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THE AMSC MOBILE SATELLITE SYSTEM

DR. CARSON E. AGNEW, Hughes Communications Mobile Satellite Services, Inc., United States; JAI BHAGAT, MCCA Space Technologies Corporation, United States; EDWIN A. HOPPER, McCaw Space Technologies, Inc., United States; JOHN D. KIESLING, Mobile Satellite Corporation, United States; MICHAEL L. EXNER, Skylink Corporation, United States; LAWRENCE MELILLO, North American Mobile Satellite, Inc., United States; GARY K. NOREEN, Transit Communications, Inc., United States; BILLY J. PARROTT, Satellite Mobile Telephone Co., United States.

TRANSIT COMMUNICATIONS, INC.
P.O. Box 90425
Pasadena, California 91109-0425
United States

ABSTRACT

The American Mobile Satellite Consortium (AMSC) is the designated provider of domestic land, maritime and aeronautical Mobile Satellite Service (MSS) in the United States. This paper describes the AMSC MSS system. AMSC will use three multiple-beam satellites to provide L band MSS coverage to the United States, Canada and Mexico. The AMSC MSS system will have several noteworthy features, including a priority assignment processor that will ensure preemptive access to emergency services, a flexible SCPC channel scheme that will support a wide diversity of services, enlarged system capacity through frequency and orbit reuse, and high effective satellite transmitted power. Each AMSC satellite will make use of 14 MHz (bi-directional) of L band spectrum. K_u band will be used for feeder links.

INTRODUCTION

The U.S. Federal Communications Commission (FCC) has mandated that Mobile Satellite Service (MSS) be provided in the United States by the American Mobile Satellite Consortium (AMSC). The eight companies that make up AMSC all filed MSS applications with the FCC on April 30, 1985 and have been determined by the FCC to be qualified MSS applicants.

AMSC filed a Joint Amendment of the original applications of its member companies on February 1, 1988. This paper is a synopsis of the technical portion of the AMSC Joint Amendment. AMSC and the services it will provide are described in a companion paper in this volume.

AMSC and Telesat Canada plan to jointly procure MSS spacecraft and provide mutual on-orbit backup. It is anticipated that the AMSC and Telesat spacecraft will be nearly identical and will occupy complementary orbital positions.

NASA has offered to launch the first AMSC spacecraft in exchange for initial system capacity for technology development and government demonstrations.

The system described here may be modified somewhat as a result of negotiations with Telesat and NASA or other changed circumstances.

SYSTEM DESIGN

The AMSC system consists of three basic elements: the space segment, user terminals, and hub stations (Figure 1). Four types of user are shown to illustrate some of the more common applications, namely, a land mobile user with an omnidirectional antenna, a land mobile user with a steered directional high gain antenna, an aeronautical mobile user, and a transportable user. Users can access the public switched telephone network through gateway stations or private networks through base stations.

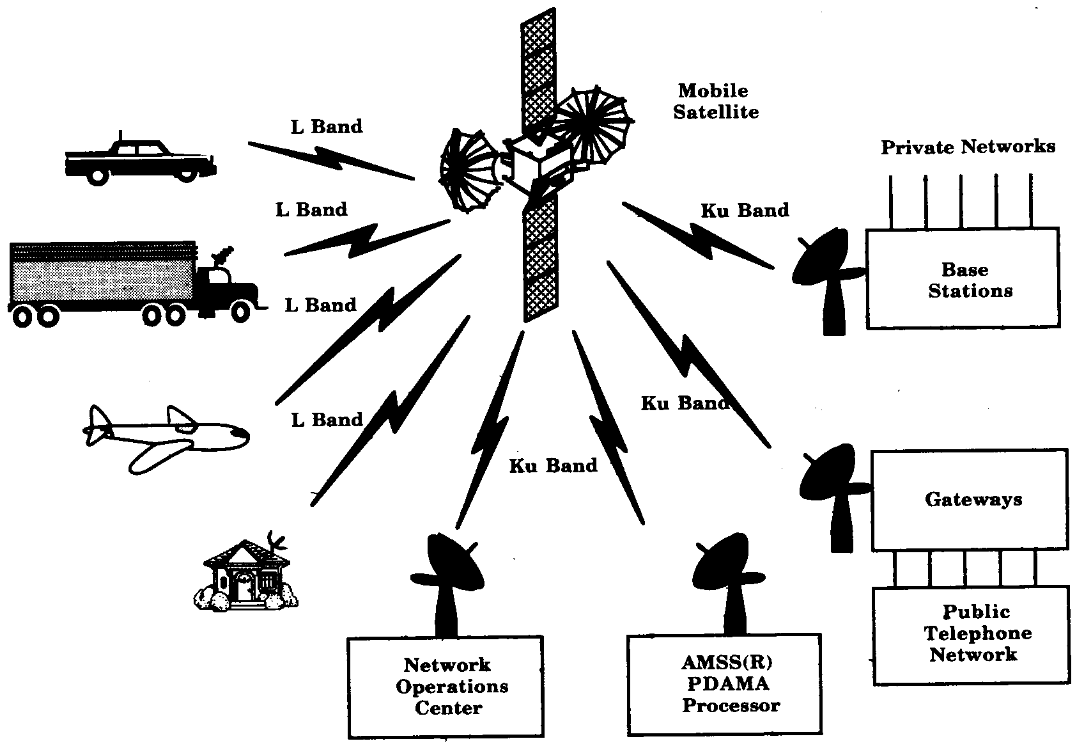

Figure 1. Network Configuration

The AMSC system uses L band frequencies for links between users and the satellite and K_u band for feeder links. All circuits are controlled by the Priority Demand Assignment Multiple Access (PDAMA) system and are routed to a K_u band gateway or base station.

All L band satellite circuits are connected to K_u band feeder link circuits in the satellite. L band-to-L band circuits require two satellite hops via a gateway or base station. There is no satellite path for direct single hop L band-to-L band circuits.

AMSC will construct and operate one K_u band Network Operations Center (NOC) for network monitoring and control. Satellite TT&C can be performed at this site or at another facility. AMSC will also operate two gateway stations for test and monitoring purposes. Operational gateway stations will be constructed and operated by common carriers purchasing space segment capacity from AMSC. Base stations will be used by private network operators.

As illustrated in Figure 1, the ground segment includes two primary classes of earth stations (user terminals and hub stations) and the Network Operations Center. These elements are described below.

User Terminals

Three classes of user terminals – mobile/omni, mobile/steered, and transportable – are required because users vary widely in average air time requirements, intended use, and their vehicle's characteristics. Communications between satellites and user terminals will be at L band.

Mobile/omni terminals will be the lowest cost terminals, but because of the low gain of omni antennas, a relatively high satellite EIRP is required for each channel. This results in high airtime charges. Mobile/omni land and maritime terminals will be able to use antennas with 3 to 6 dBi gain.

Mobile/steered terminal antennas must be actively pointed towards the satellite. This requires determining the position of the satellite relative to the vehicle, an antenna that is directional in azimuth, and a method for steering the antenna towards the satellite. These requirements result in a higher cost terminal, but also substantial reductions in airtime charges. Mobile/steered aeronautical, land and maritime terminals are expected to have antenna gains in the 10 to 14 dBi range.

When transportable terminals can be used, both terminal cost and airtime charges are minimized. Transportable antenna gain is expected to be in the range of 15 to 22 dBi.

All three user terminal classes will support voice and/or data service using ACSB or a variety of digital modulation formats. Terminal signalling and modulation standards will be developed in cooperation with manufacturers.

The PDAMA system will communicate with a micro-controller in each user terminal to dynamically allocate spectrum and network capacity to active terminals. Despite many functional differences, user terminals will share a common pool of 5 kHz channels for nearly all applications. All channels will be constructed of contiguous 2.5 kHz subchannel sets; every terminal will be capable of tuning to any center frequency in 2.5 kHz increments throughout the entire 14 MHz operating band.

All aeronautical terminals will have at least the "core" capability defined by ICAO, 1986. The core capability is a two-way 600 bps data link and is used for air traffic control. All aviation communications, including voice, will be digital.

The aircraft antenna is expected to be a phased array system including two high gain phased arrays looking abeam and mounted 45° from the horizon on each side of the aircraft, or a single high gain antenna mounted on the top of the fuselage or tail. In addition, a single low gain hemispherical antenna can be used with at least 0 dBi gain over 360° in azimuth, above 7° elevation for level flight. These antennas will be right hand circularly polarized with an axial ratio less than 6.0 dB.

Hub Stations

The AMSC network will consist of many semi-autonomous star networks. At the logical center of each star network will be a hub station. All user terminals will communicate through one or more hub stations. Hubs will be of two basic types: (1) gateway stations for interconnection of telephone and other traffic to the PSTN; and (2) base stations for termination of private networks at dispatch centers and monitoring and control sites. Like user terminals, all hub stations will be under the control of the NOC.

Hub stations will access the satellites through duplex K_u band feeder links. All hub stations will have frequency agile channel modems, each able to use any of the feeder link channels.

Gateways. Gateways will interconnect traffic with the public switched telephone network. They will typically have a capacity of 5 to 100 or more channels. AMSC expects that service providers will install gateways throughout the country. Traffic will be routed to a point of interconnection close to the final destination.

Base Stations. Hub stations used to terminate private network traffic are referred to as base stations. They are analogous functionally to base stations in the conventional private land mobile radio service. Private base stations differ in architecture from gateways only in that channels are not connected to the telephone network, except as required for private company communications. Instead, they will generally be interfaced with dispatch consoles or SCADA control stations. AMSC expects fleet operators to install a large number of K_u band base stations across the country.

Network Operations Center. The Network Operations Center (NOC) will communicate with all user terminals and hub stations through a K_u band RF subsystem consisting of frequency agile digital channel units. Precision time, referenced to the National Bureau of Standards, will be disseminated over the network control channels to synchronize the network and to provide a public service. In addition, MSS satellite ephemeris data and real-time information concerning the status of the Global Positioning System (GPS) satellites, Loran, and other navigation systems will be disseminated for use in integrated communications/surveillance networks.

PDAMA System

The Priority Demand Assignment Multiple Access (PDAMA) system controls access to the network. It monitors usage of channels and assigns channels to users. It coordinates assignment of channels in all beams on each satellite on a dynamic basis to minimize interbeam and intersystem interference. Channel assignments between user terminals and hub stations can be switched similar to the way in which cellular channels are dynamically allocated.

When a user originates a call, the user terminal communicates the call request to the PDAMA system on an L/K_u band signaling circuit. The PDAMA system sets up the call using a K_u band common signalling circuit to the hub station serving the called party. After the called party answers, the PDAMA system sets up a duplex L/K_u band circuit between the user terminal and the hub station. The PDAMA system monitors the call duration on a common signalling circuit using the K_u band link with the hub station.

When a call originates through a hub station, a similar sequence occurs. The station communicates the call request to the PDAMA system on a common K_u-K_u signalling circuit. The PDAMA system signals the user terminal on a K_u/L packet circuit. When the user terminal acknowledges, the PDAMA system assigns a duplex L/K_u circuit to the call.

The entire 14 MHz allocation is available through each beam, maximizing the flexibility of the PDAMA system to dynamically respond to market variations between beams. While the same SCPC channel cannot ordinarily be reused in adjacent beams, frequencies can be reused in beams separated by at least one beam through the use of channel interleaving and interbeam isolation.

The central PDAMA processor will recognize different levels of message priority to ensure that air traffic control and other safety-of-life services receive certain access to network capacity whenever it is needed. Additional levels of priority will be used as needed in the various hub stations, according to the specific end use involved.

The PDAMA system will be implemented using a distributed control architecture, whereby specialized private networks, such as will be required for AMSS(R) networks, will have their own dedicated PDAMA processor and software. AMSC will establish interface standards that will enable private networks to operate nearly autonomously.

The central PDAMA processor and a gateway can be collocated with the TT&C equipment in the NOC, enabling common antennas for K_u band uplinks and downlinks.

Space Segment

The fully developed space segment will consist of three high performance satellites in geosynchronous orbit. The first satellite is anticipated to be launched in 1992.

To accommodate the market demand, it is anticipated that all satellites will employ 3-axis buses with 2500 watts prime payload power, weighing 1200 kg on orbit. The nominal launch mass, including apogee stage, is 2500 kg. Each satellite will have batteries sufficient for at least 25% service capability during eclipse.

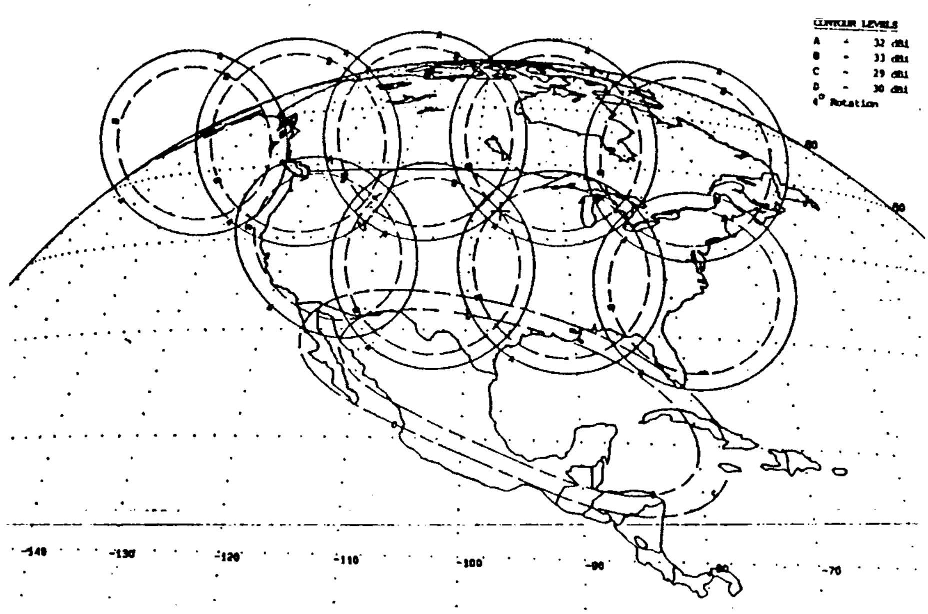

Figure 2. L Band Coverage, 101° W Orbit Location

A pair of 5.5 meter diameter unfurlable reflectors will each generate ten L band spot beams covering North America (see Figure 2). Separate transmit and receive antennas are used to minimize the effects of passive intermodulation (Hoeber, 1986). Maximum aggregate linearized L band Effective Isotropic Radiated Power (EIRP) of all beams is 60 dBW; L band G/T of each beam is 3 dB/K at edge-of-coverage.

AMSC has requested 75°, 101°, and 136° West Longitude orbital assignments. The Canadian MSAT satellite will be located near 106° W longitude. Frequencies at K_u band are 14.0 to 14.5 GHz (earth-to-space) and 11.7 to 12.2 GHz (space-to-earth); at L band, 1646.5-1660.5 MHz (earth-to-space) and 1545-1559 MHz (space-to-earth).

K_u band communications are subdivided into two groups: a K_u-K_u group and a K_u-L group. The K_u-K_u group is 10 MHz wide, including 5.0 MHz for initial operations and an additional 5.0 MHz for future expansion. The K_u-L group consists of 10 channels for use by the first spacecraft in each orbital slot, and 10 channels for an additional collocated spacecraft, if needed. Horizontal uplink polarization will be used by the U.S.; the opposite polarization will be used on the downlinks.

The AMSC satellites can be launched as a one-half payload on the Titan 3 or on another suitable launch vehicle.

NASA has offered to provide launch services to AMSC in exchange for mobile satellite capacity for MSAT-X activities. NASA includes a reservation for this launch in its current ELV manifest. NASA would use the mobile satellite capacity it would receive from AMSC for technology experiments and government demonstrations.

Table 1 shows a representative link budget for communications quality voice to an omnidirectional land mobile antenna.

Table 1. Example Link Budget for Omnidirectional Land Mobile Terminal

	Hub-to-Mobile		***Mobile-to-Hub***		
	Uplink	*Downlink*	*Uplink*	*Downlink*	
Frequency	14000	1549.5	1651.0	11700	MHz
Available RF Power (dBW)	10.0	28.1	3.0	13.0	dBW
Power Amplifier	10.0	640.0	2.0	20.0	Watts
Power Loss	-2.0	-1.8	-1.0	-1.0	dB
Transmit Antenna Gain	51.8	33.8	4.0	25.0	dBi
EIRP	59.8	60.1	6.0	37.0	dBW
Capacity	1	2650	1	2650	Erlangs
Voice Duty Cycle	35	35	35	35	Percent
EIRP/Channel	64.4	30.4	10.6	7.3	dBW
Path Loss	-207.41	-188.29	-188.84	-205.85	dB
Polarization Loss	-0.5	-0.5	-0.5	-0.5	dB
Receive Antenna Gain	25.0	4.0	33.8	50.1	dBi
Data Rate	4800	4800	4800	4800	bps
E_b	-155.4	-191.2	-181.8	-185.7	dBW/Hz
Receiver Temperature	480.0	190.0	900.0	385.0	°K
Antenna Noise	290.0	100.0	290.0	40.0	°K
Total Thermal Noise	28.9	24.6	30.8	26.3	dBK
G/T	-3.9	-20.6	3.0	23.8	dB/K
Thermal Noise Density, N_o	-199.7	-204.0	-197.8	-202.3	dBW/Hz
IM NPR	20.0	15.0		20.0	dB
E_b/N_o	44.4	12.8	16.1	16.6	dB
I_o From Other Systems	-300.0	-250.0	-250.0	-250.0	dBW/Hz
E_b/IM Level	58.2	19.0		37.3	dB
Uplink E_b/N_o		39.3		16.1	dB
K_u Fade Margin	5.0			5.0	dB
Combined $E_b/(N_o+I_o)$	39.3	11.8	16.1	10.2	dB
$E_b/(N_o+I_o)$,Minimum		8.9	8.9	8.9	dB
M=Modem Implementation Loss		0.9	0.9	0.9	dB
$(E_b/(N_o+I_o))$min + M		9.8	9.8	9.8	dB
Total Margin		2.0	6.3	0.4	dB

SERVICES

A variety of services will be offered to the users. Each service will be optimized for a particular set of user criteria. Examples of optimization criteria include: antenna cost, installation cost, usage charge, and voice quality. Similarly, aeronautical services will have their own specific requirements as defined by ARINC characteristics 741 and by ICAO/FANS. Several areas of technology are experiencing rapid development, such as digital speech processing. By the time system implementation is complete, it is expected that 4.8 kbps digitally encoded voice or ACSB will be adequate for most applications.

Position location will be available through the AMSC system through the use of Loran-C receivers, integrated MSS/GPS receivers or satellite ranging.

With the addition of a GPS processing board and the use of differential transmissions sent through the AMSC system, an integrated MSS/GPS transceiver can estimate its position to within 5 m.

Satellite ranging techniques will enable location of mobiles within a fraction of a mile with only minimal modifications of the mobile transceiver once multiple satellites are in orbit (Anderson, 1979 and 1980).

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