High Data Rate Point-to-Multipoint Transmission Over Mobile Satellite Channels: Aeronautical and Maritime Field Trials

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Abstract

There has been significant interest in higher data rate services to mobile platforms in general, and satellite-serviced mobile platforms in particular. An investigation of high data rate point-to-multipoint transmission over mobile satellite channels has been undertaken, resulting in the deployment of field trial systems for the maritime and aeronautical environments. This paper gives an overview of the transmission system design and describes the configuration and objectives of the trials. Early results are presented.

1.0 Introduction

The previously separate industries of telecommunications, information technology, media and consumer electronics are undergoing significant change as the boundaries between them are reexamined. This convergence has been hastened by the recent explosion of Internet-based applications focused on delivering text and multimedia content via the World Wide Web. This in turn has been made possible by the development of sophisticated digital compression techniques to allow the transmission of audio and video at relatively bw data rates. This technology can now be exploited to deliver the same types of services over the power and bandwidth limited mobile satellite channel.

This paper describes the Inmarsat Data Distribution Service (IDDS), an integrated system of multipoint transmission facilities that supports data transmission to mobile platforms at rates above 128 kbit/s. In particular, the configuration of a field trial system aimed at assessing the demand for and performance of the system is introduced, and the content of aeronautical and maritime field trials is described. The objectives and early results of the trials are discussed.

2.0 IDDS System Description

The IDDS is designed to serve diverse land, maritime and aeronautical mobile markets for broadcast-type services. The transmission technique used, Variable-Carrier Coded Orthogonal Frequency Division Multiplexing (VC-COFDM), is bandwidth efficient and extremely robust in the mobile broadcasting environment [1]. Each VC-COFDM channel has a maximum aggregate capacity of approximately 152 kbit/s in a bandwidth of 200 kHz. This capacity is subdivided into datagram and stream-mode services at rates from 500 bit/s to 128 kbit/s with datagram capacity further segmented into 128 individual datagram virtual circuits. Both the total capacity/bandwidth and the service mix can be varied to accommodate the service requirements at any given time. A variety of receiver configurations is possible, ranging from a low-cost audio or text-based personal receiver to a multi-channel receiver providing multimedia services.

2.1 System Characteristics

In designing the system, a number of key requirements were identified and incorporated:

1) Efficient use of satellite resources

To offer the lowest cost services possible, the system must use satellite resources efficiently. To do so, the IDDS allows capacity to be assigned among services sharing the transmission facility such that when more bandwidth is required for one service and less for another, it can be dynamically re-allocated.

Additionally, the COFDM modulation scheme is bandwidth and power efficient for mobile satellite channels and the signal has been designed such that coherent detection without differential encoding is feasible.

2) Service configurations

The system supports two basic types of services. Stream mode services are real-time data applications such as digital audio or video. Datagram services are page mode applications such as news briefs, stock quotes and weather reports. The bit rate for any service can range from 500 bit/s to 128 kbit/s.

3) Universality

The system has been designed to work across the range of environments that Inmarsat currently serves. These include maritime, aeronautical mobile, land mobile and land transportable. It is expected that this universality will lead to lower cost receivers due to the commonality of components over a larger user base.

4) Complexity

The system has been designed for the lowest operational cost that is consistent with low cost receivers. In addition, since the receiver is the system's most cost sensitive component, complexity has been transferred from the receiver to the transmitter where possible. [This also applies to the compression technology that is critical to audio and visual services.]

5) Performance

The system has been designed to provide a maximum bit error rate of 10^{-4} for all services and across all unshadowed mobile environments.

Selectable forward error-correction coding is available to provide a reduced bit error rate of 10^{-6} for error sensitive services, and repetitive transmission is used to ensure the successful reception of critical information.

Signal acquisition time after power-on or channel change is less than 11 seconds.

3.0 IDDS Field Trials

To facilitate testing and evaluation of the system and potential services, Square Peg Communications Inc. developed PC-based transmit channel equipment and radio frequency receivers. These transmitters and receivers support a maximum composite bit rate of 70 kbit/s and a maximum stream data information rate of 64 kbit/s.

Two field trials using this equipment were planned, one addressing the maritime environment and one addressing the aeronautical environment. The objectives are the trials are:

a) to clarify the requirements of the content providers and to assess the impact of the system design on them;
b) to gain insight into the terrestrial infra-structure required to convey programming from the content providers to the satellite transmission system;
c) to confirm the performance of the transmission system under actual operating conditions;
d) to determine potential mechanisms for interfacing to existing entertainment and/or multimedia systems; and,
e) to assess the reaction of users (passengers or crew) to a wide variety of potential services.

The results of the trials can be used to refine the system design and the applications programming interface (API) required to support innovative service offerings.

3.1 Maritime Field Trial

The maritime field trial was initiated by Inmarsat's Swedish signatory, Telia Mobile. It provides daily and weekly Radio Sweden audio broadcasts to an Inmarsat-A equipped merchant ship. The broadcasts are played in real time as well as stored for later playback. The trial equipment is also used to distribute daily electronic copies of the Swedish newspaper Svenska Dagbladet to the ship. Crew members can peruse the newspaper at their leisure over the ship's local area network. This trial commenced in Fall 1996.

A picture illustrating the configuration of the maritime field trial is shown in Figure 1. The downlink is monitored continually at Inmarsat and as required by Square Peg.

3.1.1 Transmitter

The field trial transmitter consists of a Pentium PC with 3 plug-in cards which implement the IDDS physical layer. This unit has the following interfaces:

a) three X.21 serial stream input ports;
b) one datagram input port (PC serial port operating at up to 56 kbit/s).

The transmitter is located at the Eik earth station in Norway and interfaces at a 70±18 MHz IF to the station's block upconverters. During the trial, operation over Inmarsat's AOR-W and IOR satellites is supported.

Monitoring and control of the transmitter is performed from Inmarsat's headquarters in London using a commercial remote control software package over ISDN.

3.1.2 Receiver

The field trial receiver consists of a 19" rack mount Pentium PC located in the radio room of the Wallenius Lines Isolde. Three plug-in cards implement the IDDS physical layer. An audio decoder card and LAN interface card are also present. In the field trial configuration, the unit has the following interfaces:

a) 600Ω balanced audio output;
b) interface to ship's onboard Novell network.

The receiver is connected to the ship's existing NERA Inmarsat-A receiver via a splitter at a 212 MHz IF access point.

The receiver has an application program interface (API) so that an application on the PC can receive datagrams and/or stream data as well as control the operation of the receiver. The maritime application presents a schedule of programs to the crew, and allows them to select which should be played live and/or saved.

The receiver also displays and logs numerous performance parameters, including estimates of:

a) E_b/N_0;
b) uncoded BER;
c) datagram packet error rate;
d) frequency offset; and,
e) Doppler rate-of-change.

This information can be used to correlate crew reports with transmission system performance.

3.1.3 Newspaper Service

Svenska Dagbladet publishes a number of editions each day. An electronic copy is made of the final edition and passed to Nobicon in a desktop publishing format. This format enables pictures, headline text and text body to be associated as an article.

Nobicon compiles this electronic newspaper (currently without pictures) into an EDIFACT format

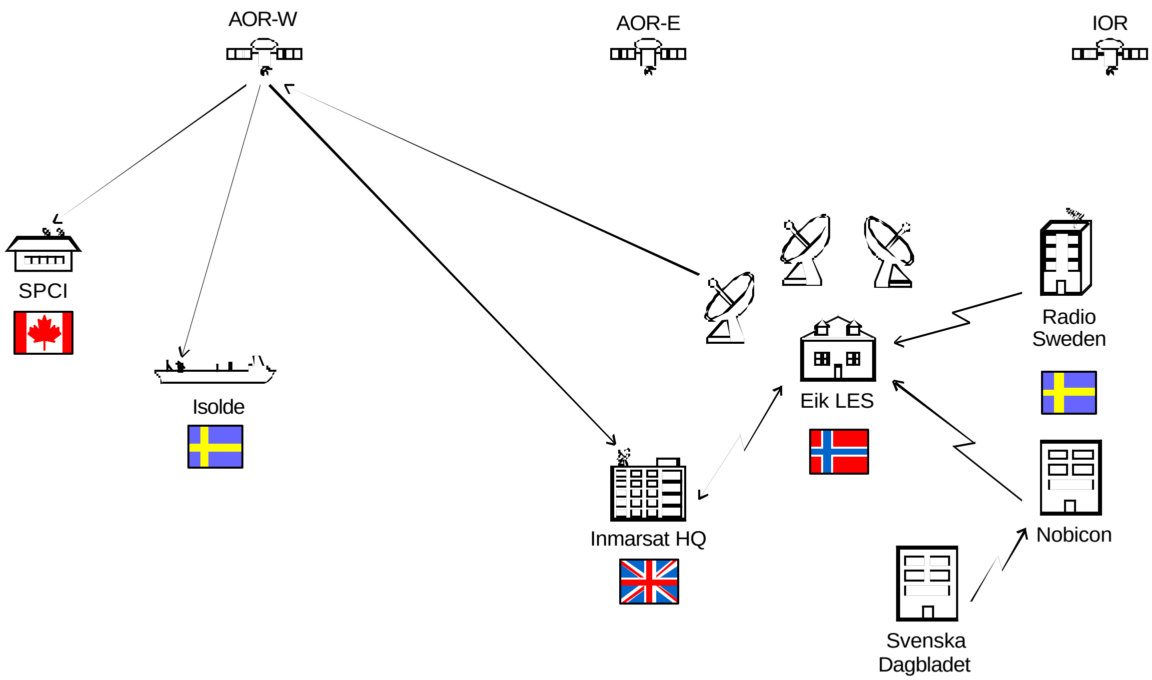

Figure 1 Maritime Field Trial Configuration

and is responsible for its distribution via network, modem and ISDN. Supported formats include:

a) HTML (for standard Web browsers);
b) .hlp file (for the Windows help utility); and,
c) Lotus Notes database entries.

For transmission to the ship, the EDIFACT file is processed to create a new one compatible with the file transmission protocol of the application and with the datagram protocol of the transmitter. At the scheduled program transmission time, the transmitter reconfigures the ensemble to the required capacity. At the same time, a computer at Nobicon makes an ISDN call to the LES. A terminal adapter with rate adaptation interfaces the ISDN line to the transmitter PC's serial port input.

At the receiver, the application detects that the program is about to start and requests the datagrams for the appropriate virtual channel. The datagrams are assembled into a file which is placed in a directory accessible via the LAN.

When the scheduled timeslot is complete, the transmitter reconfigures the ensemble for the next required service mix.

3.1.4 Radio Service

The Radio Sweden transmissions are existing programs which are originated and encoded by their digital production system. For the trial, monaural MPEG 2 Layer 3 coding with a sample rate of 24 kHz and bit rate of 64 kbit/s was used.

When a program is scheduled to start, the transmitter stream input port asserts its Data Set Ready (DSR) output and prepares to reconfigure the ensemble. At the same time, an ISDN call is placed from Radio Sweden to the transmitter site and transmission of the 64 kbit/s audio data stream begins.

At the receiver, the application detects that the program is about to start and requests the stream data for the appropriate channel. If live playback is enabled for the timeslot, it redirects this stream to the hardware decoder. It also saves the bit stream to a file on the hard disk for later playback upon operator request.

At the end of the scheduled timeslot, the ISDN call is cleared, the ensemble is reconfigured, and the receiver closes its file.

3.2 Aeronautical Field Trial

The aeronautical field trial will be conducted by the British Broadcasting Corporation (BBC) and the Voice of America (VOA). It will initially deliver real-time audio and text news to passengers on a British Airways 747-400 aircraft. As the trial progresses, other multimedia applications, including compressed video, may be evaluated. The Aero-IDDS receiver interfaces at L-band to the existing Inmarsat Aero-H Earth Station (AES) antenna and via audio/video feeds to the in-flight entertainment system. This trial is scheduled to commence in Spring 1997 and last for six to nine months.

A picture illustrating the configuration of the aeronautical field trial is shown in Figure 2.

3.2.1 Transmitter

The field trial transmitter is identical to that used in the maritime trial. It is located at the British Telecom's Goonhilly earth station.

The earth station can see three of Inmarsat's satellites - AOR-W, AOR-E and, experimentally, IOR. Subject to spectrum planning constraints, the 70 MHz feed can be split and sent simultaneously over more than one satellite, allowing the use of a single transmitter for more than one ocean region (the signal structure is such that the receiver can operate in the presence of multiple transmissions of the same signal on a single frequency).

3.2.2 Receiver

The IDDS Aeronautical Receiver is an avionics qualified Line Replaceable Unit (LRU) which packages the receiver PC in an ARINC 8 MCU enclosure. It is designed to operate with an Inmarsat SDM compliant high gain antenna (G/T = –13 dB/K). Internally, it is very similar to the maritime receiver except that its input is at L-band, there is no LAN connection, and its video output is a standard NTSC signal. All interfaces to the aircraft are via a standard ARINC connector in the rear of the unit.

Figure 3 illustrates the installation configuration for the trial aircraft. The only connection between the IDDS receiver and the AES is made via a directional coupler which splits the L-band feed from the LNA(s) to both the IDDS receiver and the Satellite Data Unit (SDU) of the AES.

The remaining interfaces from the IDDS Receiver to the aircraft are the AC power input and the audio and video outputs to the In-Flight Entertainment (IFE) system.

Upon powering up, the receiver will typically:

a) acquire an IDDS carrier from the satellite to which the antenna is pointed;
b) select the desired service(s) from among those available on that carrier;
c) store service programming to disk for later playback; and/or,
d) output services in real-time to the video and audio outputs of the system.

The operation of the receiver is controlled by script files and schedules which can be uploaded over the satellite. If the AES moves the aircraft's antenna to point at a different satellite, the IDDS receiver will recognize the loss of the signal and then repeat the above steps to acquire the new satellite (the receiver has no explicit indication from the AES of where the antenna is pointing).

The receiver also logs numerous performance parameters which can be used to correlate crew reports with transmission system performance.

3.2.3 Audio Service

The BBC and VOA are sharing an audio channel which will carry the BBC World Service and VOA news and news magazine programs. The purpose is to present updates on major news stories as near real-time as possible. MPEG 2 Layer 3 coding at 16 kbit/s is used.

The audio is encoded at the BBC's London headquarters and then transmitted over their existing European distribution system which utilizes capacity on a Eutelsat satellite. A 62 kbit/s pipe is available for the trials, allowing for the 16 kbit/s audio channel plus an additional 46 kbit/s capacity for other applications.

The signal from the Eutelsat satellite is downlinked to a demodulator and demultiplexer located at the BT Goonhilly earth station. The demultiplexed data streams are fed to the IDDS transmitter's stream ports.

At the receiver, the logic in the script file selects the audio service whenever it is available. The received data stream is passed directly from the demodulator to the audio decoder and then played via the receiver's audio output interface. From the passenger's perspective, the service appears simply as another channel from the aircraft's In-Flight Entertainment (IFE) system.

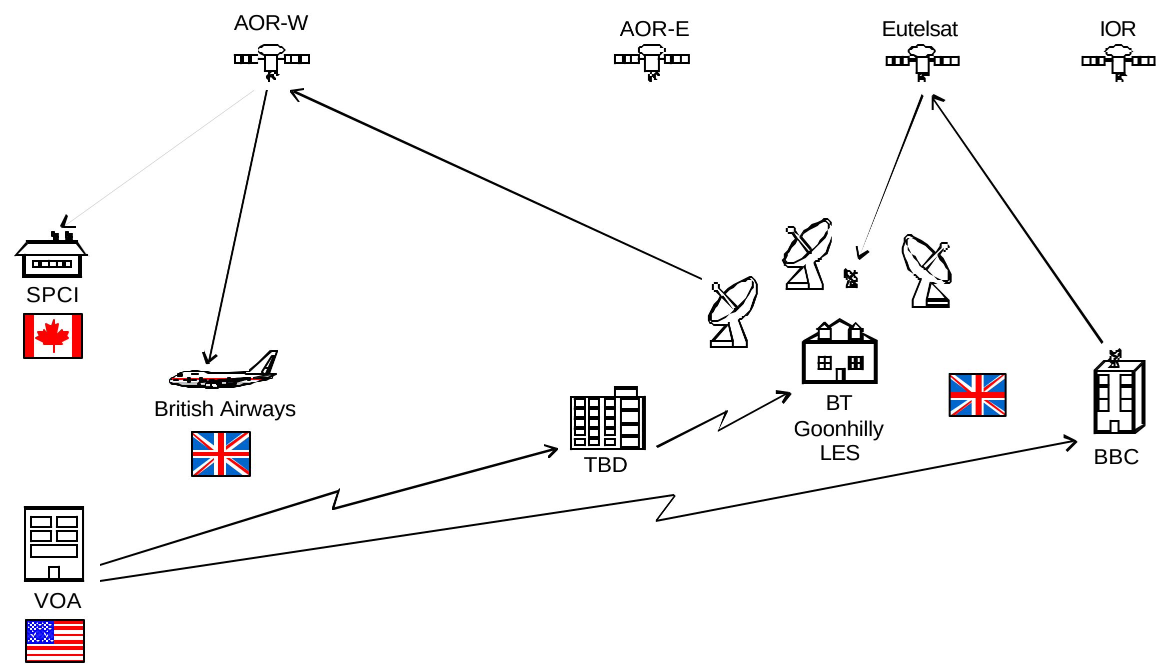

Figure 2 Aeronautical Field Trial Configuration

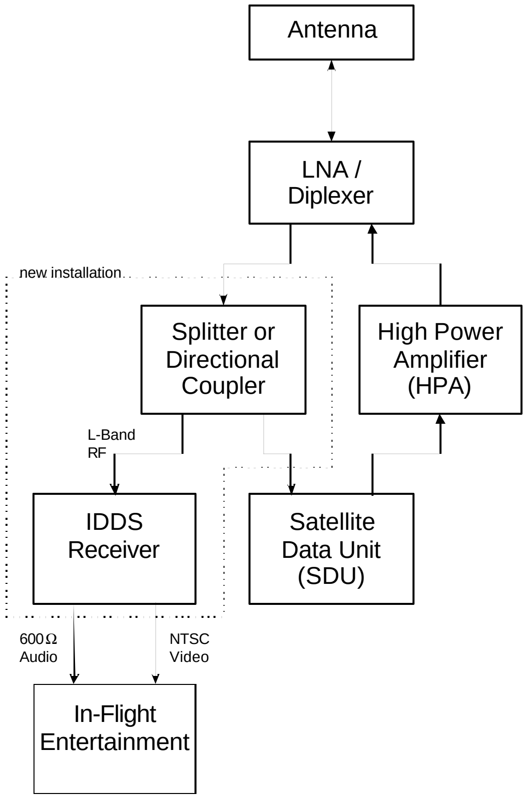

Figure 3 Aeronautical Receiver Installation

While audio is being received, the seatback video display will display stored features, or the VOA text service described below.

3.2.4 Text Service

VOA is providing a text "headline news" type service. News stories appearing on the wire feed from VOA correspondents are sent via the Internet File Transfer Protocol (FTP) to a gateway PC. From there, they are processed by a file transfer application and then sent to Goonhilly. At Goonhilly, the data is presented to the transmitter's datagram input port.

The datagram service will be allocated 1000 bit/s of capacity. News stories will be transmitted in a circular order, and the transmission system will utilize multiple transmissions of packets to ensure error-free reception.

At the receiver, the news files are stored on the hard disk and then displayed in sequence. Out-of-date stories are discarded. Before it is displayed, each news story is searched for keywords which can be used to determine the type of story (for a themed news presentation), and which of a predefined set of backgrounds should be displayed concurrently with the text.

3.3 Preliminary Results

At the time of submission of this paper, only the maritime trial was underway. Lessons learned from the early phase of this trial include:

1. It is important to synchronize the IDDS system time to a precise clock (e.g. GPS). This is crucial given that the most important news stories usually lead off a broadcast.
2. The design of the terrestrial infrastructure for delivering the content to the transmission system is critical. Careful consideration needs to be given to the synchronization and rate adaptation issues as well as to schedule coordination.

As might be expected, the overall performance of the system is dependent upon all of the links in the chain. Problems encountered to-date have mostly been with the terrestrial infrastructure and the interfaces to the content providers. Overall, the reaction of the ship's crew has been positive and the quality of the received audio excellent.

4.0 Next Steps

The priority at this time is to get the aeronautical field trial operational. Concurrently, the feasibility of adding real-time video to the aeronautical trial will be investigated.

In addition to assessing the technical feasibility and suggesting improvements to the technical approach, an important goal of the field trials is to gather the marketing data necessary to determine the viability of potential commercial services. Consequently, another important near-term task is to design and carry out surveys to assess crew and passenger reaction to demonstrated and potential IDDS services. The results will be valuable input for those considering the distribution of multimedia programming to mobile terminals.

5.0 References

[1] W. Zou and Y. Wu, "COFDM: An Overview" in *IEEE Trans. on Broadcasting*, Vol. 41, No. 1, March 1995, pp. 1-8.