Technical Development for Australia's MOBILESAT System

Kim Dinh, Nick Hart, Steve Harrison

AUSSAT Pty Ltd
GPO Box 1512
Sydney 2001, Australia
Phone: 61-2-238 7917
FAX: 61-2-238 7803

ABSTRACT

With the planned introduction in Australia of the mobile satellite service in mid-1992, MOBILESAT will be the first domestic mobile satellite system with full voice and data capability to be in operation worldwide. This paper describes the technical features which have been adopted by MOBILESAT in providing a unique system optimised for land mobile operation and the technical activities which have been carried out by AUSSAT in the past three years in supporting the development of the system.

1 INTRODUCTION

The MOBILESAT system developed for Australia shares many of the features being developed in other mobile satellite systems, as well as those of terrestrial mobile communications networks. The overall design philosophy is to provide robust, high quality services in a land mobile environment by 1992, whilst maintaining sufficient system flexibility so that future technological advances can be easily incorporated into the network. During the developmental stage, AUSSAT has also cooperated with the other mobile satellite network operators, namely INMARSAT, TMI and AMSC, with the aim of developing a common standard for the mobile satellite terminals.

In September 1989, AUSSAT and Telecom Australia released a Request for Tender for two Network Management Stations and collocated Gateway/Base stations. The successful bidder will be responsible for designing an integrated system which will optimise the interfacing protocols between the NMS, the Gateway/Base stations and the mobile terminals. The overall schedule will allow the detailed MOBILESAT system specifications to be released by 3rd Quarter 1990.

An overview of the MOBILESAT program and the market forecast for the mobile atellite services in Australia has been described in another paper at this conference[1].

In this paper, a detailed description of the technical features of MOBILESAT and related activities will be given, with particular emphasis on the following topics:

- Key network features adopted to address the market needs.
- Signalling and communications channel description.
- Experimental program carried out to support the development of the MOBILESAT system.
- Selection of the voice coding algorithm for the terminal.

2 SYSTEM OVERVIEW

The MOBILESAT system will offer, based on a single mobile terminal design, two generic mobile telephony service types, which will support voice, facsimile and full duplex data, and

PRECEDING PAGE BLANK NOT FILMED

an ancillary messaging service:

- The Public Telephony service will provide full duplex connection into the PSTN via a gateway station on a demand assigned basis.

- The Private Network Telephony service will offer a range of group call configurations through shared or private base stations. In addition to the full duplex capability, the terminal will also provide a press to talk facility which will enable a variety of group call types to be set up such that the talker's voice can be heard by all parties in the group.

- The Messaging service will route canned messages through the Network Management Station, using reserve capacity on the signalling channels. This will allow for a range of enhanced user features such as position reporting and vehicle monitoring.

The MOBILESAT network, as illustrated in Figure 1, will be implemented with two fully redundant Network Management Stations (NMS) at separate locations. One site will be configured as the primary NMS which will control the network whilst the other site will act as a backup. The NMS will allocate communications channels between the mobile terminals and the Gateway/Base stations on a per call basis using a Demand Assignment Multiple Access (DAMA) technique. Each NMS site will have a collocated Gateway/Base station which will interconnect into the Telecom ISDN network using 30 channel Primary Rate Access (PRA) circuits. Terrestrial lines will be used to interconnect the two sites for keeping the Network Management Stations in lock step, and for passing call processing information between the gateways and the primary NMS. Private base stations will communicate with the NMS using the mobile terminal common channel signalling scheme.

An FDMA architecture with a common channel signalling design has been adopted to accommodate future developments in modulation and processing technologies and to support a variety of communications standards. The modular system and ground infrastructure design will support the following key system features:

- Supporting a range of mobile terminal designs (e.g. mobile or fixed).

- Supporting different service types, qualities and priorities (e.g. data rates, link margins, and service priorities).

- Use of forward link power control to minimise the single carrier power.

- Providing an integrated network management facility that will control and monitor the whole network.

- Capability to support multiple common signalling channels.

- Compatibility with future multiple spot beam satellites.

- Supporting an ISDN terrestrial interface which will support advanced user features (e.g. call diversion, call charge advice, etc).

3 CHANNEL SPECIFICATIONS

3.1 SIGNALLING CHANNEL

MOBILESAT has been designed to provide a reliable and robust common channel signalling system that will meet the following criteria:

- Supporting a population of 100,000 mobile terminals in a single beam system.

- Supporting a call set up rate of 13 calls per second with additional messaging and system overheads.

- Establishing 99% of the channels within 5 seconds of call request.

- Providing system modularity to support different call types and future requirements (e.g. multiple beams).

The signalling system and the NMS will be configured to handle, on a per call basis, different communications channel types, service qualities and priorities. Also, as with the other networks, Bulletin Boards will be regularly transmitted to provide updates of the system status and configuration. The system design will also permit the down-loading of key mobile terminal parameters from the NMS to the mobile terminals.

All signalling and messaging information will be sent using a 96 bit signal unit, protected with rate 3/4 convolutional code. A high power (5 dB link margin) outbound TDM signalling channel will be transmitted from the NMS using BPSK modulation, at a symbol rate of nominally 9600 sps (4800 and 2400 sps will also be supported). The high data rate will simplify the carrier acquisition process in the mobile terminals and will also provide sufficient capacity to support multiple repeats of critical signalling information.

A slotted ALOHA random access protocol will be used for the inbound channels. Upto thirty-two inbound channels will be allocated to a single outbound channel. Upto eight of the available inbound channels will be used in a TDMA mode with multiple repeats for acknowledging information on the outbound TDM channel. Inbound channels will operate at 2400 bps using Aviation BPSK modulation with 5 kHz channel spacing.

The performance of the signalling channels have been extensively simulated using Australian propagation data[2,3]. In combination with a straight forward channel establishment procedure, it is estimated that over 99% of the channel set up times will be less than 2.3 seconds for mobile originated calls. A complete simulation model for the overall signalling system is currently being established by Bond University, Australia, which will enable fine tuning of the overall protocol prior to the release of the final signalling specifications.

The system has been designed so that it will also support a 6 byte two way single packet data messaging capability via the NMS by using excess capacity on the signalling channels. The NMS will act as a packet data switch which will route data received on an X.25 terrestrial network port onto the outbound channel and perform the opposite service for the inbound channels. This will enable, for example, a dispatch centre to poll a mobile terminal and obtain a response in less than 2 seconds.

3.2 COMMUNICATIONS CHANNEL

AUSSAT, in conjunction with a number of Universities, has performed extensive analyses, simulations and experiments for various modulation and coding schemes for both voice and data channels. The MOBILESAT system can be configured as either power or bandwidth limited depending on the usage criteria.

The initial system will support up to 1,500 circuits using digital voice modulation with 5 kHz channels, at a threshold C/No of around 45 dBHz, including all implementation losses. An additional 3 dB fade margin will be used to provide a high quality, robust voice service that will operate under severely shadowed links. Indeed, AUSSAT has found through simulation that the capability of the voice codec to handle burst errors is the key to providing a robust service.

Simulated results by the University of Sydney, Australia, indicate that, theoretically, TCM schemes with coherent demodulation can offer 1 to 2 dB reduction in the required signal power compared to conventional schemes. However, due to the complexity associated with carrier acquisition and synchronisation in the design of the TCM demodulator, AUSSAT has adopted a more realistic approach and selected coherent QPSK modulation with 40% Nyquist filtering for maximum bandwidth efficiency. The OQPSK approach with a Class C amplifier was not considered since it did not give the required spectrum efficiency and was found to offer no other advantages over QPSK. Even though the construction of fast acquisition (10ms) four phase demodulators at low SNR is not trivial, AUSSAT is confident that good performance is possible down to at least an Es/No of 3dB.

The call signalling information between the mobile terminals and the Gateway/Base stations will be transmitted over the channels by dropping voice frames and inserting signalling packets. This will be feasible since at the start and end of the call no voice frames will be used, and during the call the dropping of a single voice frame will have no resulting degradation in the voice quality. This simple technique will enable the channel overheads to be minimised and the channel rate to be limited to 6.6 kbps.

For the facsimile service, which will operate at upto 4.8 kbps, a similar protocol spoofing scheme to the INMARSAT specifications will be used. However, a novel ARQ scheme will also be employed to ensure error free transmission. The system design will allow easy transition to a Store and Forward facsimile service which will become available in the future. To verify the proposed scheme, AUSSAT has placed a consultancy contract to finalise the specifications and to build demonstration hardware by July 1990.

4 TECHNICAL ACTIVITIES

4.1 OVERVIEW

Over the past three years, AUSSAT has been conducting an extensive technical program to study the critical aspects of mobile satellite communications to support the development of the MOBILESAT system. This has been carried out both internally and in collaboration with other research organisations both within Australia and overseas.

One of the key activities is the experimental program which uses the Japanese ETS-V satellite as a test bed in Australia for mobile satellite experiments. This is part of a joint study between AUSSAT and the Communications Research Laboratory (CRL) of Japan.

4.2 EXPERIMENTAL PROGRAM

In order to access the ETS-V satellite, AUSSAT constructed a hub station in Sydney and equipped a van to be used as a mobile laboratory for the tests. The major experiments conducted to date include:

Propagation measurements - These were carried out in collaboration with an expert team from the Texas University at Austin to characterise the mobile satellite environment for Australia [4]. The results collected are summarised in Figure 2. This data has been used in simulation models for evaluating the signalling protocol, the voice codec and the modem performances.

Analog vs digital voice - Evaluation of the potential candidates for voice transmission over mobile satellite channel was carried out during the first half of 1989. These included both ACSSB modems supplied by Skywave, Kenwood and Bristol University, and 4.8 kbps voice codec built by the University of California at Santa Barbara (UCSB) for the Jet Propulsion Laboratory (JPL). As a result of these trials, a decision to employ a digital modulation technique was taken for the MOBILESAT system since it requires less power and its quality is comparable if not better than ACSSB.

Antenna evaluation - ETS-V has proven to be an ideal test bed for evaluating antenna performance in the real mobile environment. The antennas tested include various designs of omni-directional as well as mechanically steered (JPL, NEC, UNSW) and electronically steered (JPL) antennas.

Terminal evaluation - Complete terminal prototypes developed by NEC (digital) and Kenwood (ACSSB) for CRL were loaned to AUSSAT for evaluation in Australia in March 1989. JPL also brought their mobile van to Australia for testing in July 1989[5].

4.3 MOBILE SATELLITE HARDWARE SIMULATOR

A mobile satellite fading simulator has been constructed by AUSSAT to assist in the evaluation of the hardware in the laboratory. The simulator operates at the 70 MHz IF frequency, at which the I and Q components of the signals are modulated by the fading data. Two independent methods are employed to generate the fading data:

Measured data - a fading CW signal is received at the MOBILESAT van and is recorded in its I and Q format in the computer. The data is then calibrated and played back for the simulator.

Simulated data - a combination of a Rician model for the multipath fading and a Markov model describing the transition between the fade and non-fade states is employed. This model produces propagation data which matches very closely to the statitical characteristics, such as fade duration, non-fade duration and fade depth, obtained from the measured data [6].

4.4 VOICE CODING SELECTION

In September 1989, AUSSAT issued a request for submission of voice codec hardware for evaluation for the MOBILESAT system. The program was conducted jointly with the INMARSAT-M voice codec evaluation, and the testing of the hardware was undertaken by Australia's Telecom Research Laboratory[7].

The MOBILESAT voice codec, including FEC, operates at 6.4 kbps, with an overall channel rate running at 6.6 kbps after the insertion of the unique word. The selected codec algorithm, in addition to providing high quality voice, must demonstrate that it can perform at BER as low as 0.01 and is able to handle fades as long as 100ms. At the time this paper was written (March 1990), it was anticipated that the final choice for the codec algorithm would be made in May 1990.

A contract has also been placed by AUSSAT with the University of Wollongong, Australia, to study various methods to combat fading and to make a recommendation for an algorithm that will improve the quality of the transmitted voice during long fades of upto 100ms. The proposed scheme will be considered for incorporation into the chosen codec to further improve its performance in the severe fading conditions.

4.5 DEMONSTRATION TERMINAL

AUSSAT is currently constructing a mobile terminal which will be fitted in a passenger car for demonstration to the customers. The terminal will employ the same codec and modem algorithms as specified for the MOBILESAT terminal and will operate at C/No of 48 dB/Hz, which is the nominal operating level for the current system. The hardware is anticipated to be completed in the third quarter of 1990 and will operate with the ETS-V satellite until the AUSSAT-B satellites are in operation.

5 CONCLUSION

As the first domestic mobile satellite system to be in operation worldwide, MOBILESAT will be charged with the challenge of being a test bed for the development of the other systems which will be implemented at a later date. Intensive study has been conducted by AUSSAT in the critical areas of mobile satellite communications in the design of MOBILESAT to make use of the current state-of-the-art technologies and to provide a robust system optimised for land mobile operation.

REFERENCES

1. **Wagg,M.** 1990. MOBILESAT, Australia's Own. International Mobile Satellite Conference 1990, Ottawa, Canada.

2. **Irish,D. et.al.** 1989. A Robust Signalling System for Land Mobile Satellite Services. Proceedings of the Mobile Satellite System Architectures and Multiple Access Techniques Workshop, March 1989, Pasadena, USA.

3. **Rice,M. et.al.** Modem Design for MOBILESAT Terminal, 1990. International Mobile Satellite Conference, 1990, Ottawa, Canada.

4. **Vogel, W.J. et.al.** 1989. Land-Mobile-Satellite Propagation Measurements in Australia using ETS-V and INMARSAT-Pacific. Published by Johns Hopkins University.

5. **Dessouky,K. et.al.** 1990. Field Trials of a NASA Developed Mobile Satellite Terminal. International Mobile Satellite Conference 1990, Ottawa, Canada.

6. **Wakana, H.** 1990. A Propagation Model for Land Mobile Satellite Communications. AUSSAT Internal Report.

7. **Bundrock,A. et.al.** Evaluation of Voice Codec for the Australian Mobile Satellite System. International Mobile Satellite Conference 1990, Ottawa, Canada.

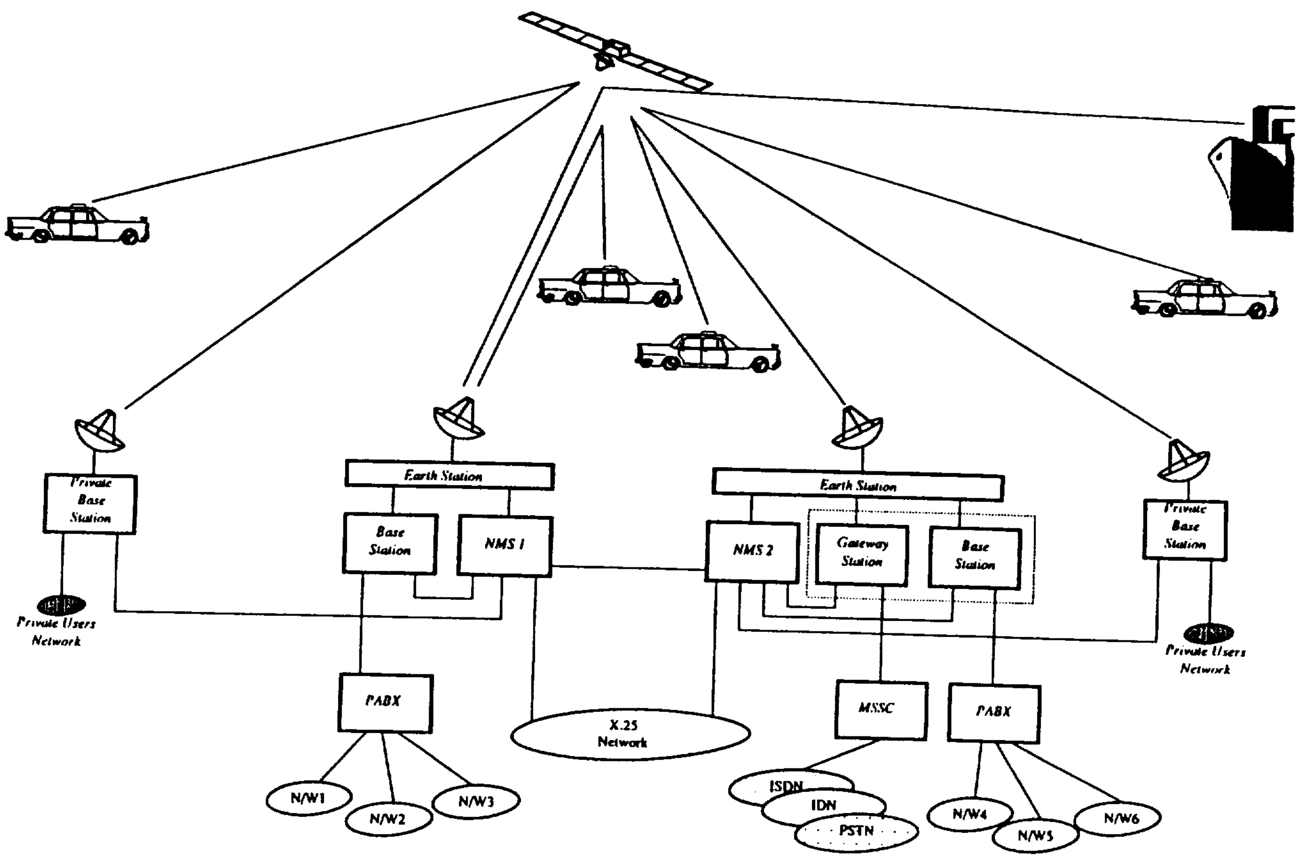

Figure 1 MOBILESAT Network Structure

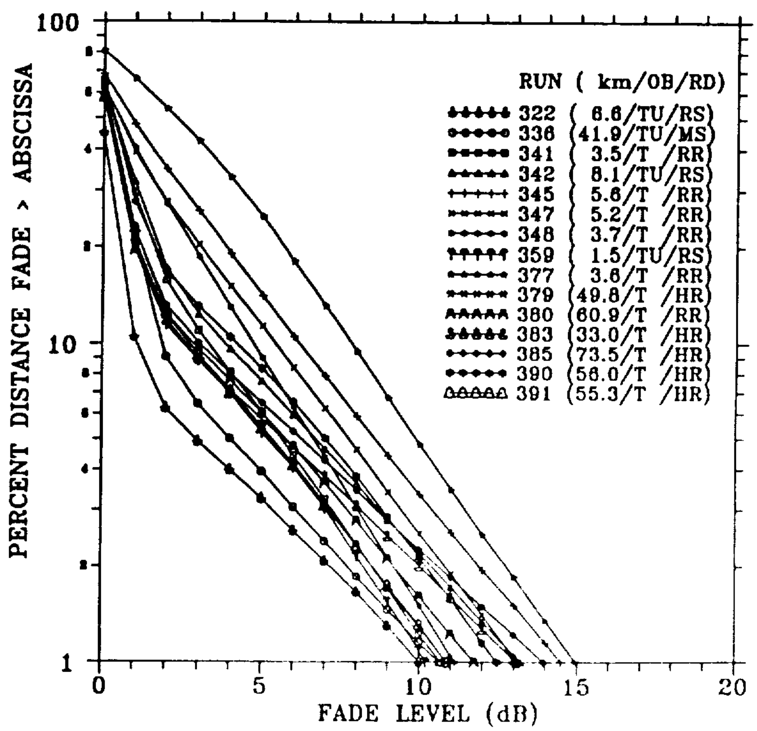

Figure 2 Propagation Data for Australia[4]