NATO Standardization Office
Bureau OTAN de normalisation

5 March 2015 NSO/0309(2015)C3B/4484

STANAG 4484 C3B (EDITION 3) – OVERALL SUPER HIGH FREQUENCY (SHF) MILITARY SATELLITE COMMUNICATIONS (MILSATCOM) INTEROPERABILITY STANDARD

Reference:
AC/322(SC/6)N(2010)0057 dated 13 September 2010

1. The enclosed NATO Standardization Agreement, which has been ratified by nations as reflected in the NATO Standardization Document Database (NSDD), is promulgated herewith.

2. The reference listed above is to be destroyed in accordance with local document destruction procedures.

ACTION BY NATIONAL STAFFS

3. National staffs are requested to examine their ratification status of the STANAG and, if they have not already done so, advise the NATO HQ C3 Staff through their national delegation as appropriate of their intention regarding its ratification and implementation.

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

Enclosure:

STANAG 4484 (Edition 3)

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NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

NATO STANDARDIZATION OFFICE
(NSO)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: OVERALL SUPER HIGH FREQUENCY (SHF) MILITARY SATELLITE COMMUNICATIONS (MILSATCOM) INTEROPERABILITY STANDARD

Promulgated on 5 March 2015

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

RECORD OF AMENDMENTS

No.	Reference/Date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This STANAG is promulgated by the Director NATO Standardization Agency under the authority vested in him by the North Atlantic Council.

2. No departure may be made from the agreement without informing the tasking authority in the form of a reservation. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

4. Ratification, implementation and reservation details are available on request or through the NSO websites (internet http://nso.nato.int; NATO Secure WAN http://nso.hq.nato.int).

RESTRICTION TO REPRODUCTION

FEEDBACK

6. Any comments concerning this publication should be directed to NATO/NSO – Bvd Leopold III - 1110 Brussels - Belgium.

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SCOPE

1.1 AIM

The overall SHF MILSATCOM interoperability standard will provide NATO with the communications network interoperability required to meet the objectives of the emerging NATO Network Enabled Capabilities (NNEC) concepts. The aim of this agreement is to define the technical characteristics necessary for direct digital interoperability among military SHF satellite communications terminals (X, C, Ku, and Ka-bands). In addition, the aim is to define communications parameters and architectures that enable efficient transport of networked communications over transponded satellite resources. These definitions will promote commonality among SATCOM earth terminal equipment which will provide for more effective interoperability among allied systems. Future architecture concepts for NATO SATCOM interoperability are being developed in the Satellite Ground Reference Architecture (SGRA). As the SGRA matures, appropriate architecture elements will be reflected in this STANAG.

1.2 IMPLEMENTATION OF THE AGREEMENT

This STANAG is considered to be implemented by a nation when that nation has issued instruction that such equipment to be procured for their forces will be manufactured in accordance with the characteristics detailed in this agreement.

1. This NATO Standardization Agreement (STANAG) is promulgated by the Chairman of the Military Agency for Standardization (MAS) under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consulting with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

1.3 PURPOSE

The purpose of this standard is to provide a system level definition of SHF Satellite Communications (SATCOM) to achieve interoperability between allied systems. This standard provides the basis to achieve interoperable communications over existing non-processing transponders (NATO, DSCS, WGS, SKYNET, SYRACUSE, SICRAL, SPAINSAT, TURKSAT, XTAR, etc.) and future SHF satellites. This standard provides the pathway to, and applicability of, the necessary information required to provide digital transmission of user supplied information, and to achieve interoperability between ground fixed, ground transportable, ground mobile, airborne, and ship borne SHF satellite terminals.

Interoperability over SHF satellites is supported by a variety of agreements, each specifically addressing an element in the communications path. This overarching agreement describes the relationships of the various SHF SATCOM STANAGs, and additional supporting technical data required to plan and establish SHF SATCOM connectivity. Edition 3 of this document takes into account emerging network-centric communications architectures and technologies, expanding the hierarchy of SHF STANAGs to include new waveforms designed for efficient transport of IP network traffic over transponded satellites.

1.4 APPLICATION AND GUIDANCE

In this agreement the word "shall" identifies mandatory system standards. The word "should" identifies design objectives that are desirable but not mandatory.

RELATED DOCUMENTS/REFERENCES

The following documents form a part of this standard to the extent specified herein. The document issue, unless otherwise specifically mentioned, shall be the latest in effect at the time of STANAG promulgation. In the event of conflict between the documents referenced and the contents of this standard, the contents of this standard shall be considered the superseding requirement.

1.5 SPECIFICATIONS, STANDARDS, AND HANDBOOKS

Table 1: Specifications, Standards and Handbooks

STANAG 4485:	SHF MILSATCOM NON-EPM MODEM FOR SERVICES CONFORMING TO CLASS-A OF STANAG 4484
STANAG 4486:	SUPER HIGH FREQUENCY (SHF) MILITARY SATELLITE COMMUNICATIONS (SATCOM) FREQUENCY DIVISION MULTIPLE ACCESS (FDMA) NON-EPM (NON-EPM) MODEM FOR SERVICES CONFORMING TO CLASS-B OF STANAG 4484
STANAG 4494	SATCOM ENGINEERING ORDER WIRE FOR CONTROL AND COMMAND
STANAG 4606	SUPER HIGH FREQUENCY (SHF) MILITARY SATELLITE COMMUNICATIONS (MILSATCOM) EPM WAVEFORM FOR CLASS B SERVICES
STANAG 4622	INTEROPERABILITY STANDARD FOR SATELLITE BROADCAST SERVICES (SBS)

STANAG 5067	STANDARD FOR INTERCONNECTION OF IPv4 NETWORKS AT MISSION SECRET AND UNCLASSIFIED SECURITY LEVELS
STANAG 4206	THE NATO MULTI- CHANNEL TACTICAL DIGITAL GATEWAY - SYSTEM STANDARDS
STANAG 4210	THE NATO MULTI-CHANNEL TACTICAL DIGITAL GATEWAY - CABLE LINK STANDARDS
STANAG 4212	THE NATO MULTI- CHANNEL TACTICAL DIGITAL GATEWAY - RADIO RELAY LINK STANDARDS
STANAG 4290	STANDARD FOR GATEWAY MULTICHANNEL CABLE LINK (OPTICAL)
AC/322-D(2010)0035 + AS1	THE NATO NII COMMUNICATIONS REFERENCE ARCHITECTURE - EDITION 1, VERSION 1.2. (NC3A RD-2844)
AC/322-D(2010)0034 + AS1	NATO SATCOM GROUND REFERENCE ARCHITECTURE EDITION 2 (NCRA RD-2534)
ITU-R S.465-5	REFERENCE EARTH-STATION RADIATION PATTERN FOR USE IN COORDINATION AND INTERFERENCE ASSESSMENT IN THE FREQUENCY RANGE FROM 2 TO ABOUT 30 GHZ
ITU-R S.580-6	RADIATION DIAGRAMS FOR USE AS DESIGN OBJECTIVES FOR ANTENNAS OF EARTH STATIONS OPERATING WITH GEOSTATIONARY SATELLITES

1.6 TYPES OF ACCESS

For the purposes of interoperability, classes of service will be defined within the context of each modem STANAG. If a core set of interoperable modes are appropriate for a given modem type, then these will be captured in the relevant STANAG. In keeping with the objectives set forth by NNEC, Edition 3 addresses the SHF access mechanisms required to support user end-to-end interoperability.

Aside from modems used in disadvantaged terminals (e.g., manpack), many more data rates are typically supported than previously required by core modes in Edition 2. As shown in *Figure 1: SHF SATCOM STANAG Hierarchy*, below, access categories in

Edition 3 will be used to group modem STANAG's based on similarities in channel access schema. Current and future modems are expected to fall into the categories of Frequency Division Multiple Access (FDMA), Shared Access, and Electronic Protective Measures (EPM).

FDMA – Modems in this class employ a fixed frequency carrier to support a single data channel. In the most common application, these modems support point-point communications between two terminals.

Shared Access – Modems in this class exploit the asynchronous nature of packet network traffic to enable TDMA access based on terminal traffic demands. The efficient sharing of bandwidth through TDMA can reduce transponder costs. This class of modems is very well suited to the types of capabilities envisioned in NATO Network Enabled Capabilities (NNEC).

Electronic Protective Measures – EPM modems employ unique waveform techniques to provide protection from interference. The initial modems in this class will support point-point communications, but they offer the ability to support shared access types of mechanisms as well. The EPM nature however, makes this class of service unique.

1.7 HIERARCHY OF DOCUMENTS, STANAGS DIAGRAM

In order to achieve interoperability using SHF SATCOM, it is necessary to understand, at the system level, how each subordinate STANAG should be utilized. *Figure 1: SHF SATCOM STANAG Hierarchy* provides a hierarchical view of the various STANAGs which comprise SHF SATCOM interoperability. The standards are grouped by the above access categories: FDMA, SA, and EPM. These access types encompass both modems that are designed in accordance with currently implemented STANAGs as well as future access types for which no current STANAG exists.

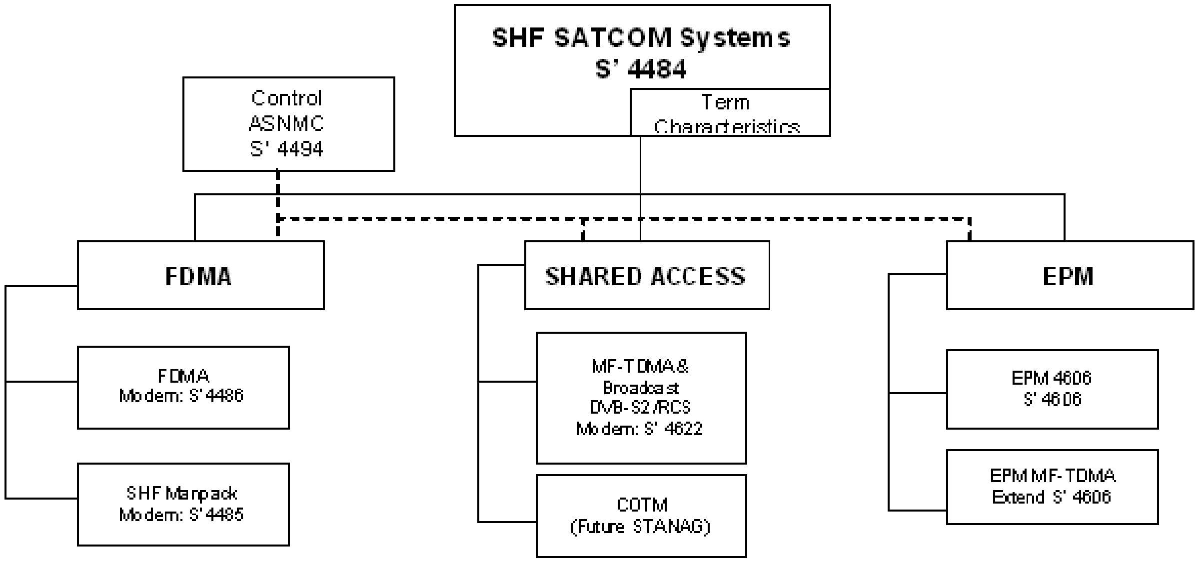

Figure 1: SHF SATCOM STANAG Hierarchy

1.8 SYSTEM DESCRIPTION, SYSTEMS DIAGRAM

The technical specifications required for interoperability are further divided by the functional areas identified in *Figure 2: SHF SATCOM Interoperability Functional Block Diagram*. The technical requirements are organized as follows: RF Characteristics, Modulation and Demodulation (modem) (i.e., Electronic Protective Measures (EPM) and Non-EPM), Baseband, TRANSEC and/or Cryptography (CRYTPO), and Network Management and Control. Operation in a NNEC environment will require definition of elements such as IP encryption, Performance Enhancing Proxy (PEP) functionality, SATCOM Convergence Routers (SCR) and additional shared access modem interoperability standards as defined above.

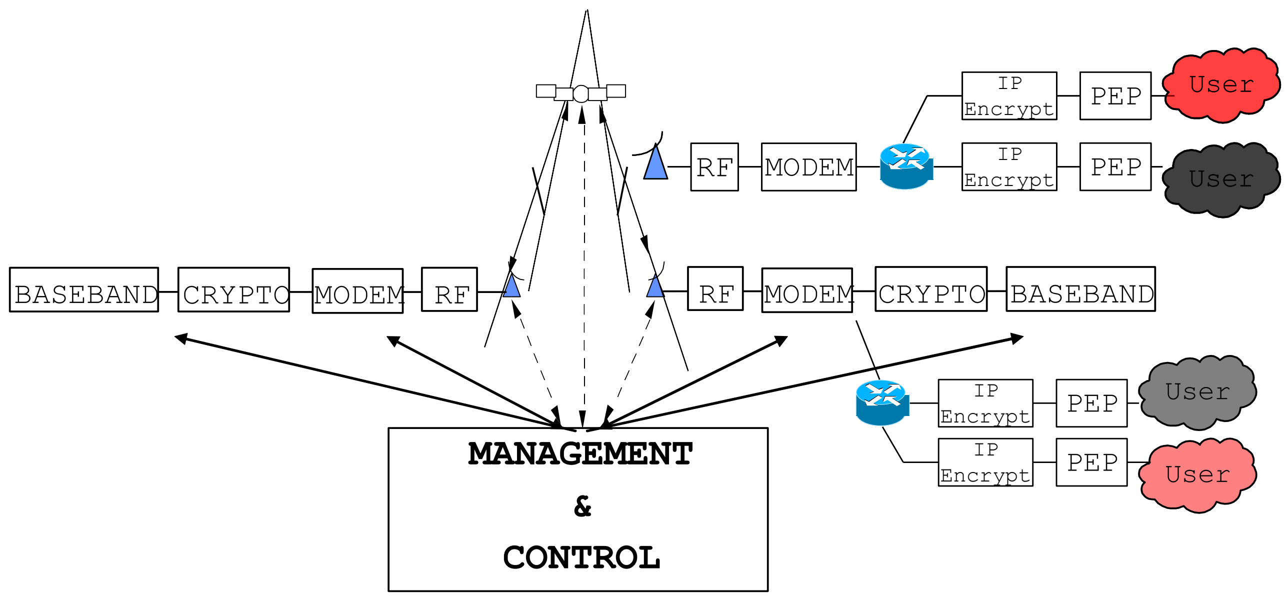

Figure 2: SHF SATCOM Interoperability Functional Block Diagram

1.9 INTEGRATED SYSTEM/STANAG DIAGRAM

Figure 3: ***Applicability of STANAG to SATCOM Terminal Elements*** shows the relationship of the STANAGs to various elements of a SATCOM terminal. In many cases, STANAGs exist or are being updated that help define the parameters necessary for interoperability.

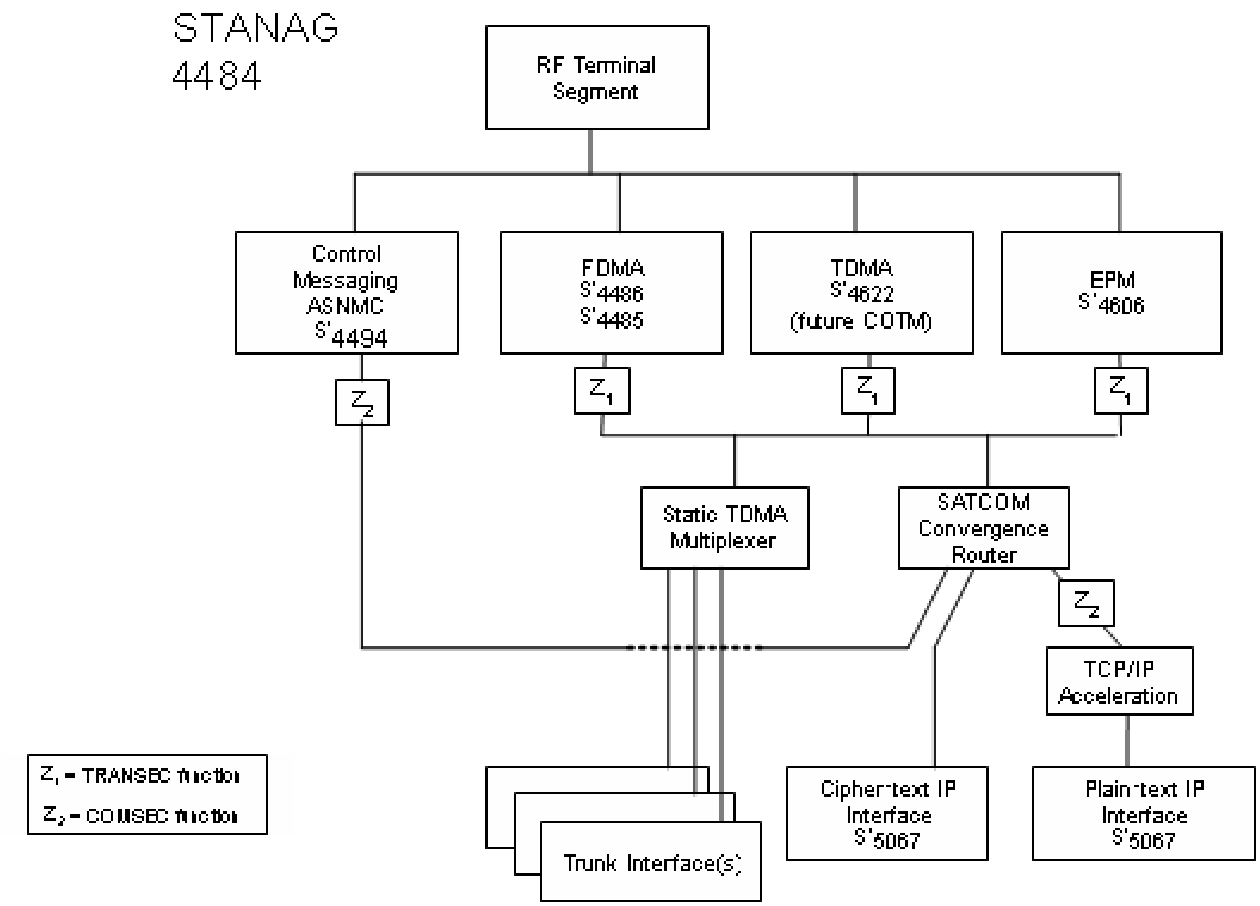

Figure 3: Applicability of STANAG to SATCOM Terminal Elements

INTEROPERABILITY REQUIREMENTS

1.10 TERMINAL CHARACTERISTICS

1.10.1 General SATCOM Earth Terminal Overview

The major SATCOM earth terminal (ET) functions are illustrated in *Figure 4: Earth Terminal Functional Illustration*.

Transmission function

The transmission function shall up-convert the IF signal to an RF signal, amplify the RF signal, and transmit the RF signal to a satellite. The transmission function includes all the equipment from the IF input to the antenna RF output.

Reception function

The reception function shall receive RF signals from a satellite, provide low-noise amplification, and down-convert the RF signal to an IF signal. The reception function includes all the equipment from the antenna RF input to the IF output.

Control and monitoring function

The ET control and monitoring functions shall support the centralized management of ASNMC, which includes power management, spectrum monitoring and centralized terminal administration. ET functions shall be as specified in 3.2.3.3 and 3.4.

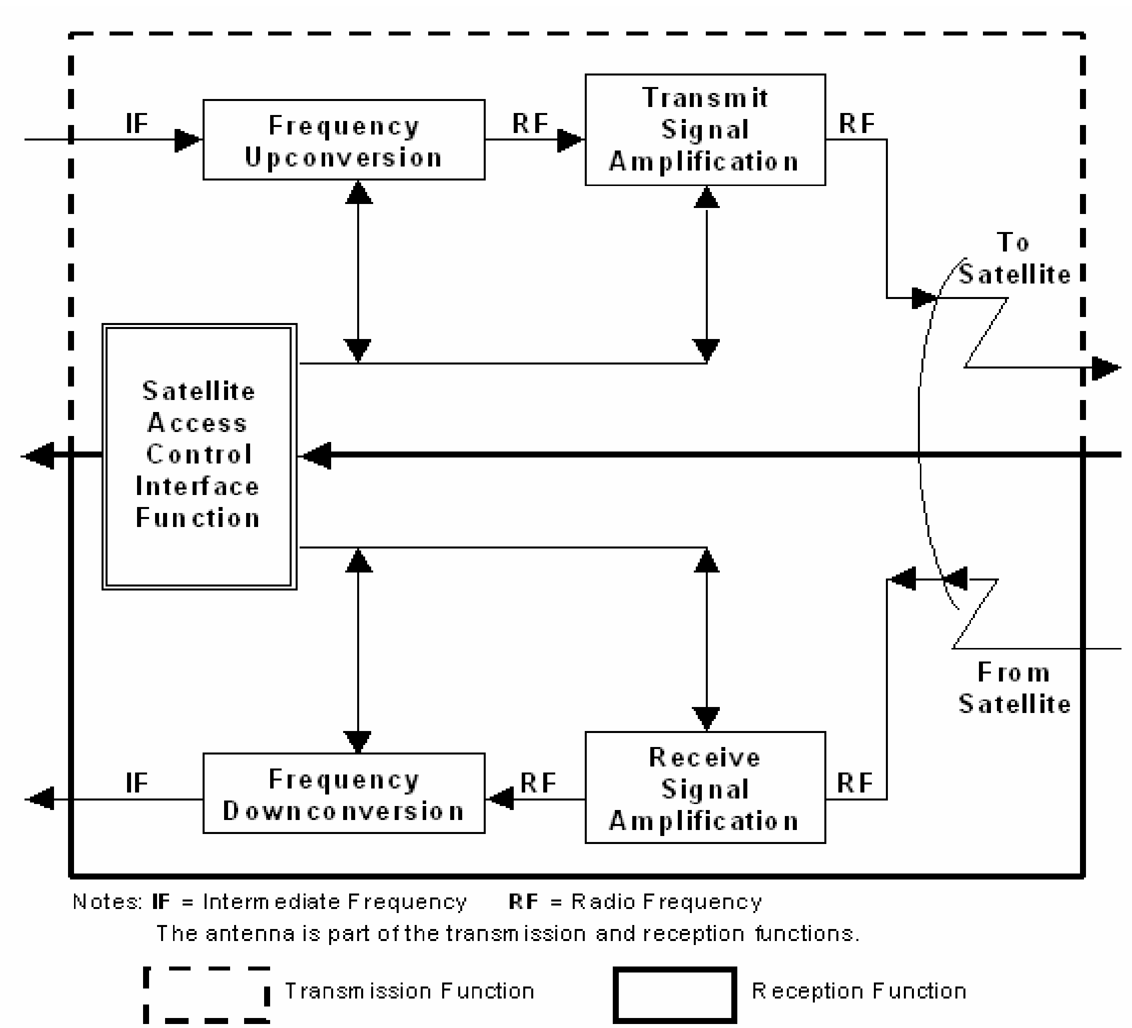

Figure 4: Earth Terminal Functional Illustration

1.10.2 Terminal Types and Classification

NATO SHF SATCOM employs a wide range of terminals. With the exception of the antenna size, transmit power and receiver sensitivity, the terminal requirements are largely the same across all the types of terminals. For the purposes of interoperability, the terminal requirements in this section provide the necessary assurance that RF emissions of terminals will not create unnecessary interference to other terminals operating on adjacent channels or satellites. When necessary, unique requirements on different classes of terminals will be called out. The following broad terminal classes are defined in the SGRA.

Manpack - A typical ET in this class is battery operated, weighs less than 40 pounds, and is transported by a single person. Antenna apertures for these terminals are typically in the range of 0.5 to 1 meter. Transmit power is severely limited due to battery operation.

SATCOM on the Move (SOTM) – A SOTM terminal refers to terminals that are integrated with terrestrial vehicles. These are intended to support communications while the vehicle is in motion, as well as while the vehicle halts at unspecified points. Typical apertures for SOTM antennas range from 0.3 to 1 meters.

Fly-Away Terminals (FAT) – Also known as SATCOM-on-the-Halt (SOTH) terminal is typically integrated into a terrestrial vehicle, but is not intended for communications while moving. The FAT terminal may include an antenna subsystem which deploys at the halt, but set up time required prior to initiating communications is typically in the range of 1 to 2 minutes. Typical apertures for SOTH antennas range from 0.5 to 1.8 meters.

Maritime SATCOM Terminal (MST) - An MST is similar in size and performance to the DSGT, but also exhibits characteristics of SOTM. Apertures for these terminals range from 1.5 to 4 meters.

Deployable SGT (DSGT) – A medium-size transportable terminal designed to be moved around the globe. They require more setup and site preparation than other non-fixed terminals, but also support greater communications capacity. Apertures for these terminals range from 1.5 to 3 meters.

Transportable SGT (TSGT) – A large transportable terminal designed to be moved around the globe. They require more setup and site preparation than other non-fixed terminals, but also support greater communications capacity. Apertures for these terminals range from 3 to 6 meters.

Satellite Ground Station/Satellite Ground Terminal (SGS/SGT) – Fixed site terminals are typically used in the application of anchor stations or gateways. These terminals typically employ apertures that range from 6 to 30 meters in diameter. With access to terrestrial power grid the transmitter powers can be very large.

1.10.3 Detailed Terminal Performance Characteristics

1.10.3.1 Transmission Function

The transmission function shall be in accordance with the requirements in this section.

1.10.3.1.1 IF Requirements.

Requirements in this section do not apply to terminals intended to operate only with embedded modem(s).

1.10.3.1.1.1 Input frequency.

Current ET technology is migrating toward the use of L-band intermediate frequencies, enabling wider bandwidths and the use of block frequency converters. A variety of L-band IF definitions exist. The overall range of 950-2050 MHz encompasses the existing L-band frequencies.

Any terminal implementing an L-band interface shall provide for at least 500 MHz of instantaneous bandwidth situated in the 950-2050 MHz range, with the exact frequency span as required for compatibility with the selected modem.

Terminals may choose to implement an IF input interface centered at the following frequencies (□represents the nominal 1-dB bandwidth):

a. 70 MHz □□18 MHz
b. 140 MHz □□36 MHz

Terminals shall implement one or more of the above IF input interfaces, in any combination.

1.10.3.1.1.2 Input Level and Impedance

Single-carrier maximum linear EIRP shall be attained with a single IF input at a level adjustable from -10 to +10 dBm. The IF input impedance shall be nominally 50-ohms, with a VSWR not to exceed 1.5:1 over the specified bandwidth.

1.10.3.1.2 RF Requirements

1.10.3.1.2.1 RF Frequency Bands

The X-band transmission function shall be tunable from 7.9 to 8.4 GHz.

1.10.3.1.2.2 Tuning

The upconversion function shall be tunable in 1.0-kHz increments, in conjunction with the modem, over the range identified in 3.1.3.1.2.1. The nominal 1-dB bandwidth shall be available at any tuned uplink frequency, as long as the 1-dB bandwidth does not extend beyond the band edges identified in 3.1.3.1.2.1.

1.10.3.1.2.3 EIRP Stability and Accuracy

For any setting of the transmit gain and a constant IF input level, the EIRP in the direction of the satellite shall not vary more than +1.0 dB or -1.5-dB in any 24-hour period. This tolerance, added on a root-sum-square (RSS) basis, includes all ET factors contributing to the EIRP variation, including output power level instability and power variations in the direction of the satellite caused by tracking errors referenced to boresight.

The formula for RSS error is:

$$\sqrt{P_1^2 + P_2^2}$$

where:

P_1 = Output power level instability in dB

P_2 = Power variations in the direction of the satellite caused by tracking errors referenced to boresight.

This does not include adverse weather conditions or any other effects not controlled by the ET. For dual band simultaneous operation, tracking performance shall be determined while tracking using the highest operational band tracking beacon.

1.10.3.1.2.4 Carrier Frequency Accuracy

The upconversion process shall not induce a frequency error greater than 1.0 kHz relative to the intended value of the received carrier frequency. Periodic re-calibration to achieve this accuracy is acceptable at intervals to be determined by the procurement documents.

1.10.3.1.2.5 Power Control

The power level of the upconversion function shall be adjustable in 0.5 dB or smaller steps, over the range defined in *Table 2: Terminal EIRP Power Control*, without disrupting signal flow. Power shall be set to within an absolute accuracy of ±1.0 dB from minimum to maximum power levels. Terminals intended to operate with embedded modems only shall meet this requirement by being power-level-adjustable at any function of the transmit chain, including the modem.

Table 2: Terminal EIRP Power Control

TYPE OF TERMINAL	MINIMUM POWER CONTROL RANGE IN dB
Manpack	5
SOTM	5
All other terminal classes	30

1.10.3.1.2.6 Transmit Phase Linearity

Departure from phase linearity of the transmission function, when operating at any point up to the maximum linear power, shall not exceed:

a. ±0.4 radians over any 36 MHz for 70-MHz IF operation.
b. ±0.5 radians over any 72 MHz for 140-MHz IF operation.
c. ±0.7 radians over any 120-MHz for any L-band IF.
d. ±0.2 radians over the center 10 MHz for any IF operation.
e. ±0.2 radians over any 1 MHz for ETs intended to operate with embedded modems only*.

Note: a, b, c, and d, above, do not apply to ETs intended to operate with embedded modems only.*

1.10.3.1.2.7 Transmit Amplitude Response

Amplitude variations of the transmission function at the input to the antenna feed, when operating at the maximum linear power, shall not exceed:

a. ±2.0 dB across the X-band output frequency band.
b. ±1.5 dB over any 36 MHz for 70-MHz IF operation.
c. ±1.5 dB over any 72 MHz for 140-MHz IF operation.
d. ±1.5 dB over any 120 MHz for L-band IF operation.
e. ±1.0 dB over the center 10 MHz for any IF operation.
f. ±0.5 dB over any 1 MHz for ETs intended to operate with embedded modems only **.

*Note**: a, b, c, d and e, above, do not apply to ETs intended to operate with embedded modems only.*

1.10.3.1.2.8 Transmit Spectral Characteristics

1.10.3.1.2.8.1 Transmit Spectral Purity

For all frequency bands, the transmit function (from IF to RF) contribution to the single-sideband power spectral density of the continuous component of the phase noise component shall not exceed the envelopes defined in *Figure 5: ET Spectral Purity*. A spurious component at the fundamental alternating current (AC) line frequency shall not exceed -30 dBc. The single sideband sum (added on a power basis) of all other individual spurious components shall not exceed -36 dBc. *Note: This paragraph does not apply to ETs intended to operate with embedded modems only.*

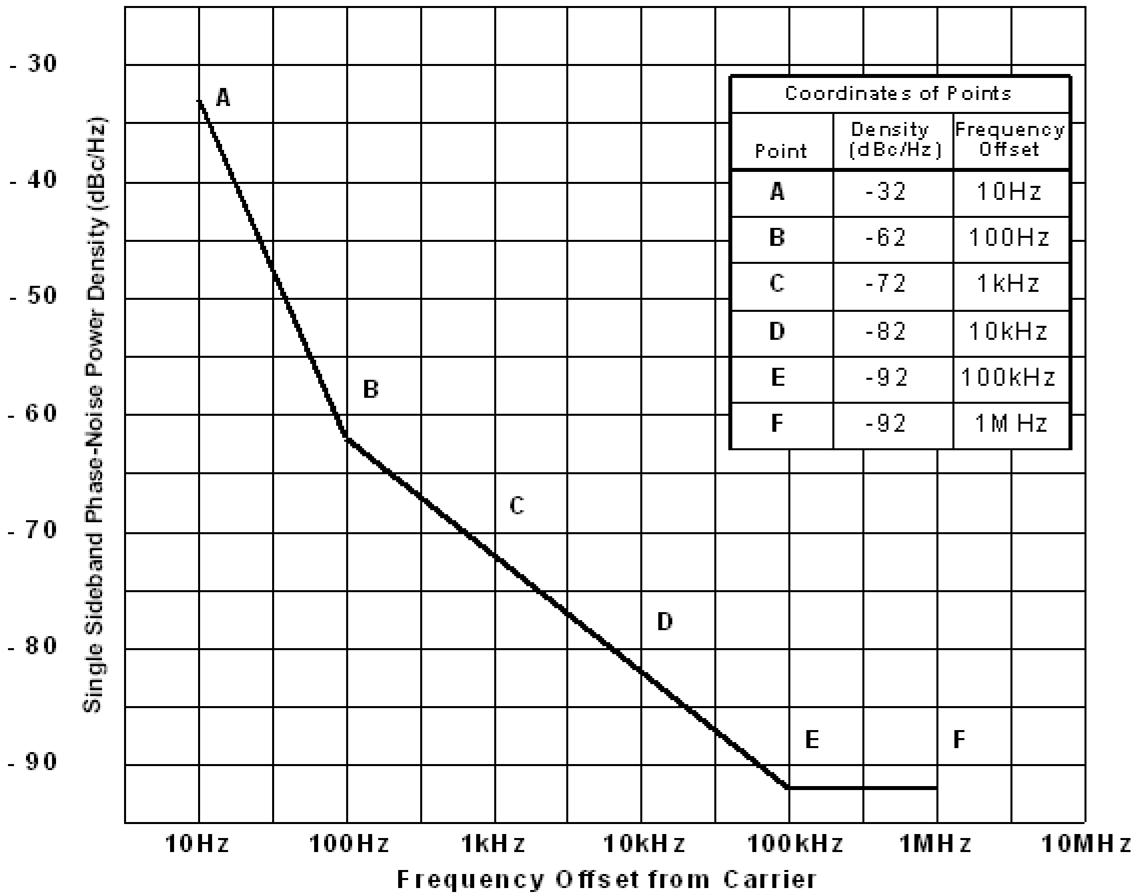

Figure 5: ET Spectral Purity

1.10.3.1.2.8.2 Transmit Noise EIRP

The maximum transmit noise EIRP spectral density shall be less than 5 dBm/Hz at the maximum linear power.

1.10.3.1.2.9 Transmission Function Extraneous Outputs

When the ET is operating at single-carrier saturated EIRP, the EIRP of extraneous emissions as measured over any 4-kHz bandwidth shall be no greater than +4 dBW, or -60 dBc, whichever is larger. This requirement excludes the 2-MHz band centered on the carrier.

1.10.3.1.2.10 Harmonic Emissions

The level of the second and third harmonics of the transmit carriers shall not exceed -60 dBc.

1.10.3.1.2.11 Intermodulation Products

The intermodulation products resulting from two equal carriers simultaneously passing through the transmission function injected at the IF interface shall not exceed the values in *Table 3: Maximum Allowable Intermodulation Product Levels*, when measured relative to the total output power level of the two carriers. The maximum allowable intermodulation product power includes the contribution of passive intermodulation products generated by the antenna and reflector structures.

Table 3: Maximum Allowable Intermodulation Product Levels

OUTPUT COMPOSITE POWER LEVEL (dB)	MAXIMUM INTERMODULATION PRODUCTS (dB)
Saturated Power -1.5	-14
Saturated Power -4.5	-19
Saturated Power -7.5	-25

1.10.3.1.2.12 Transmit-to-Receive Isolation

Transmit-to-receive isolation shall be such that there is less than 0.1 dB degradation in specified receive noise density with the transmitter operating at any EIRP level, compared to the receive performance with the transmitter turned off.

1.10.3.1.2.13 Intermodulation Products in the Receive Band

For X-band operation, intermodulation products appearing at the low-noise amplifier (LNA) input in the receive band, due to two equal power transmit carriers, shall be no greater than -135 dBm. The requirements of this paragraph shall be met with each transmit carrier at any frequency in the transmit band and with each transmit carrier having an EIRP of 3 dB less than the maximum linear power. This requirement applies to those ETs requiring multicarrier transmissions.

1.10.3.1.2.14 Transmit Spectrum Inversion

No inversion of spectrum shall exist between any IF input and the antenna output for ETs operating with a non-embedded modem(s). Terminals with embedded modems shall be interoperable with terminals that do not have embedded modems.

1.10.3.1.2.15 Transmit Phase Perturbation

The rate of change of the phase imposed on the output signal shall not exceed 20 degrees per 0.2-second interval, in response to the vibration, physical, and thermal shock to be encountered by the terminal during operation.

1.10.3.1.2.16 Amplitude Modulation (AM) to Phase Modulation (PM) Conversion

The AM to PM conversion shall be no more than 8 degrees/dB for the transmission function operating from maximum linear power up to saturated power. The AM to PM conversion shall be no more than 4 degrees/dB for the transmission functioning at any power level up to maximum linear power.

1.10.3.1.3 RF Transmission Radiation Wave Functions (Antenna)

1.10.3.1.3.1 Antenna Sidelobe Levels

1.10.3.1.3.1.1 X-band Earth Terminals

The antenna sidelobe requirements are described in a and b, below:

a. $D/\lambda \geq 50$ - Consistent with the guidance in ITU-R S.580-6, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed

$G(\theta) = 29\text{-}25 \log_{10}(\theta)$ dBi for 1° or 100 λ/D (whichever is larger) $\leq \theta \leq 20°$
$G(\theta) = -3.5$ dBi for $20° < \theta \leq 26.3°$
$G(\theta) = 32\text{-}25 \log_{10}(\theta)$ dBi for $26.3° < \theta \leq 48°$
$G(\theta) = -10$ dBi for $48° < \theta \leq 180°$

where:
G = gain relative to an isotropic antenna
θ = off-axis angle in the direction of the satellite referred to the main-lobe axis
D = antenna diameter
λ = wavelength (same units as D)

b. D/□ < 50 – Consistent with the guidance in ITU-R S.465-5, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$G(\theta) = 32\text{-}25 \log_{10}(\theta)$ dBi, for 100 $\lambda/D \leq \theta \leq 48°$
$G(\theta) = -10$ dBi, for $48° < \theta \leq 180°$

where symbols are defined in 3.1.3.1.3.1.1.a.

1.10.3.1.3.2 Antenna Polarization, Transmitting

The X-band Earth Terminal antenna shall be capable of transmitting right-hand (clockwise) circular polarization (RHCP). Terminals may also support the capability for transmitting left-hand (counter-clockwise) circular polarization (LHCP). The configuration options for LHCP may include the ability to switch between LHCP and RHCP as well as the ability to operate simultaneously in both polarizations.

1.10.3.1.3.3 Antenna Axial Ratio

The axial ratio applies to all directions within the cone defined by the antenna tracking, pointing errors, or both. The axial ratio for X-band circularly polarized beams shall be no greater than 2.0-dB over the transmit band. It is noted that satellites which support dual-polarization will require more stringent performance in terms of cross-polarization isolation. For terminals operating over dual-polarization satellites, the recommended target for cross-polarization discrimination is 24.80 dB. This equates to an axial ratio of 1.0 dB.

1.10.3.2 Reception Function

The ET reception function shall conform to 3.1.3.2.1 through 3.1.3.2.3.11 when the maximum power-flux density at X-band is: -140.0 dBW/meter^2 in any 4-kHz band.

1.10.3.2.1 RF Reception Radiation Wave Function (Antenna)

1.10.3.2.1.1 Antenna Polarization.

The antennas for all X-band terminal types shall be capable of receiving left-hand (counter-clockwise) circular polarization (LHCP). Terminals may also support the capability for receiving right-hand (clockwise) circular polarization (RHCP). The configuration options for RHCP may include the ability to switch between LHCP and RHCP as well as the ability to operate simultaneously in both polarizations.

1.10.3.2.1.2 Antenna Axial Ratio

The axial ratio applies to all directions within the cone defined by the antenna tracking, pointing errors, or both. The axial ratio for X-band circularly polarized beams shall be no greater than 2.0-dB over the receive band. It is noted that satellites which support dual-polarization will require more stringent performance in terms of cross-polarization isolation. For terminals operating over dual-polarization satellites, the recommended target for cross-polarization discrimination is 24.80 dB. This equates to an axial ratio of 1.0 dB.

1.10.3.2.1.3 Pointing Loss

Antenna pointing loss shall not exceed 0.8 dB for systems employing tracking and 1.0 dB for systems without tracking. For maximum operational wind velocities, the pointing loss shall not exceed 2.0 dB for both tracking and non-tracking systems.

1.10.3.2.2 RF Requirements

1.10.3.2.2.1 RF Frequency Band

The X-band down-conversion function shall be tunable from 7.25 to 7.75 GHz.

1.10.3.2.3 IF Requirements

The IF output shall comply with 3.1.3.2.3.1 through 3.1.3.2.3.11.

1.10.3.2.3.1 Output Frequency

Current ET technology is migrating toward the use of L-band intermediate frequencies, enabling wider bandwidths and the use of block frequency converters. A variety of L-band IF definitions exist. The overall range of 950-2050 MHz encompasses the existing L-band frequencies.

Any terminal implementing an L-band interface shall provide for at least 500 MHz of instantaneous bandwidth situated in the 950-2050 MHz range, with the exact frequency span as required for compatibility with the selected modem.

Terminals may choose to implement an IF output interface centered at the following frequencies (□represents the nominal 1-dB bandwidth):

a. 70 MHz □□18 MHz
b. 140 MHz □□36 MHz

Terminals shall implement one or more of the above IF output interfaces, in any combination.

1.10.3.2.3.2 Receive Chain Gain and IF Interface Characteristics

The receive chain (antenna interface to terminal IF interface) shall exhibit the following characteristics:

a. The post-LNA contribution to system noise temperature shall not exceed 0.2 dB.
b. The receive chain absolute gain shall be sufficient to raise the IF interface noise power spectral density, when pointing to a cold sky away from a geosynchronous satellite at an angle of 30-degrees, to at least -95-dBm/Hz.
c. The RF-to-IF gain adjustment shall be at least 20 dB in steps of 1 dB or less.
d. The output impedance at the terminal IF interface shall be 50 ohms, with a VSWR less than 1.5:1 over the specified bandwidth.

1.10.3.2.3.3 Tuning

The downconversion function shall be tunable in 1.0 kHz increments, in conjunction with the modem starting at the lowest frequency for the RF band defined in 3.1.3.2.2.1. The nominal 1-dB bandwidth shall be available at any tuned downlink frequency, as long as the 1-dB bandwidth does not extend beyond the band edges defined in 3.1.3.2.2.1. The full IF bandwidth shall be available at any IF setting in 3.1.3.2.3.1.

1.10.3.2.3.4 Bandwidth

The nominal 1-dB bandwidth of the downconversion function shall be a minimum of 36 MHz at the 70-MHz input, a minimum of 72 MHz at the 140-MHz input, and a minimum of 120 MHz for an L-band input.

1.10.3.2.3.5 Conversion Frequency Accuracy

The downconversion process shall not induce a frequency error greater than 1.0 kHz relative to the intended value of the received carrier frequency. Periodic re-calibration to achieve this accuracy is acceptable at intervals to be determined by the procurement documents.

1.10.3.2.3.6 Receive Phase Linearity

The RF-to-IF phase response of the reception function shall not deviate from linear by more than the following amounts:

a. ±0.4 radians over any 36 MHz for 70-MHz IF operation.
b. ±0.5 radians over any 72 MHz for 140-MHz IF operation.
c. ±0.7 radians over any 120-MHz for any L-band IF
d. ±0.2 radians over the center 10 MHz for any IF operation.
e. ±0.2 radians over any 1 MHz for ETs intended to operate with embedded modems only.

1.10.3.2.3.7 Receive Amplitude Response

The RF-to-IF amplitude variation of the reception function shall not exceed the following amounts:

a. ±2 dB for the input frequency band defined in 3.1.3.2.2.1.
b. ±1.5 dB over any 36 MHz for 70-MHz IF operation.
c. ±1.5 dB over any 72 MHz for 140-MHz IF operation.
d. ±1.5 dB over any 120 MHz for L-band IF operation.

e. ±1 dB over the center 10 MHz for any IF operation.

1.10.3.2.3.8 Receive Spectral Purity

The spectral purity of any translated carrier shall be as defined in 3.1.3.1.2.9.

1.10.3.2.3.9 Receive Spurious Output

The sum total of spurious signal power including phase noise measured at the IF output shall be at least 20 dB below the thermal noise power measured in the bandwidth specified in 3.1.3.2.3.4, with a maximum signal into the LNA. No one spurious signal shall be greater than an equivalent signal 10 dB below the noise level in the narrowest bandwidth of interest. The requirements of this paragraph shall be met under the following simultaneous conditions: (1) transmitting multiple carriers at the maximum linear power, and (2) receiving two carriers at the maximum input signal level to the LNA.

1.10.3.2.3.10 Receive Spectrum Inversions

No inversion of spectrum shall exist between any RF input and the down-conversion function output for terminals operating with a non-embedded modem(s). Terminals with embedded modems shall be interoperable with terminals that do not have embedded modems.

1.10.3.2.3.11 Receive Signal Level Stability

For any setting of the receive gain, and for a constant RF flux density level, the receive function output level shall not vary more than ±2.0 dB in any 24-hour period. This tolerance includes all ET factors contributing to the gain variations, including the antenna beam pointing and tracking errors referenced to boresight added on a root-sum-squared basis. This does not include adverse weather conditions or any other affects not controlled by the ET.

1.10.3.2.3.12 Receive Phase Perturbation

The rate of change of phase imposed on the output signal shall not exceed 20 degrees within a 0.2-second interval, in response to vibration, physical and thermal shock to be encountered by the terminal during operation.

1.10.3.3 Control Function

The ET shall meet the requirements of 3.1.3.3.1 and 3.1.3.3.2.

1.10.3.3.1 RF Control and Monitoring Parameters

With the exception of disadvantaged terminals (manpack and COTM/COTH) Earth terminal RF functions shown in *Table 4: ET Control and Monitoring Parameter* shall be controlled and monitored. In addition to these RF control parameters, additional control capabilities are described in Section 3.3, which discusses broader NNEC related management of SATCOM transport through the Advanced SATCOM Network Management and Control (ASNMC) system.

The transmit gain, as computed, shall be within ±2 dB of actual gain, neglecting any frequency dependencies in accordance with 3.1.3.2.3.6. Transmit gain is computed by adding (1) the upconversion function gain, (2) the gain/loss from the upconversion function output to the power amplifier input, and (3) the power amplifier gain.

The receive gain, as computed, shall be within ±5 dB of actual gain. Receive gain is computed by adding (1) the gain from the LNA input to the downconversion function input and (2) the down conversion function gain.

Table 4: ET Control and Monitoring Parameters

CONTROL	MONITORING
Transmit gain of each upconversion function Frequency setting of each upconversion function Frequency setting of each downconversion function	Transmit gain setting of each upconversion function Frequency setting of each upconversion function Frequency setting of each downconversion function
	Receive gain setting of each downconversion function Transmit gain setting of the power amplifier Total transmit power level at the power amplifier output Equipment fault status Receive gain setting from LNA input to each downconversion function output Transmit gain/loss setting from the output of each Upconversion function to the input of the HPA

1.10.3.3.2 Terminal Control and Monitoring Interface

Control and monitoring parameters should be exercised via a remote control interface. The ET remote control and monitoring interface should be in accordance with either RS-485 or IEEE 802.3 (Ethernet).

1.10.3.4 Frequency References

The external and internal frequency reference requirements are listed in 3.1.3.4.1 and 3.1.3.4.2, respectively.

1.10.3.4.1 External Frequency Reference

All terminal classes should accept an external 5-MHz frequency reference conforming to STANAG 4430. A 10-MHz reference may also be supported

1.10.3.4.2 Internal Frequency Reference

All terminal classes should provide an output port of the internal frequency source of each upconversion and downconversion function.

1.11 BASEBAND CHARACTERISTICS

This section specifies the open systems external baseband interface standards that are required to ensure satisfactory operation of a SHF satellite ground terminal to support services defined in STANAG 4484. Adherence to this standard will allow a variety of national satellite ground terminal configurations to be easily connected to external terrestrial facilities, including both military and commercial networks.

As NATO communications evolve toward the NNEC, SATCOM networks will naturally migrate towards the support for IP packet transport. In this evolution, baseband interfaces will trend towards open standards such as Ethernet, with increasing levels of packet processing taking place within the boundaries of the SHF terminal. This section will also address these trends and the interoperability requirements on baseband processing within the terminal. A detailed architecture for network-centric SATCOM is being developed in the SGRA. As concepts for interoperability between satellite and ground networks evolve, this STANAG will be updated to reflect new requirements.

1.11.1 Synchronous Serial Interfaces

The following table documents the standard electrical and mechanical interfaces that have historically been required for implementation in SHF Terminals. These standards define the synchronous, serial interface between the SATCOM terminal and the terrestrial infrastructure. Static multiplexers are commonly used to aggregate multiple terrestrial services into a single circuit for transport over the satellite. Multiplexer interoperability is not addressed in this STANAG. Synchronous serial interfaces on ET’s shall be implemented in accordance with one or more of these standards.

Table 5: Recommended External Serial Interfaces

ELECTRICAL I/F	FUNCTIONAL I/F	DATA RATE
ITU-T V.10	ITU-T V.24	up to 100 kbit/s
ITU-T V.11	ITU-T V.24	Up to 10 Mbit/s
ITU-T V.12		Up to 52 Mbit/s
ITU-T G.703 unbal. (75 ohms coax.)		2048, n x 64 kbit/s (n = 2 to 31)
STANAG 4206/4210 (cable)		256 or 512 kbit/s
STANAG 4206/4212 (radio relay)		256 or 512 kbit/s
STANAG 4206/4290 (cable-optical)		256 or 512 kbit/s

1.11.2 Internet Protocol (IP) Packet Interfaces

SHF satellite communications have been supporting IP routed traffic for many years over fixed trunk FDMA circuits between IP routers. The evolution toward NNEC creates a new class of baseband interface for IP packet transport. The difference between network-centric IP transport and IP over FDMA is the extent to which the terminal takes an active role in packet processing/forwarding functionality.

1.11.2.1 Baseband Interface

Terminals that support non-synchronous packet transport shall provide an interface to the terrestrial infrastructure that complies with the IEEE 802.3. Packet processing functionality within the terminal shall be capable of processing IPv4 (IETF RFC-791) formatted packets. Dual-stack processing to support IPv6 (IETF RFC-2460) formatted packets is currently projected to be a requirement by 2014.

1.11.2.2 Quality of Service

In forwarding IP packets, quality of service is a key function that enables priority traffic to be supported during periods of congestion or communications degradation. Terminals that support packet transport services shall provide for priority forwarding through the use of Differentiated Services (DiffServ) code points (DSCP). The explicit definition of DSCP’s and the associated per hop behaviors will be in accordance with the policies established by the terrestrial network being supported.

1.11.2.3 Packet Routing

IP routers are commonly used to aggregate multiple IP flows into a single stream for transport over the satellite. In this context, these routers are referred to as SATCOM Convergence Routers, as defined in the SGRA. Standards for convergence routers are well established in the commercial marketplace and interoperability guidance is provided in STANAG 5067.

1.11.2.4 Performance Enhancing Proxy (PEP)

The transport control protocol (TCP) developed for the internet is not well suited to the unique environment of communications through geosynchronous earth orbiting satellites. TCP link accelerators are recommended over satellite links. Standards-based products shall be used, which comply with SCPS-TP: ISO DIS 15893 and CCSDS 714.0-B-1, in accordance with the guidance in STANAG 5067.

1.11.3 Crypto/IP Crypto

The use of convergence routers to aggregate IP packet flows for transport over the satellite requires the use of in-line network encryption (INE) devices to provide logical isolation between IP traffic at differing security levels. It must be noted that packet processing functions which are unique to the satellite terminal, e.g. QoS, PEP, can be negatively impacted by the use of in-line network encryption. PEP devices can only function when arriving packets are unencrypted. QoS relies on specific fields in the packet header for prioritization and queuing. In cases where the satellite modem is actively involved in queuing and forwarding packets, INE used to encrypt packets sent to the terminal must be configured to pass the necessary QOS fields over to the ciphertext side, unencrypted.

1.12 MANAGEMENT AND CONTROL

The efficient utilization of SHF SATCOM resources requires interoperability of the terminals and modems with the Advanced SATCOM Network Management and Control (ASNMC) system. The fully integrated Network Management and Control System shall allow NCSA to administer the mission planning, network monitoring, control, and management oversight functions for all network assets from a single centralized location. The ASNMC system shall support automation and integration of these functions in order to minimize manpower requirements while maximizing SATCOM network availability. Information from each element of the distributed subsystems controlled by the Network Management and Control System shall be made readily available from a Relational Database Management System (RDBMS).

The ASNMC provides for the following capabilities:

- Centralized power management for all TSGTs,
- Spectrum Monitoring in some terminals (including a Platform of Reference)
- Centralized Terminal Administration at the SACC/SBCC

A brief summary of these capabilities is provided here for information purposes. Additional detail will be available in the appropriate control STANAG.

1.12.1 Centralized Power Management

Centralized power management is required to ensure that the space segment resources are utilized most efficiently. The link control is exercised from the SACC/SBCC. The link power control may also be manual, in which case the transmit power will be identified in the SGS budget. Each terminal shall provide the following minimum configuration capabilities to enable power management.

- Control source (Local to TSGT/Central manual/Central automated)

- Beacon (used/ignored)
- Distant Eb/No (used/ignored)
- Automatic gain distribution between individual link adjustments and total power adjustment (activated/deactivated)
- Composite HPA Power independent control (activated/deactivated)
- Key damping factors
- Transponder Saturation Control mode

1.12.2 Spectrum Monitoring

Spectrum Monitoring provides a visual and numerical representation of the SATCOM carriers operating on NATO transponders. That visual/numerical representation ensures (through human inspection/automated characterization) that all authorized links are within prescribed parameters. Authorized links are defined as those that are authorized per NCSA. This representation can also be used to identify Unauthorized Accesses (UA). When the SACC/SBCC is not within the footprint of a transponder, a remote spectrum monitoring capability is employed which allows data to be received from a deployed network controller terminal and exploited at the SACC/SBCC.

1.12.3 Centralized Terminal Management

The administration of SHF terrestrial terminals is accomplished through a Network Management System (NMS) using Simple Network Management Protocol (SNMP) or Open Data Base Connector (ODBC) capability, integrating system support, operating & control and service delivery activities through the approved processes. The concept is that all managed objects contain an SNMP agent for communicating with the management system. All components of the NATO SATCOM Control should be supported by attributes. All attributes are read by a NMS in order to get an overview of the related system. In certain cases, some attributes may be written by the NMS. The attributes supported by the NATO SATCOM Control are collected in the NATO SATCOM Control Management Information Base (MIB). This NMS, using SNMP or Open Data Base Connector capability, reports to an overarching Super-Controller server provided by NATO, essentially for event/alarm concentration/correlation, post-processing and archiving by the NATO provided server.

Typical objects within a terminal are:

- For each modem: all parameters managed by that modem (baseband data rate, buffer congestion status, modulation/demodulation characteristics, Bit Error Rate…)
- For each Radio Frequency, IPA, Up/Down converter, amplifier sub-systems, switching matrixes, power supply system: all parameters managed by each subsystem.
- The antenna controller parameters (azimuth, elevation, time of last adjustment)
- More generally any controlled equipments/sub-system (outdoor and indoor equipments of the SATCOM terminal)

At SACC/SBCC, the centralized level has all tools to enable monitoring, extraction of statistics, configuration or troubleshooting of equipment of all SHF SATCOM terminals. However, in some circumstances, local intervention is possible and reliable communication means must be made available between the centralized level and the remote terminal. SACC / SBCC is the focal point for compiling statistics regarding the terminal and link outages/availability, summary of faults and alarms, and eventually correlating the SATCOM link information with satellite telemetry reports and any other network related information available.

At each TSGT, the ASNMC Local Control Agent (LCA) interfaces with the TSGT local control, through which the ASNMC can access information on the following equipment:

- Modems (to the exception of EPM modems)
- Converters
- HPA, LNBs
- Beacon
- Antenna Control Unit
- All TSGT baseband equipment (management router, IP Crypto/concentrator, black router)
- Air conditioner, UPS, Power Distribution, Diesel Generator,
- Equipment, Frequency Reference System, Spectrum Analyzer

ANNEXES

1.13 ACRONYM LIST

AC	Alternating Current
AM	Amplitude Modulation
ANSI	American National Standards Institute
ASNMC	Advanced SATCOM Network Management and Control
bps	Bits Per Second
CMA	Control, Monitor, and Alarm
CW	Continuous Wave
C3I	Command, Control, Communications, and Intelligence
dB	Decibel
dBc	Ratio of a non-carrier power component to the total power in a carrier (in dB)
dBi	Gain in dB relative to an isotropic antenna
dBm	dB relative to 1-milliwatt
dBW	dB relative to 1-watt
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoDISS	DoD Index of Specifications and Standards
DSCS	Defense Satellite Communications System
EIA	Electronic Industries Association
EIRP	Effective Isotropic Radiated Power
ESD	EIRP Spectral Density
ET	Earth Terminal
FED-STD	Federal Standard
Gant	Antenna gain
GHz	Gigahertz
G/T	Antenna gain-to-noise temperature
HPA	High-Power Amplifier
Hz	Hertz
IESS	INTELSAT Earth Station Standard
IF	Intermediate Frequency
INTELSAT	International Telecommunications Satellite Organization
ISO	International Organization for Standardization
ITU-R	International Telecommunications Union Radio-communication Sector
K	Kelvin degrees
kHz	Kilohertz
LNA	Low-Noise Amplifier
m^2	Square Meters
Mbps	Megabits Per Second
MHz	Megahertz
MIL-STD	Military Standard

NATO	North Atlantic Treaty Organization
NCSA	NATO Communications and Information Systems Services Agency
N/A	Not Applicable
PM	Phase Modulation
Psat	Saturated power
Plinear	Maximum-linear power
RF	Radio Frequency
RMS	Root-Mean-Square
RSS	Root-Sum-Square
Rs	Symbol rate
Rx	Receive
SATCOM	Satellite Communications
SCPS-TP	Space Communications Protocol Specification - Transport Protocol
SHF	Super High Frequency
SNMP	Simple Network Management Protocol
SOW	Statement of Work
STANAG	Standardization Agreement (NATO)
Tx	Transmit
USAT	Ultra Small Aperture Antenna
VSWR	Voltage Standing Wave Ratio

1.14 DEFINITIONS

Definitions of terms.

Closed Network - A system in which the entire transponder is dedicated for the use of a single user. The performance characteristics for a closed network do not require specifications related to interconnection with other users and can be defined in terms of RF characteristics. The requirements for this system are those that ensure one user's emissions will not interfere with those of others.

Earth Terminal (ET) - The portion of a satellite system that receives and transmits RF signals between the earth and a satellite.

Effective Isotropic Radiated Power (EIRP) - The product of the power supplied to an antenna and its gain relative to a hypothetical antenna that radiates or receives equally in all directions.

Extraneous Emissions - Emissions that result from spurious tones, bands of noise, or other undesirable signals, but that exclude harmonics and multicarrier intermodulation products.

Heavy, Large Fixed ET - A typical ET in this class can be of unlimited weight and size, whose electronic functions, exclusive of the antenna, are usually housed in a building. The antenna may be installed either inside or outside a protective radome. Site preparation may be required. Set-up time is not limited.

Medium, Fixed ET - A typical ET in this class weighs less than 27,216 kilograms (60,000 pounds) and has a volume less than 142 cubic meters (5,000 cubic feet). The electronics may be housed within a building or in vans. A moderate amount of site preparation may be required. Set-up time is not limited.

Small, Fixed, Covert Operations ET. - A typical ET in this class weighs less than 11,340 kilograms (25,000 pounds) and has a volume less than 57 cubic meters (2,000 cubic feet). A moderate amount of site preparation may be required. Set-up time is less than 6-hours. This ET is rarely moved. It is not used while in motion.

Large Transportable ET - A typical ET in this class weighs less than 4,536 kilograms (10,000 pounds) and has a volume less than 37 cubic meters (1,300 cubic feet). A small amount of site preparation may be required. Set-up time is less than 1-hour. This ET is not intended to be used while in motion.

Small Transportable ET - A typical ET in this class weighs less than 2,268 kilograms (5,000 pounds) and has a volume less than 21 cubic meters (750 cubic feet). A small amount of site preparation may be required. Set-up time is less than 30-minutes. This ET is not intended to be used while in motion.

Mobile ET - A typical ET in this class can be used while in motion and during halts at unspecified points. This includes operation in aircraft, ships, and vehicles.

Saturated Power - The single-carrier output power level of an active device (typically a high-power amplifier (HPA)) where the input power change-to-output power change ratio is 10:1.

Linear Power - Measured with active devices online corresponding to terminal availability specifications. Defined as the lesser value of a or b below.

a. Single carrier maximum-linear power. The single carrier maximum-linear power equals the carrier power when the power spectral density in the modulated carrier sidelobes, 1.5 times symbol rate removed from the carrier center frequency, is -30-decibel (dB) relative to the power spectral density at the carrier center frequency.
b. Two carrier maximum-linear power. The maximum combined transmit power of two equal amplitude continuous wave (CW) carriers, when the third order intermodulation product power is –25 dB relative to the combined power of the two CW carriers.

Satellite System - A communications system that includes two or more ETs, a communications satellite or a space platform, and a control system.

1.15 COMMERCIAL TERMINAL CHARACTERISTICS

In addition to the requirements in Section 3.1.3, the following band specific requirements apply to terminals operating at C, Ku, and Ka frequencies.

1.15.1 Transmission Function

1.15.1.1 RF Frequency Bands

The transmission function shall be tunable in one or more of the SHF frequency bands listed in *Table 6: Transmit Uplink Frequency Bands*

Table 6: Transmit Uplink Frequency Bands

SHF FREQUENCY BAND	FREQUENCY (GHz)
C-band	5.850 to 6.650
Ku-band	13.750 to 14.500
Commercial Ka-band	27.500 to 30.000
Military Ka-band	30.000 to 31.000

1.15.1.2 RF Transmission Radiation Wave Function (Antenna)

1.15.1.2.1 Antenna Sidelobe Levels

1.15.1.2.1.1 C- and Ku-band Earth Terminals

The antenna sidelobe requirements are described below in a, b, and c.

a. $D/\lambda \geq 50$ - Consistent with the guidance in ITU-R S.580-6, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$G(\theta) = 29-25 \log_{10}(\theta)$ dBi for $1°$ or $100 \lambda/D$ (whichever is larger) $\leq \theta \leq 20°$

$G(\theta) = -3.5$ dBi for $20° < \theta \leq 26.3°$

$G(\theta) = 32-25 \log_{10}(\theta)$ dBi for $26.3° < \theta \leq 48°$

$G(\theta) = -10$ dBi for $48° < \theta \leq 180°$

where:

G = gain relative to an isotropic antenna

θ = off-axis angle in the direction of the satellite referred to the main-lobe axis

D = antenna diameter

λ = wavelength (same units as D)

b. D/λ < 50 – Consistent with the guidance in ITU-T S.465-5, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$G(\theta) = 32 - 25 \log_{10}(\theta)$ dBi, for $100\ \lambda/D \le \theta \le 48°$
$G(\theta) = -10$ dBi, for $48° < \theta \le 180°$

where symbols are defined in 4.5.1.1.2.1.a

1.15.1.2.1.2 Ka-band Earth Terminals

The antenna sidelobe requirements are described in a and b, below:

a. D/λ ≥ 50 - Consistent with the guidance in ITU-R S.580-6, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$G(\theta) = 29 - 25 \log_{10}(\theta)$ dBi, for 1° or $100\ \lambda/D$ (whichever is larger) $\le \theta \le 20°$
$G(\theta) = -3.5$ dBi, for $20° < \theta \le 26.3°$
$G(\theta) = 32 - 25 \log_{10}(\theta)$ dBi, for $26.3° < \theta \le 48°$
$G(\theta) = -10$ dBi for $48° < \theta \le 180°$

where:
G = gain relative to an isotropic antenna
θ = off-axis angle in the direction of the satellite referred to the main-lobe axis
D = antenna diameter
λ = wavelength (same units as D)

b. D/λ < 50 - Consistent with the guidance in ITU-T S.465-5, the gain of the antenna shall be such that at least 90 percent of the sidelobe peaks do not exceed:

$G(\theta) = 32 - 25 \log_{10}(\theta)$ dBi, for $100\ \lambda/D \le \theta \le 48°$
$G(\theta) = -10$ dBi, for $48° < \theta \le 180°$

where symbols are defined in a, above.

1.15.1.2.2 Antenna Polarization, Transmitting

Antenna polarization shall conform to one or more of the following subparagraphs, as applicable:

1.15.1.2.2.1 C-band Earth Terminal

The antenna shall be able to transmit linear (horizontal and vertical) and circular (right-hand and left-hand) polarization, but not simultaneously. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

1.15.1.2.2.2 Military Ka-band Earth Terminals

The antennas for all military Ka-band terminal types shall be capable of transmitting right-hand (clockwise) circular polarization (RHCP). Terminals may also support the capability for transmitting left-hand (counter-clockwise) circular polarization (LHCP). The configuration options for LHCP may include the ability to switch between RHCP and LHCP as well as the ability to operate simultaneously in both polarizations.

1.15.1.2.2.3 Commercial Ka-band Earth Terminal

The antenna shall be able to transmit linear (horizontal and vertical) and circular (right-hand and left-hand) polarization; the antenna is not be required to transmit both polarizations at the same time. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

1.15.1.2.2.4 Ku-band Earth Terminal

The antenna shall be able to transmit both horizontal and vertical linear polarization senses. However, simultaneous operation in both senses of polarization should not normally be required. The ET feed(s) shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

1.15.1.2.3 Antenna Axial Ratio

The requirements for axial ratio of transmit ET antennas are described below. The axial ratio applies to all directions within the cone defined by the antenna tracking, pointing errors, or both.

1.15.1.2.3.1 Circular polarization Military Ka-band

The transmit axial ratio for all terminals operating in the Military Ka-band shall be no greater than 1.0 dB.

1.15.1.2.3.2 Circular Polarization, C-band

The axial ratio for C-band circularly polarized beams shall be as described below:

a. Antennas with diameter larger than 2.5 meters.

   The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.09 (27.3 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

b. Antennas with diameter 2.5 meters or smaller.

   The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.3 (17.7 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

1.15.1.2.3.3 Linear Polarization, C-band

The axial ratio of transmission for linearly polarized beams shall be over the transmit bands described below:

a. Antennas with diameter larger than 4.5 meters.

The voltage axial ratio of transmission in the direction of the satellite shall exceed 31.6 (30.0 dB polarization discrimination) within a cone defined by the antenna tracking/and or pointing errors.

b. Antennas with diameter 4.5 meters or smaller.
The voltage axial ratio of transmission in the direction of the satellite shall exceed 22.4 (27.0 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors.

1.15.1.2.3.4 Linear Polarization, Ku-Band

The axial ratio of transmission for linearly polarized beams shall be as described below:

a. Antenna with diameter larger than 2.5 meters.
The voltage axial ratio of transmission in the direction of the satellite shall exceed 31.6 (30.0 dB polarization discrimination) everywhere within a cone centered on the main beam axis. The antenna tracking and/or pointing errors defines the cone angle.

b. Antenna with diameter 2.5 meters or smaller.
The voltage axial ratio of transmission in the direction of the satellite shall exceed 20.0 (26.0 dB polarization isolation) everywhere within a cone defined by the antenna tracking and/or pointing errors.

1.15.2 Reception Function

The ET reception function shall conform to 3.1.3.2.2 through 3.1.3.2.3.11 when the maximum power-flux density is as follows:

a. C-band:
-152.0 dBW/meter^2 in any 4-kHz band where $0° \le \theta \le 5°$;
-149.5 dBW/meter^2 in any 4-kHz band where $5° < \theta \le 25°$;
-142.0 dBW/meter^2 in any 4-kHz band where $25° < \theta \le 90°$.

b. Ku-band:
-150.0 dBW/meter^2 in any 4-kHz band where $0° \le \theta \le 5°$;
-147.5 dBW/meter^2 in any 4-kHz band where $5° < \theta \le 25°$;
-140.0 dBW/meter^2 in any 4-kHz band where $25° < \theta \le 90°$.

c. Ka-band:
-115 dBW/meter^2 in any 1-MHz band.

1.15.2.1 RF Reception Radiation Wave Function (Antenna)

1.15.2.1.1 Antenna Polarization

Antenna polarization shall conform to one or more of the following subparagraphs, as applicable.

1.15.2.1.1.1 C-band Earth Terminal

The antenna shall be able to receive linear (horizontal and vertical) and circular (right-hand and left-hand) polarization, but not simultaneously. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1 degree (clear sky).

1.15.2.1.1.2 Military Ka-band Earth Terminal

The antennas for all military Ka-band terminal types shall be capable of receiving left-hand (counter-clockwise) circular polarization (LHCP). Terminals may also support the capability for receiving right-hand (clockwise) circular polarization (RHCP). The configuration options for RHCP may include the ability to switch between LHCP and RHCP as well as the ability to operate simultaneously in both polarizations.

1.15.2.1.1.3 Commercial Ka-band Earth Terminal

The antenna shall be able to receive linear (horizontal and vertical) and circular (right-hand and left-hand) polarization; the antenna is not be required to receive both polarizations at the same time. The ET linear feed shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

1.15.2.1.1.4 Ku-band Earth Terminal

Fixed Site terminals shall be able to receive linear (horizontal and vertical) polarization simultaneously. The ET shall be adjustable to match the satellite polarization angle to within 1-degree (clear sky).

1.15.2.1.2 Antenna Axial Ratio

Receive ET antennas shall comply with the axial ratio requirements in section 4.3.1.2.3

1.15.2.2 RF Requirements

1.15.2.2.1 RF Frequency Bands

The downconversion function shall be tunable in one or more of the SHF frequency bands listed in *Table 7: Receive Downlink Frequency Bands*.

Table 7: Receive Downlink Frequency Bands

SHF FREQUENCY BAND	FREQUENCY (GHz)
C-band	3.400 to 4.200
Ku-band	10.950 to 12.750
Commercial Ka-band	17.700 to 20.200
Military Ka-band	20.200 to 21.200