# EVOLUTION OF INMARSAT SYSTEMS AND APPLICATIONS

## The Land Mobile Experience

Eugene Staffa and Ram Subramaniam
Inmarsat
40 Melton Street
London NW1 2EQ, England
Tel: +44 71 728 1000
Fax: +44 71 872 9538

## ABSTRACT

Inmarsat has provided mobile satellite communication services for land mobile applications for well over a decade. Having started with the Inmarsat-A voice and telex system, Inmarsat is committed to the evolution of services towards a global personal, handheld satellite communicator. Over the years, users have benefited from the evolution of technologies, increased user friendliness and portability of terminals and ever decreasing cost of operations. This paper describes the various present systems, their characteristics and applications, and outlines their contributions in the evolution towards the personal global communicator.

## INTRODUCTION

Since its inception in 1979, Inmarsat has beeen a major force in mobile communications. Inmarsat provides mobile satellite communications via geostationary satellites which, by virtue of their large area coverage and rapid interconnections via public switched networks, have played an important role in international communications. Inmarsat is the leading provider of emergency and disaster communications and of a variety of other mobile and transportable applications. Inmarsat land mobile services can thus be characterised as either providing an extension to public networks, or providing communications users with mobility. Table 1 provides the characteristics of the various systems.

### Extending The Public Networks

Despite increasing investment in telecommunications infrastructure, there are many areas where Inmarsat is the only feasible solution for geographic, demographic or economic reasons. Inmarsat can serve the communication needs of international companies locating in areas of poor communications availability until the terrestrial networks catch up with demand. The alternative would be to postpone the decision to locate there - with the consequent loss of business opportunity, possibly millions of dollars worth of economic activity, and forgone job creation and contribution to the local economy. Inmarsat is today helping to develop the oil fields of Nigeria and Siberia, provide communications support for export control in southern Africa, and helps CIS and China in their transition to market economies, to mention only a few typical uses.

With the liberalization of the regulatory environment in many less developed countries, established businesses increasingly turn to Inmarsat as the means of securing a reliable telephone, fax or data link, essential to the conduct of their business, particularly outside the capital cities. In this way Inmarsat enables them to have the same high quality international communications that their competitors might enjoy elsewhere, contributing significantly to the expansion of global trade.

Over the past fifteen years, business demand for communications, particularly international direct dial access, has risen dramatically. The temporary or a transient use of Inmarsat-A system is serving to fill a void in countries such as smaller island communities in the Pacific or the Caribbean, or remote areas of Asia, Africa and Latin America.

Inmarsat has always been prominent in providing the UN and other international and national development organisations with means to manage their field operations and logistics in areas without terrestrial communications facilities. Inmarsat allows these agencies a more cost effective deployment of their resources in all parts of the world.

### Mobility

Mobility in terms of mobile satcoms can mean a

vehicle mobile applications (i.e. terminals mounted on trucks, trailers, trains and utility vehicles), a transient, short-term temporary use by field teams operating away from base, or a transportable or portable use by individual users such as journalists or medical emergency or rescue personnel.

As the Inmarsat-A portable terminals decreased in size and cost, they have become the virtual backbone of the world emergency and disaster communications. They have been used by teams belonging not only to the UN agencies, but also to the Red Cross and other national and international organizations. They use Inmarsat for coordination or operations, supplies distribution management and they particularly appreciate the rapid deployment capability and reliability, often under extremely difficult circumstances. Their use has speeded up disaster relief to stricken areas and helped alleviate human suffering both in disasters and also in situations producing flows of refugees The current International Decade for Natural Disaster Reduction (IDNDR) will likely increase demand for mobile satcoms even further.

Similarly, the portability and simplicity of use has made Inmarsat-A communications tool of choice to hundreds of media teams all over the world to cover summits, scenes of natural disasters and wars. The Inmarsat-A portable terminal is an icon representing the mobile satellite industry that is recognisable to millions over the world.

## INMARSAT-A

Inmarsat-A is an analog telephone and telex system. It operates on a single channel per carrier basis using frequency modulation and hence provides a linear channel supporting full duplex operation. In normal operation voice compandors are switched in to improve the subjective quality of the link. The summary of the technical characteristics are given in Table 1.

### Network Configuration

The Inmarsat-A system comprises four independent communications networks (Satellite Ocean Regions), each network containing an opertional and spare satellite, mobile earth stations (MESs), a network coordination station (NCS) and land earth stations (LESs).

Land earth stations act as gateway between the PSTN and Inmarsat space segment. These are owned and operated by Signatories, who are also responsible for land line connections to the PSTN. Each LES has a parabolic antenna with a diameter in the range of 10-13m for transmission to and from the satellites. The uplink is at C-band and includes Automatic Frequency Compensation (AFC) System. Inmarsat-A NCS Services are provided at a designated Land Earth Station in each of the four satellite network regions. Each network co-ordination station is connected via terrestrial links to the Inmarsat Network Control Centre (NCC) in London. The NCS plays a key role in the network and is responsible for co-ordinating the access to communications channels between all LESs and MESs within the network, thereby ensuring full connectivity. The major NCS functions include SCPC call processing, monitoring of proper operation of signalling channels, database management and housekeeping, etc.

Inmarsat-A has been in service for more than 10 years and during these past years it has evolved both in the service it provides and the terminal design. In addition to the two primary services, voice and telex, a number of enhanced services have been added. The data and facsimile are two of the early services using the telephone channel. Full CCITT Group III operation is supported - the line speed (2400/4800/9600 bits/sec) being determined by the terrestrial connection.

### High Speed Data

Recently, two new services were introduced - 56kbits/s - 64 kbit/s High Speed Data (HSD) and Duplex High Speed Data (DHSD). Currently available from several MES manufacturers are 56 or 64 kbit/s option kits, consisting of an additional digital encoder and modulator; the typical electrical interfaces for HSD are CCITT V.35 and RS-422. The HSD signal is sent to one of several LES that provide for automatic or semi-automatic interconnection to terrestrial switched digital networks, e.g. COMSAT, Eik or Goonhilly.

For Duplex High Speed Data (DHSD) operation, fully automatic, single number dialling has been adopted. The DHSD call starts as a duplex voice grade circuit, until the MES is switched to data mode. The development of HSD and DHSD services has provided the media community and oil/gas industry users with a means to transmit voluminous data files as well as still video pictures in more effective manner.

Another typical application is transmission of high quality voice (7.5 kHz), for example to provide **real time** broadcast quality to a news bureau. A G.722 audio codec and a transportable Inmarsat-A MES (available from several manufacturers or rental

agencies) are used by a news reporter to a news organization or bureau. It should be be noted that in the direction from the bureau to the reporter, a regular analogue voice channel is used as well.

For DHSD, typical additional real-time applications may be video-teleconferencing, or use the capacity for the provision of a multiplexed channel, offering a number of digitized voice, fax and data channels.

**Terminal Evolution**

Along with the service evolution, the land transportable terminal design have also evolved to provide smaller, lighter and easy to use terminals. At the start of service, the terminals were bulky, several hundred of thousands cubic centimetres, weighing more than 75 kg and consuming about 400 watts during the transmit. These terminals provided only voice and/or telex capability. In contrast, the contemporary transportable terminal could weigh as little as 23 kg including the foldable antenna. Inmarsat-As can be assembled in a few minutes and use simple antenna pointing system to enable correct orientation to the selected satellite. It would consume only about 280 watts during transmit.

**INMARSAT-B**

Inmarsat-B, which will start commercial service during this year, is the digital version of the Inmarsat-A system. It is also capable of operating with the spot beams of Inmarsat-3 satellites. Being an advanced digital system, there is scope for reduction in the space segment resource requirement, and therefore for a reduction in the end user charges. This fact will be particularly welcome by high volume users, as well as by new ones who will now see the economic hurdle to becoming an Inmarsat user considerably lowered. This, in turn, should give a renewed impetus to the use of satcoms by both the business community and by the international emergency and aid organisations.

The system provides voice, data, fax group calls and telex. Near toll quality voice is provided using 16 kbits/s voice codec algorithm. The G/T requirement of the terminal is the same as of Inmarsat-A (-4 dBK), hence the antenna requirements remain the same. One compact Inmarsat-B MES already available weighs 18 kg including a flat panel antenna. Its polymer packaging case is watertight when packed, and rain-proof when deployed, and can withstand a 30-inch drop on concrete. A DHSD facility is designed to be standard: it can support up to 8 simultaneous telephone or up to 20 data channels. The summary of the technical characteristics is given in Table 1.

**INMARSAT-C**

The Inmarsat-C system was designed as a low cost, compact data messaging system for operation at sea and in a wide range of land mobile applications. The system has been in commercial operation since January 1991. The system operates on a packet transmission basis over the Inmarsat satellite which is able to interface to a range of terrestrial messaging systems including telex, X.25, voice band data and various electronic mailbox services. The summary of the system characteristics are given in Table 1.

The Inmarsat-C system provides Store and Forward Messaging, Data and Position Reporting, Polling and Enhanced Group Call services. The Store and Forward mode provides the user a reliable means of sending data or text messages between the mobile terminal and the fixed network subscriber via the satellite and either the public or private terrestrial services.

The data reporting protocol permits the user to send short messages of up to 32 bytes via a special channel. This service can operate on a "reserved" basis where the terminal sends a data report at pre-determined times or on an unreserved basis when it is sent at random. An acknowledgement of delivery is always provided. The polling service is used to initiate transmission of a data report from a mobile terminal. The polling signal defines how and when the terminal should respond and can address single or multiple terminals and optionally, it can also be limited to a defined geographical area. The Enhanced Group Call (EGC) service is a fundamental part of the Inmarsat-C system and provides the ability to broadcast messages to mobiles in a very flexible manner. The Land Mobile Alerting function is a special type of data reporting packet, used for alerting the LES and/or other service providers about an emergency (or a high priority message) via an Inmarsat-C terminal.

Inmarsat-C terminals for mobile applications are compact in size (4500 $cm^3$) weighing 3.5 kg, with a detachable antenna unit including HPA/LNA weighing about 2 kg. The antenna is omnidirectional and hence pointing to the satellite is not required.

The briefcase or portable terminals are lighter (4 kg) and smaller in size, with an integrated antenna. These terminals have directive high gain antennas to reduce the power consumption, hence it could operate

with batteries. No assembly is required, only simple antenna pointing to ensure correct orientation to the selected satellite. These terminals are the first generation of Inmarsat personal communication products.

The chief attractions of Inmarsat-C are its low cost terminals and the inexpensive communications charges, particularly for very short messages. Other very useful attributes are the public network interconnection and the ability to work with a variety of peripheral equipment via a digital interface. This powerful combination of user economics and engineering flexibility enables a virtually limitless range of applications.

**Road Transport**

One of the main successes for Inmarsat-C has been in the support of fleet management for the road transport industry. With this system, it is possible to set up closed user networks with any number of vehicles, as well as one or any number of individual users in an open network configuration. Fleet management is possible by continuous contact between the driver (and/or vehicle computer) and the dispatcher. Short data reports from vehicles, containing the position information determined by the integral GPS receiver, can be received and temporarily stored at the LES for delivery by a terrestrial link. They could be transmitted directly to a Inmarsat-C at the dispatcher's office, using a 'double hop'. This method, obviating the need for a terrestrial line altogether, can be very useful in cases where the terrestrial link is unavailable or unreliable.

Regular position reports can be displayed on a digital map in a dispatcher's office, together with a possible accompanying message. The ability to poll individual vehicles or entire fleets is seen by trucking operators as a most exciting feature - one that cannot be obtained over very large areas by terrestrial means. The satcom-based method of fleet management and control has saved many trucking companies thousands of dollars annually, making the investment in Inmarsat-C pay for itself in a very short time. There are several end-to-end solutions already on the market and 'one-stop-shops' for system implementation are now established on both sides of the Atlantic, e.g. in the Netherlands, the UK, Brazil and elsewhere.

Even simple two-way messaging can provide substantial benefits in the mobile environment. A very good example of this is the use of Inmarsat-C by a number of UN agencies, particularly by the UN High Commissioner for Refugees in Bosnia and elsewhere, substantially improving the logistics control and improving the emergency response capability. Other humanitarian agencies have used Inmarsat-C in support of their activities in food distribution in Russia and Africa.

Tracking of vehicles, trailers or cargo containers is another very good prospect for Inmarsat-C. It requires development of a securely mounted 'package' with a low-profile antenna and a reliable stand-alone power supply. The market for such device is estimated at several hundreds of thousands of units worldwide. Similarly to road transport, rail transport requires reliable data reporting and polling system, available over long distances and vast areas. Particularly in case of accidents in remote areas, satcoms are indispensable. Countries like China, Russia, Australia and others on all continents have tested Inmarsat-C for this purpose. The results are very encouraging and may lead to significant implementation schemes in the near future.

**Electronic Office On The Move**

Because of its worldwide reach and easy portability, Inmarsat-C is becoming a favourite with print journalists, aid workers and even the general business traveller. The most alluring feature of the system is the ability to send text files, even fairly large (up to 32 kbytes), composed on a PC attached to the Inmarsat-C transceiver, directly to a fax number, to another PC via PSTN or PSDN, and to send and retrieve messages from a mailbox set up at the LES or at any other appropriate point along the network. Recent advances in applications development also allow a direct connection to e-mail networks, enabling the Inmarsat-C user to become a remote or mobile X.400 user!

**Rural, Remote and Backup Communications**

Low investment cost as well as the ever expanding array of access modes and applications make Inmarsat-C an ideal system for all sorts of situations where voice contact is not required or is not necessary. Entry or retrieval of information in remote locations, whether by rural hospitals or by educational institutions or businesses, is a fast developing Inmarsat-C market. Several specific software applications are now under development in various parts of the world, for example to address rural banking requirements. An attractive applications area for Inmarsat-C networking is establishment of communications networks for dispersed communities, for example in Latin America, Africa and Asia.

## SCADA

Remote sensors and control devices coupled with an Inmarsat-C transceiver allow Supervisory Control and Data Acquisition (SCADA). Large 'fleets' of SCADA terminals are envisaged for water management, pipeline and power lines monitoring, and remote industrial process control. In addition, applications for earthquake monitoring, hurricane or tropical storm warning, and flood reporting are being developed.

## INMARSAT-M: A BREAKTHROUGH IN LOW COST MOBILE SATCOMS

In response to demand for smaller, lighter and cheaper mobile satcoms, Inmarsat has developed Inmarsat-M, the world's smallest, lightest and cheapest satcom voice terminal. This new digital standard, being made commercially available at this time, offers voice, fax group 3 and 2400 bits/s data facility. It will likely become a system of choice for tens of thousands of new users.

Inmarsat-M shares a common access control and signalling subsystem with the Inmarsat B system, thereby allowing significant economies of scale to be achieved in all ground segment components of the system.

The Inmarsat-M system provides duplex telephony employing an SCPC channel supporting a speech codec rate of 6.4 kb/sec (including FEC) in both forward and return directions, using an overall channel rate of 8 kbits/sec. Speech quality is adequate to allow connection to the public switched telephone network (PSTN).

For land application, there are primarily two types of terminals - one to serve the vehicle market and the other to the portable market. The vehicle mounted terminals have two units. The outdoor unit consists of the directional antenna, the HPA, the LNA and the diplexer(s). The indoor unit consists of the rest of the electronics. The high gain required to achieve the G/T of -12 dBK warrants a directional antenna with about 14 dBi gain, hence tracking is required. A 5-element cavity-backed spiral one dimensional array antenna with wide elevation and narrow azimuth beam was the first generation of antennas. These type of antennas are high profile and rather heavy. The evolution and technological development of antennas have produced an attractive low profile phased array antenna which can be mounted in place of the sun-roof of a car. Both of these antennas require mechanical steering in the zimuth plane to track the satellite. An electronically steered adaptive monopole antenna would also achieve the required G/T with a reasonable profile and acceptable appearance for the vehicle mounted market.

### 'Portable' Users

The portable terminals are usually packaged in a briefcase type enclosure, with dimensions about 450x300x80mm. These have either detachable antenna or built-in antenna, under the cover of the case. In either case, patch arrays are used to obtain the gain required. Some design have folded antenna to achieve higher gain (about 18 dBi), in order to reduce the power consumption. This enables the terminal to operate with batteries for up to an hour without recharging.

This means that an independent satellite phone phone with an unlimited reach, is now available to the businessmen, explorers, surveyors, engineers, reporters, medical staff, security and government officials, with even greater ease than that offered by Inmarsat-A. As is the case with the existing Inmarsat-A and Inmarsat-C communications, productivity of people operating satcoms outside the available public networks is dramatically improved, reaping benefits many times in excess of the investment or operating costs of satcoms.

### Thin Route Operations: Extension of Public Networks

Isolated land-locked or island communities can use Inmarsat-M as a cost-effective means of establishing a direct-dial telephone and fax service. The benefit of immediate and reliable communications is surely going to be felt not only in case of emergencies, but also in the conduct of business hitherto impossible due to lack of communications. In rural areas, communications availability is not always keeping up with demand. This is especially true for many farming regions, as well as for remote mining operations, logging, explorations and other temporary or transient activities.

### Mobile Users

In Inmarsat-M, the mobile users - in trucks, cars, trains - can for the first time enjoy the benefits of satellite voice service. A low profile antenna enables Inmarsat-M installation not only on trucks, but also on a complete range of utility and even personal vehicles.

This creates a tremendous market opportunity even before further planned miniaturisation takes place. Similarly to Inmarsat-C, Inmarsat-M has been already trialled for the use by the railways, both on moving trains - for passenger use as well as the crew - and for the track maintenance teams and in case of emergencies. Inmarsat-M proved a very viable and cost-effective solution.

## PAGING

Satellite paging is designed to complete the family of Inmarsat services, responding to several important user requirements: very low cost (around five hundred dollars); ability to work in the urban environment; offering a limited coverage even inside buildings (i.e. without the direct sight of a satellite); and, being receive only device, not requiring special licences or regulatory considerations. The messages can be broadcast in one or more ocean regions simultaneously, depending on the level of service subscribed to.

The service, with its pocket-sized alphanumeric receivers, will be a boon to international travellers, and is expected to be taken up by a whole range of vehicular users. Additionally, both Inmarsat-M and Inmarsat-C briefcase terminals can have an integrated pager for receiving alerts or short messages independently of whether actually turned on or logged in. The user can then call back when convenient.

## WHAT THE FUTURE HOLDS

Inmarsat is continually striving towards goals of user friendliness, easy portability and lower cost. For Inmarsat-C, the work on the Applications Programming Interface (API) should go a long way towards complete modularity of various elements from LES to the MES and peripherals.

Inmarsat-M services and terminals may change further with introduction of more powerful Inmarsat-3 satellites in the 1995/6 timeframe. The spot beam capability of these satellites has opened up a wide range of possibilities of evolution of Inmarsat products such as smaller terminals (notebook size), and smaller, cheaper and more attractive antennas (e.g. vertical rod, disc and small horn) for vehicle mounted applications. On the service side, higher rate data and fax service, secure voice service, credit card facility and ISDN functions will all evolve in the coming years.

Inmarsat-C and Inmarsat-M are significant contributions towards small, easy to use personal satellite communications. But the ultimate goal to reach is a hand portable personal global communicator, so called Inmarsat-P. Development work on it is well underway for introduction around the end of the decade.

**Table 1: Inmarsat systems technical characteristics**

| Characteristics | Inmarsat-A | Inmarsat-B | Inmarsat-C | Inmarsat-M |
|---|---|---|---|---|
| Typical antenna gain (dBi) | 20 | 20 | 2 | 14 |
| Typical antenna example | Parabolic Reflector | Dish/flat | Quadr. helix | Spiral/Lin. arr. |
| Typical antenna size | 1.2 m dia | 1 m dia | 100 x 25 mm cyl | 0.4m dia/length |
| MES figure of merit (dBK) | -4 | -4 | -23 | -12 |
| MES EIRP (dBW) | 36 | 33 | 13 | 22 |
| Voice coding rate (bit/s) | N/A | 16k APC | NA | 4.2 IMBE |
| User data rate (bit/s) | 9.6k | 9.6k | 600 | 2.4k |
| Comm. channel rate/modulation | FM | 24k/OQPSK | 1200/BPSK | 8k/OQPSK |
| Interleaving time (s) | N/A | N/A | 8.64 | N/A |
| Forward link satellite EIRP (dBW) | 18 | 16 | 21.4 | 17 |
| Channel spacing (kHz) | 50 | 20 | 5 | 10 |
| HSD/DHSD option | 56/64 kbit/s | 64 kbit/s | N/A | N/A |
| Scheduled service date | 1982 | 1993 | 1991 | 1993 |