An Aircraft Earth Station for General Aviation

R. Matyas, J. Broughton, Canadian Astronautics Limited,
1050 Morrison Drive, Ottawa, Ontario K2H 8K7,
Phone: (613) 820-8280, FAX (613) 820-8314

R. Lyons, S. Spenler, SkyWave Electronics Limited, 300 March Road,
Suite 304, Kanata, Ontario K2K 2E2, Phone: (613) 592-0908,
FAX (613) 592-2104

J. Rigley, Communications Research Centre, 3701 Carling Avenue,
P.O. Box 11490, Station "H", Ottawa, Ontario K2H 8S2,
Phone: (613) 991-9309

ABSTRACT

While the focus has been international commercial air traffic, an opportunity exists to provide satellite communications to smaller aircraft. For these users equipment cost and weight critically impact the decision to install satellite communications equipment. Less apparent to the operator is the need for a system infrastructure that will be supported both regionally and internationally and that is compatible with the ground segment being installed for commercial aeronautical satellite communications.

This paper describes a system concept as well as a low cost terminal that are intended to satisfy the small aircraft market.

INTRODUCTION

The provision of aeronautical communications by satellite is gaining increasing acceptance for long range commercial aircraft. International consortia of service providers are currently procuring ground earth stations (GES') in order to offer operational service via the INMARSAT system; some are presently conducting field trials and providing limited service in conjunction with aircraft earth station (AES) manufacturers and airlines.

The provision of voice and data communications capability for smaller aircraft is of considerable interest in view of the very large number of such aircraft in use. Recent studies indicate a potential market of 11,500 AES' worldwide. It is anticipated that these AES' will differ in significant respects from those being developed for commercial airlines.

Canadian Astronautics Limited (CAL) and SkyWave Electronics Limited (SkyWave) are presently developing a low cost, compact, single channel AES. This equipment will allow pilots and passengers to communicate with the worldwide public or private telephone and data networks through services offered by Teleglobe Canada and its international partners in France and Australia, and others.

Topics covered in this paper include compatibility with the INMARSAT aeronautical system, packaging philosophy, effective deployment of subsystems in the aircraft, AES architecture, and field trial objectives.

SERVICES

Aeronautical communications using geostationary satellites overcomes the line of sight limitations of VHF radio and the unreliability of long range HF radio. Global coverage except at the poles will be in place early in 1991.

International (Inmarsat) and regional (TMI,AMSC, AUSSAT) mobile satellite system operators will provide access to the public switched telephone and data networks through their GES'. Accordingly, telephony services now provided in an office can be extended to an aircraft. These services will support the following [1,2].

Passenger Correspondence

- Voice communications via standard telephone handset.
- Data transmission via laptop personal computer.
- Facsimile transmission via portable fax unit.

Cockpit Communications

- Voice communications via headset.
- Pro-forma and coded messages via customized interface unit.

SYSTEM ARCHITECTURE

Aero Interoperability

The General Aviation (GA) service is based on standards by Inmarsat [3], ARINC [4] and ICAO which have application to both international and domestic commercial aeronautical satellite networks. Figure 1 depicts the GA system architecture.

Both Commercial and GA services will adopt Inmarsat-compatible Access/Control/Signalling (ACS) channels. GA circuit-mode voice channels can be expected to evolve with improvements in lower rate vocoder and modulation technologies providing lower cost service and AES equipment.

Voice Communications

The Inmarsat SDM specifies a 9600 bps vocoder followed by a 21 kbps Aviation-QPSK modulator with rate- 1/2 error correction coding (FEC) for C-channel voice communications. Background bit error rate monitoring is performed to permit BER measurements and dynamic power control information to be exchanged via the C-channel sub-band. This sub-band includes some additional capacity for low rate user data and system messages.

In the GES-to-AES direction, the A-QPSK carrier is voice-activated to conserve satellite power during periods of speech inactivity. On the reverse C-channel, the modulator uses continuous-mode A-QPSK with the power level dynamically adjusted under command from the GES.

For the GA service it is expected that a standard will be developed that uses 4800 bps digitally encoded voice. Pending a decision, the GA AES discussed here will allow for the use of either 9600 bps voice or a more bandwidth efficient modulation - ACSSB. ACSSB voice has been field proven for the Ontario Air Ambulance Service [2].

AES DESIGN APPROACH

The challenge in designing a satellite terminal for General Aviation is to produce a unit whose cost, weight and size are suitable for smaller aircraft while at the same time retaining complete compatibility with the commercial aviation ground segment and Inmarsat standards. This has been accomplished by the following simplifications to the ARINC 741 baseline [4].

- Use of a single telephone channel with switched user interfaces.
- Reduction of the number of functional units relative to an ARINC-741 configuration by integrating (1) satellite data, beam steering and RF units, and (2) the LNA and diplexer with the antenna. This will reduce both equipment and installation costs.
- Use of a single top-mount antenna to minimize the number of fuselage modifications.
- A level of built-in test capabilities commensurate with expected aircraft usage.
- Designing each unit for 28 VDC power which is generally available on smaller aircraft, rather than AC power.
- Incorporating integral unit thermal cooling rather than relying on rack cooling which may not be available or practical in a small aircraft.
- Billing by aircraft registration eliminates the need for credit card reading equipment.
- Reduction and simplification of inter-unit connections and interfaces to other avionics.

AES CONFIGURATION

The GA AES comprises four distinct functional elements: a user interface, a transceiver, a high power amplifier and an antenna. The AES configuration is shown in Figure 2. These units are described as follows.

User Interface

The User Interface (UI) supports voice/data set connections, provides visual indication of operational status and incorporates features to support factory integration and test, and maintenance. The UI is placed in an aircraft where appropriate, allowing local or remote user access.

Transceiver

The transceiver incorporates a channel unit, an IF/RF unit including frequency reference and an antenna controller.

The channel unit includes a communications controller, a modem and a baseband to IF frequency converter. The communications controller implements sub-network and link layer protocols, converts asynchronous user data to synchronous form, performs low level system diagnostics, controls the modem and services commands including supervisory local/remote functions from the user interface and P-channel data. The modem implements P-, R-, T- and C-channel protocols and transfers signal units to/from the link level software in the communications controller. The modem also programs the synthesizers in the frequency converter. The baseband to IF frequency converter independently synthesizes transmit and receive frequencies in 2.5 kHz steps over the allocated uplink (34 MHz) and downlink (29 MHz) bandwidths. It also performs AFC and Doppler frequency correction under control of the controller. The relative P-channel frequency offset is used to precompensate for the Doppler frequency shift on the transmitted carrier.

The IF/RF unit performs independent block frequency conversion for each of the transmit and receive chains between the intermediate and L-band frequencies. A high stability ($\pm 3 \times 10^{-7}$), low phase noise 6 MHz reference oscillator is also included.

The antenna controller supports open- and closed- loop antenna steering and includes the antenna drivers. Open loop control involves computing satellite direction based on geo-stationary satellite position and aircraft attitude and position data provided on an ARINC-429 bus from an onboard navigation system such as an INS or GPS receiver. Closed loop operation involves a wide area scan of the directional antenna for satellite acquisition followed by dithering of antenna pointing during tracking mode. A signal quality estimate derived in the modem from the received signal is the basis for closed loop beam control.

High Power Amplifier

The HPA is a high power Class A amplifier capable of supporting modulations requiring linear amplification as well as future multicarrier operation if needed. The unit provides a 48 dBm 1 - dB compression point. High output power capability of the HPA allows for flexible deployment in a wide range of aircraft accounting for losses due to long cable runs. A modular design provides for lower outputs if needed.

Antenna

The top mount antenna subsystem described more fully in [5] incorporates the antenna, low noise amplifier and diplexer and provides full azimuth coverage (without gaps) as well as elevation coverage from 5°-90°.

Prototype Terminal

The prototype terminal characteristics are included in Tables 1 and 2. The prototype C-channel is expected to use ACSSB for voice with 9.6 kbps vocoded speech provided in production units. The prototype will be available for field trials with a test hub in the fall of 1990.

ACKNOWLEDGEMENT

This development has been supported by Supply and Services Canada, Transport Canada and Communications Canada. The co-operation of Teleglobe Canada is also gratefully acknowledged.

REFERENCES

1. J. Rigley, "Aeronautical Mobile Satellite Service: An Overview", Proceedings Canadian Satellite User's Conference, Ottawa, 1989.

2. R. Huck, "Satcoms and general aviation" in Never Beyond Reach, B. Gallagher ed., INMARSAT, London, 1989, pp. 164-169.

3. "Aeronautical System Definition Manual", Inmarsat, London, England.

4. "Aviation Satellite Communications System - ARINC Characteristic 741-1, Parts I and II", Aeronautical Radio, Inc., Annapolis, Maryland.

5. P. Strickland, "Low Cost Electronically Steered Phased Array for General Aviation", this conference proceedings.

Table 1
GA AES Characteristics

Access, Control, Signalling and Data Channels	P-, R- and T- channels per Inmarsat Aeronautical SDM. BER < 10^{-5} with FEC
Voice Channel	Full duplex ACSSB (prototype): 2.5 Mean Opinion Score Digital vocoding (future) Voiceband FAX A-BPSK data (prototype)
Channel Bandwidth	P,R,T channels: 2.5 kHz C channel: 5 kHz
Frequency Range	Receive: 1530 - 1559 MHz Transmit: 1626.5 - 1660.5 MHz
EIRP (dBW)	R/T-Channels:13.2 dBw (600 bps) 16.2 dBW (1200 bps) ACSSB C-channel: 20.3 dBW (average)
Antenna Installation/Coverage	Top-Mount (360° AZ;5-90° EL)
Antenna Steering	Open loop (baseline)
G/T	-13 dB/K
Environmental	RTCA DO/160B

Table 2
Configuration

Assembly	Size	Weight
Antenna/Radome	1.4m x 0.2m x 0.35m	12 kg
Transceiver	8 MCU avionics enclosure	10.5 kg
HPA	8 MCU avionics enclosure	9.8 kg
Cockpit User Interface	7.6cm x 14.6cm x 17.8cm	1.5 kg

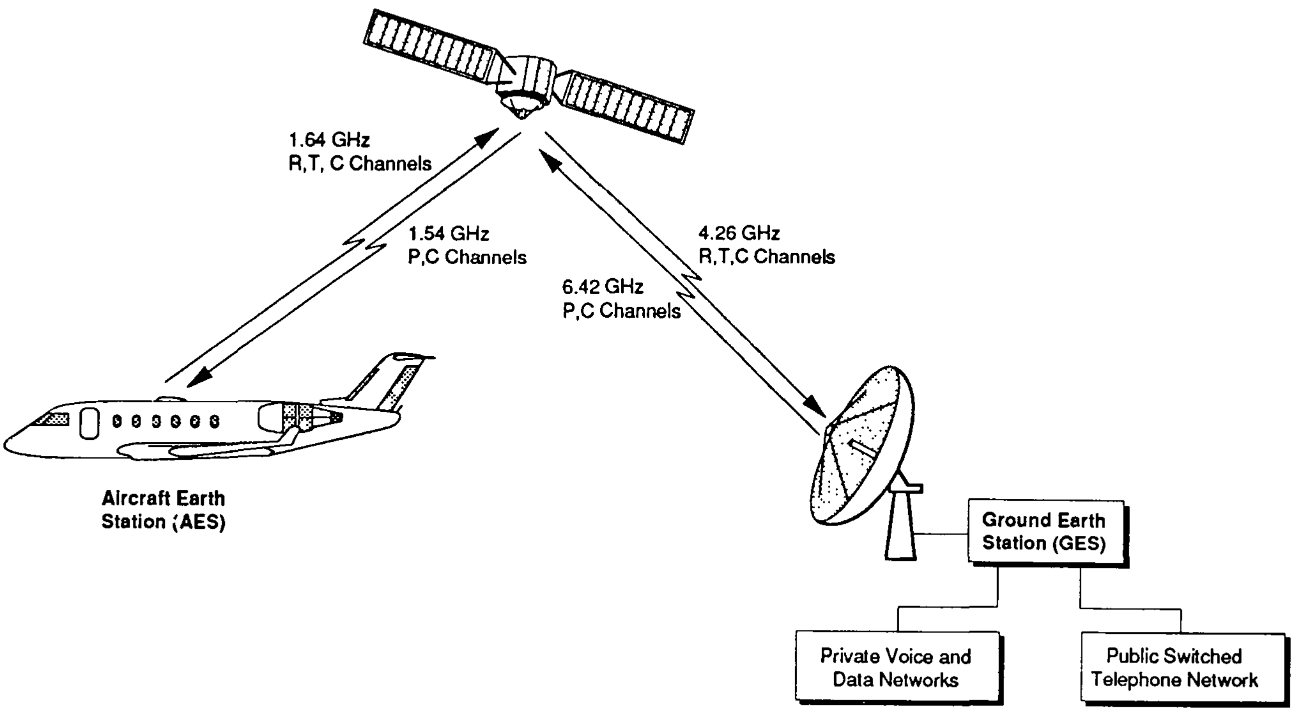

Figure 1 GA System Architecture

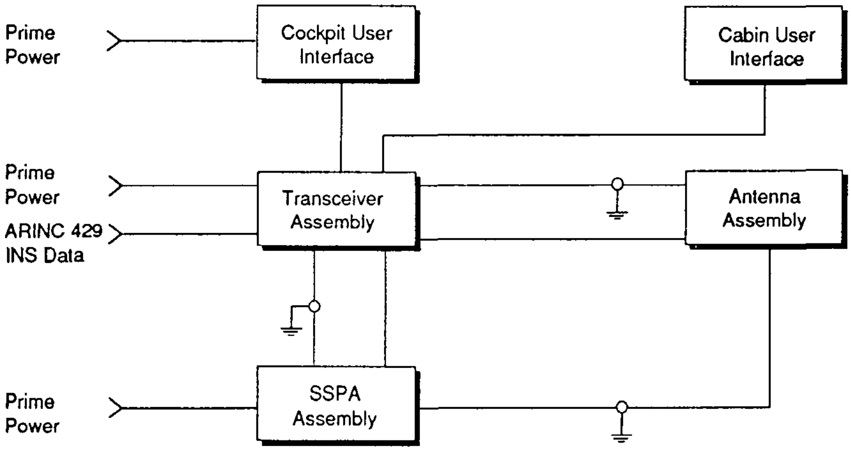

Figure 2 AES Configuration