ADVANCED

COMMUNICATIONS

TECHNOLOGY

Inmarsat Mini-M System

Test Report

Prepared for:

United States Coast Guard
Systems Directorate

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1. Introduction

One of the objectives of the Mobile Communications Infrastructure project is to conduct in-depth evaluations of mobile satellite systems that appear to meet Coast Guard communications requirements. The goal in testing these systems is to quantify how well they work, to evaluate their performance, and to see how each of these systems could fit the needs of the Coast Guard. There are a variety of parameters we will measure for each system. Most of the measurements will be of the overall system, not the individual pieces. These will include coverage, availability, reliability, accuracy, interoperability, bandwidth, latency, ease of use, and cost.

This report addresses testing on the Inmarsat Mini-M system. All testing was performed in the Advanced Communications Lab at the R&D Center. A Thrane & Thrane CAPSAT mini-M terminal was provided for our testing by LandSea Systems of Virginia Beach, VA. Since the unit was only available for a limited time, no testing was done with a STU-III for secure applications. Also, to keep the total transmission time down, the duration of the BER and Throughput tests were shorter than required for complete accuracy.

Although we have conducted no field testing of the system, the Fourteenth District has installed Mini-M units on four WPB 110's and one WLB(R) for evaluation. Some information on their evaluation is included here. The point of contact for the 14th District is LCDR George Privon, (808) 541-2021.

2. Inmarsat Mini-M System

2.1 Inmarsat System[1]

The origins of the International Maritime Satellite Organization (Inmarsat) date back to NASA satellite experiments during the 1960s. The World Radio Conference in 1971 approved the 1.5/1.6 GHz frequency bands for Mobile Satellite Services (MSS) setting the stage. Since the existing International Telecommunications Satellite Organization (Intelsat) did not include MSS in its charter (fixed services only), work began on a new organization to provide MSS. The primary emphasis was on maritime satellite communications for maritime safety. Inmarsat was thus formed on July 16, 1979 and began operation on February 1, 1982 using transponders leased from Marisat, ESA (MARECS satellites), and Intelsat. The purpose of Inmarsat is to provide satellite-based commercial communications services to ships, aircraft, and other mobile users.

The Inmarsat organization was patterned after the existing Intelsat organization. Countries join the organization by ratifying the Inmarsat Convention and each country owns a share (and pays) proportional to their usage of the system. There are currently more than 80 member countries. Each government designates an organization or company to be the investor/operator for that

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[1] This information is reprinted from the R&D Center report "Technology Assessment of Mobile Satellite System Alternatives" (reference 1).

country (called a Signatory). The U.S. Signatory is Comsat; and it is regulated by the FCC, which also issues Mobile Earth Station (MES) licenses. The eighteen largest ownership Signatories plus four others elected on the basis of geographic representation form the governing Council. The day-to-day work is handled by a staff of about 500 called the Directorate. The Inmarsat Headquarters is located in London, UK.

2.1.1 Space Segment

Inmarsat provides global coverage between 70°N and 70°S latitudes using four geostationary satellites. Inmarsat splits the world into four ocean regions, with one satellite per region. The orbital slots are listed in the Table 2-1 below. Inmarsat recently upgraded all of their satellites to higher-powered Inmarsat-3 satellites. The last was successfully launched in February 1998.

Table 2-1 Inmarsat Orbital Slots

Ocean Region	Orbital Slot
Atlantic Ocean Region East	15.5°W
Atlantic Ocean Region West	54.0°W
Pacific Ocean Region	178°E
Indian Ocean Region	64.5°W

2.1.2 Ground Segment

Inmarsat uses a three-level ground segment. The master Network Control Center (NCC) is located at Inmarsat headquarters in London, UK. Each ocean region then has a Network Control Station (NCS) which assigns channels to users and earth stations within the ocean region. Each ocean region is also served by a number of earth stations. These are called Coast Earth Station (CES) by maritime users, Land Earth Stations (LES) by land mobile users, and Ground Earth Stations (GES) by aeronautical users. The earth station operators link the satellite network and terrestrial telephone, data, and telex networks. They are usually, but not always, Signatories. Each CES connects with one satellite; therefore, an earth station operator requires four CESs to provide worldwide coverage. Each category of Inmarsat service (defined below) requires an independent set of modulation & processing equipment. Each CES can support one or more services. Earth station operators each establish their own rates and value-added services, which regions to operate in, and which services to support. If the operator is not the Signatory for that country then they pay the Signatory for satellite airtime. The Signatory pays Inmarsat. Transmissions between the CESs and the satellites are in the C-band.

2.1.3 User Segment

Inmarsat publishes a Systems Definition Manual for the services it offers. Each terminal design is then type-approved by Inmarsat. Sales and pricing of the terminals are determined by the manufacturer. All of the services operate in the same general manner. For MES originated calls, the mobile user selects which CES to use within the current ocean region. The CES then completes the connection through its terrestrial connections. For shore originated calls, agreements by the Public Switched Telephone Network (PSTN) operator will determine to which CES calls are routed. In the U.S., calls can be made through Comsat's CESs by dialing a toll-free number and then the MES number. Transmissions between MESs and the satellite are in the L-band.

2.2 Mini-M Service

2.2.1 System Specifications

2.2.1.1 Inmarsat-M

Inmarsat-M which was introduced in 1993 was the world's first personal portable mobile satellite phone. It is a digital system that provides voice, data, and fax services. There were 8,500 units in service as of February 1996. It uses a directional 0.6 m parabolic antenna. Maritime units use a tracking antenna within a radome. There are more than 25 terminal manufacturers making maritime and land mobile (briefcase-sized) units. The terminals cost between $10,000–$12,000 with a usage cost of $2–$6 per minute depending upon which CES is used.

2.2.1.2 Inmarsat Mini-M

The launch of the Inmarsat 3 satellites, with high power spot beams allowed Inmarsat to introduce the Mini-M service in 1996. It operates the same as the regular M service, but the higher power in the spot beams allows the terminals to be smaller and less expensive. By the end of 1996, there were 150 users. The terminals are available in land mobile and maritime versions and are laptop sized. The antenna is also very small, either a flat panel (top of laptop) or a 0.2 m tracking antenna inside a radome for the maritime version. They cost about $5,000 with a usage cost of $3 per minute.

Table 2-2 Inmarsat M and Mini-M Compared

Inmarsat Service	Year Started	Services	Data Rate	Antenna	Terminal Size	Cost	Usage Cost
M	1992	Digital voice, data, fax	Voice: 4.8 kbps, Data: 2.4 kbps	0.6 M parabolic dish (tracking in	10 kg	$10–$12K	$2–$6/min
Mini-M	1996	Digital voice, data, fax	Voice: 4.8 kbps, Data: 2.4	0.2 m (tracking in	2.5 kg	$5K	$3/min

2.2.2 Thrane & Thrane Model TT 3060A CAPSAT Mini-M Terminal

This Inmarsat Mini-M terminal was evaluated at the R&D Center during March and April 1998. It was provided to us by LandSea Systems of Virginia Bach, VA. The unit is a small, portable device consisting of a transceiver, a handset, and a removable antenna (see Figure 2-1). The total weight of the system is less than 2.2 kg. The unit supports voice, fax, and data capabilities. The

CAPSAT operates for voice communications the same as a standard telephone. For facsimile (fax) communication, the unit operates as a Class III fax and as a modem the unit operates as a Hayes compatible 2400 bps device. Although the unit supports an RS-232 serial interface at up to 19.2 kbps, the maximum data rate on the air is limited to 2400 bps for any mode of operation. The user interface is via the handset with external interfaces for fax and telephone (RJ-11) and data (DB-9). As a portable unit, the CAPSAT has rechargeable NiCad batteries that can be replenished with fast or trickle chargers. Detailed system specifications are located in Appendix A.

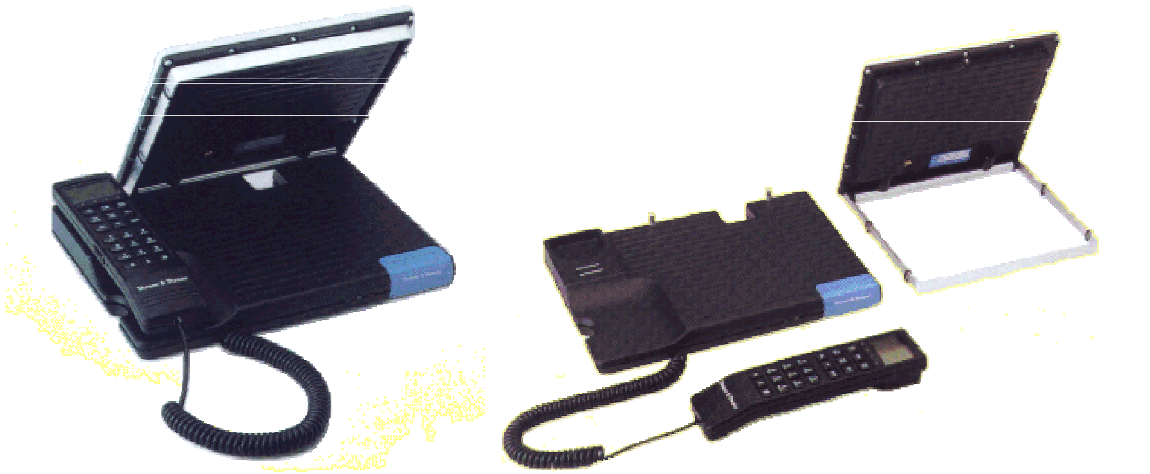

Figure 2-1 Thrane & Thrane CAPSAT Mini-M Terminal[2]

2.2.3 Thrane & Thrane Model TT-3064A Maritime Mini-M Terminal

This Inmarsat Mini-M terminal has not been evaluated at the RDC because the system performance characteristics are identical to the CAPSAT unit discussed above. The unit is intended for use in a maritime environment and as such has a sensor stabilized antenna, an individual handset cradle, and a remotely locatable transceiver (see Figure 2-2). This unit has an antenna that is only 21 cm in diameter and 24 cm high and weighs just 2.2 kg. The unit has ignition controlled power-on and does not have rechargeable batteries. The Fourteenth District purchased Thrane & Thrane transceivers with KVH antennas (called Tracphone 25 system) for their vessel installations. Specifications for both of these are included in Appendix A.

[2] CAPSAT pictures from LandSea Systems web site, http://www.landseasystems.com/

Figure 2-2 Thrane & Thrane Maritime Mini-M Terminal

3. System Testing

A Thrane & Thrane CAPSAT Model TT-3060A Inmarsat Mini-M terminal was provided to the R&D Center for testing by LandSea Systems Inc. of Virginia Beach, VA. This unit is the portable version described above. A series of tests were conducted on the unit in the Advanced Communications Lab at the R&D Center.

For all tests, the CAPSAT antenna was located on the roof and the transceiver and handset in the Lab. The antenna was pointed at the satellite using a compass and the audible beeps of the antenna-pointing feature. The antenna was oriented to 150°magnetic with an elevation of 41°which is the azimuth and elevation for the AORW satellite from the R&D Center (satellite location charts from the CAPSAT manual are included in Appendix B). The call was established as an international call using LES 13 (Stratus) because this is the company that LandSea has a service contract with. Detailed test data is included in Appendix C.

3.1 Voice Testing

3.1.1 Test bed

Voice testing of the CAPSAT unit was accomplished by using the CAPSAT to place telephone calls to telephone sets in the Advanced Communications Lab and at Coast Guard Headquarters. The transmission path for the voice tests went from the CAPSAT to the satellite, to the LES, through the PSTN, to the telephone extension being called (illustrated in Figure 3-1).

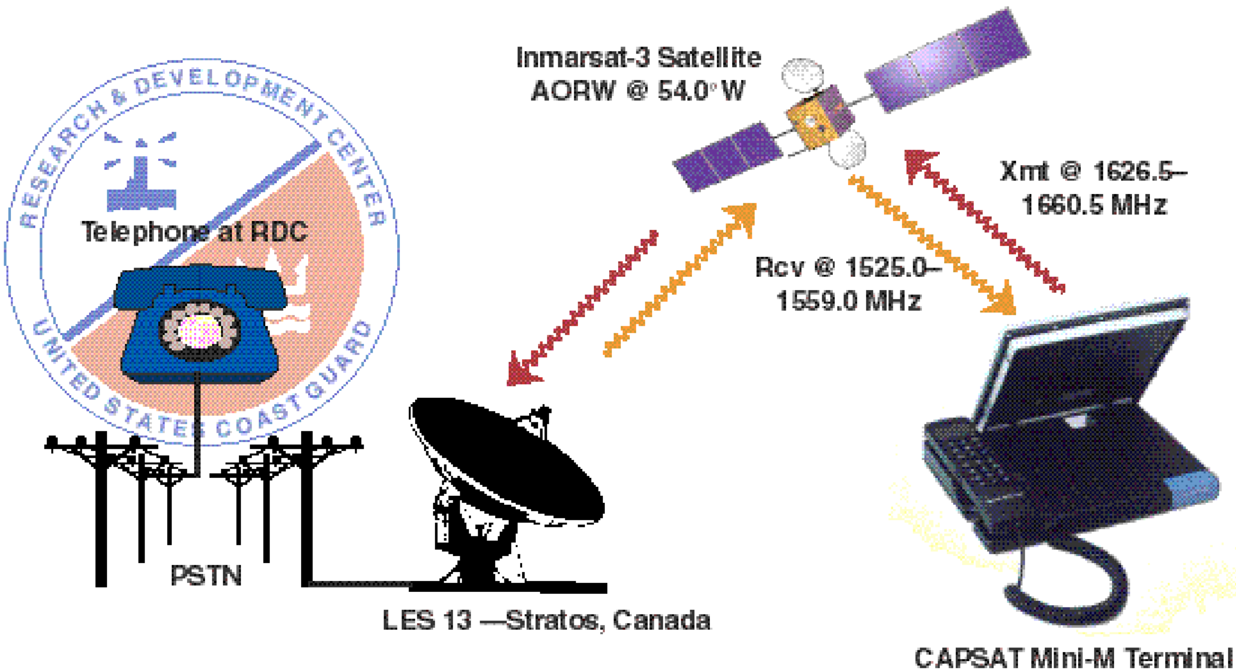

Figure 3-1 CAPSAT Voice Testing Diagram[3]

3.1.2 Voice Tests

Only two measurements were made on the voice calls, the call connection time and the call quality. The call connection time was very consistent. It took about 5 seconds to establish the connection with the LES and 11 seconds total from dialing the call until the telephone rang at the far end. The quality of the connection was very good. Due to the geostationary satellite hop, there is about $^{1}/_{2}$ second roundtrip delay. This takes a little bit of time to get accustomed to, but after a while is not as noticeable.

Inmarsat Mini-M is an all-digital system, which means that the analog voice signal must be digitized prior to modulation on the carrier. The CAPSAT modulates the carrier at 5.6 kbps, using O-QPSK modulation. The CAPSAT uses a 4.8 kbps AMBE algorithm for the voice coding. Of this, 3.6 kbps are used to digitize the voice and 1.2 kbps for FEC. This algorithm renders voice quality that is quite good. There is a slight tinny-ness to the quality; however, voice recognition is preserved and there is good resistance to background noise. In addition, fast speech is still intelligible, although some words become clipped at the beginning. Pauses in the conversation are very quiet, with no background static.

The users in the Fourteenth District have been very satisfied with the voice quality. They report that the quality is superior to that experienced on the HF system.

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[3] Inmarsat-3 satellite picture from Inmarsat web site, http://www.inmarsat.org/

3.2 Data Channel Testing

Bit Error Rate (BER) testing was done to assess the raw performance of the data communications channel. In addition, we wanted to measure how well the system performed when the signal strength was degraded. In the field this could be caused by blockage, interference, operating at the edge of the satellite footprint, or signal fading. In the Lab this was simulated using attenuators.

The call connection time for data calls was slightly longer than that for the voice calls. It typically took 5 seconds for the connection to be established with the LES, another 12 seconds for the remote end to ring, and then about 9 seconds for the modems to synchronize and establish the data connection. Thus, the total time to establish a data connection was typically 26 seconds.

3.2.1 Test Bed

Bit Error Rate (BER) testing of the CAPSAT unit was accomplished by using the CAPSAT to place a data call to a modem (a US Robotics Sportster 56k fax/data model) in the Advanced Communications Lab. The physical channel was established between the CAPSAT and the modem in the lab. The data transfer scheme was established and controlled by a pair of Network Communications Corporation (NCC) Network Probes model NP6650, one connected to the CAPSAT and one connected to the modem. The transmission path for the data tests thus went from the NP6650 to the CAPSAT, to the satellite, to the LES, through the PSTN, to the telephone extension in the Lab, to the modem and then to the other NP6650. Since the channel is full duplex, data was transmitted in both directions simultaneously. This is illustrated in Figure 3-2 below.

In order to vary the signal strength of the connection, variable attenuators were added inline between the CAPSAT transceiver and the antenna. Also, since the CAPSAT uses an active antenna with DC power supplied from the transceiver to the antenna using the same coaxial cable as the RF channel, a pair of Bias Tee's were used so that only the RF signal was attenuated, and not the DC power.

Figure 3-2 CAPSAT Data Channel Testing Diagram[4]

3.2.2 BER Tests

A data call was established by remotely controlling the CAPSAT with the NP6650 using a serial interface and standard AT command sets. Although the carrier is modulated at 5.6 kbps, the CAPSAT system has a maximum data transfer rate of 2.4 kbps; the rest of the bit rate is used for error control and correction. Once a 2400 bps data connection was established between the CAPSAT and the remote modem, both NP6650s were switched from VT100 terminal emulation to Bit Error Rate Test (BERT) mode. In the BERT mode, the NP6650s transmitted and received standardized data packets. The tests were conducted for periods of 10 minutes using the 63-bit pattern. The bit errors, character errors, bit count, character count, elapsed time, errored time, forced errors, time out of synchronization, severely errored seconds (SES), degraded minutes (DM), BER, and Character Error Rate (CER) were all recorded. The data recorded on the NP6650 connected to the CAPSAT represents the CAPSAT receive data and the data recorded on the NP6650 connected to the remote modem represents the CAPSAT transmit data (contained in Appendix C).

A series of tests were conducted starting with the system tuned for maximum signal strength. This was used as the 0 dB reference. Then the variable attenuators were used to reduce the signal strength as additional tests were run. As expected with digital systems, the performance of the

[4] Modem picture from 3Com web site, http://www.3com.com/ and Network Probe pictures from the NCC web site, http://www. netcommcorp.com/

system was virtually error free up to a point at which the system would not establish a connection to the LES (15 dB attenuation). This is graphed in Figure 3-3. A value of 1E-15 is used to represent a BER of 0, and a BER value of 1 (0E-0 on the log scale) is used for no connection at 15 dB attenuation. As can be seen, the system operated with 0 BER with 10dB or less attenuation. With attenuation beyond this, the BER increased. BERs of 3.25E-04 and 1.02E-04 were recorded on the receive side with 12 and 14dB of attenuation selected respectively. BERs of 8.19E-05 and 0 were recorded on the transmit side with 12 and 14dB of attenuation selected respectively. The system would not function with 15dB of attenuation selected. Although the length of the tests were too short to be totally accurate such as the 0 BER recorded for 14 dB attenuation on the transmit side, they give an indication of performance.

Average throughputs of 2373 bps on the receive side and 2332 bps on the transmit side were determined from the BER tests. This is close to the claimed 2400 bps data rate. Since the typical mode used is 8-bit ASCII with 1 stop bit, 1 start bit, and no parity bit per character, the actual **byte** rate is on the order of 240 Bps.

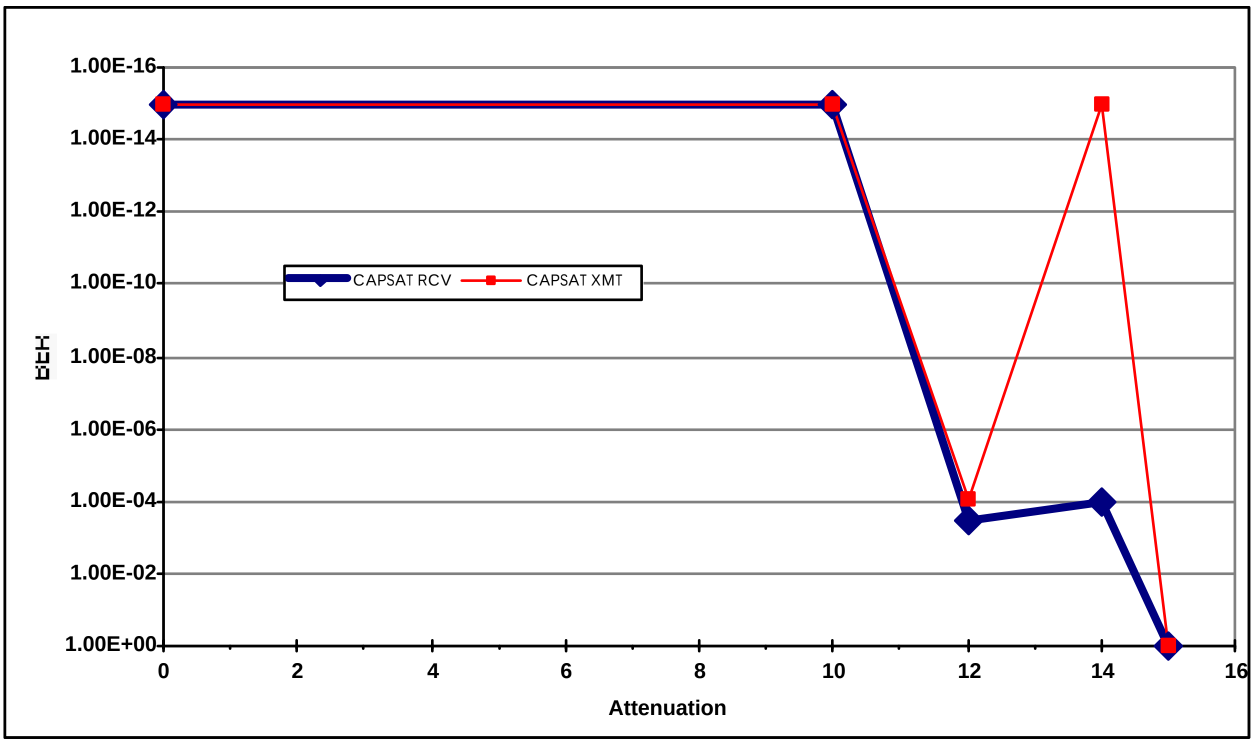

Figure 3-3 CAPSAT BER performance

3.3 Networking Performance Testing

In addition to the data channel level testing, we also evaluated the system's performance at the transport and network layers. This was done by establishing a PPP connection over the satellite data channel and then using standard TCP/IP based software utilities to measure the performance.

3.3.1 Test Bed

For these tests, a laptop computer running Windows 95 was connected to the CAPSAT. Using the SHIVA™ Dial-in Networking software, data calls were made to the Quickstream™ Remote Access Server (RAS) connected to the R&DC LAN in the Advanced Communications Lab. The data channel portion of the linkage is the same as described above. The SHIVA software established the PPP connection with the RAS. At this point a TCP/IP network connection existed between the laptop and the R&DC LAN and the tests were conducted using standard TCP/IP software tools.

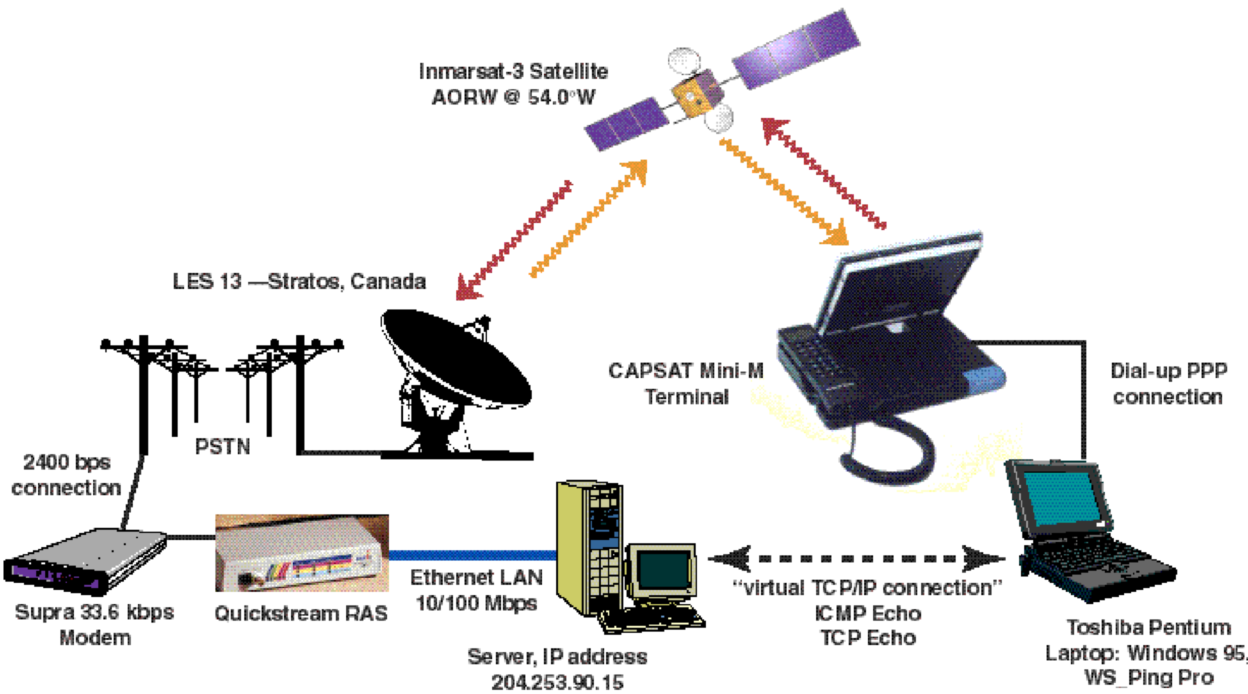

Figure 3-4 CAPSAT Network Performance Testing[5]

3.3.2 Latency tests

Latency is the end-to-end delay in the system. In a data transmission, this metric can be just as important as speed or bandwidth of the channel. Delay is introduced into the link in various manners. The first and most obvious would be the length of the path. Other sources of the delay are the earth station, buffering, system loading, and congestion. Latency is a measure of the end-to-end network delay. The latency metric is determined by using a network diagnostic tool called "PING." Ping sends an "echo request" in the form of an ICMP data packet to the IP echo port on a remote host and displays the results for each "echo reply." The round trip time for each request and reply are recorded. The software used was the Windows 95/NT version of WS_PING Pro by Ipswitch Software. With this software, the user can specify the size of the packet, the number of

[5] Quickstream picture from Sonic Systems web site, http://www.sonicsys.com/

packets, the time between packets, and the wait time for a reply to be user specified. With a 32-byte packet, the average latency was 2,772 milliseconds. With a 50-byte packet, the average latency was 2,971 milliseconds. The difference of course is the length of time required to transmit the extra bits (which is non-negligible on this slow speed link). Going through the calculations below, yields a system delay (without transmission time) of approximately 2.2 seconds roundtrip.

System latency Calculation:

```
32 byte ping packet + 40 bytes TCP/IP overhead = 72 bytes
72 * 2 (transmitted in each direction) = 144 bytes
144 bytes * 10 (bits/byte) = 1440 bits
1440 bits / 2400 bps = 0.6 sec
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2,772 ms – 600 ms = 2172 ms

3.3.3 Bandwidth

Bandwidth is the width of the communication channel. While the raw data channel was measured at close to 2400 bps, the actual TCP/IP throughput is much less due to the protocol overhead. This was measured using the Throughput feature of the new (beta) version of WS_PING Pro. The software allows the user to specify the number of packets, the size of the packets, the timeout value, and the delay between the packets. The throughput function sends the TCP segments to the TCP echo port, records the amount of time to send and receive the data, and calculates the throughput. This throughput is based on the actual data sent and received, not including the protocol overhead added at each layer, so is a true measure of the actual throughput at the Transport Layer.

A test was done using 35 packets at a specified size of 1,024 bytes. As can be seen in the graph below (Figure 3-5), the size of the data packets actually sent gradually increases. This is a function of the TCP algorithms. As the size of the packets increases, the effective throughput also increases. This is to be expected because of the protocol overhead incurred using TCP/IP. There is however, a maximum throughput based upon the raw channel speed. In Figure 3-5 the maximum throughput achieved is 1.43 kbps. Although the curve is leveling off, it does not appear to have reached the maximum value yet. Some additional trials were then run with larger packet sizes specified (Figure 3-6). In this graph, it appears that a steadystate throughput of about 1.525 kbps has been reached.

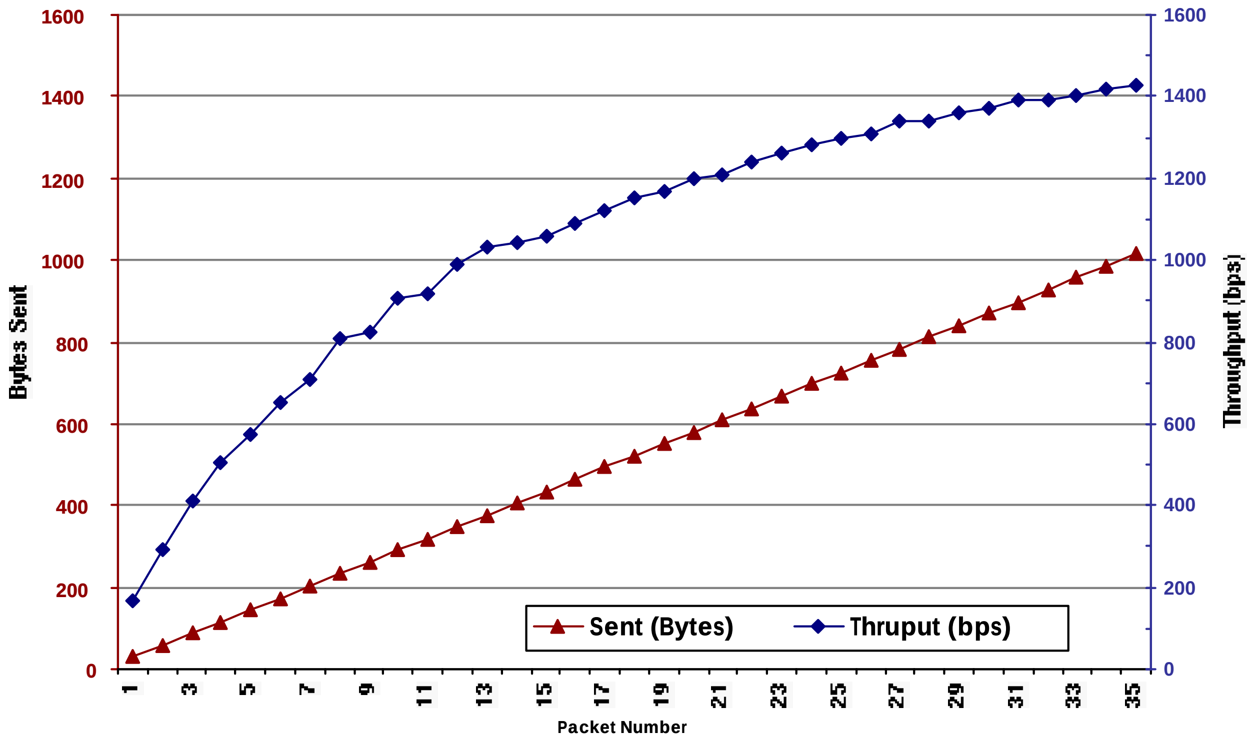


Figure 3-5 CAPSAT TCP/IP Throughput

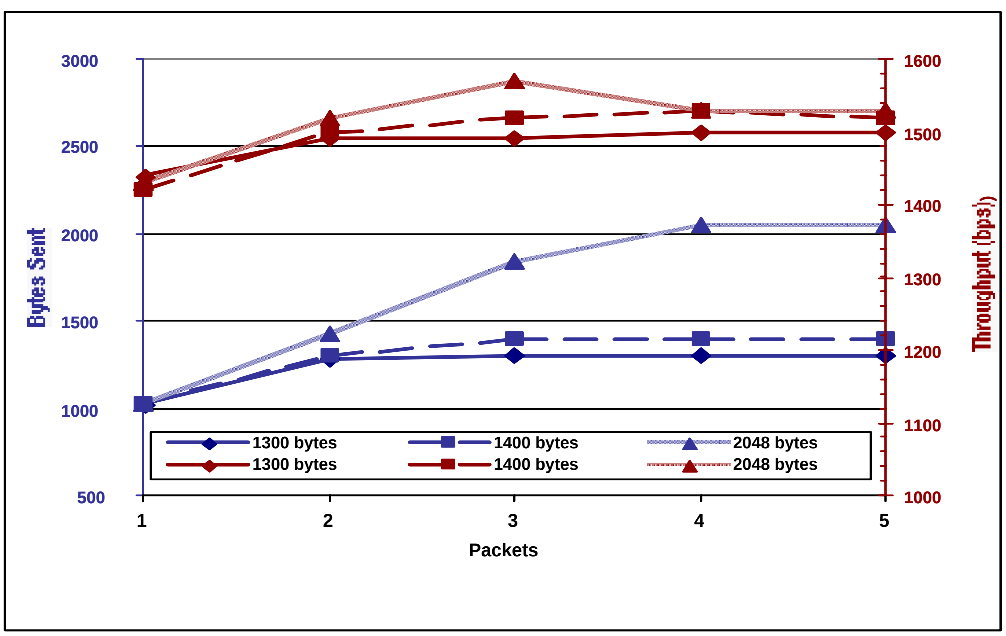


Figure 3-6 CAPSAT TCP/IP Throughput Using Larger Size Packets

3.4 System Assessment

3.4.1 Coverage

Coverage is the geographic area in which a mobile user has access to the satellite system. The new higher-powered Inmarsat –III satellites have several spotbeams. The diagram below (Figure 3-7) indicates the predicted coverage. The colored rings indicate the Region covered by each satellite using the main beam. The dark blue shading indicates the area covered by the spotbeams. No measurements were done to assess how well Inmarsat achieves the indicated spotbeam coverage. The system has been used by the 14th District units quite successfully throughout their AOR. They have used the system on trips up to 3,000 NM from homeport.

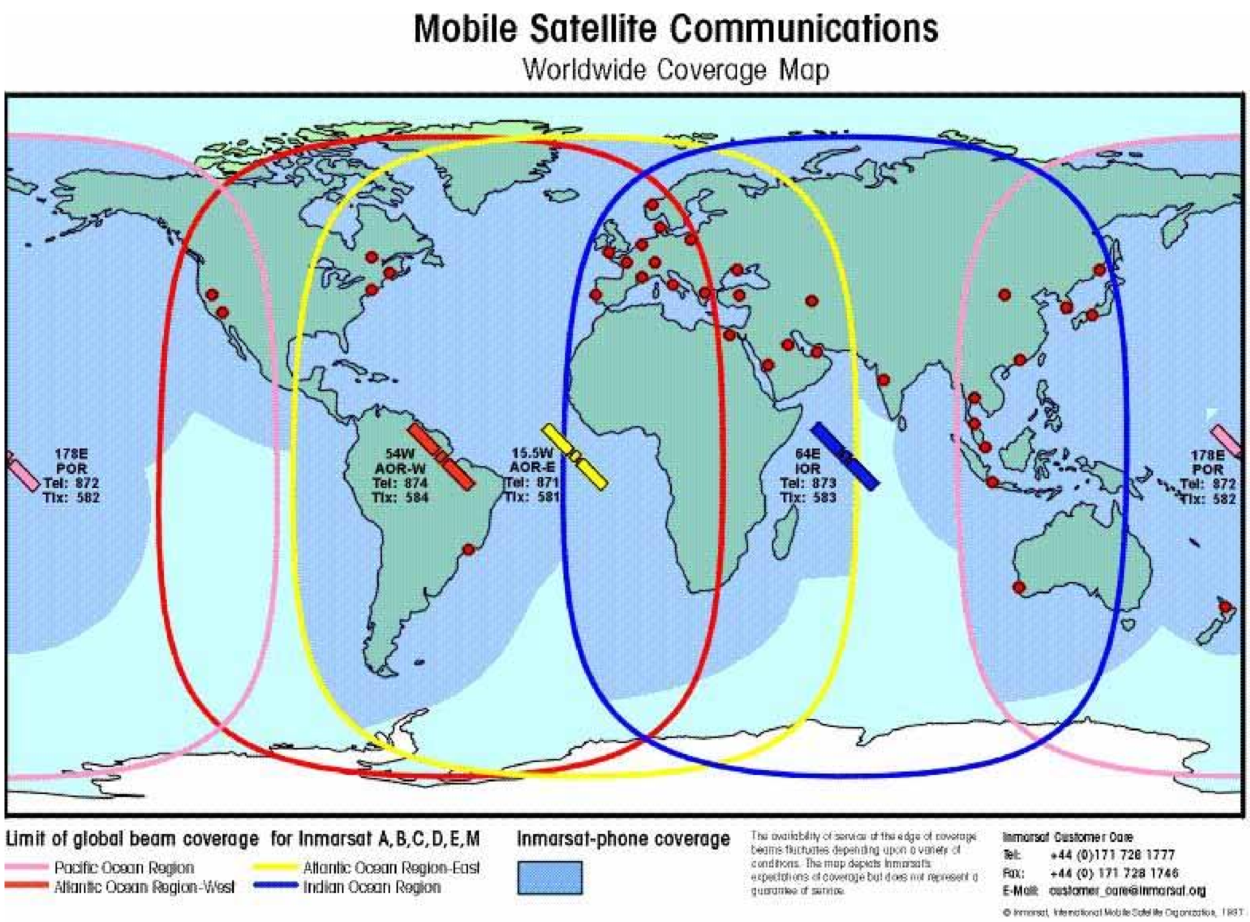


Figure 3-7 Inmarsat Coverage Map

3.4.2 Availability

Availability is the amount of unit time on any given day that the system is available for use. Reasons for non-availability could include: traffic exceeds the capacity of the system or the system is temporarily out of service. With a geostationary system, if you are within the coverage area, the satellite should always be available. The main factor in lack of availability then would be system congestion. Failure of user equipment would not be a reason for system non-availability. This was not addressed by R&DC testing. Users in the 14th District have never suffered from lack of availability. Due to the position of the antenna (centered on the top of the pilothouse, forward) the vessels experience blockages due to the mast when operating on certain headings. There is only about 5° of blockage however.

3.4.3 Reliability

Reliability is a measure of how dependable a system. The CAPSAT unit appeared to be very reliable. We experienced no equipment failures during testing. The 14th District units have also been very reliable.

3.4.4 Cost

A typical maritime Mini-M unit would cost about $5,000. Installation for these new, smaller, units would be fairly simple with a total cost of less than $1,000. The system is also fairly easy to use, so training costs would be low. Inmarsat terminals do not typically have any monthly access fees. The unit we tested had a usage charge of $3/minute. The government rate available through DITCO is cheaper however.

3.4.5 Interoperability

Interoperability is a measure of how well the system interfaces or integrates with existing systems. Inmarsat Mini-M is a circuit-switched system that connects to the PSTN. From the user’s perspective, it functions very similar to a standard telephone. In addition to having 2400 bps modem capabilities, it can also transmit facsimiles (also at 2400 bps). Fax transmissions were not tested at the R&D Center, but the 14th District has done so successfully.

3.4.6 Ease of Use

Since the system operates just like a standard telephone, it is very easy to use. The installations in the 14th District are well received by the crews of the vessels. They have reported no difficulties in using the system.

3.4.7 Security

Secure communications are possible by using a STU-III connected to the CAPSAT. This feature was not tested by the R&D Center. The 14th District has not tested this yet, but has plans to do so in the near future.

4. Conclusions

Inmarsat Mini-M is a viable option for voice and data communications. The voice quality is quite good and secure voice is possible with a STU-III. Data communications work, although somewhat slowly. The data channel is virtually error-free up until the point where there is insufficient signal for the unit to work at all. There is a fairly large margin to allow for signal fade and operations on the fringe of the satellite footprint. The raw channel rate of 2400 bps provides a maximum usable TCP/IP throughput of about 1.5 kbps. There is also a system roundtrip delay of about 2.2 seconds. This delay will be most noticeable when conducting small back-and-forth data transfers such as database queries and web surfing.

Inmarsat Mini-M is currently the only option for ships operating outside of the AMSC coverage area (CONUS plus 200 miles). Within the AMSC coverage area, AMSC provides a similar level of voice quality and data performance for about half the usage cost.

As Iridium comes online, it will probably be a better solution for both voice and data applications. The costs (both equipment and usage) at this point look to be similar. However, even though the Thrane & Thrane Maritime Mini-M unit is very small, the Iridium unit will be smaller still. In addition, an aeronautical version of Iridium will be available. The biggest advantage to Iridium however will be the shorter delay time since the satellites are much closer to Earth. This will translate into less noticeable pauses in voice conversations and faster response on transactional data applications. Iridium is scheduled to be tested starting in August or September of 1998.

5. References

1. Gregory Johnson, Jon Turban, Robert Erickson, "Technology Assessment of Mobile Satellite System Alternatives," USCG R&D Center report, April 1998.
2. Thrane & Thrane CAPSAT manual.
3. LandSea Systems web site http://www.landseasystems.com/
4. Inmarsat web site http://www.inmarsat.org/
5. KVH Web site http://www.kvh.com/

6. Acronyms

AC	Alternating Current
AMBE	Adaptive Multi-Band Encoding
AMSC	American Mobile Satellite Company
AOR	Area Of Responsibility
AORE	Atlantic Ocean Region East
AORW	Atlantic Ocean Region West
BER	Bit Error Rate
BERT	Bit Error Rate Test
bps	bits per second
C	Celsius
CES	Coast Earth Station
cm	centimeter (0.01 m)
CONUS	CONtinental United States
dB	Decibel
DC	Direct Current
DTMF	Dual-Tone Multi-Frequency
fax	facsimile
FEC	Forward Error Correction
GES	Ground Earth Station
GHz	Giga-Hertz (1,000,000,000 Hertz)
GSM	Global System for Mobile communications
Hz	Hertz (cycles per second)
Inmarsat	International Maritime Satellite Organization
Intelsat	International Telecommunications Satellite Organization
IOR	Indian Ocean Region
IP	Internet Protocol
K	Kelvin
kbps	kilobits per second (1,000 bps)
kg	kilogram (1,000 grams)
kHz	kiloHertz (1,000 Hertz)
LAN	Local Area Network
lbs	U.S. pounds
LES	Land Earth Station

m	meter
MES	Mobile Earth Station
MHz	MegaHertz (1,000,000 Hertz)
mm	millimeter (0.001 m)
ms	millisecond (0.001 second)
mW	milliWatt (0.001 W)
NCC	Network Control Center
NCS	Network Control Station
NiCad	Nickel-Cadmium
O-QPSK	Offset Quadrature Phase Shift Keying
POR	Pacific Ocean Region
PPP	Point-to-Pont Protocol
PSTN	Public Switched Telephone Network
R&D	Research and Development
RAS	Remote Access Server
RHCP	Right-Hand Circular Polarization
RX	Receive
SCPC	Single Channel Per Carrier
SIM	Subscriber Identity Module
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TX	Transmit
Vac	Volts, AC
Vdc	Volts, DC
W	Watt
WRC	World Radio Conference

Appendix A

CAPSAT Specifications

A-1 Thrane & Thrane Model TT3060A CAPSAT

A-2 Thrane & Thrane Model TT3064A Maritime

A-3 KVH Tracphone 25

A-1 Thrane & Thrane Model TT 3060A CAPSAT Mini-M Terminal Specifications

Features:

- Built-in NiCad batteries and 9-18 Vdc charger for true portable use, with 48 hours listen time and 2.5 hours talk time.
- Extremely light, compact and power conserving mobile telephone for worldwide transfer of telephone calls, fax prints and data/e-mail messages.
- Handset, fax/2-wire RJ-11 phone port and Hayes compatible 2.4kbps data port each with their own call ID (4 in total).
- Removable true water tight and sealed antenna, with acoustic signal strength indicator. The small and discrete flat panel antenna may be relocated up to 70 meters (225 feet) from the basic telephone.
- Secure and tailored operation via built-in SIM card reader.
- Optional STU-IIB/STU-III and picture transmission software packages.
- All magnesium laptop sized, with a weight of less than 2.2 kg (5 lbs.).
- The TT-3060A is operated from the handset just like a normal GSM telephone, from the 2-wire DTMF phone interface, from a connected fax machine or from the data port using Hayes AT command sets.
- Normal operation of the telephone is possible during battery charge operations and an ac fast charger and spare battery packs are available as options.
- General Specifications: Inmarsat-phone spot-beam operation. Meets or exceeds current and proposed specifications.

Specifications:

ANTENNA: Directional RHCP Patch Array with +/- 15 degree elevation and +/- 15 degree vertical beam width.

G/T: -17 dB/K minimum.

EIRP: 11 -17 dBW in 2 dB steps.

ANTENNA CABLE: SMB/SMB male. Maximum cable loss 10 dB at L-Band, 1.8 ohms DC resistance.

OPERATING FREQUENCIES: Receive 1525.0 - 1559.0 MHz Transmit 1626.5 - 1660.5 MHz.

CHANNEL SPACING: 1.25 kHz.

Rx-MODULATION: 5.6 kbps O-QPSK SCPC (voice/fax/data), 6kbps BPSK TDM

Tx-MODULATION: 5.6 kbps O-QPSK SCPC (voice/fax/data), 3kbps BPSK TDMA.

VOICE: 4.8 kbps AMBE 3.6 kbps voice, 1.2 kbps FEC.

ASYNC. DATA RATE: Max 2.4 kbps.

PHONE INTERFACE: 2-wire 600 ohm CCITT Rec. G.473, standard DTMF telephones, RJ-11 jack.

FAX INTERFACE: 2-wire 600 ohm CCITT Rec. G.473, T.30 Group-III Fax, max. 2.4 kbps, RJ-11 jack.

DATA INTERFACE: Serial EIA standard RS-232E, Hayes compatible, max. 19.2 kbps, DB-9 female connector.

PRINTER INTERFACE: Serial EIA standard RS-232E, max. 19.2 kbps, DB-9 female connector.

SIM CARD: GSM like operation, ISO-7816.

POWER SUPPLY: 9-18Vdc, typical 370mW listen mode, 8W talk mode and 20W in fax/data mode.

SOLAR PANEL INTERFACE: 15-25Vdc input.

BATTERY CAPACITY: Typical listen time 48 hours, talk time typical 150 minutes and fax/data time 50 minutes.

STANDARD AC ADAPTER: 90-265 Vac, 40-70 Hz, 5W, charge time 5-6 hours.

OPTIONAL AC ADAPTER: 90-265 Vac, 40-70 Hz, 15W, charge time 2 hours.

AMBIENT TEMPERATURE: -25C to 55C operating, -40C to 80C storage.

RELATIVE HUMIDITY: 95% non-condensing at 40C.

VIBRATION SURVIVAL: Random 5-20 Hz 0.05 g/Hz, 20-150 Hz -3dB/Oct. (1.7g rms).

SHOCK: Half sine, 20g/11 ms.

DIMENSIONS AND WEIGHT: H x W x D, 52mm x 270mm x 200mm, 2.2 kg (including handset, battery pack and antenna).

A-2 Thrane & Thrane Model TT3064A Maritime Mini-M Terminal Specifications

Features:

1. Handset, fax/2-wire RJ-11 phone port and Hayes compatible 2.4 kbps data port each with their own call ID (4 in total).

2. World's smallest automatic 2-way maritime satellite tracking antenna.

3. Secure and tailored operation via built-in SIM card reader.

4. Optional STU-IIB/STU-III and picture transmission software packages.

5. Easy to install below-deck transceiver unit, with separate handset/cradle unit for conveniently located installation.

Description:

6. The TT-3064A Maritime Telephone provides high quality telephone calls, fax prints, data transfers or e-mail messages, to any destination in the world.

7. The extremely small antenna and the very compact design of the below-deck transceiver unit, makes installation of the Maritime Telephone convenient for a large variety of vessels, ranging from large coasters to private yachts.

8. The TT-3064A is operated from the handset just like a normal GSM telephone, from the 2-wire DTMF phone interface, from a connected fax machine or from the data port using Hayes AT command sets.

9. The two-way tracking antenna is only 21 cm in diameter and 23 cm high, and may be located up to 70 meters from the below-deck transceiver unit.

10. The below-deck transceiver unit offers a wide range of auxiliary inputs and outputs, e.g. for a remote bell and ignition control of power on.

11. The flexible design of the handset/cradle unit allows easy access to fax, auxiliary phone, and data connections. The elaborated configuration possibilities include locked telephone number directory service as well as call log possibilities.

Specifications:

Inmarsat-phone spot-beam operation. Meets or exceeds current and proposed specifications.

ANTENNA: Sensor stabilized platform with directional RHCP Antenna. No cable unwrap. Maximum pointing error +/-10 deg.

SHIP MOTIONS: Roll +/- 25 deg. Pitch +/- 15 deg. Yaw +/- 8 deg, surge 0.2g. Sway +/- 0.2g. Heave +/- 0.2g. Turning rate +/- 12 deg/s 1 deg/sq-2, Headway 30 knots

G/T: -17 dB/K minimum

EIRP: 8-14 dBW in 2 dB steps.

ANTENNA CABLE: TNC/TNC female. Maximum cable loss 15 dB at L-Band, 1.8 ohm at DC

OPERATING FREQUENCIES: Receive 1525.0 - 1559.0 MHz Transmit 1626.5 - 1660.5 MHz.

CHANNEL SPACING: 1.25 kHz.

Rx-MODULATION: 5.6 kbps O-QPSK SCPC (voice/fax/data), 6kbps BPSK TDM

Tx-MODULATION: 5.6 kbps O-QPSK SCPC (voice/fax/data), 3kbps BPSK TDMA.

VOICE: 4.8 kbps AMBE 3.6 kbps voice, 1.2 kbps FEC.

ASYNC. DATA RATE: Max 2.4 kbps.

PHONE INTERFACE: 2-wire 600 ohm CCITT Rec. G.473, standard DTMF telephones, RJ-11 jack.

FAX INTERFACE: 2-wire 600 ohm CCITT Rec. G.473, T.30 Group-III Fax, max. 2.4 kbps, RJ-11 jack.

DATA INTERFACE: Serial EIA standard RS-232E, Hayes compatible, max. 19.2 kbps, DB-9 female connector.

PRINTER INTERFACE: Serial EIA standard RS-232E, max. 19.2 kbps, DB-9 female connector.

SIM CARD: GSM like operation, ISO-7816.

HANDS FREE MICROPHONE: 02.5 mm connector.

HANDS FREE SPEAKER: 32 Ohm, 03.5 mm connector.

IGNITION CONTROLLED POWER ON: Optoisolated input. PTR screw connector.

EXTERNAL RINGER: RS410-type-N open collector output. PTR screw connector.

MUTE OUTPUT: RS410-type-N open collector output. PTR screw connector.

POWER SUPPLY: 10-32Vdc floating.

SPRAY (EME): Solid droplets from any direction.

ICING (EME): Up to 25mm of ice (no operation).

PRECIPITATION (EME): Up To 100 mm/hour

WIND (EME): 100 knots (normal operation)

AMBIENT TEMPERATURE: -25• C to 50• C operating, -40• C to 80• C storage.

RELATIVE HUMIDITY: 95% non-condensing at 40• C.

VIBRATION (EME): 4-10Hz 2.54mm, 10-15Hz 0.76mm, 15-25Hz 0.40mm, 25-33Hz 0.23mm

SHOCK: Half sine, 20g/11 ms.

DIMENSIONS AND WEIGHT:

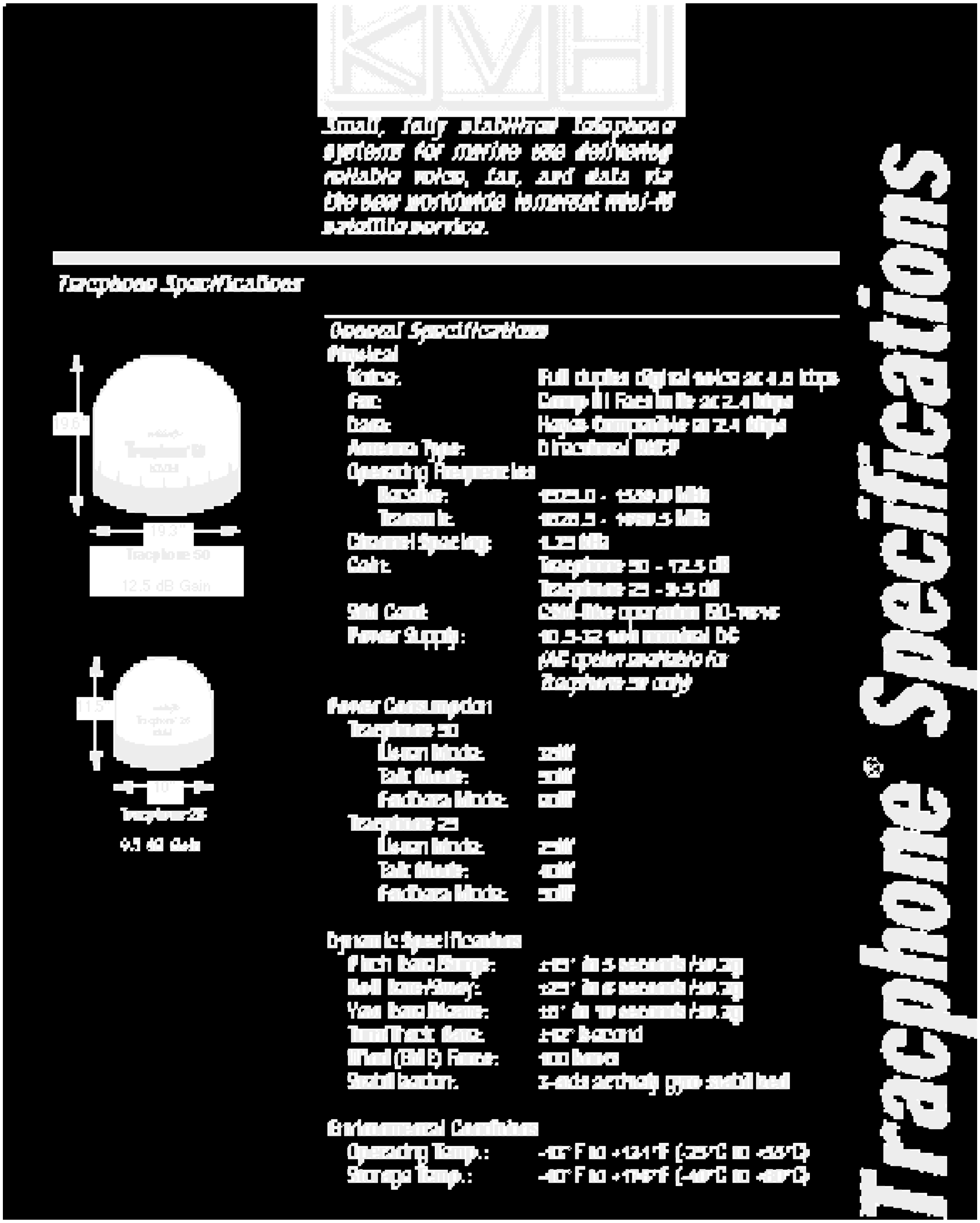
Electronics Unit (TT-3034B): H x W x D, 25mm x 268mm x 211mm, 1.3 kg.

Maritime Stabilized Antenna (TT-3007C): Dia. x H, 210mm x 240mm, 2.2 kg Incl. FEU and connector.

Cradle for the Handset (TT-3622A): H x W x D, 160 mm x 61 mm x 27 mm, 0.15 kg.

Handset (TT-3620B): H x W x D, 200 mm x 52 mm x 33 mm, 0.25 kg.

A-3 KVH Tracphone 25


Small, fully stabilized telephone systems for marine use delivering reliable voice, fax, and data via the new worldwide Inmarsat mini-M satellite service.

Tracphone® Specifications

Tracphone Specifications

Tracphone 50

12.5 dB Gain

Tracphone 25

9.5 dB Gain

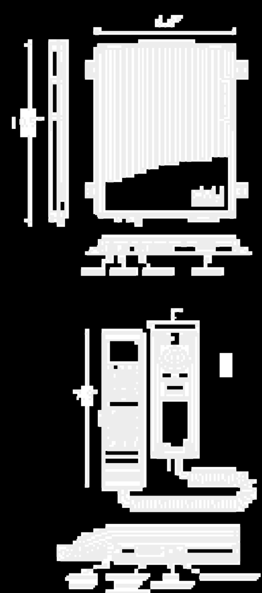
General Specifications

Physical	
Voice:	Full duplex digital voice at 4.8 kbps
Fax:	Group III Facsimile at 2.4 kbps
Data:	Hayes Compatible at 2.4 kbps
Antenna Type:	Directional RHCP
Operating Frequencies	
Receive:	1525.0 - 1559.0 MHz
Transmit:	1626.5 - 1660.5 MHz
Channel Spacing:	1.25 kHz
Gain:	Tracphone 50 - 12.5 dB
	Tracphone 25 - 9.5 dB
SIM Card:	GSM-like operation ISO-7816
Power Supply:	10.5-32 volt nominal DC (AC option available for Tracphone 50 only)
Power Consumption	
Tracphone 50	
Listen Mode:	35W
Talk Mode:	50W
Fax/Data Mode:	90W
Tracphone 25	
Listen Mode:	25W
Talk Mode:	40W
Fax/Data Mode:	50W
Dynamic Specifications	
Pitch Rate/Surge:	±15° in 5 seconds/±0.2g
Roll Rate/Sway:	±25° in 6 seconds/±0.2g
Yaw Rate/Heave:	±8° in 10 seconds/±0.2g
Turn/Track Rate:	±12°/second
Wind (EMI) Force:	100 knots
Stabilization:	3-axis actively gyro stabilized
Environmental Conditions	
Operating Temp.:	-[illegible]°F to +131°F (-25°C to +55°C)
Storage Temp.:	-40°F to +1[illegible]°F (-40°C to +[illegible]°C)

Tracphone Specifications – continued

Interface Specifications

Phone Interface:	2-wire 600 ohm, CCITT Rec G.473, Standard DTMF Telephones, RJ-11 Jack
Fax Interface:	2-wire 600 ohm, CCITT Rec G.473,T.30 Group-III Fax, max. 2.4 kbps, RJ-11 Jack
Data Interface:	Serial EIA standard RS-232E, Hayes Compatible, max. 2.4 kbps, DB-9 female connector
Printer Interface:	Serial EIA standard RS-232E, max. 19.2 kbps, DB-9 female connector



Physical Specifications

Tracphone 50 Antenna Unit

Height/Diameter:	19.8 in (50 cm)/19.3 in (49 cm)
Weight:	28 lbs (12.8 kg)
RF Cable Length:	65 ft standard (20 m), 115 ft max. (35 m)

Tracphone 25 Antenna Unit

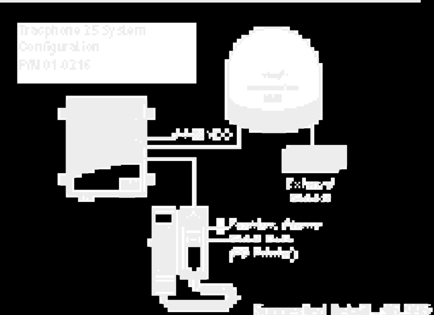
Height/Diameter:	11.5 in (29.4 cm)/10 in (25 cm)
Weight:	11 lbs (5 kg)
RF Cable Length:	33 ft standard (10 m), 115 ft max. (35 m)

Transceiver

Dimensions:	10.5 in x 8.3 in x 1.0 in (27 cm x 21 cm x 2.5 cm)
Weight:	2.9 lbs (1.3 kg)

Handset

Dimensions:	7.9 in x 2.0 in x 1.2 in (20 cm x 5 cm x 3 cm)
Weight:	1.0 lbs (0.47 kg)



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Appendix B

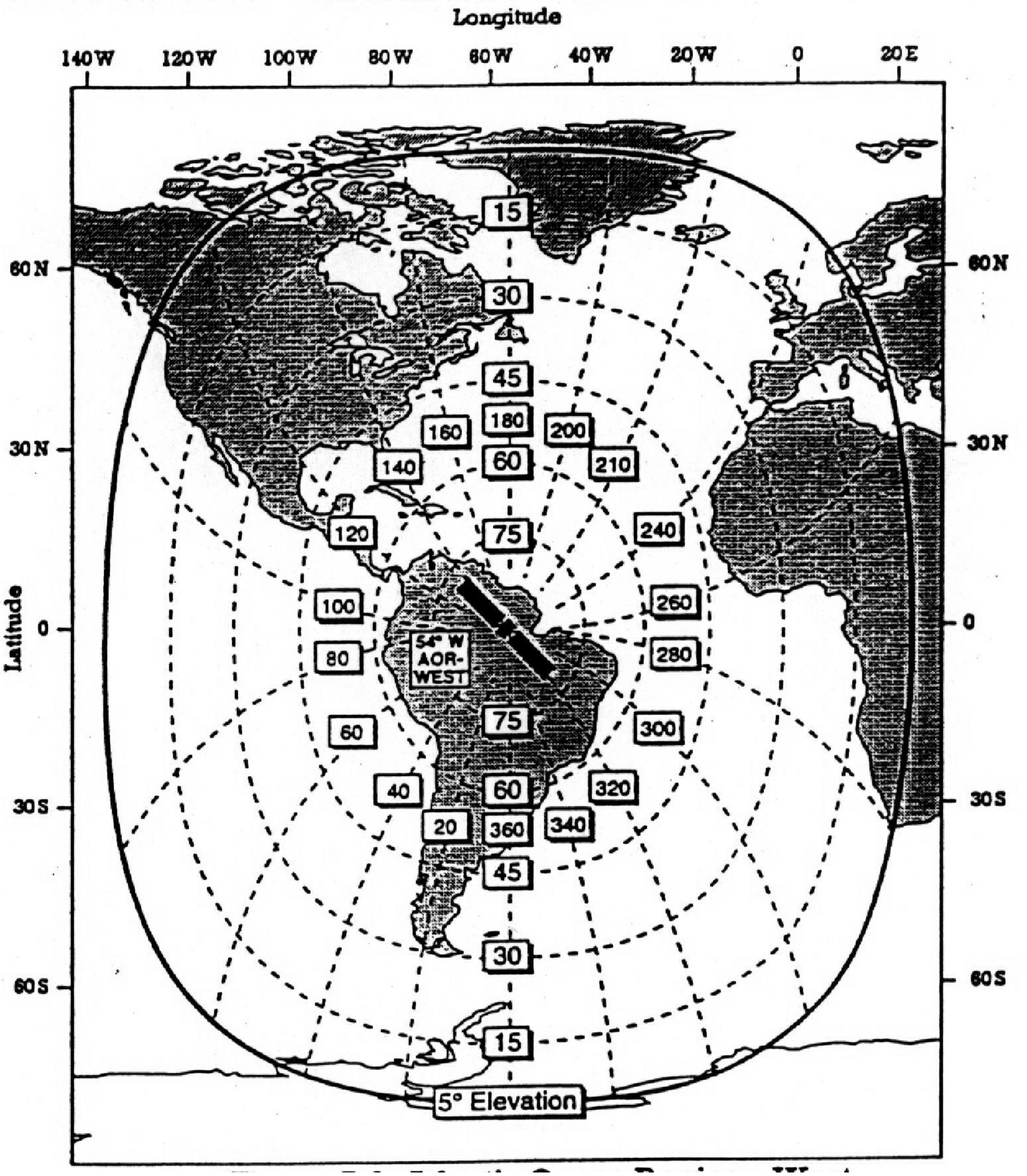
Satellite Location Diagrams

B-1 Inmarsat AORW Azimuth and Elevation

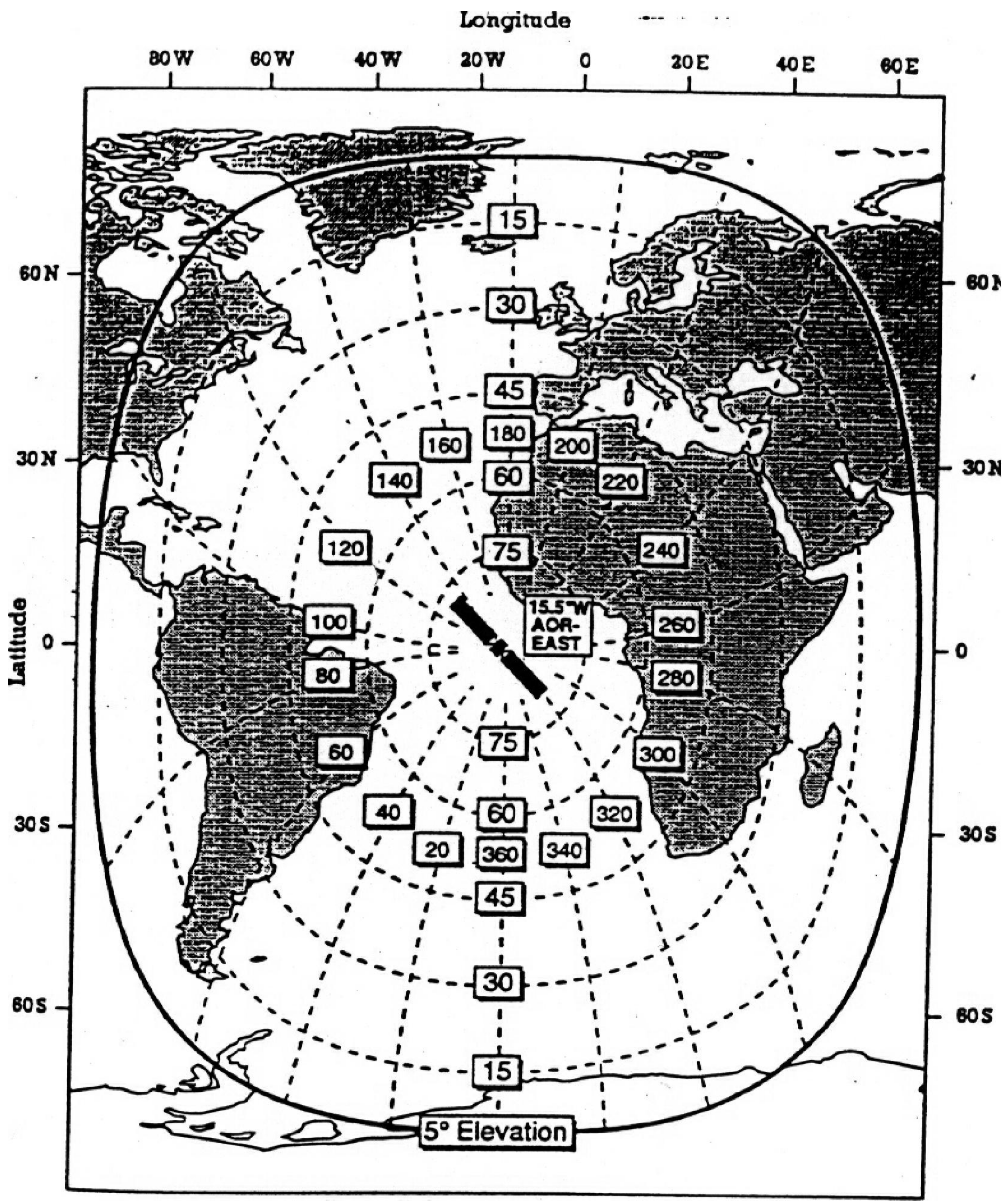
B-2 Inmarsat AORE Azimuth and Elevation

B-3 Inmarsat POR Azimuth and Elevation

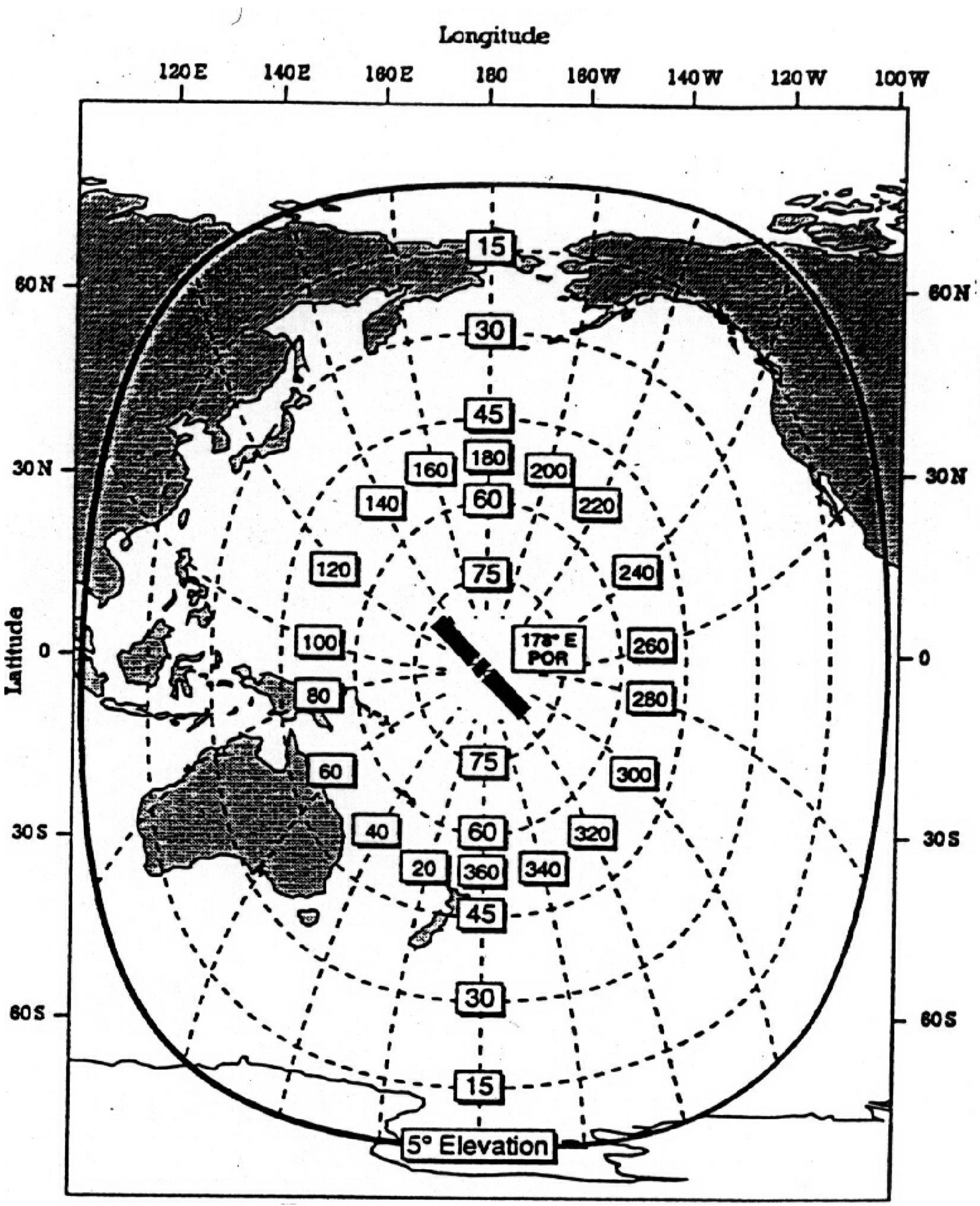
B-1 Inmarsat AORW Azimuth and Elevation



B-2 Inmarsat AORE Azimuth and Elevation



B-3 Inmarsat POR Azimuth and Elevation



Appendix C

Detailed Test Data

C-1 CAPSAT BER Data

Table C-1 CAPSAT Receive Test Data

Attenuation (dB)	0	10	12	14
Bit Errors	0	0	369	114
Character Errors	0	0	44	14
Bit Count	1.141.800	1.123.528	1.135.776	1.113.304
Character Count	142.725	140.441	141.972	139.163
Elapsed Time	00:09:56	00:09:50	00:09:54	00:09:58
Errored Time	00:00:00	00:00:00	00:00:05	00:00:01
Forced Errors	0	0	0	0
Out of Sync	0	1	5	1
SES	0	0	5	1
DM	0	0	3	1
BER	0.00E+00	0.00E+00	3.25E-04	1.02E-04
CER	0.00E+00	0.00E+00	3.10E-04	1.00E-04
Elapsed Seconds	596	590	594	598
Throughput	2394.7	2380.4	2390.1	2327.1

Table C-2 CAPSAT Transmit Test Data

Attenuation (dB)	0	10	12	14
Bit Errors	0	0	90	0
Character Errors	0	0	14	0
Bit Count	1.117.624	1.112.504	1.100.056	1.112.360
Character Count	139.703	139.063	137.507	139.045
Elapsed Time	00:09:59	00:09:56	00:09:50	00:09:56
Errored Time	00:00:00	00:00:00	00:00:04	00:00:00
Forced Errors	0	0	0	0
Out of Sync	0	0	5	0
SES	0	0	4	0
DM	0	0	3	0
BER	0.00E+00	0.00E+00	8.19E-05	0.00E+00
CER	0.00E+00	0.00E+00	1.01E-04	0.00E+00
Elapsed Seconds	599	596	590	596
Throughput	2332.3	2333.3	2330.6	2333.0

C-2 CAPSAT Throughput Data

Table C-3 Throughput Testing, parameters: Count = 35, Size = 1024 bytes, Timeout = 20000ms, Delay = 5ms

Packet #	Sent (Bytes)	Rcvd (Bytes)	Time (ms)	Throughput (bps)
1	29	29	2,746.07	168
2	58	58	3,182.07	291
3	87	87	3,385.04	411
4	116	116	3,658.07	507
5	145	145	4,030.09	575
6	174	174	4,259.03	653
7	203	203	4,573.01	710
8	232	232	4,598.07	807
9	261	261	5,077.05	822
10	290	290	5,115.04	907
11	319	319	5,574.09	915
12	348	348	5,613.05	991
13	377	377	5,830.03	1030
14	406	406	6,192.04	1040
15	435	435	6,549.01	1060
16	464	464	6,753.02	1090
17	493	493	7,015.02	1120
18	522	522	7,235.05	1150
19	551	551	7,485.09	1170
20	580	580	7,704.02	1200
21	609	609	7,999.07	1210
22	638	638	8,198.08	1240
23	667	667	8,441.08	1260
24	696	696	8,678.05	1280
25	725	725	8,904.00	1300
26	754	754	9,180.02	1310
27	783	783	9,349.06	1340
28	812	812	9,645.03	1340
29	841	841	9,876.02	1360
30	870	870	10,129.00	1370
31	899	899	10,306.00	1390
32	928	928	10,672.08	1390
33	957	957	10,860.07	1400
34	986	986	11,077.06	1420
35	1015	1015	11,329.09	1430
35 packets, 36540 bytes in 251235 ms. average:1.16 kilobits/sec median:1.15 kilobits/sec				

Table C-4 Throughput Testing, parameters: Count = 5, Size = 1300 bytes, Timeout = 20000ms, Delay = 5ms

Packet #	Bytes Sent	Rcvd (Bytes)	Time (ms)	Bytes Received
1	1024	1024	Time:11370.09	1440
2	1284	1284	Time:13730.04	1490
3	1300	1300	Time:13922.09	1490
4	1300	1300	Time:13852.08	1500
5	1300	1300	Time:13838.01	1500
5 packets, 12416 bytes in 66715 ms. average:1.48 kilobits/sec median:1.49 kilobits/sec				

Table C-5 Throughput Testing, parameters Count = 5, Size = 1400 bytes, Timeout = 20000ms, Delay = 5ms

Packet #	1400 bytes	Rcvd (Bytes)	Time (ms)	1400 bytes
1	1024	1024	Time:11516.01	1420
2	1304	1304	Time:13820.04	1500
3	1400	1400	Time:14710.08	1520
4	1400	1400	Time:14578.00	1530
5	1400	1400	Time:14718.00	1520
5 packets, 13056 bytes in 69343 ms. average:1.50 kilobits/sec median:1.52 kilobits/sec				

Table C-6 Throughput Testing, parameters Count = 5, Size = 2048 bytes, Timeout = 25000ms, Delay = 5ms

Packet #	2048 bytes	Rcvd (Bytes)	Time (ms)	2048 bytes
1	1024	1024	Time:11417.07	1430
2	1433	1433	Time:15021.01	1520
3	1842	1842	Time:18673.00	1570
4	2048	2048	Time:21348.06	1530
5	2048	2048	Time:21319.03	1530
5 packets, 16790 bytes in 87780 ms. average:1.52 kilobits/sec median:1.53 kilobits/sec				