

The ORBCOMM Data Communications System

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ABSTRACT

The ORBCOMM system is designed to provide low-cost, two-way data communications for mobile and remote users. The communications system is ideally configured for low data rate applications where communicating devices are geographically dispersed and two-way communications through terrestrial means is cumbersome and not cost effective.

The remote terminals use VHF frequencies which allow for the use of very small, low-cost terminals. ORBCOMM has entered into joint development agreements with several large manufacturers of both consumer and industrial electronics to design and build the remote terminals. Based on prototype work, the estimated retail cost of these units will range from \$50 to \$400 depending on the complexity of the design.

Starting in the fall of 1993, ORBCOMM will begin service with a demonstration network consisting of two operating satellites. By the end of 1994, a full operating network of 26 satellites, four Gateway Earth Stations, and a Network Control Center will be in place.

The full constellation will provide full coverage of the entire world with greater than 95% communications availability for the continental U.S.

This paper describes the ORBCOMM system, the technology used in its implementation, and its applications.

INTRODUCTION

There is a multitude of communications options open to industry and government organizations. However, most are either expensive or lack sufficient coverage of remote areas to be cost effectively used for low density communications needs in geographically remote locations. Industrial investments of billions of dollars have been made in VSATs, microwave communications systems and leased line services to provide the appropriate communications network for their Supervisory Control and Data Acquisition (SCADA) systems. These systems are cost effective for the high data rate, high volume communications needs of SCADA where continuous communications is required for legal and/or operational efficiency reasons.

Although the requirement for high data rate, high reliability

communications in many operations is unquestionable, there is also a need for cost effective communications for low data rate information. These communications requirements are characterized by short messages of approximately 100-200 bytes in length, sent on an infrequent basis. These communications are primarily non-time-critical messages which either increase the efficiency of the operation, enhance the overall safety and reliability of the operation, or improve the business functions within the operation. The communications link is usually to and from remote and geographically dispersed locations, where no existing infrastructure such as cleared land, power, etc. exists.

A good example of such a communications requirement is data collection and fail-safe control at interstitial points on a pipeline. The major control points along the pipeline, such as feed points, pump stations, and major valve outs, for the most part are under the control of SCADA or manual systems. However, there is a need for collecting data, such as pressures and temperatures, at intermediate locations. This type of information is important in implementing a fail-safe system for remote stretches of pipeline. In this application, data is monitored continuously and alarms are triggered if limits are exceeded. The communication requirement is small, roughly 100 bytes of data every half hour with very infrequent alarms sent to the dispatcher. Action is taken to isolate the problem by remotely or automatically commanding a gas actuated valve. Communications with these locations are critical to identify the problem area and take the appropriate action to correct the problem.

Low data throughput applications such as these make the cost of existing communications systems prohibitive to the implementation of distributed controls in remote areas. Microwave systems can cost as much as \$300,000 to install in a single site. VSAT terminals at a remote location can cost \$50,000. Ku-Band mobile satellite terminals could possibly be installed as fixed terminals at the cost of about \$3,000 to \$4,000. Such capital intensive investments make the cost per byte too high to justify the incremental benefit of fault isolation.

Finally, a very large application of remote communications is personal messaging to personnel in remote locations. The geographic extent of the many industries forces field crews to roam outside of the coverage of existing terrestrial based radio and cellular systems. Such lack of coverage results in poor communications with the crew and a reduction in operational efficiency. The existence of a low-cost messaging system for mobile users can help alleviate this specific problem.

This is only one example of an industrial requirements for low data throughput communications. Until recently these problems have been identified, but there has not been a solution which adequately and cost effectively satisfies these needs. The remainder of this paper will introduce and describe the ORBCOMM communications service based on low Earth orbiting (LEO) satellite technology and VHF operating frequencies. The unique combination of a dispersed network of LEO satellites and communications equipment operating at VHF frequencies will, for the first-time,

provide a low cost communications system with 100% geographic coverage of the Earth. With these two powerful attributes, the ORBCOMM data communications network promises to provide many operational benefits to mobile and remote users.

IMPLEMENTATION

The ORBCOMM system is being implemented specifically to provide a communication channel for short messages from vehicles or equipment which travel over wide areas or which are located in remote areas which cannot be economically served by existing technologies. The ORBCOMM system is being engineered to provide this service at low cost. All of the other existing or proposed systems lack one or more of the three key characteristics of the ORBCOMM system:

- a) Ubiquity -- 100% geographic coverage is not planned by any terrestrial system;
- b) Low Cost -- Until ORBCOMM, ubiquity required high first and recurring costs;
- c) Messaging Proficiency -- Other systems provide messaging as an adjunct to their primary voice or positioning services.

As with other data communication systems, ORBCOMM consists of a set of message processors interconnected by digitally modulated radios. The ORBCOMM network consists of subscriber terminals (STs), the network control center (NCC), satellites and gateway earth stations (GES). The subscriber terminals are the point of

origination and/or destination for all messages in the system. The NCC, via the Gateway stations, serves as the interconnection point between the fixed data networks and the population of subscriber terminals.

Subscriber terminals are very small message processing devices with integral RF modems used to access the ORBCOMM system. These devices are typically handheld or integrated into another communications or computing device. ORBCOMM subscriber terminals are the smallest, lightest and least expensive commercial satellite transceivers available. Subscriber terminals can be configured to support a variety of applications.

The most basic service is a low data rate (2400 bps uplink, 4800 bps downlink, low latency) data collection service for applications in monitoring remote equipment. Since the system has two-way communications capability, more sophisticated supervisory control applications are possible for monitoring remote systems and taking action when required. The full ORBCOMM service can provide personal and data messaging and position determination, allowing for inexpensive E-mail type communications with the home office or between mobile user terminals.

The Network Control Center (NCC) is the connection point between public and private data networks and the ORBCOMM network. The NCC serves as the message processing center, performing message switching for the entire U.S. ORBCOMM network. Remote equipment or personnel anywhere in the U.S. is accessed through a single connection to the NCC. The NCC sits at

the center of a star network of gateway earth stations. Collocated at this site are the additional service functions required for providing certain value added services, the satellite control center and the customer service and billing functions.

The ORBCOMM satellites are essentially message routing and queuing computers in low-Earth orbit, accessed by various radio links. The ground based elements of the ORBCOMM Network are interconnected by a constellation of low-Earth orbiting satellites. The satellites to be used to provide the initial service weight less than 100 pounds each and can be launched, eight at a time, on Pegasus XL launch vehicles. Despite the relatively low weight, each satellite: contains eight receivers and three transmitters; uses three axis, gravity-gradient assisted, magnetic attitude control system and has a capability of about 70 watts of orbit-average power. The satellites also contain GPS receivers, used to assist in the determination of the spacecraft orbit for the attitude control system and to provide satellite position and velocity information to subscriber terminals with position determination capability.

Service introduction plans envision various classes of satellites launched in a phased approach. The initial phases use very small lightweight satellites. Follow-on phases will use larger, more capable spacecraft, tailored in capacity as the size of the emerging market becomes more predictable.

The Gateway Earth Stations (GESs) interconnect the network control center computer to a satellite's computer so that messages can be passed between the STs

visible to that satellite and the NCC. Gateway Earth Stations pass data packets to and from the satellite computers to the message handling systems of the network control center. The initial ground segment configuration includes four GESs in the contiguous United States, located so as to maximize the amount of mutual visibility between the gateway sites and the subscriber terminal population. Each GES will be required to track only one spacecraft at a time. Multiple spacecraft coverage will be obtained through the diversity of sites.

The GES consist of medium gain (14 - 17 dBi) tracking antennas, RF and modem equipment, and communications hardware to send and receive packets to and from the Network Control Center. The gateways are fully redundant and designed for unattended operation.

ORBCOMM does not provide international service through its satellite network. However, NCCs in other countries can be interconnected, via the public switched network, in order to provide international service.

VHF SPECTRUM CONSIDERATIONS

The VHF spectrum used by ORBCOMM was allocated at WARC-92 to the "Little LEO" systems.

The 137.0-138.0 MHz band, used for satellite to ST and GES communications, was identified as the most suitable downlink because it is allocated only to space services. Use of this band by space research and space operations has been declining in recent years because it is a relatively narrow allocation, unable to support the high data rate down links found on most modern spacecraft.

The use of relatively narrow band carriers for the ORBCOMM 137 MHz services suggests that sharing between LEO MSS systems would be quite practical. The required technique has been to coordinate access between the various narrow-band carriers of separate systems.

The 148.0-149.9 MHz band, used for ST and GES to satellite communications, was identified as the most suitable uplink because it had an existing allocation to space operations, was close enough in frequency to the downlink to allow a common antenna and did not appear to have any intractable coordination issues.

Current users of this band include a relative large number of terrestrial mobile systems. In order to operate in this band, the ORBCOMM satellites use a technique called the Dynamic Channel Activity Assignment System (DCAAS) to allow the subscriber terminals to communicate effectively in the presence of nearly co-channel uplink interference. This system allows uplink channel frequencies to be reassigned in response to measured and predicted statistical time variation of channel use by the interfering services.

The entire uplink band is scanned in 2.5 kHz intervals using a measurement filter identical to the modulation matched filter once per 5 seconds. The instantaneous power level in each slot is recorded. This power level is included in a weighted time average for that slot. The slots are then ranked from the lowest to highest power levels. In addition, the spacecraft receivers keep a record of the packet error rate on each channel in use in order that the dynamic channel allocation algorithm

can measure the quality of channels in use.

The DCAAS process, onboard each satellite, keeps a continuous rank ordering of channel slots from 'best' to 'worst'. The top 'N' channels on the list, with 'N' equal to the number of spacecraft subscriber receivers, are the ones used in current communication. This set of satellite receive frequencies is continuously relayed to the STs via an order wire channel.

COST INFORMATION

The ORBCOMM system is being engineered to allow subscriber terminal prices to range from \$100 to \$400 depending on the level of features included in the unit. Operation in the VHF frequency bands providing message communication only allows these price levels to be attained. Electronic components, subsystems and units designed and produced in volume for the VHF frequency band are already produced in high volume for a variety of other applications, such as push-to-talk radios and television sets. As a result, many of the components and the large scale integration processes required in the fabrication of ORBCOMM subscriber units are in use today in high volume manufacturing plants around the world. This will bring the benefits of economies of scale allowing consumer level pricing. This is not the case for the L-Band or Ku-Band components required for other satellite based systems. The many high quality, push-to-talk VHF radios available at prices ranging from \$150 to \$500 validate the low-price potential of the ORBCOMM equipment.

Service price will incorporate a

recurring monthly access charge and usage charges based on the level of messaging activity. Retail prices will typically be the equivalent of \$0.25 to \$1.00 per 100 byte message. Pricing alternatives will be offered including: peak and non-peak pricing, volume discounts, and sliding scale pricing.

IMPLEMENTATION SCHEDULE AND REGULATORY STATUS

The ORBCOMM system is being constructed according to a phased implementation schedule. Two spacecraft are to be launched in October 1993, providing "intermittent" service. At the time of the launch of these spacecraft, the full ground system will be in place. Intermittent service will be used to conduct "beta" tests and to serve markets for which 6-10 communications opportunities per day are a suitable first step. Throughout 1994, ORBCOMM will be launching additional spacecraft. Service with minimal delays will be available at the beginning of 1995.

ORBCOMM expects final regulatory approval by August of 1993. The first two spacecraft are being constructed and launched under authority of an experimental license, which also grants permission to conduct market trials for up to 1000 terminals. The FCC has given ORBCOMM permission to begin construction of the complete constellation prior to the granting of the full license.

BETA TESTING PROGRAM

With less than a year to go to start commercial service, active measures are being taken to obtain the input of the various industries in the development of the communications network through a

series of beta test programs. ORBCOMM is currently planning several beta tests with pipeline operators, marine equipment suppliers and other potential market leaders. The purpose of these tests is to develop and test the remote communications equipment as well as gain critical operating experience with the network. ORBCOMM is also developing a beta test program for a meter reading service for remote locations.

ORBCOMM is relying on industry participants to provide significant value added services to the industry. ORBCOMM realizes the crucial benefit of user input to the development of the network and is promoting active user involvement in every step of the development cycle.

SUMMARY

By focusing on low density communications between remote and mobile users in geographically dispersed locations, ORBCOMM will fill a communications need that is currently not met in any cost effective way. The combination of low Earth orbiting satellites and VHF operating frequencies provides a low cost communications service with 100% geographic coverage of the Earth. The low cost of the communications service will for the first time make access to remote locations for lower volume data communications economically feasible. ORBCOMM will begin service in 1994 with applications directly targeted at communications needs which until now have not been adequately addressed.