70 percent of the cells are active.[4]

Convenience

The customer expects convenience in a personal communication system. Experience in the worldwide cellular industry has clearly shown the trend to small, light weight, handheld telephones. This subscriber unit driven system was designed having learned from those experiences. The Iridium system will diminish a lot of the limitations to personal communications by providing readily available, easily used, high quality communications where they have not existed before.

Capability

The Iridium system is the next logical step in personal wireless communications. Ground-based cellular systems have steadily grown as their convenience and capability have been accepted. Yet there are substantial geographic and financial problems in building a global ground-based system. A range of options were studied before the low altitude constellation option was picked for Iridium. This option provides global coverage and allows robust connectivity to pocket size handsets. Higher altitude satellites, including geosynchronous, were considered but were not accepted since closing the link to a small handset is difficult in many situations and the round trip voice delay is a concern.

PRODUCTION EFFICIENCIES

The Iridium program must be a commercial success with a profit for the investors. Future revenues must cover the cost of operating the system and provide a return on the initial investment for system development. Motorola is studying the ways that this personal communications program can benefit from high volume commercial production techniques, not only in the subscriber units but also in the satellites, to make it more cost effective. Some of the areas for cost efficiencies include emphasis on high quality, statistical process control, advanced technologies, improved design and manufacturing methods, and also improvements in assembly and test.[2]

Motorola was one of the first winners of the Malcolm Baldridge National Quality Award. Emphasis on excellence is continuing through a quality program that strives for six sigma quality in all aspects of work--this equates to no more than 3.4 defects per million operations. All of the partners and suppliers must also meet these high quality standards.

Motorola is a world leader in the design and production of electronic components and wireless communication equipment. This lead is the result of working to stay up to date in producing electronic components as the technology continues to reduce the size of components. Motorola engineers can design and produce Application Specific Integrated Circuits (ASICs) and Multi Chip Modules (MCMs) approaching the limits of the state of the art. Proven techniques will be applied as appropriate to reduce the cost, size, weight, or risk of developing the necessary hardware.

Electronic circuit density has increased as the technology has progressed from components with

long leads to MCMs. Even MCMs transitioned to fine pitch leads with very close spacing, while the newer technology has now advanced to direct attachment without leads. These improvements have come with challenges in design and manufacturing. One approach is the use of advanced robotic assembly lines for the assembly and test of these devices. In addition, advanced simulation tools are needed for the design and analysis of these components. Motorola is using these capabilities in several existing programs including Space Station Freedom communication system work. Technology improvements continues to yield parts that are lighter, smaller, more reliable, and more repeatable in performance from unit to unit even directly off the assembly line. Technology reuse from adapting a previous design is used to speed production and improve reliability.

Reuse is emphasized throughout the design and production process. One area that has paid off is improvements in software that allow a design engineer to enter parameters in a data base and that data is tied to all of the design, analysis, and even production steps. This one time entry of data reduces the chance of a data entry error. This reduces errors and speeds up the equipment set up for the production process.

Concurrent engineering is being used to reduce total acquisition costs and improve reliability. The goal of concurrent engineering is to get all disciplines involved early in the design process to reduce future design changes by insuring that all considerations for manufacturing and testing the product are factored into the initial design. In this way a more complete design is developed that can be built with few changes and satisfy all requirements.

SUMMARY

Global handheld personal communication will greatly improve our ability to place or receive a call anywhere in the world at anytime. The Iridium system will provide this portable telephone capability with pocket size handsets. A constellation of low altitude satellites allows quality service with low power, handheld telephones. Global personal communications are coming with one person, one number service at anytime, anywhere in the world--the Iridium system is leading the way.

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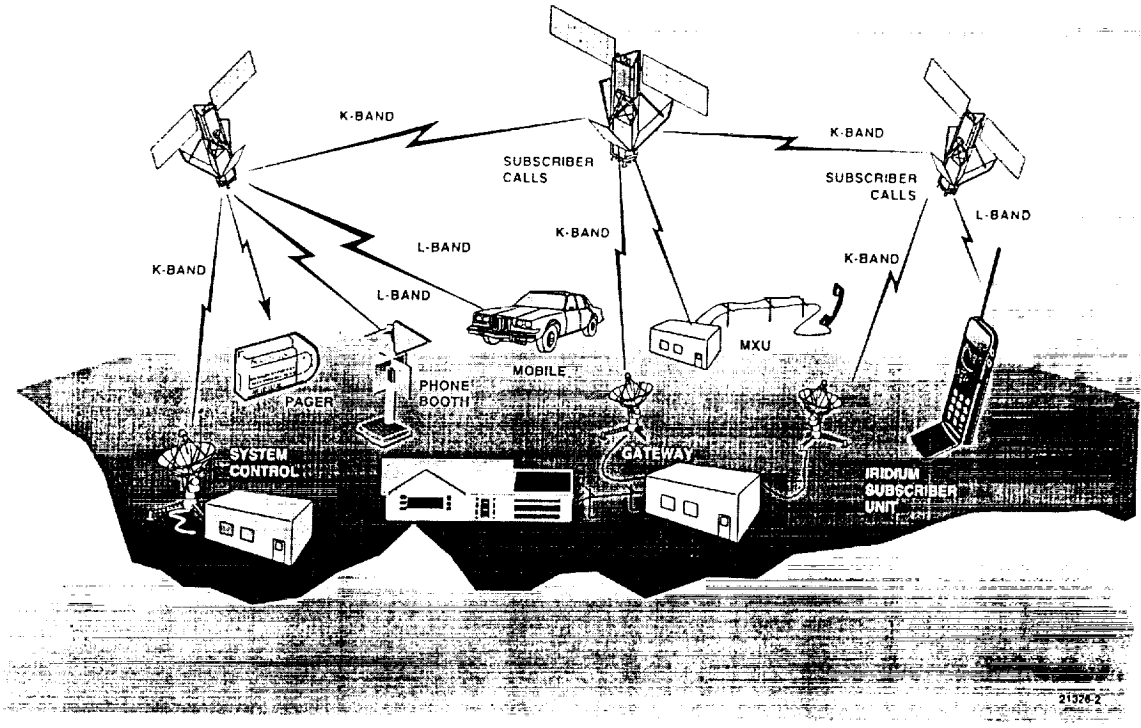

Figure 1. Iridium System Overview

Figure 2. Iridium Handset