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Implementation of Inmarsat Mobile Satcom Systems

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ABSTRACT

This paper describes the new mobile satcom systems being implemented by Inmarsat. Inmarsat has traditionally provided professional communication to ships and is now actively implementing new systems for use on land, in the air and at sea. These new systems can provide near global communication for anyone on the move.
By 1993 four new systems will provide telephony, telex, data, group calls and facsimile at affordable cost to a very wide range of users.

A table giving the main technical parameters for Inmarsat Aeronautical, Inmarsat-B, C and M systems is also provided.

AERONAUTICAL SYSTEMS

Inmarsat started the development of an Aeronautical system in 1985. It was soon realised that there was a need for a low cost data system using an omnidirectional antenna and a medium gain antenna for voice and higher speed data. The aeronautical community is well organised and standards are set in the so called Airline Electrical Engineering Committee (AEEC) in which Inmarsat put forward the proposals which eventually became ARINC standard 741. Further information on the Aeronautical system is provided in separate contributions.

Low antenna gain system

The low gain system provides typically 600 bit/s data, but can be set at higher or lower rates depending on the satellite link C/N0. The data modulation is a modified form of DEBPSK called Aviation BPSK with convolutional rate 1/2 FEC. Interleaving is also used to counter multipath. The multipath is typically 10 dB less than the desired signal and typical fading bandwidth is 400 Hz. The antenna gain is around 0 dBi and provides hemispherical coverage with a single antenna.

Medium antenna gain system

The medium gain aeronautical system is based on an antenna system with around 12 dBi gain. This was highest gain considered practical and requires a

surface area of approximately 0.25 square metre using a phased array antenna.
This antenna supports rates up to 9.6 kbit/s used for voice, data and fax services.
Again convolutional rate 1/2 coding and interleaving is used, to conserve bandwidth OQPSK is used.
Some of the challenges with this system has been design of phased array antennas with low phase shift as function of beam steering. The design of OQPSK demodulators operating at Es/N0 of 0 dB was also required.

Protocols

The highest amount of engineering has been spent on the access control and protocols. The system can provide a wide range of bitrates in a very flexible manner. Multichannel operation can also be provided. This complexity and flexibility has been considered essential to provide a system which is likely to be used for the next 20 years.

INMARSAT-C SYSTEM

This system provides two way data at 600 bit/s from a small low cost terminal. The system can provide store and forward telex, data calls, electronic mail, position reporting, fleet management and safety services. An interesting application is Supervisory Control And Data Acquisition (SCADA) where remote control and monitoring is done via satellite.
Inmarsat-C is using a hemispherical antenna and operates in half duplex. Inmarsat-C terminals are designed for installation on both vehicles and small ships. They are also available as briefcase terminals small enough to be carried as hand luggage on aircrafts.

Optimising channel performance

The maritime channel suffers from multipath typically 7 dB weaker than the direct satellite signal and with a fading bandwidth as low as 0.7 Hz. The system is designed to provide very reliable (99 %) message transfer and this is accomplished by using long interleaving (8.64s). Modulation is CPSK using rate 1/2 convolutional encoding. To obtain good performance in landmobile channels which suffer from short, but frequent link interruption a repeated long unique word is used to establish carrier reference quickly after interruptions. The channel format does not have CW or bittransition preambles and this has been demanding for the burst demodulators.
The use of channel state information by the convolutional decoder has enabled the system to tolerate blockages up to 3 s in a 8.6 s frame. Without the channel state information only 1.5 s could be tolerated.
The system is designed for operation down to 5 degrees elevation angle, but many reports from ships shows that the system works down to 1 degree. There has even been reports of operation below -0.5 degrees. It seems that there are certain elevation angles which have high attenuation. They repeat every 0.4 to 0.5 degrees below the Brewster angle.

Testing in the landmobile environment has also shown good results. The combination of reasonably high bitrate, interleaving, channel state information, ARQ and non directive antenna gives a good throughput even in quite bad channels.

Protocols

The largest amount of effort has been spent on the protocols. The handling of a large number of users, ARQ and store and forward buffers is a very complex task. Inmarsat equipment is made by many manufacturers and specifications can surprisingly often be interpreted different ways. The use of a pre-operational system has enabled Inmarsat to iron out many of these potential problems.

INMARSAT-B SYSTEM

The Inmarsat-B system is the second generation Inmarsat-A system used by some 11,000 ships worldwide. It significantly improves bandwidth and power efficiency and is also designed to work with the Inmarsat-3 spotbeam satellites. The system can provide voice, data, fax, group calls and telex. Both data and fax can operate at rates up to 9.6 kbit/s which much faster than through Inmarsat-A. Near toll quality voice is provided using a 16 kbit/s algorithm. The algorithm is transparent to voiceband data and fax at rates up to 2.4 kbit/s.
The antenna requirements are identical to Inmarsat-A's and this simplifies terminal design for the manufacturers.
The system is designed to provide high (99%) link availability and satisfy the requirements for the maritime distress system (GMDSS).
The narrow antenna beamwidth attenuates multipath even at low elevation angles and allows good frequency reuse between satellites.
The Inmarsat-B system will be attractive to professional maritime users who want high quality and low usage charges.
The Inmarsat-B and Inmarsat-M systems have common protocols and can share Access Control and Signalling Equipment at the fixed side, thereby greatly reducing cost.

INMARSAT-M SYSTEM

The Inmarsat-M system is designed for large new land-mobile and maritime markets and to fill the gap between Inmarsat-C and B. The system will provide communications quality voice, group calls, fax and duplex data at 2.4 kbit/s.
The largest market segment is landmobile which imposes a number of constraints. Vehicle installation limits the antenna hight and the diameter should not be much greater than 0.5 m. Frequency re-use can be improved by having a narrow beamwidth in Azimuth. This limits the antenna gain to around 13 dBi. The maritime version uses 2 dBi higher antenna gain to provide a 95% link availability with the same forward link satellite EIRP.
The low antenna gain and the need for low usage charges dictates high power efficiency.
The limited amount of spectrum dictates high bandwidth efficiency.

Voice coding selection

Subjective voice quality is strongly dependant on the voice coding rate. As there are no real standards which sets the minimum acceptable quality for mobile satcom system connecting to the PSTN, the selection of the bitrate was difficult. The rapid development of voice coding algorithms did not make the selection easier. Inmarsat considered seriously 9.6 kbit/s, 4.8 kbit/s, 2.4 kbit/s and ACSSB voice codecs before selecting 4.8 kbit/s. It was considered that during the system development time quality of such codecs would almost reach the quality of the 9.6 kbit/s algorithm used for Aeronautical public correspondence. An evaluation programme was set up to select the best codec and this was scheduled to be as late in the programme as possible to take advantage of the latest developments. Initially some 20 organisations planned to submit hardware for testing, of these only 8 did deliver and 5 of these were tested under a wide range of conditions. Inmarsat and Aussat joined forces during the testing which was done by Telecom Research Laboratories in Australia. The sensitivity to bit errors of the voice coding algorithm varies significantly within a voice frame. Selective FEC is used to increase robustness and to save power. The FEC increases the bitrate to 6.4 kbit/s, but maintains quality even at a 4 % bit error rate.

Optimising channel performance

The landmobile channel is characterised by short link interruptions due to blockage of the line-of-sight path to the satellite. Typical blockage duration is 50 ms, but varies directly with vehicle speed. A significant number of link interruptions last 1 second. Short interruptions are overcome by using speech prediction and repetition. This bridges gaps up to 60 - 90 ms which are in majority. Longer interruptions result in squelching.

In order to minimise the effect of blockages longer than 60-90 ms the modem reacquires very fast, typically within 60 ms for interruptions lasting up to 1 s. The signal format has short (60 ms) subframe with a CW and Unique Word preamble. A typical demodulator stores 25 ms of the signal and use different algorithms to estimate course frequency, fine frequency, phase and bit timing. As a subframe only contains 480 bits and the clock accuracy is 10E-5 the clock phase can only drift 1.8 degree. The demodulator therefore only needs to determine the best clock phase.

The Inmarsat-M system can provide data and fax at 2.4 kbit/s. The objective is to provide a bit error rate of less than 10E-5 on a Gaussian channel. The data are encoded using a 3/4 convolutional code and sent twice after encoding with a time difference of 120 ms. The demodulator combines both transmissions before convolutional decoding. Interleaving is not used in order to reduce delays which is important with duplex data used interactively.

Table 1: Inmarsat systems technical characteristics

Characteristics	Inmarsat-B	Inmarsat-C	Inmarsat-M	Aeronautical	
Satellite Service Type	MM (LM)	MM/LM	MM/LM	AM	AM
Typical antenna gain (dBi)	20	1	12/14	12	0
Typical antenna example	Dish	Quadr. helix	Backf/Lin arr	Phased array	Quadr helix
Typical antenna size	1 m dia	100x 25mm cyl	0.4m d/0.5m l	0.5 X 0.5 m	100x 25 mm
MES figure of merrit (dB/K)	-4	-23	-10/-12	-13	-26
MES EIRP (dBW)	33	13	25/27	26	14
Signalling rate/mod forw link	6k/BPSK	1.2k/BPSK	6k/BPSK	600/ABPSK	600/ABPSK
FEC type/rate	Conv/ 1/2	Conv/ 1/2	Conv/ 1/2	Conv/ 1/2	Conv/ 1/2
Signalling rate/mod ret link	24k/OQPSK	1.2k/BPSK	3k/BPSK	600/ABPSK	600/ABPSK
FEC type/rate	Conv/ 3/4	Conv/ 1/2	Conv/ 1/2	Conv/ 1/2	Conv/ 1/2
Voice coding rate (bit/s)	16k APC	NA	4.8k CELP	9.6k	NA
User data rate (bit/s)	9.6k	600	2.4k	9.6k	300
Comm channel rate/modulation	24k/OQPSK	1200/BPSK	8k/OQPSK	21k/OQPSK	600/ABPSK
Interleaving time (s)	NA	8.64	(0.12)	0.04	0.67
Forw link satellite EIRP (dBW)	16	21.4	17	21	24
Comm channel C/N0 (dBHz)	49	37	42	48	36
Channel spacing (kHz)	20	5	10	17.5	2.5
Scheduled service date	1992	1990	1992	1990	1990