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SATELLITE COMMUNICATIONS EXPERIMENT FOR THE ONTARIO AIR AMBULANCE SERVICE

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ABSTRACT

Since 1976, the Government of the Province of Ontario, Canada, has operated an aircraft ambulance service for the benefit of remote communities. To support a decision to upgrade the air ambulance attendants to paramedic status, the Ministry of Health solicited the cooperation of Communications Canada/ Communications Research Centre to conduct a satellite communications experiment. The objectives of the experiment were to develop a reliable voice communications system between the paramedics and the doctors in certain larger medical centres.

The experiment used INMARSAT's Atlantic Ocean Region satellite which provides coverage to the western border of Ontario. Forward downlink power from the satellite is in great demand, so two highly power-efficient modulation schemes were chosen for evaluation during the experiment. These were amplitude-companded single-sideband (ACSSB) and linear-predictive coding in conjunction with DMSK modulation. Although both systems have been tested over the satellite, flight tests to date have concentrated on ACSSB. Good performance with a signal-to-noise ratio of about 10 dB has been demonstrated from many parts of the province with the elevation angle to the satellite ranging from five to twenty degrees and with the aircraft both in-flight and on the runway.

The experiment is presently in the service evaluation phase. It will evolve into a limited pre-operational service later in 1988.

INTRODUCTION

Since 1976 the Government of the Province of Ontario, Canada, has operated an aircraft ambulance service from northern Ontario communities to larger medical centres in the southern parts of the province. The air ambulances have been staffed by attendants trained to initiate and maintain basic life support procedures only. A 1986 report, prepared by the Air Ambulance Section of the Ministry of Health, assessed the air ambulance program and recommended that the aircraft be staffed by paramedics who could provide more extensive life support services than the ambulance attendants. Subsequently, training of paramedics has commenced and they are expected to enter service in April 1988.

The radio links currently used by the air attendants must also be upgraded for paramedic use. Patients being evacuated from remote locations frequently require attention before take-off and the first thirty or forty minutes on the airstrip can be critical. Radio coverage for this situation and frequently when the aircraft is flying north of 50°N is not available with the present VHF system. After evaluation of a number of alternatives, Ontario Government officials came to the conclusion that INMARSAT's satellite facilities showed the greatest promise for fulfilling the service requirements. A cooperative experimental program was established with Communications Canada/ Communications Research Centre, Teleglobe Inc. (Canada's INMARSAT signatory) and INMARSAT. The objectives of the program were to develop the necessary technology, to establish suitable institutional arrangements, to perform technical flight trials and to provide a service evaluation opportunity for the users.

In this paper we describe the technical considerations in the design of the experiment, the special equipment developed and qualified, the conduct of the flight trials, the evaluation of the results and the plans for transition to an operational service.

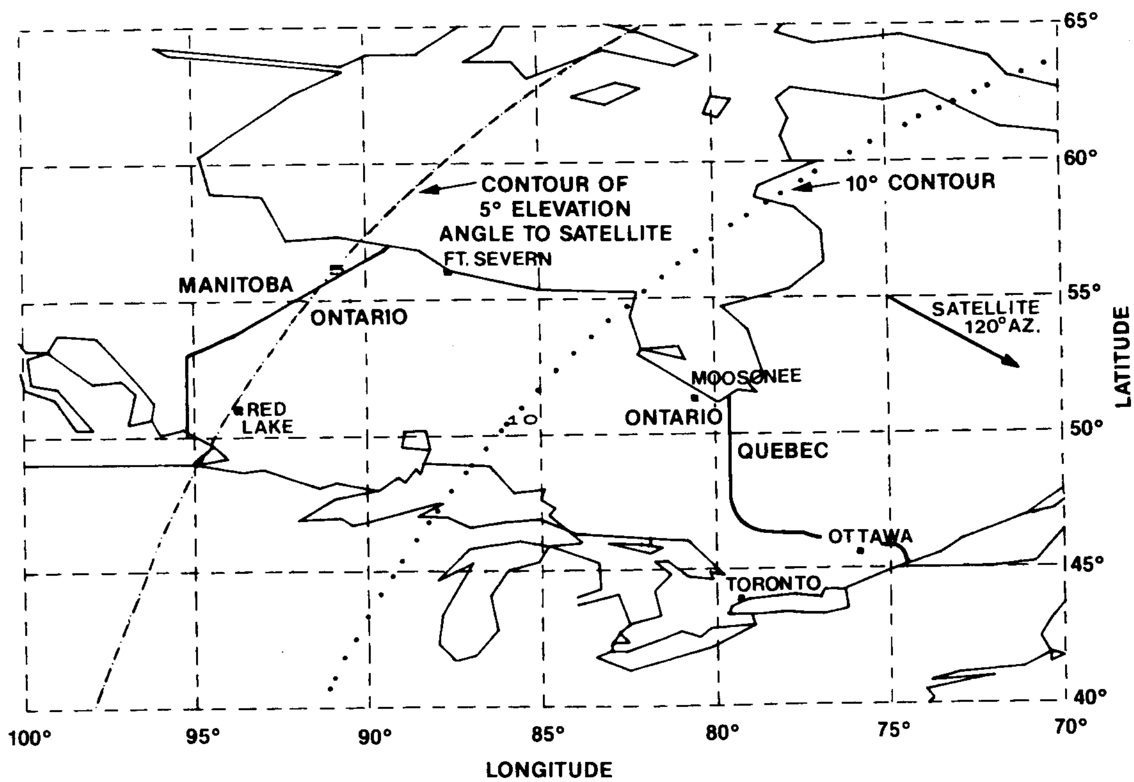

Fig. 1: Coverage of the INMARSAT AOR satellite over Ontario

GENERAL CONSIDERATIONS

Northern Ontario is at the edge of the coverage area of the Atlantic Ocean Region (AOR) satellite at 26° W. longitude. Fig 1 shows that much of the proposed service area lies between the contours of five and ten degrees elevation angle to the satellite. When using a 10 to 12 dB gain aircraft antenna at such low angles, discrimination against multipath signals scattered from the ground is not possible. The consequent direct signal-to-multipath ratio (C/M) is 8-10 dB with less than 100 Hz Doppler spreading of the multipath [Neul, 1987].

The maximum economic forward-link EIRP available from the satellite is judged to be 21 dBW. With this downlink power and a typical aircraft terminal G/T of -15 dB/K, only 45 dB-Hz unfaded received signal-to-noise power density ratio is available. This is 7 to 8 dB too low for the frequency modulation system used for INMARSAT ship terminals and so more efficient voice coding and modulation techniques must be used, at some sacrifice in terms of received signal quality.

Two schemes are being evaluated during the experimental program. These are amplitude-companded single sideband (ACSSB) and 2400 b/s linear predictive coding (LPC) coupled with DMSK modulation [Lodge, 1986]. Both these schemes operate well at 45 db-Hz with a C/M of 8 dB. Ministry of Health officials currently favour ACSSB because of the good speaker recognizability and intelligibility down to 36-37 dB-Hz. A drawback is the requirement for a more expensive linear power amplifier for the aircraft transmitter in place of the standard Class C amplifier. A seven-module transistor amplifier providing 50 watts average output, 140 watts peak power and better than 20 dB C/IM was developed for the program.

LINK BUDGETS

Although the target of the linear power amplifier development program was to produce an amplifier with sufficient power to communicate using the standard marine band frequencies, permission was sought from INMARSAT to use the Search-and-Rescue (SAR) channel during the experiment period as a precaution. The SAR channel has 15 dB extra gain and so requires only a quarter of the transmit power from the mobile compared with the marine band.

Table 1 shows the link budgets. For the ACSSB system, signal levels given are long-term average values. Peak envelope power (1% of the time) is 3dB above these levels.

Table 1. Link Budgets

Uplink	To Aircraft	Return
Frequency	6423.9	1644.4
Transmit Power (Watts)	6.0	9.5
Feed Loss (dB)	1.0	3.8
Transmit Gain (dB)	54.2	12.3
EIRP (dBW)	61.0	18.3
Path Loss (dB)	200.6	189.0
Polarization Loss etc. (dB)	1.0	1.0
Satellite G/T (dB/K)	-13.0	-11.0
Uplink C/N_0 (dB-Hz)	75.0	45.9
Downlink		
Frequency (MHz)	1541.4	4200.4
Satellite EIRP (dBW)	21.0	-8.0
Path Loss (dB)	188.4	196.9
Polarization Loss etc. (dB)	1.0	1.0
Earth Station G/T (dB/K)	-15.0	31.0
Downlink C/N_0 (dB-Hz)	45.2	53.6
Overall C/N_0 (dB-Hz)	45.2	45.2

THE AIRCRAFT EQUIPMENT

Disposition

The air ambulance used for the experiment was a twin-turbofan Cessna Citation 1. Normally a small five-passenger executive jet, this aircraft was equipped with two stretcher positions, two attendant seats and a selection of medical equipment. The electronics equipment for this experiment was located under the floor of the nose baggage compartment and so was exposed to the full range of environmental conditions. The diplexer, LNA and antenna selection switch were mounted under the cabin floor, between the control cables. The control panel and headset were located near the starboard attendant seat, while the antennas were mounted inside the front port and starboard cabin windows.

Antennas

We chose window-mounted antennas in order to commence the experiment in a relatively short time. An electronically-steered external antenna will eventually be required for the follow-on operational phase, but will require extra time and funds. The type of antenna used consisted of a three-element vertical phased array of square microstrip patch elements, providing thirty degrees elevation beamwidth, sixty degrees azimuth beamwidth and 10% bandwidth. Transmit peak gain was 12.3 dB RHCP, receive gain 11.6 dBic and the beam was squinted by 17.5 degrees so that when mounted in the cabin window, the beam was aimed at an elevation angle of 7.5 degrees.

EXPERIMENT PROCEDURES AND RESULTS

Ground-Based Tests

The experimental program started with performance verification of the prototype equipment while ground-based. The aircraft equipment was installed in a mobile laboratory which was parked near the 9 metre (C-band) base station installation located at the Communications Research Centre. Full-duplex tests of both the LPC/DMSK and ACSSB equipment were run over the INMARSAT satellite. Recordings of received voice signal quality were made at different transmit power levels and measurements of received C/N_0 were made to confirm the link budgets.

Flight Tests

The first flight test was held on the 24th November 1987 and consisted of a short flight in the Ottawa area to verify equipment operation using ACSSB modulation. The second flight was run from Ottawa to Moosonee on James Bay (fig. 1). The elevation angle to the satellite decreased from 20° at Ottawa to 12.8° at Moosonee. The ACSSB communications quality during the flight and while on the airstrip at Moosonee was at the expected level of about 45 dB-Hz C/N_0. During flight, communications were maintained over a 90° range of aircraft headings, centred on 030° (starboard antenna) or 210° (port antenna). The satellite azimuth was 120°. Communications quality at the extremes of this range was reduced to 37 dB-Hz, which was fully intelligible thought somewhat "gravelly". Note that this is a signal-to-noise ratio of only 2dB.

The third test flight ran from Ottawa to Moosonee, then to Fort Severn on Hudson Bay, to Red Lake near the western border of Ontario and then back to Ottawa (fig. 1). At Red Lake, the elevation angle to the satellite was only five degrees. Communications at Red Lake, both while in the air and on the airstrip were at the 45 dB-Hz level while the aircraft was on a suitable heading. No problems were observed attributable to the low elevation angle.

The final test flight of 1987 concentrated on routing of communications to and from the aircraft, through the base station in Ottawa and via an auto-ringdown telephone link to the Central Air Ambulance Communications Centre ("Medcom") in Toronto. Off and on-hook signalling from the aircraft were performed using the # and * DTMF tones which passed satisfactorily through the ACSSB equipment. A tone decoder at the base station then activated the telephone line to Medcom and alerted the dispatcher. Satisfactory results were obtained with the experimenter on the aircraft talking to the Medcom dispatcher and, when patched through Medcom, to other centres and even to a cellular mobile.

TRANSITION TO OPERATIONS

The experiment is currently in the service evaluation phase. The air ambulance attendants, dispatchers and doctors will have two evenings per week for about a two month period in which to use the satellite communications system in a non-operational role. Human factors specialists, under contract to the Ontario Government, will help in orientation of the users to the new radio system and will assess their reactions to it. Their recommendations will be useful in integrating the new system into the Medcom network with the minimum disruption.

On May 1st, 1988, the satellite communications system is scheduled to enter limited pre-operational service. A tariff is being negotiated by Teleglobe, based on a minimum usage of 200 minutes per month.

The present base station will be used as an interim operational base station until Teleglobe can take over this role with a station of their own. The mobile transmit frequency will be changed to 1642.9 MHz which is in the lower-gain marine band rather than the SAR channel. Because of the lower gain, the aircraft terminal transmit power will need to be increased to about thirty watts from the ten watts previously used.

CONCLUSIONS

The air ambulance experiment has shown that existing satellite facilities can be used to provide voice links to general aviation aircraft. Communications were reliable to five degrees elevation angle with no performance degradation, airborne or on the airstrip. Several improvements remain to be implemented for the operational service. The first in priority is to replace the window-mounted antennas with an externally-mounted electronically-steerable antenna. Others concern details such as an improved method for transmission of signalling and supervisory information and to take into account any recommendations resulting from the human factors study.

ACKNOWLEDGEMENTS

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