STANAG N° 4481
(Edition 1)

NORTH ATLANTIC TREATY ORGANISATION
(NATO)

NATO STANDARDIZATION AGENCY
(NSA)

STANDARDISATION AGREEMENT
(STANAG)

SUBJECT: **Minimum Technical Equipment Standards for Naval HF Shore-to-Ship Broadcast Systems**

Promulgated on

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Rear Admiral, NONA
Director, NSA

STANAG N° 4481
(Edition 1)

RECORD OF AMENDMENTS

No.	Reference/date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardisation Agreement (STANAG) is promulgated by the Director, NSA under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation 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.

DEFINITIONS

4. **Ratification** is "In NATO Standardisation, the fulfilment by which a member nation formally accepts, with or without reservation, the content of a Standardisation Agreement" (AAP-6).

5. **Implementation** is "In NATO Standardisation, the fulfilment by a member nation of its obligations as specified in a Standardisation Agreement" (AAP-6).

6. **Reservation** is "In NATO Standardisation, the stated qualification by a member nation that describes the part of a Standardisation Agreement that it will not implement or will implement only with limitations" (AAP-6).

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page iii gives the details of ratification and implementation of this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions. Page iv (and subsequent) gives details of reservations and proprietary rights that have been stated.

FEEDBACK

8. Any comments concerning this publication should be directed to NATO Standardization Agency (NSA) - NATO HQ – boulevard LEOPOLD III - 1110 Brussels - BELGIUM

NATO STANDARDIZATION AGREEMENT

MINIMUM TECHNICAL EQUIPMENT STANDARDS FOR NAVAL HF SHORE-TO-SHIP BROADCAST SYSTEMS

ANNEXES:

A. Terms and Definitions
B. Technical Standards for HF Broadcast Transmitters (Shore) and HF Broadcast Receivers (Ship)
C. Baseband Channelization and Modulation
D. Single Tone Modem Evaluation Procedures (for information only)
E. Benefits of Interference Excision (for information only)

RELATED DOCUMENTS

STANAG 4203	Technical Standards for Single Channel HF Radio Equipment
STANAG 4285	Characteristics of 1200/2400/3600 Bits per Second Single Tone Modulators/Demodulators for HF Radio Links
STANAG 5031	Minimum Standards for Naval HF, MF, and LF Shore-to-Ship Broadcast Systems

AIM

1 . The aim of this agreement is to define the minimum technical standards for naval shore-to-ship broadcast (shore transmitting and ship receiving) equipment that will permit interoperable communication using HF transmission and appropriate baseband modulation/demodulation techniques.

AGREEMENT

2. Participating nations agree to introduce equipment for naval shore-to-ship broadcasts to meet the minimum standards set out in Annexes B and C, stating which of the baseband modulation standards they will adopt, for both transmission and reception.

IMPLEMENTATION OF THE AGREEMENT

3. The STANAG is considered to be implemented when a Nation’s Naval shore-to-ship broadcasts meet the minimum standards set out in Annexes B and C and appropriate receiving equipment has been installed in ships.

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TERMS AND DEFINITIONS

BANDWIDTH, OCCUPIED

The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage B/2 of the total mean power of a given emission. Unless otherwise specified by the CCIR for the appropriate class of emission, the value of B/2 should be taken as 0.5 percent.

BANDWIDTH, NECESSARY

For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

CARRIER

An oscillator or wave, usually periodic, some of the characteristic of which is intended to be constrained by modulation to follow the variations of a signal or of other oscillation.

FREQUENCY, DISPLAY

The frequency indicated on the dial settings of RF equipment.

HIGH FREQUENCY (HF)

For the purposes of this STANAG, HF is defined to be the frequency band from 1.5 to 30 MHz.

MODULATION

The process of varying some characteristics of the carrier wave in accordance with the instantaneous value of samples of the intelligence to be transmitted. See CARRIER.

MODULATION, AMPLITUDE (AM)

The form of modulation in which the amplitude of the carrier varies in accordance with the instantaneous value of the modulation signal.

PEAK ENVELOPE POWER (PEP)

The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions.

RATT

The system of communication by teletypewriter over radio circuits.

SIMPLEX OPERATION

Operating method in which transmission is made possible alternately in each direction of a telecommunication channel, for example, by means of manual control.

SINGLE SIDEBAND (SSB) TRANSMISSION

That system of carrier transmission in which one sideband is transmitted and the other sideband is suppressed. The carrier wave may be either transmitted or suppressed.

SUBCARRIER FREQUENCY SHIFT

The conveying of telegraphic information by shifting an audio frequency carrier which is then used to modulate a radio frequency carrier for radio transmission. When only two discrete steps of subcarrier frequency shift are involved it is also known as Two-Tone Keying.

TRANSMISSION, SIDEBANDS

When a carrier frequency is amplitude modulated by a modulating signal, the band of frequencies produced on either side of the carrier frequency include components whose frequencies are, respectively, the sum or difference of the carrier and the modulating frequencies. The sum frequencies form the "upper sideband" and the difference frequencies form the "lower sideband".

REFERENCES

ACP 167(G)	Glossary of Communications-Electronics Terms
ITU	Radio Regulations

TECHNICAL STANDARDS FOR HF BROADCAST TRANSMITTERS (SHORE) AND HF BROADCAST RECEIVERS (SHIP)

FREQUENCY RANGE

1. Designated ranges in the HF band from 2-24 MHz. In certain cases, the range will be extended to 2.0 MHz to 29.999 MHz.

TUNING

2.(a) Transmitter and receiver equipment shall tune to integral multiples of 100 Hz, starting at 2.0 MHz. It is desirable that the receiver be able to tune in increments of 10 Hz.

(b) The frequency of the carrier (suppressed or not) shall be the reference frequency and it is desirable that this also be the equipment display frequency.

FREQUENCY TOLERANCE

3.(a) The absolute frequency of the suppressed carrier of the transmitter and the reinserted carrier of the receiver shall be within ± 10 Hz of the designated carrier frequency for J3E emissions and within ± 2 Hz for all other emissions.

(b) The frequency of all tones in the baseband is to be within ± 3 Hz. of the stated frequency.

FREQUENCY RESPONSE

4.(a) The audio frequency baseband, which the transmitter shall accept at its input, and the receiver shall deliver at its output, shall be at least 350 Hz to 3050 Hz.

(b) The variation in R.F. output amplitude of the transmitter, during USB operation, shall not exceed ± 2 dB, with respect to the level at 1000 Hz, over the frequency range f_c + 350 Hz to f_c + 3050 Hz (where f_c is the frequency of the suppressed carrier).

(c) For the receiver the variation in AF output amplitude over the range 350 Hz to 3050 Hz shall be within ± 2 dB of the response at 1000 Hz.

DIFFERENTIAL DELAY DISTORTION

5. The maximum differential envelope (group) delay distortion over 80% of the passband must not vary by more than 0.5 ms.

EMISSION CHARACTERISTICS

6. The necessary and occupied bandwidth shall be within the limits established by the Radio Regulations of the ITU for each class of emission:

	Description	**Designation**	**Occupied Bandwidth**	**Description**
a)	Single Channel RATT - FSK	1K24F1B	1.3 KHz.	Frequency Modulation; Telegraphy; Without Subcarrier; 1.24 KHz. Necessary Bandwidth.
b)	Single Channel RATT - FSK	1K24J2B	1.3 KHz.	Single Sideband Suppressed Carrier; 1.24 KHz. Necessary Bandwidth
c)	Multi-Channel RATT - FSK	2K70J2B	2.8 KHz.	Single Sideband Suppressed Carrier; Two or More Telegraphy Channels; FSK Modulated Subcarriers; 2.7 KHz. Necessary Bandwidth
d)	Single Channel RATT using STANAG 4285	2K70J2B	2.8 KHz.	Single Sideband Suppressed Carrier; PSK Modulated Subcarrier; 2.7 KHz. Necessary Bandwidth

Note: Emissions (a) and (b) use different modulation techniques but yield the same on-air signal.

MODULATION

7.(a) The mandatory classes of emission for HF broadcasts are F1B and J2B. [It is highly desirable that transmitters be capable of supporting other naval communication requirements that use one or more of the following modes of emission: A1A, F1C, F7B, J3E and B7D].

(b) Transmissions using single sideband suppressed-carrier modulation shall have the carrier and the undesired sideband suppressed to at least 40 dB below the peak envelope power (PEP).

(c) It is highly desirable that receivers be capable of reception, in the appropriate frequency band, of any of the mandatory classes listed above.

SPURIOUS EMISSIONS

8. The power of any spurious emission shall be at least 40 dB below the peak envelope power within ± 10 KHz of the carrier frequency; and at least 60 dB below the peak envelope power at any other frequency.

INTERMODULATION PRODUCTS

9. The power of the third order intermodulation distortion product shall be at least 36 dB below the output level of either of two equal tones modulating the transmitter at rated peak envelope power (PEP).

MODE OF OPERATION

10. Equipment shall be capable of operating in the single frequency simplex mode.

SWITCHING TIME

11. The time interval from keying-on a transmitter until the transmitted RF signal amplitude has increased to 90 percent of its steady-state value is the transmitter attack time. This delay, excluding the time necessary for automatic antenna tuning, shall be less than 25 ms.

12. The time interval from keying-off a transmitter until the transmitted RF signal amplitude has decreased to 10 percent of its key-on Steady-state value is the transmitter decay time. This value shall be less than 10 ms.

13. The receiver AGC attack time shall not exceed 10 ms and the release time shall not exceed 25 ms.

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BASEBAND CHANNELIZATION AND MODULATION

OVERVIEW

1. Equipment conforming to this STANAG may by the use, where appropriate, of extra baseband equipment be used to transmit or receive information by means of one or more of three available systems of baseband channelization and modulation.

   (a) Single Channel using FSK modulation
   (b) Multi-Channel using FSK modulation
   (c) Single Channel using PSK modulation

SINGLE CHANNEL - FSK MODULATION

2. Single Channel RATT employing two-tone FSK (F1B or J2B), shall use a frequency shift of 425 Hz ± 5 Hz about the assigned frequency with the space frequency being the higher. In order to permit suppressed or reinserted carrier frequencies to be set at multiples of 100 Hz, the assigned frequency should be selected so that the mark frequency ends in 75 Hz. It is recognised that equipment uses different offsets from the suppressed or reinserted carrier (i.e. 1700 and 2000 Hz) in order to achieve the mark and space frequencies. This will not cause an interoperability problem as long as the single channel wideshift of ± 425 Hz is used. A diagram, which illustrates how interoperability can be achieved is attached as an Appendix to this Annex.

MULTI CHANNEL - FASK MODULATION

3. Multi-Channel RATT, implemented using two-tone FSK, shall be sent using sub-carriers centred on frequencies (255 + 170n) Hz, where n is an integer from 1 to 16 and the sub-carrier shift is ± 42.5 Hz ± 1 Hz. When frequency diversity is used, channels 1 and 9, etc. up to channels 8 and 16 are twinned together. Not all 16 channels need to be used. A multi-channel emission shall normally be operated in such a matter that one of the channels may be received by ships as a single channel. The channel concerned shall normally be that associated with a value of n = 3 in the formula quoted.

SINGLE CHANNEL - PSK MODULATION

4.(a) Naval HF broadcasts will undergo a transition from the present FSK mode of emission to phase shift keying (PSK) of a sub-carrier of 1800 Hz. The required characteristics of the single tone modulator and demodulator are contained in

STANAG 4285. For the purposes of this STANAG the following sections of STANAG 4285 are required in order to achieve interoperability.

(i) **Annex A - Main Body Only (No Appendices)**

Required Characteristics of 1200/2400/3600 Bits per Second Single Tone Modulators/Demodulators for HF Radio Links.

(ii) **Annex E - Main Body Only (No Appendices)**

Error Correction Coding, Interleaving and Message Protocols for use with the Standard Modulation Formats

(b) Although Annex E of STANAG 4285 is marked "for information only", it is required in order to achieve interoperability on NATO naval broadcasts and therefore is mandatory within this STANAG. The other sections of STANAG 4285 not referenced in para. 4(a) are still considered "for information only" within the context of this STANAG.

5. A transition from the current FSK RATT broadcasts to the PSK mode of emission will be effected where required. The minimum user data rate will be 75 bits per second (bps). Higher speeds, including 150 bps, 300 bps or higher may be implemented when necessary.

EXAMPLE SINGLE CHANNEL RATT

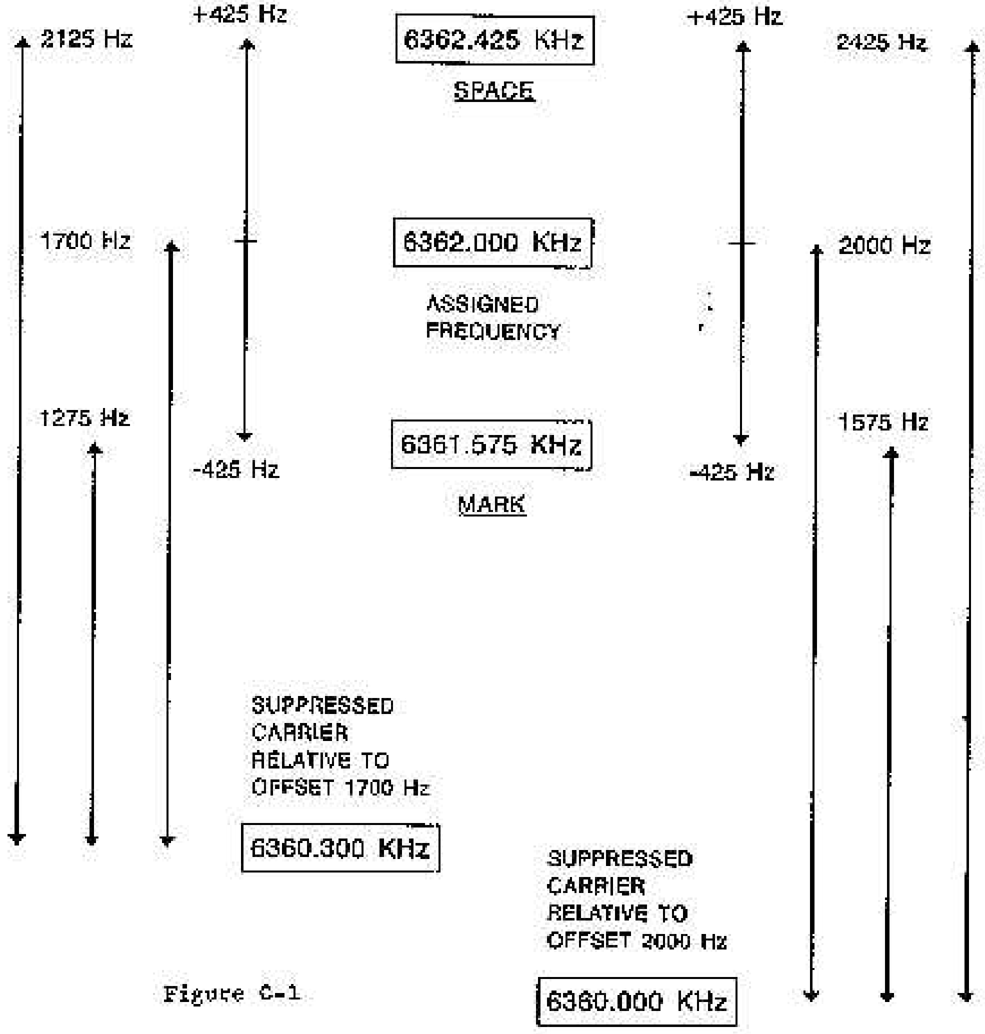

FIGURE C-1

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SINGLE TONE MODEM EVALUATION PROCEDURES

PURPOSE

1. This STANAG 4285 waveform, described in Annex C, has been sufficiently defined to permit a number of manufacturers to develop modulator and demodulator (modem) equipment. It will be necessary for participating nations to ensure that their equipment is capable of interoperability as specified in this STANAG.

2. The STANAG 4285 waveform may be demodulated using a variety of different receive algorithms. The manner in which the algorithms are implemented will have a **significant** impact on the performance of the demodulator during different HF channel conditions. This Annex is intended to provide some guidance in selecting and characterizing a modem that will be required to operate over a wide range of ionospheric conditions.

INTRODUCTION

3. HF ionospheric radio communication is subject to a number of channel impairments including multipath, fading, noise, Doppler shift, interference; and variable signal strength over the area of operation. Testing, evaluation, and comparison of modem equipment over actual HF ionospheric paths can be difficult, expensive and time consuming. At best, on-air trials can only be carried out on a limited number of paths over a finite period of time. Generally, the path conditions vary greatly during the trial and it can be particularly difficult to quantify the channel characteristics over a specific period.

4. It has been recognised for some time that a good correlation exists between the results obtained during laboratory tests conducted on channel simulators and the test results obtained during on-air equipment trials [1]. The use of an appropriate channel simulator permits comparisons to be made under identical controlled circumstances, which can be varied to represent the range of anticipated operating conditions [2, 3].

5. In order to compare simulation results, obtained by different testing organizations, it is necessary that the statistical behaviour of the HF channel simulators be the same. One model, that is commonly used and commercially available, has been developed by the National Telecommunication Information Agency (4,5). An overview of this model and an approach to testing 4285 modems is contained in Annex B of STANAG 4285.

6. The selection of STANAG 4285 waveform for naval broadcasts was based on extensive test program conduct at SHAPE Technical Centre [6]. Laboratory tests were conducted using the STC HF Channel Simulation Facility [3]. Once the laboratory tests were completed a series of on-air trials were done in order to verify the performance of various serial tone waveforms.

TESTING METHODOLOGY

7. The test configuration, specified in Annex B of STANAG 4285, will provide an overall evaluation of different demodulators under typical HF channel conditions. Naval broadcasts, which transmit continuously at 300 bps, need a test suite which is representative of the operating conditions which will be encountered.

8. STC defined a test suite for use during its naval broadcast waveform evaluation study and documented the results so that the manufacturers, testing and procurement agencies, and research facilities could use the results as a performance baseline in future tests [6]. Procurement agencies may wish to evaluate equipment based on these tests or have the manufacturers supply performance data obtained during equivalent tests.

TEST CONFIGURATIONS

9. Typical test configurations [3] are shown in figures D-1 and D-2. Modems may be tested in the baseband mode or in the rf mode depending on the facilities available. The ionospheric simulator should be based on the model described in para. 5 of this Annex and capable of performing the tests described in this Annex.

TEST CONDITIONS

10. **Characterization Versus Signal-to-Noise Ratio**

Nine different signal-to noise ratio tests are recommended. The simulator parameters for these tests are given in Table D-1.

Table D-1: Bit Error Rate Versus Signal-to-Noise Ratio for the Following Conditions

	DOPPLER SPREAD (0 = NON-FADING)		POWER OF PATH 2 RELATIVE TO	DELAY SPREAD	
TEST #	PATH 1	PATH 2	PATH 1	MS.	TEST TYPE

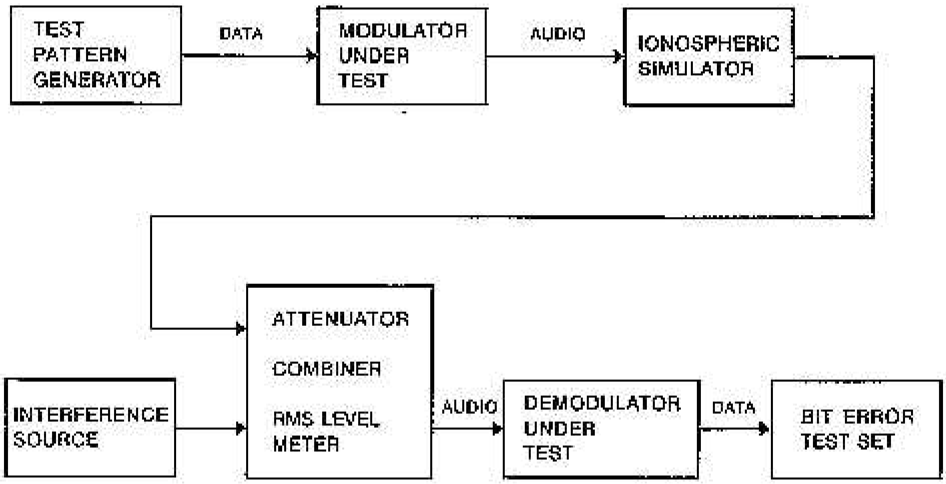

FIG. D-1 **<u>CHANNEL SIMULATION FACILITY - BASEBAND MODE</u>**

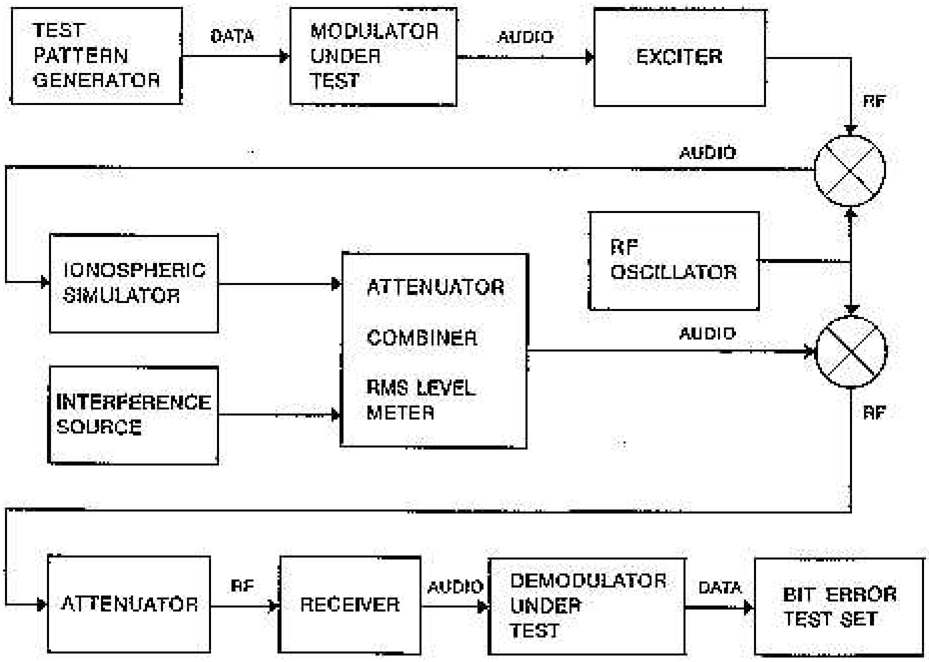

FIG. D-2 **<u>CHANNEL SIMULATION FACILITY - RF MODE</u>**

11. **Characterization Versus Doppler Spread**

Tests 6 and 7 measure bit error rate versus Doppler spread performance for two independent, equal average power, fading paths under slow and moderate fading conditions with minimal multipath. Additional tests, with Doppler spreads from 2.0 to 8.0 Hz., will indicate performance under more severe fading conditions.

12. **Characterization Versus Multipath Spread Performance**

Tests 8 and 9 measure bit error rate performance for two independent, equal average power, fading paths under slow and moderate fading conditions with severe multipath. Additional tests, with multipath delays of 1.0 to 8.0 ms will indicate performance under different circuit conditions.

13. **Synchronization-on-Data Performance**

Rapid synchronization to the received waveform by the demodulator is necessary for several reasons. It permits rapid acquisition and evaluation of the on air signal when initially tuning to a desired channel. Secondly, long fades may result in a temporary loss of the signal and rapid resynchronization will minimize the amount of lost traffic. The time to acquire synchronization may be determined by the following procedure:

a. Interrupt a noise free signal for a period of time that is sufficient for the demodulator to discard any signal timing information and to enter the resync mode.

b. Restore the signal and measure the delay until delivery of correct data at the output of the demodulator.

c. Repeat the test several times in order to determine a consistent average.

d. Repeat the procedure with various noise levels. A noise level sufficient to give a BER of 0.01 provides a reasonable test under stressed conditions [6].

14. **Characterization of Interference Performance**

Reception of naval broadcasts may be subject to one or more types of interference. The set of tests, described in Table D-2 will determine the performance of the demodulator under different conditions [3].

Table D-2: Interference Tests

Test A	CW Measure bit error rate versus signal-to-interference ratio. Interference frequency at centre of signal spectrum.
Test B	Impulse CW Measure bit error rate versus duty cycle. Interference frequency at centre of signal spectrum. Pulse width equal to symbol duration. Pulse amplitude equal to: (a) Signal Amplitude (b) Signal Amplitude -6 Db
Test C	Swept CW Measure bit error rate versus signal-to-interference ratio. Sweep from f_c - $f_{b/2}$ to f_c + $f_{b/2}$ where f_c is the centre frequency of the signal and f_b is the symbol rate. Sweep time (a) 0.5 seconds (b) 20 seconds
Test D	FSK Measure bit error rate versus signal-to-interference ratio. Fsk shift is 850 Hz. Tone frequencies f_c ± 425 Hz. Keyed at 75 bps, 511 pseudo-random data sequence.

TEST TIME

15. One of the difficulties in comparing HF modem performance on noisy fading channels is determining that the channel characteristics for the modems during each test period are statistically similar. This is necessary in order to insure that the observed performance difference is attributable to modem performance and not a better channel for one modem. It is necessary to run tests for extended lengths of time on each bit-error measurement in order to achieve this condition. The length of time required per measurement value is dependent upon the Doppler spread of the channel, the number of paths, the modem characteristics, and the bit-error rate resulting from the tests. Test time guidelines are described in Annex B of STANAG 4285.

REFERENCES

[1] CCIR Recommendation 520-1, Use of High Frequency Ionospheric Simulators.

[2] CCIR Recommendation 549-3, HF Ionospheric Channel Simulators.

[3] Pennington, J., Evaluation of the STC Channel Simulation Facility, SHAPE Technical Centre TN-145 (NU, 1987).

[4] Watterson, C.C. et al., An Ionospheric Channel Simulator, ESSA Tech. Memo ERLTM-ITS 198 (1969).

[5] Watterson, C.C. et al., Experimental Verification of an Ionospheric Channel Model, ESSA Tech. Rept. ERL 112-ITS.

[6] Clark, D.A., Freberg, D.E., van't Hoog, H., BRASS Broadcast: Modem Waveform Definition Study, SHAPE Technical Centre TN-468 (NU, 1993).

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BENEFITS OF INTERFERENCE EXCISION
(FOR INFORMATION ONLY)

1. The HF band is highly congested and interference from other users is often encountered. The performance of the demodulator, under interference conditions, will be **improved considerably** through the use of an adaptive interference excision filter. On-air tests have shown that an increase of 20 to 30 percent in correct reception of naval broadcast messages may be achieved through the use of this technique [1].

2. Adaptive excision filters are well suited for incorporation within a STANAG 4285 modem. The flat spectrum, which results from transmitting a single high baud-rate subcarrier, is ideally suited to the application of simple, but effective, adaptive excision techniques.

3. The effectiveness of adaptive excision filtering, with single-tone modems, depends on several factors: the filtering technique; nature of the interference (i.e. CW, FSK); signal-to-interference ratio; signal-to-noise ratio (excluding interference); ionospheric channel characteristics; and the user data rate. Generally, the lower the user data rate and the narrower the bandwidth of the interference, the more effective the excision.

4. There are a number of implementation techniques which may be employed and their effectiveness needs to be determined using the interference tests described in Annex D.

REFERENCE

[1] Clark, D.A., Freberg, D.E., van't Hoog H., BRASS Broadcast: Modem Waveform Definition Study, SHAPE Technical Centre TN-468 (NU, 1993).

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