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LAND-MOBILE SATELLITE DEMONSTRATION SYSTEM

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ABSTRACT

A land-mobile satellite demonstration system is described. The system was developed by Rockwell International with the cooperation of COMSAT Maritime Services and the International Maritime Satellite Organization (INMARSAT) and utilizes the INMARSAT MARECS B2 satellite at 26 degrees W. The system provides data transmission using a poll-response prototcol with error detection and retransmission at a 200-b/s rate. For most tests, a 1.8-inch monopole antenna was used, along with a satellite EIRP normally used for four voice channels. A 30-watt mobile transmitter was used.

Key system objectives were to:

- Investigate propagation effects at low elevation angles to the satellite using a simple nondirective antenna
- Develop and demonstrate a MODEM which would accommodate system frequency errors and doppler shifts which total six times the data rate, short preambles, and the need for rapid bit as well as carrier synchronization.

The paper gives a brief summary of the results and describes the overall system consisting of three elements in addition to the satellite, namely the mobile unit, the base station, and the office terminal and map display. Throughput statistics from one trip are summarized.

INTRODUCTION

In October 1987, Rockwell International initiated a land mobile test and demonstration program.

Figure 1 illustrates the three elements developed for the test program:

1. A satellite transceiver equipped van which by December 1987 had been driven several thousand miles during testing including a trip from Iowa to Washington, DC, and back on two different routes. The van is equipped with both GPS and LORAN-C navigators which report position through the satellite system every two minutes in addition to user text messages.

2. A base station installed at COMSAT's facilities at Southbury, Connecticut.

3. A trucking company dispatcher's terminal consisting of a data terminal and electronic map display. The dispatching unit is portable and may be connected to the base station at Southbury, Connecticut, by dial-up telephone line.

Table 1 summarizes the system specification.

The dispatch terminal, base station, and mobile unit each include a COMPAQ II computer. In addition, the base station and mobile unit computers each house TMS32020 computer-based signal processors which provide the RF modem function.

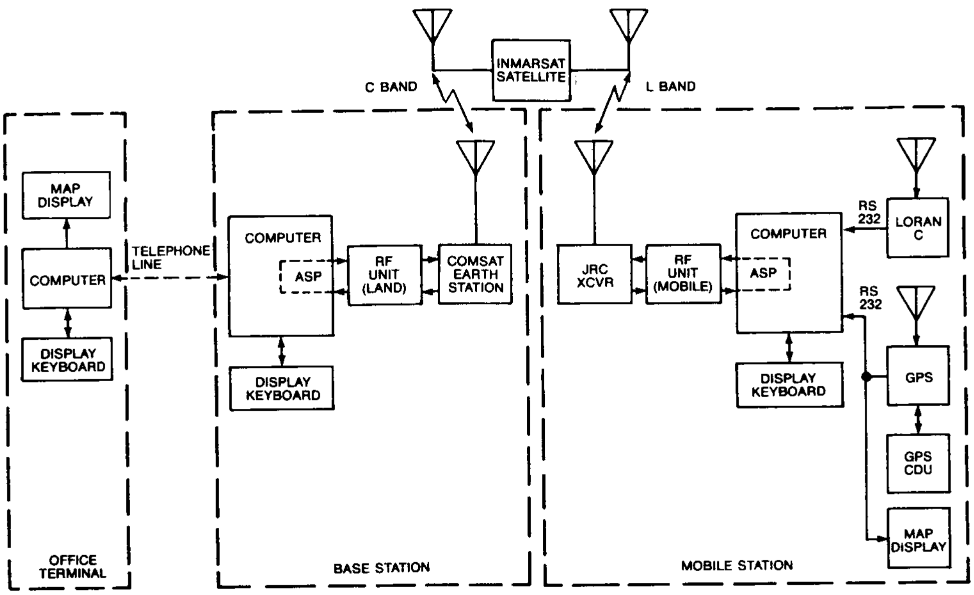

Fig. 1. Block diagram of demonstration

Table 1. System specification

System protocol	Poll response, half duplex
System data rate	200 b/s
Modulation	DPSK
Message block lengths	See figure 2
Error control	Cyclic redundancy check (CRC) with automatic repeat request (ARQ)
Return link	Burst mode
Mobile transmitter power	30 watts
Mobile transmit frequency	1642.8 MHz
Mobile antenna	Omnidirectional $\lambda/4$ Monopole
Forward link	Continuous with fill between blocks
Mobile receive G/T	-27 dB/k
Mobile receive frequency	1541.3 MHz
Mobile position sensor	GPS and LORAN C

A principal technical uncertainty resolved by these experiments was satellite-to-mobile propagation reliability at low power and low satellite elevations, to a mobile unit using an inexpensive omnidirectional antenna. A simple 1.8-inch (quarter-wave length) vertical antenna over a ground plane proved to be the best because of the low elevation angles (9°) in the Cedar Rapids, Iowa, region.

During more than 100 hours of testing, polling messages were sent to the mobile unit every 2 or 3 seconds requesting a mobile unit response. Statistics were automatically recorded on the

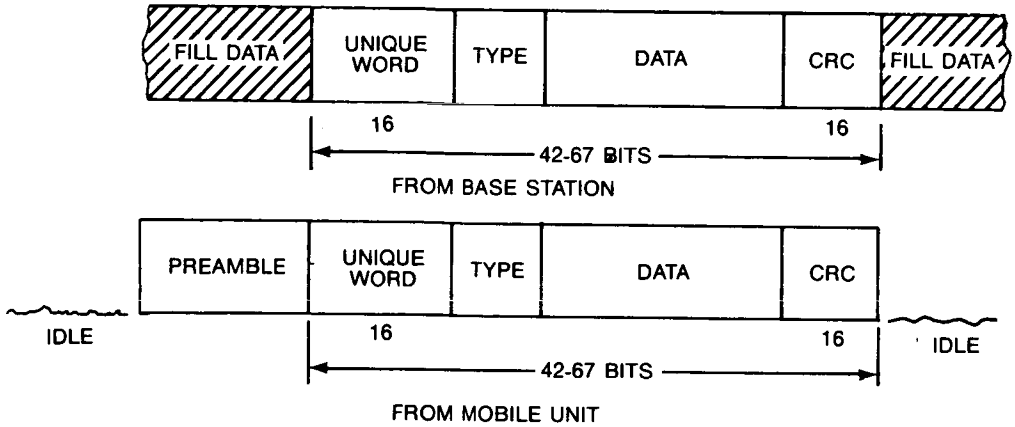

Fig. 2. Message formats

number of successful polls and responses at the mobile unit and at the base station, and were summarized every two minutes. As expected the principal propagation problem was related to blockage and not multipath fading. Detailed results are reported in Reference [1].

A major achievement of this program was the development of an RF modem which could quickly detect a 200-b/s phase-modulated signal burst with an E_b/N_o of 7.5 dB when the carrier uncertainty due to oscillator errors and satellite and mobile unit doppler shifts is plus or minus 600 Hz. Thus, the signal-to-noise ratio in the initial 1200-Hz detection bandwidth is -0.28 dB. This modem included a coarse frequency determining algorithm for the wide bandwidth low S/N initial detection, a frequency locked loop differential demodulator, and a unique symbol timing algorithm for bit-timing detection. In addition, it was necessary to develop a real-time multitasking operating system for the TMS32020 in order to implement these functions in one processor. A detailed discussion of this modem is provided in Reference [2].

Subsystem Descriptions

Dispatch Terminal: This unit communicates with the mobile unit through a dial-up 1200-b/s full-duplex data circuit to the base station and through the base station to the mobile unit via the satellite link at 200 b/s. It consists of a computer and map display and simulates, for one truck, the features which would be available to a dispatcher or other controller of a multi-truck fleet.

The position of each truck is displayed both as a numerical latitûde and longitude and also visually on a map display. The display has several map scales ranging from 1/3 of the world, down to a few city blocks.

The dispatch terminal may request position updates from the mobile units at 2-minute to 8-hour intervals. Immediate position updates may be requested as well. Preformatted (canned) message and free text message capability is also provided.

Mobile Terminal: This unit consisted of:

1. components of a Japan Radio Corp. JUE 35A/B INMARSAT Standard-A shipboard terminal which included the LNA, Diplexer, PA, Main Unit, and Keyboard/Display. The JRC keyboard display was used to place the terminal in a test state that allowed fixed tuning for receive and transmit; therefore, did not require interaction with INMARST's link protocols.
2. An omnidirectional quarter wave monopole antenna.
3. A Rockwell NAVCORE® 1 GPS receiver.
4. A LORAN-C receiver and antenna.
5. A COMPAQ II Personal Computer, containing the TMS32020 board that served as the digitally implemented modem. The PC also was used as the mobile terminal keyboard and display.
6. Internally developed hardware to interface the PC/Modem with the JRC main unit. Figure 3 is a photograph of the mobile terminal display showing an extensive library of preformatted text messages which can be selected with a few key strokes. This mode of operation is more suitable for a driver than free text entry, although this was also provided.

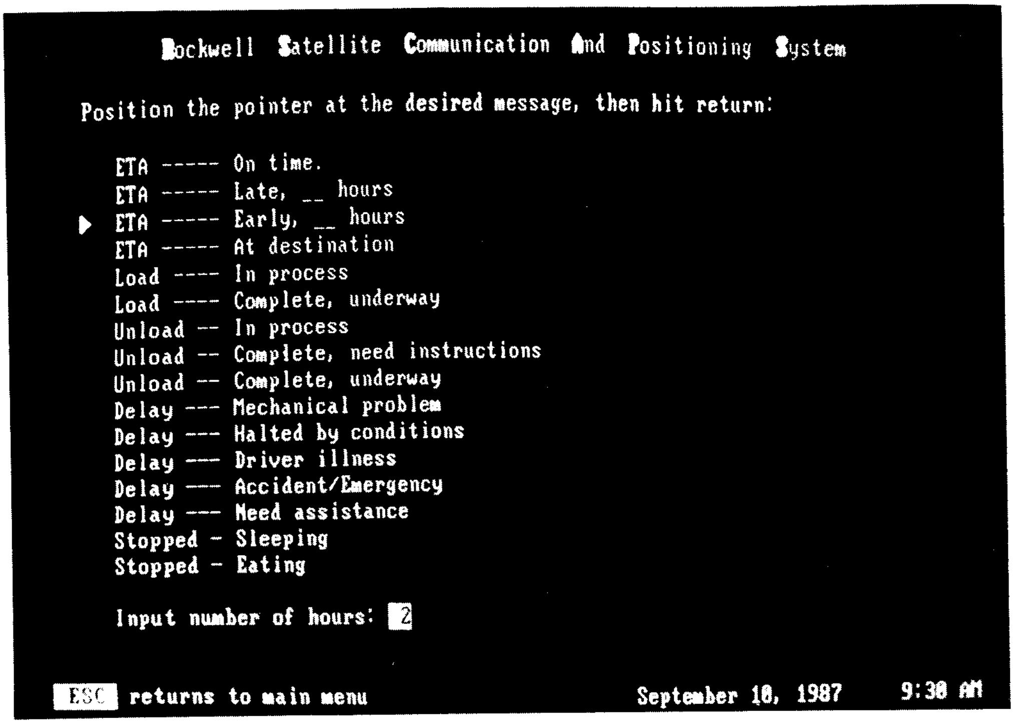

Fig. 3. Photograph of mobile terminal display

Base Station: The operation of the base station, while invisible to the user, is central to the system architecture in that it controls all satellite link functions. For experimental and test purposes, both the mobile unit and the dispatcher can send and receive text messages from the base station screen and keyboard; however, in normal operation the base station is unattended.

The base station consists of a COMPAQ II computer and its internally housed TMS32020 signal processor serving as the RF modem along with an 8-inch rack-mounted unit containing the transmit and receive oven crystal standards, several IF stages and a PSK modulator.

The base station computer contains an internally mounted autoanswer wire-line modem for communication with the dispatch terminal and a hard disk for statistics and software storage. Experimental statistics are extracted at the end of a test drive via the modem line to the dispatch location.

PROPAGATION TEST RESULTS

A major purpose of this project was to take extensive system performance data. System performance is primarily a function of the link between satellite and mobile terminal with signal variations due to blockage by buildings, trees, and terrain and due to multipath fading.

The principal means for quantitizing the performance of the system is to monitor the success of the routine short message transactions which take place every three seconds in an idle system and as often as every two seconds when multiple segement messages are passed. The success of the transaction at the base station is determined by correct reception of the response message as indicated by a correct 16-bit cyclic redundancy check (CRC)code. These data are summarized every two minutes coincident with completion of a position report. Both the LORAN-C and the GPS positions are also recorded, Figure 4, shows a GPS position report at 41° 41′ 45″ N Latitude, 92° 18′ 90″ W Longitude. The LORAN-C report shows a discrepancy with GPS of about 2200 feet. This is within the normal error range for LORAN-C.

The message throughput statistics contain the number of messages transmitted, error-free messages received, and the number of retransmits listed by message type. Also shown is the number of messages received from the mobile unit. These statistics are updated at the base

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TIME    03:00 PM  GPS time     BASE  STATION
  GPS LAT    41  41' 45" N     GPS LONG   92  18' 09" W
LORAN LAT    41  41' 58" N   LORAN LONG   92  17' 34" W
SEGMENT TYPE        0      1      5      6      7    TOTAL
# Transmits         5      0      0     29     15      49
# Received         10      5      0     29      0      44
# Retransmits       0      0      0      1      4       5
# CRC Errors                                           2
SSSSSSSSSSSSSRSSSRRRSSSSSSSSSSSSSSSSSSSSSSSSRSSSSSSS
TOTALS SINCE STARTING
          2647  Transmitted                1884  Received
           403  Retransmitted               107  CRC Errors
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Fig. 4a. Base station statistics — 2 minute report

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TIME    02:00 PM  GPS time     MOBILE  UNIT
  GPS LAT    41  41' 45" N     GPS LONG   92  18' 09" W
LORAN LAT    41  41' 58" N   LORAN LONG   92  17' 34" W
SEGMENT TYPE        0      1      5      6      7    TOTAL
# Transmits        12      5      0     30      0      47
# Received          5      0      0     29     13      47
# Retransmits       2      0      0      0      0       2
# CRC Errors                                           2
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Fig. 4b. Mobile unit statistics — 2 minute report

station and the mobile unit. Every time the mobile unit is required to give its position, the summary, as shown in Figure 4, is recorded on disk memory.

While the base station report shows the overall round trip success of the transactions, the mobile unit report allows one to separate the performance of the satellite-to-mobile link from the performance of the mobile-to-satellite link.

The statistics in Figure 4 show the results during a September 30, 1987, trip from Cedar Rapids to Pella, Iowa, in flat terrain on Interstate 80 headed west at the positions shown which is near highway mile marker 205. The statistics cover the period from 1:58 to 2:00 PM CDT on the van which is the interval from 2:58 to 3:00 PM EDT at the base station in Southbury, Connecticut.

During this time, the base station interrogated the mobile unit 49 times and received 44 responses with correct CRC codes. Five interrogations received no response. Unique words were correctly received for two of these five with CRC errors while the other three were lost entirely.

Successful responses (S) and unsuccessful responses resulting in a retransmit (R) are shown in Figure 4 as a string of 49 characters.

These message totals are composed of five message types ranging in length from 42 to 67 bits.

The mobile unit received and responded to 47 messages. Thus, in this case two were lost on the forward link and three more on the return link.

Table 2 gives an example of data obtained from the message throughput statistics for a major portion of the trip. The number of messages transmitted and error-free messages received at the mobile unit and the base station are shown for 16-minute intervals. The LORAN-C and GPS positions of the van at the end of each 16-minute interval are also shown. During the time shown, 79.8% of the messages sent by the mobile unit were received by the base station and 86.4% of the messages from the base station were received by the mobile unit.

It is possible to correlate the message throughput statistics with the propagation environment. For example, at 2:30, the van exited I-80 west and headed south on county roads toward Pella. Since the satellite was located southeast of the van at an elevation angle of about 7 degrees, blockage of the signal from buildings and trees was expected. This is revealed by the message throughput after 2:30 which dropped to 75.6% of the messages received by the base station and 78.8% of the messages received by the mobile unit.

Table 2. Summary of 1-hr 25-min run

Mobile unit			Loran-C pos	GPS pos	Base station	
Time intv	Transmitted	Rcvd			Transmitted	Rcvd
1:56 - 2:14 P	424	424	Lat 41 42′ 00 N Long 92 34′ 07 W	41 42′ 46″ N 92 34′ 25″ W	430	355
2:14 - 2:30 P	361	370	Lat 41 41′ 34″ N Long 92 52′ 32″ W	41 41′ 12″ N 92 52′ 57″ W	384	311
2:30 - 2:46 P	367	367	Lat 41 33′ 34″ N Long 92 56′ 31″ W	41 33′ 19″ N 92 56′ 23″ W	385	318
2:46 - 3:02 P	313	323	Lat 41 24′ 16″ N Long 92 54′ 54″ W	41 24′ 00″ N 92 55′ 06 W	396	236
3:02 - 3:21 P	260	261	Lat 41 23′ 49″ N Long 92 56′ 04″ W	41 23′ 34″ N 92 56′ 12″ W	425	157
Total	1725	1745			2020	1377

Message throughput
Mobile unit to base - 1377/1725 = 0.798

Base to mobile unit
1745/2020 = 0.864

CONCLUSIONS

These tests have demonstrated the feasibility and usefullness of an LMSS. Of significance was the ability to provide a usable communication link at low elevation angles and minimal link margins.

REFERENCES

1. Nicholas, D. C., "Land Mobile Satellite Propagation Results" Proceedings of the Mobile Satellite Conference, Pasadena, CA, May 3-5, 1988.

2. Henely, S. J. et. al., "Modem for Land Mobile Satellite Channel" Proceedings of the Mobile Satellite Conference, Pasadena, CA, May 3-5, 1988.