RECOMMENDATION ITU-R M.1467*

PREDICTION OF A2 AND NAVTEX RANGES AND PROTECTION OF A2 GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM DISTRESS WATCH CHANNEL

(Question ITU-R 92/8)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that the International Convention for Safety of Life at Sea (SOLAS) 1974, as amended, prescribes that all ships subject to this Convention shall be fitted for the global martime distress and safety system (GMDSS) by 1 February 1999;

b) that some administrations have yet to establish A2 services for the GMDSS;

c) that Question ITU-R 92/8 identifies the need for promulgation of minimum performance criteria for the protection of the service, and guidance to accelerate the upgrade of shore-based facilities for GMDSS operation in the A2 sea area,

recommends

1 that administrations currently upgrading, or planning to upgrade, their shore-based facilities for GMDSS operation in the A2 sea area should use the information contained in Annex 1.

NOTE 1 – Administrations are invited to develop appropriate software to enable the calculations, described in Annex 1, to be performed.

ANNEX 1

Prediction of A2 and NAVTEX ranges

1 Overview

In order to establish a new A2 sea area it is necessary to account for variations in the propagation conditions. A2 coverage is by groundwave, which is largely stable, enabling the extent of the service area to be confirmed by measurement, as is recommended by the IMO, before committing capital expenditure.

The design criteria to be used for establishing A2 and NAVTEX sea areas are defined by the IMO in Annex 3 to their Resolution A.801(19).

2 Prediction of A2 and NAVTEX ranges

2.1 IMO performance criteria

The criteria developed by the IMO for determination of A2 and NAVTEX ranges are reproduced in Table 1 and should be used in the determination of ranges for A2 and NAVTEX services.

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* This Recommendation should be brought to the attention of the International Maritime Organization (IMO).

TABLE 1

Performance criteria for A2 and NAVTEX transmissions

Distress channel	Radiotelephony	DSC	ARQ NBDP	NAVTEX
Frequency (kHz)	2 182	2 187.5	2 174.50	490 and 518
Bandwidth (Hz)	3 000	300	300	500
Propagation	Groundwave	Groundwave	Groundwave	Groundwave
Ships power (W)	60	60	60	
Ships antenna efficiency (%)	25	25	25	25
RF full bandwidth signal/noise ratio (*S*/*N*) (dB)	9	12	18 min(1)	8
Mean Tx power below peak (dB)	8	0	0	0
Fading margin (dB)	3	Not stated		3
IMO reference for above	Res. A.801(19)	Res. A.804(19)	Rec. ITU-R F.339	Res. A.801(19)
Availability required (%)	95	Not stated	Not stated	90

DSC: digital selective calling

NBDP: narrow band direct printing

(1) Stated as 43 dB(Hz) under stable and 52 dB(Hz) under fading conditions with 90% traffic efficiency.

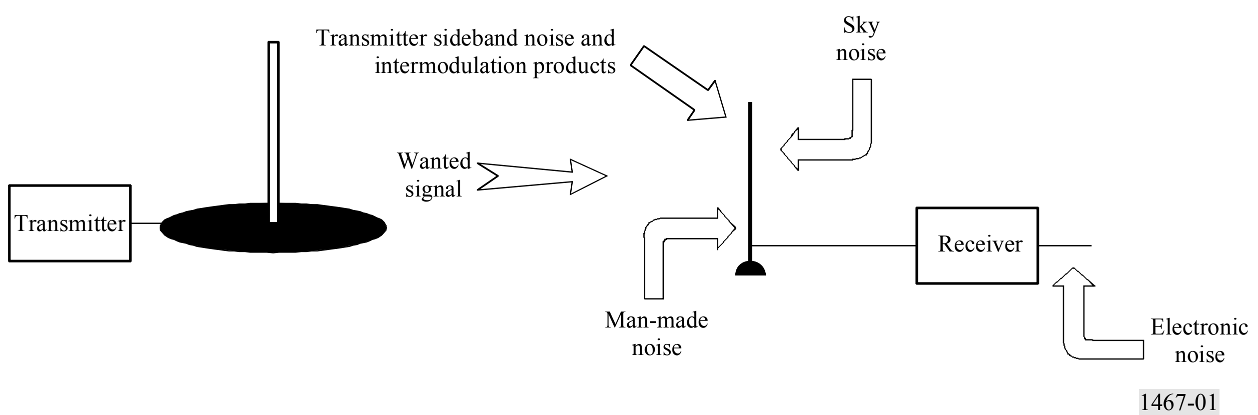
2.2 Achieving the required quality of signal

2.2.1 The effect of received noise

On a very quiet site, man-made noise dominates below 4 MHz and galactic noise above. These combine, at the receive antenna with seasonal levels of atmospheric noise, and also transmitter sideband noise, as shown in Fig. 1 below. Recommendation ITU-R P.372 should be used to account for atmospheric and normal man-made noise levels.

FIGURE 1

Determination of required carrier-to-noise ratio (*C*/*N*)



Paragraph 3.5 should be used to ensure that the levels of transmitter sideband noise and intermodulation products reaching the receive antenna by groundwave do not exceed the tolerable limit for protection of the A2 DSC watch frequency.

2.2.2 *C*/*N* required for single sideband (SSB) radiotelephony

In order to maintain the intelligibility of a received SSB radiotelephony signal it is necessary to provide the operator with a minimum AF signal/noise plus distortion ratio (SINAD), which in turn defines the RF *C*/*N* required at the receive antenna.

The capture range for an A2 receive system should be calculated assuming an RF *C*/*N* density figure of 52 dB(Hz) at the shore-based receive antenna. This will ensure that a ship’s transmitter operating with a peak-to-mean ratio of 8 dB provides the shore-based operator with a 9 dB *S*/*N* in a 3 000 Hz bandwidth, as stipulated by the IMO.

The receive antenna and multicoupler should be designed to offer good linearity to minimize the risk of intermodulation products being generated on the watch frequencies. With good electronic design the noise generated within the receive system itself can be ignored below 3 MHz.

2.2.3 *C*/*N* required for NAVTEX broadcasts

The transmit range for NAVTEX broadcasts should be calculated assuming an RF *C*/*N* density figure of 35 dB(Hz) at the ship's antenna. This will ensure that the NAVTEX receiver is provided with an RF *S*/*N* of 8 dB in a 500 Hz bandwidth, as stipulated by the IMO.

2.3 Accounting for ships topside noise

Topside noise refers to the environmental noise generated by ship-borne machinery, and other sources, and a figure is required for entry into NOISEDAT and other programs. Table 2 shows a number of published figures, and for reference purposes includes galactic and quasi-minimum noise levels, which is accepted as representing the best achievable noise floor.

TABLE 2

Naval environmental categories for topside noise

Environmental category	dB below 1 W ref. 3 MHz
DOD Cat 1 mobile platform	–137.0
IPS ship (ASAPS and GWPS)	–142.0
AGARD ship	–148.0
Quasi-minimum noise	–156.7
Noise galactic (Rec. ITU-R P.372)	–163.6

ASAPS: advanced stand alone prediction system

GWPS: groundwave prediction system

The Australian Department of Defence (DOD) and Advisory Group for Aeronautical Research and Development (AGARD) have both published relevant figures. The AGARD figure represents a naval vessel under normal cruise conditions, whilst the DOD figure represents the maximum level under battle conditions with all machinery in operation.

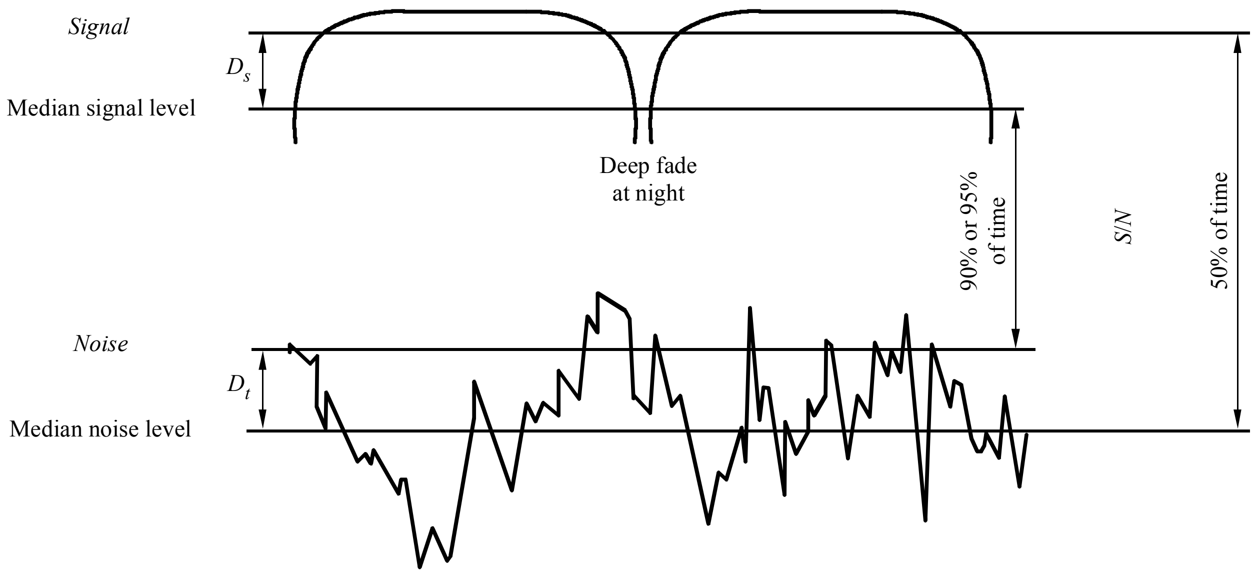
The levels of noise to be expected on commercial vessels can be expected to range between these figures. The IPS Radio and Space Services (IPS) of the Australian Department of Industry have adopted an intermediate figure in their GWPS, which is well accepted as representing the noise level encountered on container vessels, pleasure cruisers, and utility ships. This figure, –142 dBW, should be used in prediction of coverage area of shore-based GMDSS transmitters.

2.4 Determination of external noise factor, F_a, for the required availability

An A2 area in the GMDSS is defined as the area within which ship stations can alert shore stations by using DSC on MF and communicate with the shore stations using MF radiotelephony, (class of emission J3E). The communications ranges for voice signals are shorter than for DSC and the IMO criteria for determination of A2 areas should therefore be based on the communication of voice signals.

The range achieved by a transmitter or a receiver depends upon the radiated power, the propagation loss, and the ability of the receiver to discriminate between the wanted signal and the unwanted noise or interference. The level of each component in the received signal will drift as the propagation conditions change with time, and therefore arrive at the receive antenna in varying proportions. The final system design should therefore ensure that the level of the signal will exceed the level of the noise by an adequate amount for an adequate proportion of the time. This proportion is called the availability, and is determined by quantifying the behaviour of the signal and the noise with time as shown in Fig. 2.

FIGURE 2



D_s: lower limit in signal level variation
D_t: upper limit in signal level variation

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Equation (1) should be used to calculate an upper value F_a for the external noise factor which corresponds to the required availability:

$$F_a = F_{am} + \sqrt{D_t^2 + D_s^2} \qquad \text{dB above } k\,T_0\,B \qquad (1)$$

where:

F_{am}: median external noise factor

D_s: variation in signal level expected for the required time percentage, to which is ascribed the figure of 3 dB specified by the IMO as fading margin

D_t: variation in noise level expected for the required percentage of time.

90% availability is required for NAVTEX broadcasts, and so the upper decile value D_u should be substituted for D_t in equation (1).

95% availability is required for A2 coverage. To achieve this, substitute $D_t = D_u + 3$ dB in equation (1).

First F_{am} and D_u should be determined by running the Noise1 program, which comes with the ITU NOISEDAT package. The program requests seasons required, site location, frequency, level or category of man-made noise, and type of data output required (select F_a), local mean time, and statistical parameters required (select overall median). For prediction of external noise factor on ship stations, the reference figure of –142 dBW should be used to account for topside noise, if no better data is available.

The data is presented in seasonal blocks as shown in Table 3, the data fields being explained in Table 4.

TABLE 3

Sample NOISEDAT output

LAT = –51.45,		LONG = –57.56,		DUMMY SITE					
WINTER	FMHZ = 2.182,		QUIET RURAL NOISE						
			OVERALL NOISE						
TIME BLOCK	ATMO	GAL	MANMADE	OVERALL	DL	DU	SL	SM	SU
0000-0400	59.3	44.2	43.9	59.6	7.2	9.2	2.3	3.5	2.6
0400-0800	54.0	44.2	43.9	54.5	4.1	1.9	3.2	3.4	2.7
0800-1200	28.2	44.2	43.9	45.9	4.3	9.0	2.2	3.4	1.3
1200-1600	31.0	44.2	43.9	46.0	4.2	8.9	2.2	3.3	1.3
1600-2000	53.5	44.2	43.9	53.9	10.4	12.2	3.6	3.9	2.9
2000-2400	54.3	44.2	43.9	55.2	7.2	9.2	2.3	3.7	2.6

TABLE 4

Fields presented for use in the NOISEDAT output

Field	Symbol	Description
TIME BLOCK		Time block during which original measurements were made
ATMO		Level of atmospheric component
GAL		Level of galactic component
MANMADE		Level of man-made component
OVERALL	F_{am}	Median level of F_a
DL	D_l	Lower decile of deviation from median
DU	D_u	Upper decile of deviation from median
SL	σD_l	Standard deviation of D_l
SM	σF_{am}	Standard deviation of F_{am}
SU	σD_u	Standard deviation of D_u

The median and upper values for F_a should be organized as shown in Table 5, and the seasonal spread in the value of F_a for the required availability should be plotted as a bargraph in Fig. 3. This presentation enables the process to be reviewed if any anomalies occur.

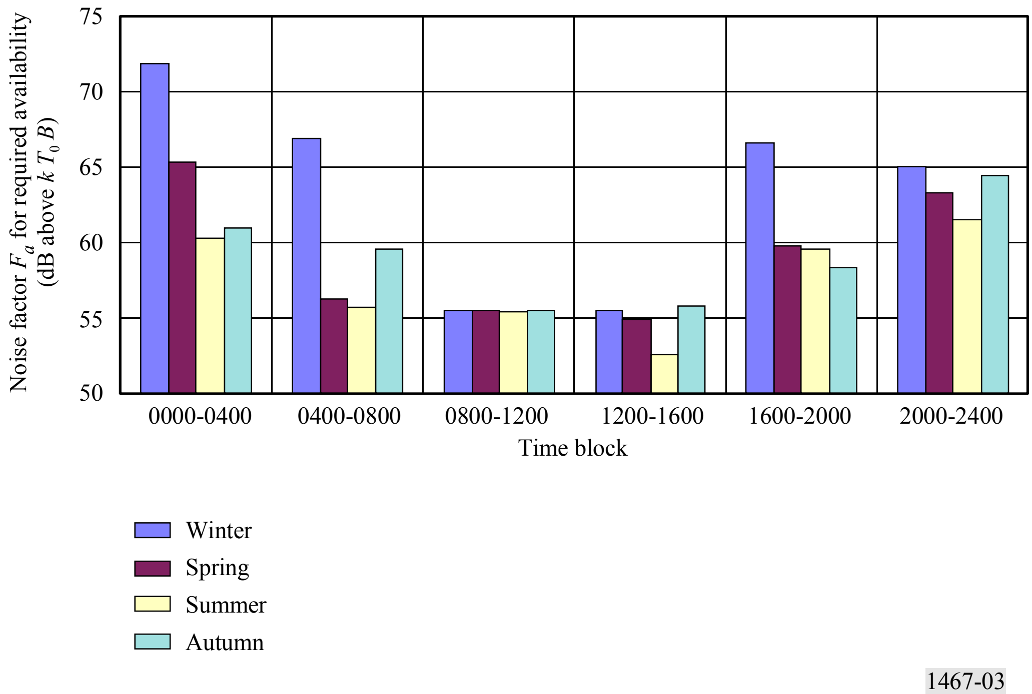
TABLE 5

External noise factor, F_a

	Median value, F_{am}				F_a for required availability $F_{am} + \sqrt{D_t^2 + D_s^2}$			
Time block	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
0000-0400	59.6	55.9	52	52.2	71.7	65.2	60.2	60.9
0400-0800	54.5	43.7	45.9	46	66.8	56.2	55.6	59.5
0800-1200	45.9	45.9	45.8	45.9	55.4	55.4	55.3	55.4
1200-1600	46	41.9	37.7	45.8	55.4	54.8	52.5	55.7
1600-2000	53.9	43.2	43.6	43.9	66.5	59.7	59.5	58.2
2000-2400	55.2	55	54.4	55.8	64.9	63.2	61.4	64.3

FIGURE 3

Seasonal spread in external noise, F_a, calculated for required availability



In the example shown, a figure of 72 dB should be taken for calculation of A2 range.

2.5 Accounting for propagation by groundwave

2.5.1 Introduction

Horizontally polarized waves will not propagate along the surface of normal ground, as the electric vector runs tangential to the surface causing a current to flow, which results in absorption and heavy transmission losses. For this reason groundwaves have to be vertically polarized, and can only be generated by a vertical antenna, or to a limited extent by an antenna which is not perfectly horizontal, either because one end is higher than the other, or because the elements droop.

The prime mover for groundwave propagation is the cymomotive force (c.m.f.) exerted by the transmit antenna. In free space, power flux-density (W/m^2) decreases inversely with the square of distance, and so the field strength decreases inversely with distance and has a value equal to the product of c.m.f. and distance. The c.m.f. is synonymous with the effective monopole radiated power (e.m.r.p.), which is the power (kW) which would have to be fed into a short lossless monopole to achieve the same c.m.f., and in dB terms the two have the same value. A short lossless monopole on a perfect ground fed with 1 kW has a c.m.f. of 300 V, which is the reference used in the groundwave curves given in Recommendation ITU-R P.368.

Subsequent calculation of the transmitter power required should take account of the following losses associated with the antenna:

– the transmitter output power may be de-rated by an antenna offering a poor match;

– power will be absorbed by the ground and the feeder;

– whereas an ideal monopole will produce maximum radiation along the ground, the radiation from a real antenna will peak a few degrees above the ground and tuck in to a lower value along the ground.

2.5.2 Proof of performance tests

IMO Resolution A.801(19) stipulates that the range of the A2 sea area should be verified by field strength measurement. The c.m.f. of any shore-based transmitter and antenna should therefore be determined by operating the transmitter continuously at peak power, and measuring the resulting field strength using a portable field strength meter. This should be done on an arc around the station with an approximate radius of 1 km in the required directions of propagation. The precise location of the antenna and each measurement point should be fixed using a GPS navigator. The c.m.f. on each bearing is then the product of field strength (mV/m) and range (km) for each measurement point. The antenna drive point current should also be recorded before and after the measurement.

The procedures in this Recommendation should be used by administrations to determine the c.m.f. required to establish coverage, which should then be demonstrated by the equipment supplier, effectively eliminating uncertainties in performance due to local ground conditions, and the antenna and station earthing system.

2.5.3 Determination of extent of A2 service area

The extent of the A2 service area is determined by the range over which SSB communication is effective at 2 182 kHz between ship and shore. The ship is considered to be fitted with a 60 W transmitter, feeding a short monopole antenna with an efficiency of 25%, as given in Table 1. The range is fixed by the maximum distance at which the ship can be from the shore station to produce a *S*/*N* of 9 dB in a 3 kHz bandwidth out of the receive antenna at the shore station. The shore transmit station must transmit sufficient power to return the same *S*/*N* at the output of the ship's receive antenna.

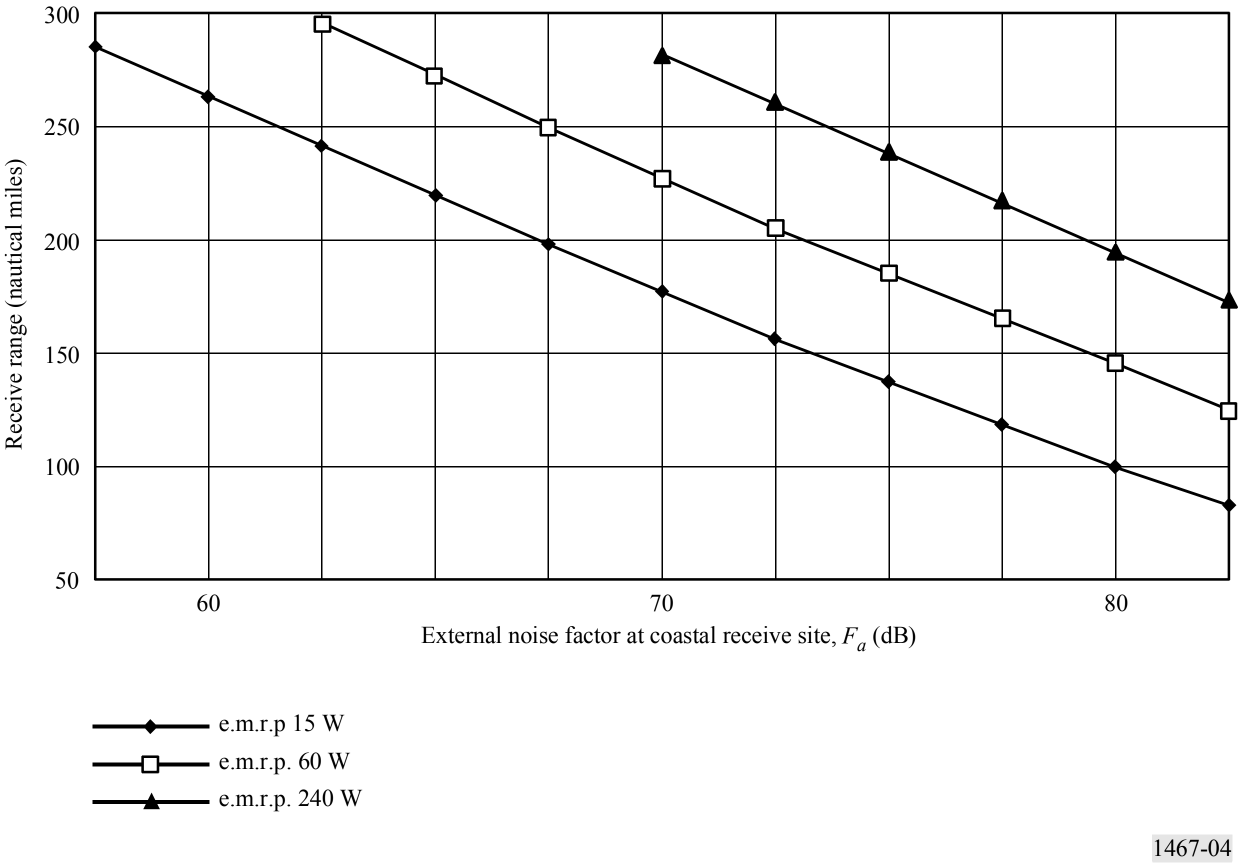
The range in both directions depends upon the sensitivity of the receive antenna, which depends upon the levels of natural and man-made noise present, and the ability of the antenna to discriminate between the wanted signal and the unwanted radiated noise. Although some improvement can be achieved by using a directional receive antenna, this often proves to be uneconomic and impractical, and is outside the scope of this Recommendation. It will be assumed that a short whip antenna is used for reception, that it has been installed on clear ground on an earth mat, and that it is regularly maintained to avoid the effects of corrosion. The noise factor of the receive system connected to the antenna can be ignored at 2 182 kHz.

2.5.3.1 Determination of shore-based receive range

The IMO minimum range thus achieved should be determined for all seasonal values of F_a using the 15 W curve in Fig. 4. Additional curves have been included to demonstrate the benefit of vessels using higher transmit powers.

FIGURE 4

Distress receive range versus F_a for various transmitted ships powers



2.5.3.2 Determination of shore-based transmit power required

Effective two-way SSB radiotelephony requires matched conditions in both directions. Since the transmission loss is the same in both directions the power required to return a call depends primarily upon the difference in noise levels at each end, and also the difference in transmit antenna efficiency. However the following additional factors have a direct impact on the power to be transmitted by the shore station:

– peaks and troughs in the radiation pattern of the receive antenna on the ship, due to interaction with the ship's hull;

– losses due to the condition of the ship's receive antenna on the ship.

Tests on scale models of a number of vessels indicate that variability in gain of receive antennas is typically ±5 dB. Furthermore, allowance should be made for ships whose antennas are in poorly maintained condition. A figure of 10 dB has been included in the calculation of shore-ship power budget to take account of these factors.

To determine the radiated power required from the shore-based transmitter the external noise factors for the receive stations on shore, F_{ac}, and ship, F_{as}, should first be established as described in § 2.4. The minimum e.m.r.p. required to return a GMDSS call at the same *S/N* to a ship on the limit of the service area should then be calculated using equation (2):

$$P_{e.m.r.p.} = (F_{as} - F_{ac}) - 16 + R_{pm} \qquad \text{dB(kW)} \tag{2}$$

where:

R_{pm}: peak-to-mean ratio of the transmitter used on the shore station (dB).

The transmitter power required, P_{Tx}, should then be determined from equation (3), in which L_a should account for all the losses associated with the antenna described in § 2.5.1:

$$P_{Tx} = P_{e.m.r.p.} + L_a \qquad (3)$$

Substituting typical figures $(F_{as} - F_{ac}) = 10$ dB, $R_{pm} = 3$ dB, and $L_a = 3$ dB yields a typical value of 1 000 W for the minimum required transmitter power at the coast station.

If the antenna efficiency Eff_{ant} is required it should then be determined from equation (4):

$$Eff_{ant} = P_{e.m.r.p.} / P_{Tx} \qquad (4)$$

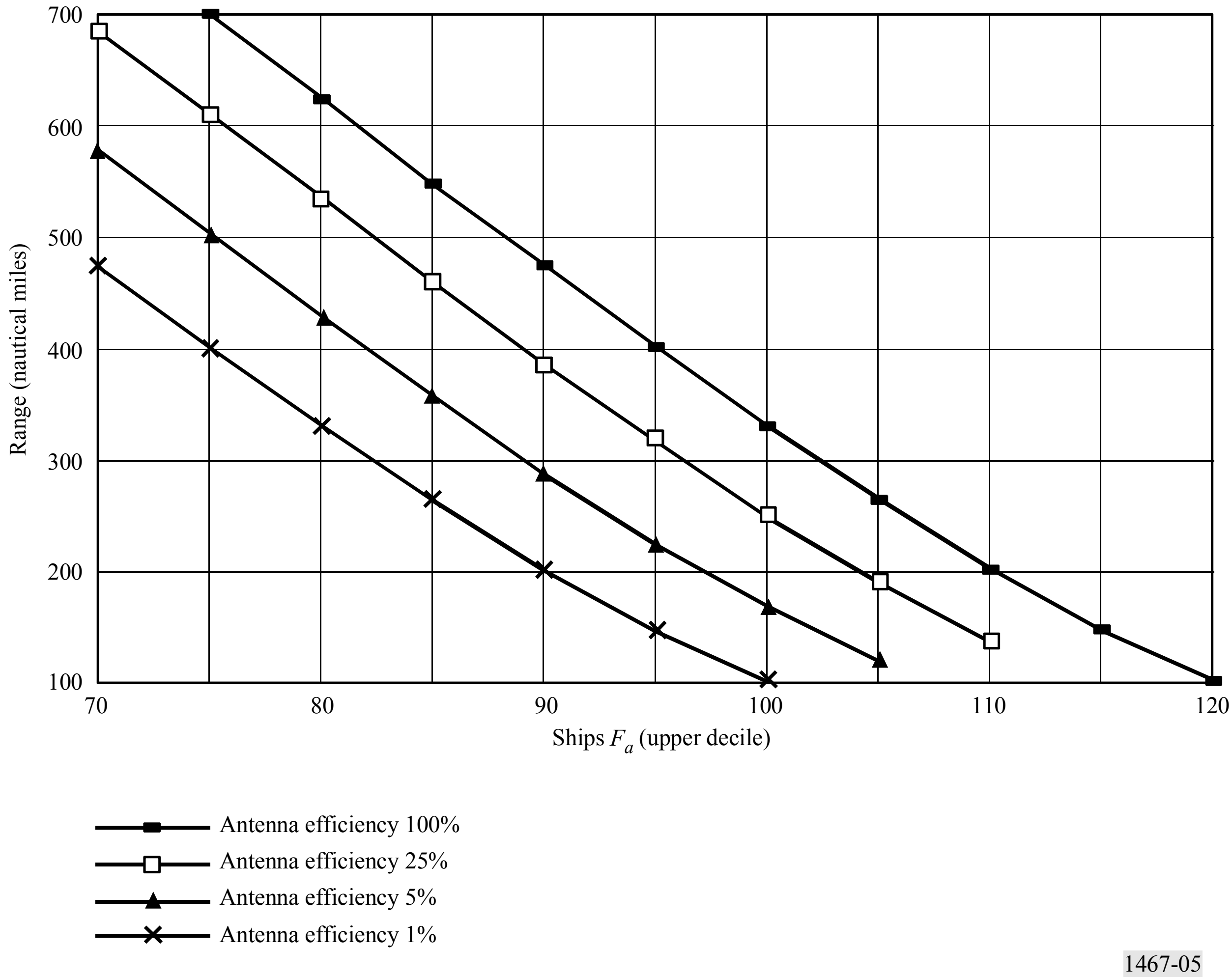
2.5.4 Determination of the range achieved using NAVTEX operation

The range achieved by a given NAVTEX transmitter depends upon the efficiency of the transmit antenna, and the external noise factor on board the ship, as shown in Fig. 5. The antenna efficiency depends upon the quality of the earth system provided, and once the required c.m.f. has been determined, it should be measured as described in § 2.5.2, and the efficiency determined.

FIGURE 5

NAVTEX range for a 1 kW transmitter, versus ships F_a

(For 5 kW transmitter, reduce F_a by 7 dB)



IMO Resolution A.801(19) specifies 90% availability and so the upper decile value for F_a should be calculated using the statistical data produced by NOISEDAT.

3 Protection of A2 watch frequency

The IMO specify that the distress channels should be watched 24 h per day. The system should be designed so that the watch function is not desensitized by noise or interference. It is essential therefore that all transmit channels assigned for use on the transmitting station are selected so that no intermodulation products are allowed to fall within the frequency bands of the watch channels.

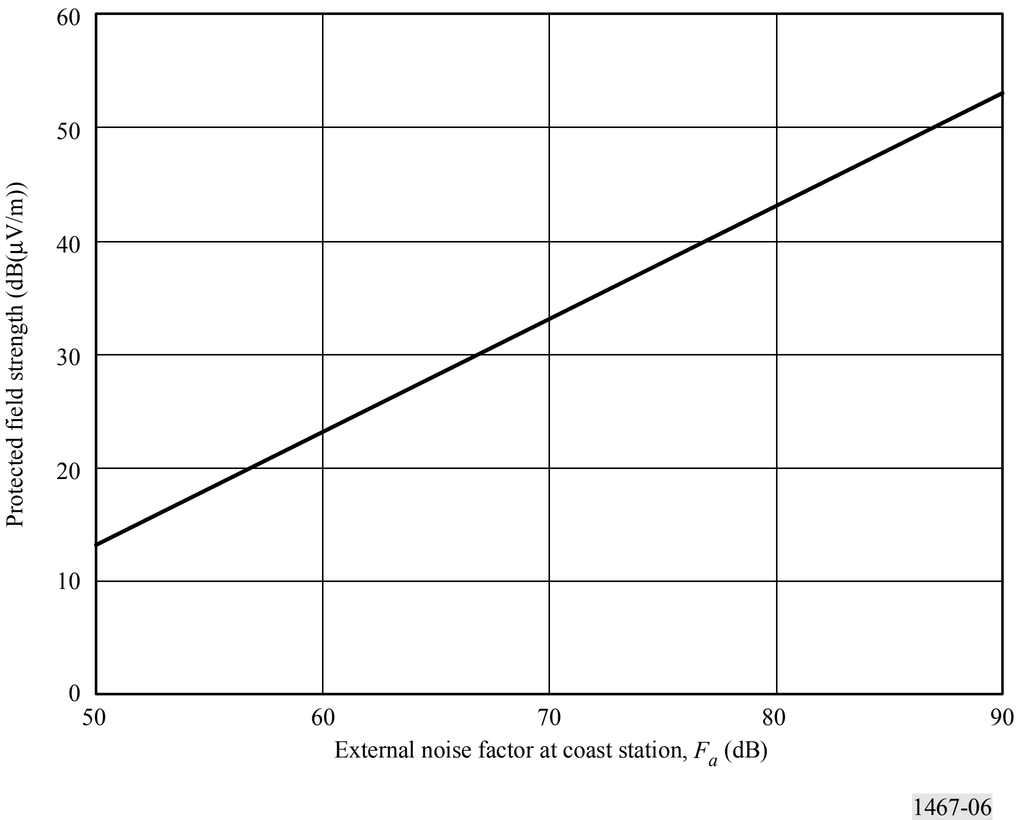
For very close channel separations the watch process can be threatened by energy in upper sideband of the adjacent SSB transmission falling within the receiver passband, where the wanted signal could be swamped by blocking or reciprocal mixing. Where channel separation is large enough to remove the threat of reciprocal mixing, a further, but lesser threat to the watch process may be sideband noise from the transmitter falling in the receiver passband.

The resulting DSC signal level reaching the shore station will depend upon the declared A2 range for the shore station, and in turn depend upon the sensitivity, F_a.

The level to be protected would be the level reaching the shore station after suffering a 3 dB fading loss, and is shown in Fig. 6.

FIGURE 6

Protected DSC field strength at receive site



3.1 Impact of site separation on system performance

3.2 Estimating the level of the interference field

The tolerable amount of sideband noise leaving the transmit antenna, and the level of adjacent channel isolation required by the watch receiver both depend upon the separation between the transmit and receive antenna, and Fig. 7 provides a reference power P_{ref} (mW), which corresponds to the radiated power which would produce a field strength at the receive antenna equal to the DSC field strength to be protected and Fig. 8 provides a rule of thumb to relate this to transmitter and receiver characteristics.

FIGURE 7

A2 Tx power yielding field strength equal to protected DSC field strength at receive site

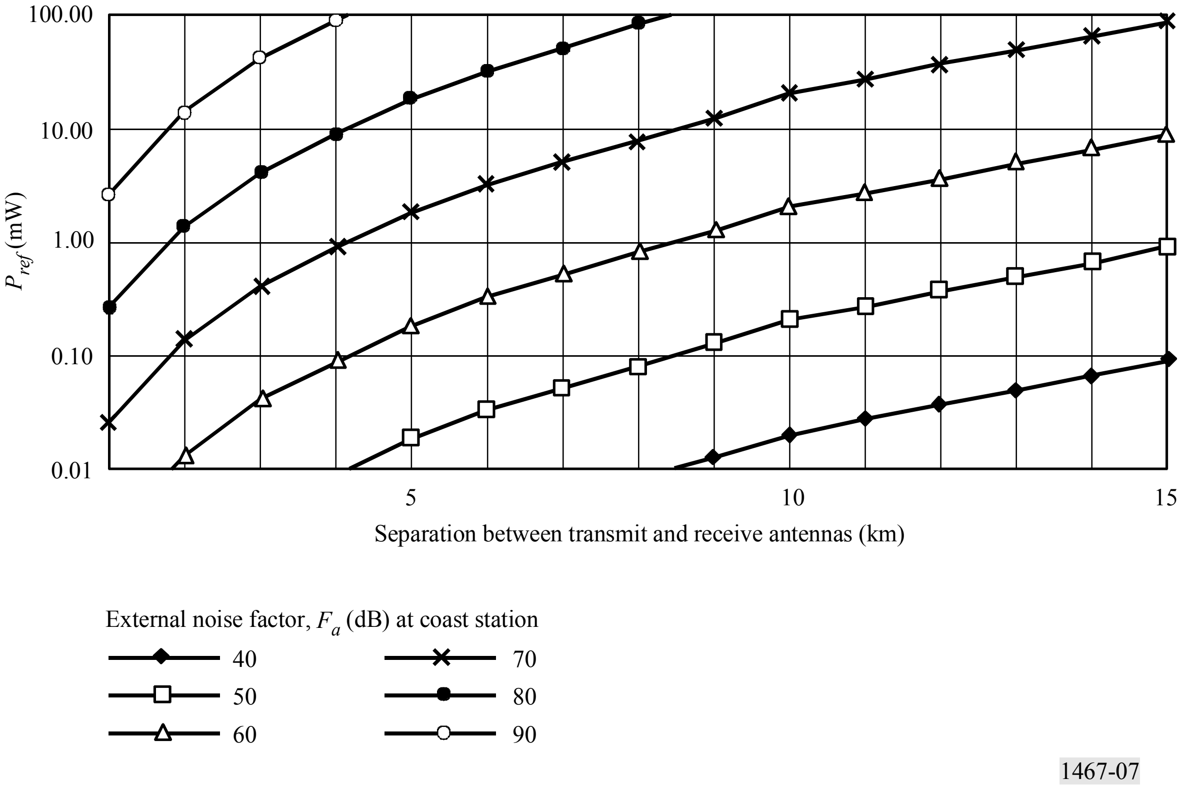
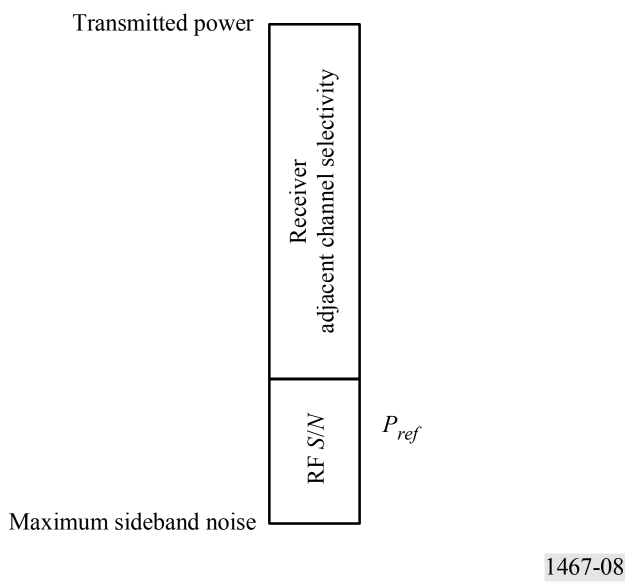


FIGURE 8

Relationship between transmitter and receiver characteristics



3.3 Required adjacent channel selectivity

The level of adjacent channel isolation required by the watch receiver depends upon the separation between transmit and receive antennas. Figure 7 provides a reference power, P_{ref}, which corresponds to the radiated power which would produce a field strength at the receive antenna equal to the DSC field strength to be protected. If the receiver has an adjacent channel isolation figure of I_{adj} (dB), then the maximum power radiated by the station should be limited to:

$$P_{rad} = P_{ref} + I_{adj} \tag{5}$$

Three grades of receiver may be considered for providing the DSC watch: commercial communications receivers, ships DSC watch receivers, or high performance crystallized DSC watch receivers, conforming with Table 6:

TABLE 6

Selectivity (dB)	Offset (Hz)
6	Between 150 and 220
30	Less than 270
60	Below 400
80	Less than 550

3.4 Protection from adjacent channel interference

The maximum permitted transmitter power should be determined using equation (6):

$$P_{Tx} = 30 + 10 \log(P_{ref}) + I_{adj} - 10 \log(Eff_{ant}) \tag{6}$$

where:

P_{Tx}: transmitter power (dBW)

I_{adj}: adjacent channel isolation figure for the receiver

Eff_{ant}: antenna efficiency.

For example, consider a receiver of the grade used on board ship having a typical adjacent channel isolation figure of 60 dB, on a site offering an F_a of 65 dB located 2.5 km from a transmit antenna with an efficiency of 75%. Fig. 7 gives a P_{ref} of 0.1 mW and so the maximum level of radiated power would be 60 dB above 0.1 mW, which is 100 W. Allowing for antenna efficiency the maximum transmitter power would be 133 W. In order to benefit from a 500 W transmitter a pre-filter offering an additional 4 dB adjacent channel isolation would be required.

3.5 Protection from transmitter sideband noise

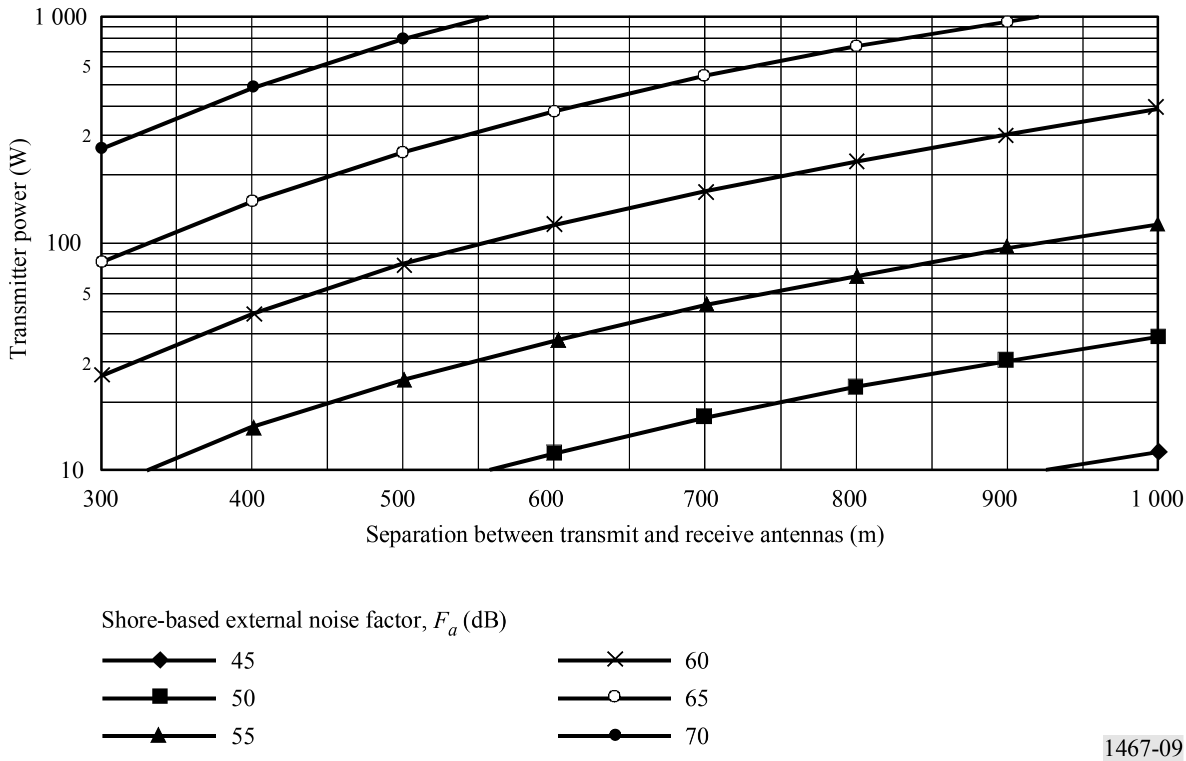
The maximum tolerable level of sideband noise is determined by the required C/N at the receive antenna. In the above example, for a S/N of 10 dB, the maximum tolerable level of sideband power would be 10 mW, which is quite low, and may call for use of a post-selector to reduce the noise leaving the transmitter modulator unit.

3.6 Co-site operation

Figure 9 shows the effect of reducing the separation between the transmit and receive antenna below 1 km to 300 m, the minimum value computed using GRWAVE. By way of example, if a station close to the shoreline had a maximum annual median external noise factor F_a of 65 dB then from Fig. 4 the range achieved would be just over 200 nautical miles. If the adjacent channel isolation were 80 dB, then for an e.m.r.p. of 200 W the antenna separation should be not less than 450 m.

FIGURE 9

Transmitter power versus antenna separation for 80 dB adjacent channel isolation



Under such circumstances a long feeder would be required to attain the separation required. As the frequency increases there is a considerable reduction in external noise and increase in feeder loss. At 2 MHz the external noise factor is very much greater than the system noise factor, and for a system noise factor of 15 dB up to 10 dB of feeder loss would be tolerable on a well designed and maintained system. A cost-effective way to avoid the cost of a very long low loss coaxial cable would be to use a separate antenna for A2.

4 Software requirements

4.1 Noise calculation

To simplify the determination of range for A2 and NAVTEX transmissions a modified form of NOISEDAT is ideally required including calculation of F_{am} in accordance with the procedures of this Recommendation.

4.2 Intermodulation

In order to protect the DSC watch channels from the harmful effects of interference caused by intermodulation products, a new program is ideally required to enable the frequencies assigned for use on a shore-based transmitting station to be checked to ensure that no intermodulation products are produced within the passbands of the DSC watch receivers, down to at least the 9th order. Such software should account for the offset spectrum occupied by SSB transmissions to be used.