N94-22800

The Westinghouse Series 1000 Mobile Phone: Technology and Applications

Brian Connelly
Westinghouse Electronic Systems
P.O.Box 746 MS 8419
Baltimore, MD 21203
Phone: 410-765-8814
Fax: 410-765-2386

ABSTRACT

Mobile satellite communications will be popularized by the North American MSAT system. The success of the overall system is dependent upon the quality of the mobile units. Westinghouse is designing our unit, the Series 1000 Mobile Phone, with the user in mind. The architecture and technology aim at providing optimum performance at a low per unit cost. The features and functions of the Series 1000 Mobile Phone have been defined by potential MSAT users. The latter portion of this paper deals with who those users may be.

I. INTRODUCTION

Westinghouse is designing a mobile satellite telephone, the Series 1000, for use with American Mobile Satellite Corporation's and Telesat Mobile Inc.'s mobile satellite (MSAT) service. The phone supports voice with a built in handset, facsimile with a standard telephone port, and data with an RS-232 port.

The Series 1000 Mobile Phone is the first generation of a line of Westinghouse mobile satellite communications products, and will be available in late 1994. Industry has been eagerly anticipating the MSAT system on which it is intended to operate, which is well documented in current literature [1-2].

II. THE WESTINGHOUSE APPROACH

Westinghouse has combined proprietary techniques with advanced technology to create a design that will render outstanding performance at a low per unit cost. Westinghouse is leveraging its capabilities in digital signal processing, microwave design, and software development to assure a mobile phone that is completely compatible with the MSAT ground network.

One of the major design challenges of the Series 1000 Mobile Phone is overcoming the stringent link margin requirements (Table I). The system does enjoy an unusually high satellite EIRP, but the Ricean fading characteristic of satellite channels presents complex design issues. Without a proper design, a prolonged fade can cause the satellite position to be lost, information to be dropped, fax machines to timeout, or the call to be disconnected. As such, the Series 1000 Mobile Phone design must incorporate fade mitigation and compensation techniques. At very low look angles, the problem is made more challenging by an increased number of obstructions. Look angles for a few representative cities are:

Acapulco	69°
Miami	52°
Los Angeles	46°
Chicago	39°
Boston	32°
Vancouver	29°
Quebec	28°
Honolulu	23°
Anchorage	9°

The most common obstruction will be trees. Because

Table I Series 1000 Mobile Phone Characteristics

Transmit Frequency	1626.5 - 1660.5 MHz
Receive Frequency	1525.0 - 1559.0 MHz
Modulation	QPSK
Channel Rate (Inbound)	6750 bps
Channel Rate (Outbound)	6750 bps
Voice Codec Rate	4200 bps
Antenna Polarization	RHCP
Channel Spacing	6.0 KHz
Channel Increments	0.5 KHz
FEC Encoding	
at 2400 bps information rate	Rate 1/2
at 4800 bps information rate	Rate 3/4
in packet-switched mode	Rate 1/3

Link Budget	*Uplink*	*Downlink*
Satellite EIRP		30.8 dBW
Satellite G/T	2.7 dB/K	
MP EIRP	12.5 dBW	
MP G/T		-16.0 dB/K
Path Loss	187.2 dB	187.7 dB
Other Losses	3.4 dB	4.8 dB
(C/No)	**53.2 dBHz**	**50.9 dBHz**
(C/No) threshold	47.3 dBHz	47.3 dBHz
Link Margin	**5.9 dB**	**3.6 dB**

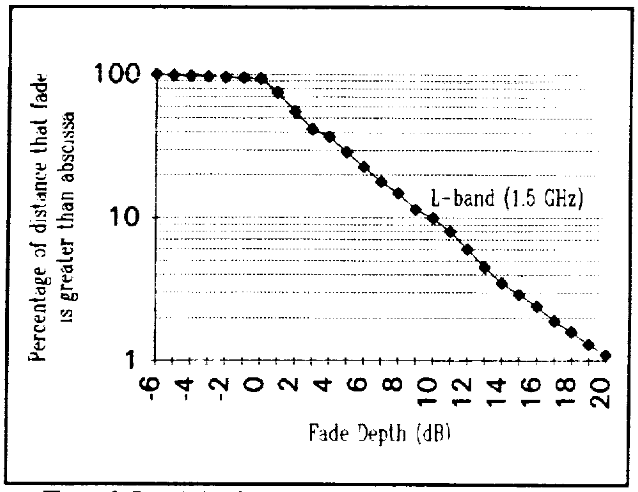

Figure 1 Cumulative fade distributions in heavy foliage at 45°

the Series 1000 Mobile Phone offers interoperability with the existing cellular network, more populous areas with building obstructions will be covered by the cellular system.

L-band propagation statistics have received some attention in recent years [9]. Most notably, the Applied Physics Laboratory of Johns Hopkins University has performed detailed measurements, at the MSAT frequencies, of fade statistics from roadside trees and mountainous terrain. An example of the kind of fade distribution with which the Series 1000 Mobile Phone must contend is shown in Figure 1. This data was collected from the Baltimore-Washington parkway in central Maryland during summer; thus the deciduous trees were in full bloom with maximum moisture. The elevation angle is 45°. The Series 1000 Mobile Phone is designed to handle fade depths of this magnitude.

The duration of the fades is another important statistic when considering the effects of signal propagation.

The major system functions of the Series 1000 Mobile Phone are shown in Figure 2. The configuration will change somewhat depending upon the application, but the basic building blocks remain the same.

Digital Signal Processing

The digital signal processing (DSP) subsystem performs the physical layer protocols of the Series 1000 Mobile Phone. Perhaps the most innovative design area, the DSP subsystem houses the following critical functions:

▸ Demodulator - Implemented on a single chip, it employs a proprietary optimization method to obtain soft decision bits from a QPSK modulated signal. It also performs carrier acquisition and tracking, symbol timing acquisition and tracking, and signal strength calculations used by the beam steering controller.

▸ Coding Sequence - This refers to a series of bit-manipulation techniques used for forward error correction and channel encryption. Convolutional encoding and Viterbi decoding are used. The signal is interleaved to prevent bursty errors, and it is scrambled for security.

▸ Voice Codec - An improved multi-band excitation (IMBE) algorithm developed by DVSI is used. It operates at 6400 bps with an information rate of 4200 bps. As this codec is also being used on the Inmarsat and Optus systems, it is quickly becoming an international defacto standard.

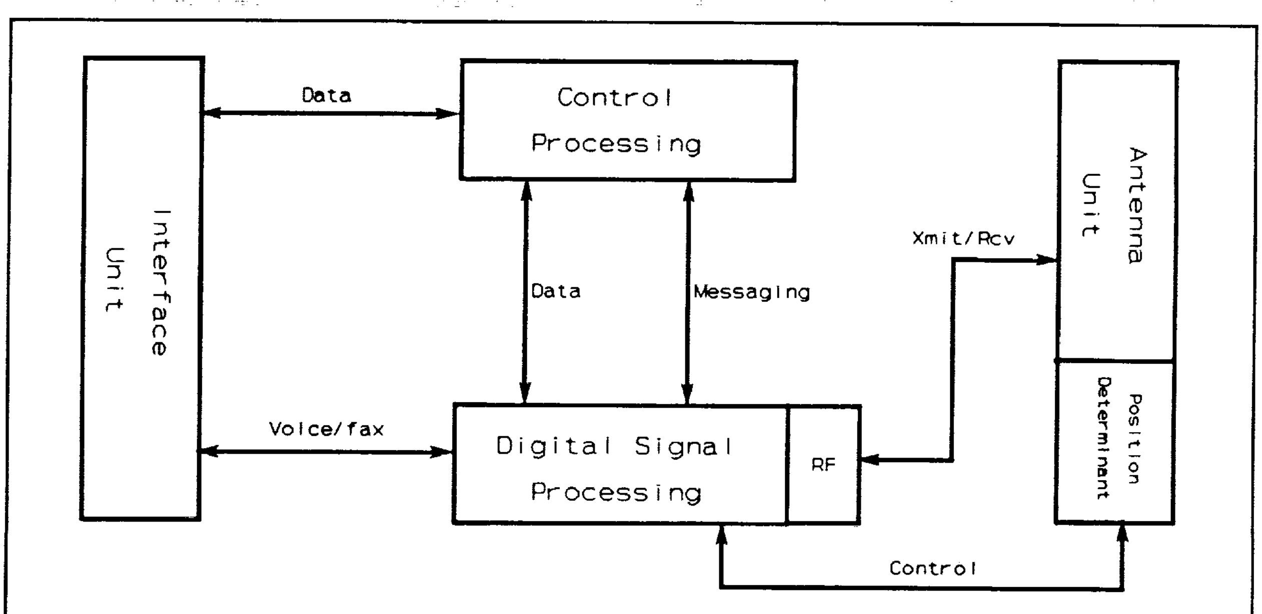

Figure 2 Functional Block Diagram of the Series 1000 Mobile Phone

▸ Noise Cancellation - Many applications, such as use inside trucks or hands-free operation, will require some form of noise cancellation. This is either an analog or digital process in which background noise is cancelled while the user is speaking. Additionally, noise may be suppressed while the user is silent. Noise suppression affords no increase in signal-to-noise ratio, but there is a perceived performance improvement.

▸ Fax Protocol - The MSAT system is unique in that it uses real time facsimile (fax) transmission over the satellite link with automatic repeat request (ARQ) functionality. The LAP-B ARQ adds the ability for error-free communications over the satellite link. The user may select whether or not they wish to use ARQ, in case they would prefer a shorter phone call with more errors in transmission. Real-time transmission offers some distinct advantages, including billing procedures identical to a regular voice call and confirmation of message delivery.

Control Processing

The control processing (CP) subsystem will perform all the upper layer, byte-level protocol functions. The link layer signalling protocol is used to communicate with the Group Controller (GC) for call management. Another set of protocols is used for network management and signalling. For the data mode, this includes X.25 and several MSAT-specific data communication protocols. Call setup and release protocols define the procedures for establishment and takedown of voice, data, and fax calls.

When the Series 1000 Mobile Phone is not engaged in a call, the CP subsystem will continuously monitor the GC bulletin board channel. This will provide network status information updates, incoming call indications, congestion control parameters, and other control messages. The CP will also respond to GC commands.

The algorithm to detect the crossover of beams is performed in the CP subsystem. Packet error rates are calculated for the beam the Series 1000 Mobile Phone is using and the signalling channels in other beams. Depending on the quality of the channels, the Series 1000 Mobile Phone decides when a switch of beams should occur and notifies the GC appropriately.

Antenna Unit

Several types of antennas are available for use with the Series 1000 Mobile Phone. For land vehicle applications, a phased array will be offered. This antenna is a flat plate about a foot in diameter. The gain of the antenna in the direction of the signal will not drop below 9 dB. Because the phased array is aesthetically pleasing on smaller vehicles, it is expected to be the most popular antenna type.

The mechanical antenna configuration is less rugged, but in some ways preferred. Acquisition time for this antenna will be slower, about 6 seconds. But the mechanical antenna can dither at small intervals, and thus can maintain extremely accurate satellite tracking when used in conjunction with an angular position determinant.

A third alternative is an omni-directional mast antenna. In order to meet performance specifications the size of the mast needs to be about 3 feet. Nevertheless it will meet the needs of certain niche applications.

The frame formats on the MSAT voice channels call for large periods of time, as long as 0.48 seconds, with no signal being transmitted. For the directional antennas, this makes it extremely difficult to track the satellite based solely on signal strength. In half a second, a vehicle could potentially change its orientation by as much as 25-30 degrees. As such, it is desirable to use an angular position determinant to steer the antenna. Accelerometers and gyros may be used, but they are expensive and not well suited to a rugged environment. A compass or magnetometer would do the job more cost effectively, but they are subject to local magnetic perturbations. An angular rate sensor is another potential solution, with the drawback of long-term drift.

User Interface

The Series 1000 Mobile Phone is capable of more than just simple voice and data satellite transmission. It is also equipped with convenient user features and enhanced functionality.

The Westinghouse Series 1000 Mobile Phone offers complete interoperability with the existing cellular network, including the ability for live call hand-off. Thus, the MSAT system should be understood as complementary to the cellular industry. Cellular interoperability involves complex billing and licensing issues as well as intricate call hand-off procedures. A more thorough examination of this issue is detailed in [3].

Another feature available from Westinghouse Series phones is satellite trunked radio operation. Satellite trunked radio service provides a communication net that allows all suitably equipped mobile phones in a closed user group (CUG) to receive voice transmissions from all other mobile phones in the same CUG, and from the base station. Communications originate from mobile phones on a push-to-talk basis, and are re-transmitted at the base station so that other mobile phones in the net will be able to hear both sides of the conversation. The service is implemented on a single circuitswitch channel shared by the all the CUG members. Satellite trunked radio will be particularly useful for small rural fleets.

For position location, a global positioning system (GPS) option can be added to the Series 1000 Mobile Phone. Position determination is necessary in fleet management, maritime, and aeronautical applications. The position determination system may also be located external to the Series 1000 Mobile Phone, as in the case of a vehicle already equipped with a position determinant.

Table II Features of the Series 1000 Mobile Phone

Alphanumeric Handset Display
PC Connectivity
Programmable from Keypad
Hands-Free Operation
Speed Dialling
Call Waiting
Call Hold
Call Transfer
Call Barring
Conference Calling
Call Forwarding
Voice Mail
Handheld Option
Horn Alert

Other features of the Series 1000 Mobile Phone pattern those already common in cellular and landline operation. The conveniences that the user has become familiar with at home will not have to be compromised with the Series 1000 Mobile Phone. A brief list of some of the important features is shown in Table II.

III. APPLICATIONS

The discriminating factor for the MSAT system lies in the ubiquitous nature of satellite coverage. As such, the MSAT market is concentrated in non-urban areas where cellular coverage is not available. Approximately 15 million people are in these areas, unserved by the cellular network. Satellite extension service will target government and business arenas, as well as the cellular consumer that is frequently moving in and out of coverage.

Seamless Voice

Many businesses require communications across a wide area not completely covered by cellular [5-7]. Building and construction crews, for example, require constant communications with a relatively transient team of people and machinery. These crews move in and out of cellular coverage based on the job, but a single Series 1000 Mobile Phone communications system would always meet their requirements.

Law enforcement and fire-fighting personnel in rural areas would find use for a Series 1000 Mobile Phone, and would have the added benefit of a secure link because of the scrambling inherent in the MSAT system. And when a search-and-rescue operation is required, or for disaster management, they have the advantage of instant connectivity at remote sites. Rescue teams will also be able to make use of the aeronautical capability of the Series 1000 Mobile Phone. Emergency medical personnel are able to obtain remote professional support, report breakdowns, and alert destination hospitals of their status.

Geological surveys are becoming increasingly important, especially if precious natural resources are involved. A satellite mobile system is useful in this scenario for monitoring the survey workers and coordinating supplies and assistance. Mining is another activity that requires coordination of men, materials, and machinery over vast areas. Efficiency and safety in mining and excavation are improved a great deal with constant reporting to a home facility.

The cellular network is growing at an astounding rate. But over long driving distances cellular communications can be sparse and inadequate. The MSAT system will always have a niche market because it offers not only unlimited range, but communication that is reliable and secure, as well as fax and data services.

Transportation and Fleet Management

Perhaps the most significant market demand for MSAT services is that of wide-area trucking. A Series 1000-based fleet management system may be used for:

- real-time schedule and routing updates,
- reporting cargo status for refrigeration units, high-value goods, or toxic materials,
- reporting vehicle performance for maintenance and spares planning,
- locating vehicles in distress,
- monitoring vehicle travel patterns for many vehicles over a large area,
- optimizing pickup strategy in order to maximize load capability and minimize fuel and mileage,
- and allowing two-way communication with drivers.

Larger fleets may wish to adapt their system with a specialized interface unit or software so that drivers would have an automated menu-driven system. If several fleet management centers are involved, the MSAT system may be combined with a VSAT system to yield a single consolidated network [8].

Fleet management, however, is not limited to the trucking industry. Oil companies have the added requirement of marine fleets and on- and off-shore drilling rigs. Also their pipelines, which require remote monitoring and control, are well suited to mobile data transmission.

The existing North American system for railcar location allows updates on a daily basis and is considered by most to be unsatisfactory. Improved terrestrial systems have been proposed, but are costly and inefficient. Satellite mobile services would provide a single system for passenger and freight applications.

Marine

The AMSC/TMI system will operate up to 200 nautical miles (370 km) off coastal waters. Inmarsat, an international mobile satellite system, currently operates in this region but is restricted from operating inland. Inmarsat data shows that 75% of all shipboard communications occur within the 200 nautical mile perimeter. Furthermore, there is significant commercial activity along the major rivers and Great Lakes involving cargo ships, tug boats, and barges.

Ships at sea are usually equipped with sophisticated navigation and position location tools, but shore-based fleet managers are divorced from this information because of inadequate communications links. Two-way communications is preferred in order to send a wide range of data to and from the ships. For example, charts and maps could be updated in real-time, weather and ice reconnaissance information could be relayed, and fishing productivity could be increased through coordinated tracking.

IV. CONCLUSION

The basic design of the Westinghouse Series 1000 Mobile Phone has been explained. The Series 1000 is a sophisticated design which affords a wide variety of interface options including voice, fax, data, GPS, cellular, and satellite trunked radio services. The market demand for this product is high, and several potential market areas have been discussed.

REFERENCES

[1] G. Johanson, N. Davies, W. Tisdale, "Implementation of a System to Provide Mobile Satellite Services in North America," *Third International Mobile Satellite Conference*, Pasadena, CA, June 1993.

[2] G. Davies, W. Garner, et al, "The AMSC/TMI Mobile Satellite Services (MSS) System Ground Segment Architecture," AIAA 14th International Communications Satellite Systems Conference, Washington, D.C., March 1992.

[3] P.W. Baranowsky, "MSAT and Cellular Hybrid Networking," *Third International Mobile Communications Conference*, Pasadena, CA, June 1993.

[4] Wozencraft & Jacobs, *Principles of Communication Engineering*, New York: Wiley, 1965.

[5] J.D. Kiesling, "Land Mobile Satellite Systems," *Proceedings of the IEEE*, Vol 78, No 7, July 1990.

[6] O. Lundberg, "The Future of Mobile Communications," *ITU's Telecom Conference*, Geneva, October 1987.

[7] A. Pedersen, "User Applications of Mobile Satellite Services," *Vehicle and Information Systems Conference*, 1989.

[8] K.M. Murthy and K.G. Gordon, "VSAT Networking Concepts and New Applications Development," *IEEE Communications Magazine*, May 1989.

[9] J. Goldhirsch and W. Vogel, "Mobile Satellite System Fade Statistics for Shadowing and Multipath from Roadside Trees at UHF and L-band," *IEEE Transactions on Antennas and Propagation*, Vol 37, No 4, April 1989.