REPORT 1032-1

RADIO NOISE ENVIRONMENT ON BOARD VESSELS

(Question 30/8)

(1986-1990)

1. Introduction

1.1 Recommendation No. 302 of the World Administrative Radio Conference (Geneva, 1987) invited the CCIR to continue its study with a view to improving all technical and operational sharing criteria relating to the use of the HF coast radiotelephone channels in the bands allocated exclusively to the maritime mobile service.

1.2 Quesion 30/8 is in response to Recommendation No. 302 and *inter alia* identifies the need to study the preferred method of measuring man-made noise on board ships (see § 4.1), as well as the sources and levels (see § 4.2).

1.3 This Report describes a method developed to measure the whole ship noise environment in the vicinity of the ship's antennas and presents some preliminary results. It is intended that such a system would enable a satisfactory estimation of the performance of on board communication systems, and an improved definition of expected noise levels on board ships.

1.4 The Report also suggests a means of identifying sources of noise on board ships and measuring their levels.

2. Measurement of noise environment

2.1 *Measurement model*

The preferred model for describing the noise is the cumulative distribution of the band-limited noise envelope, known as the "amplitude probability distribution" (APD), as used in Report 322. This is a plot of probability against field strength and gives the proportion of the measurement time for which the noise envelope exceeds any given level of field strengh. The coordinate scaling is chosen so that the exceedance statistics of a Rayleigh distributed variable, such as the envelope of band-limited thermal noise, plots as a straight line with a slope of −0.5 and a root-mean-square (r.m.s.) value with a probability of exceedance of 0.368 (E_R and P_R in Figure 1).

The form of typical ship noise APDs is similar to that of atmospheric APDs in that they may be approximated by two straight lines. The normal component of the noise provides a straight line, with a prescribed slope, residing at higher probability values. This converges with a line with higher slope at the lower probability values, caused by higher amplitude impulsive noise. However, in contrast to atmospheric noise, there appears to be no useful relationship between the levels of variance of these two components. Therefore, the APD cannot be defined in terms of the noise variance and the V_d;

$$\text{where} \quad V_d = 20 \log_{10} \frac{V_{rms}}{V_{mean}}$$

Because of the factors affecting the level of atmospheric noise, these APDs are specific to geographical location, time and season. APDs recorded under one set of these conditions may be transformed to another. This is accomplished by deconvolving the expected atmospheric APD (obtained from Report 322) from the measured APD and replacing it with the alternative atmospheric APD. The statistical uncertainties are, of course, combined in the usual way.

Also, these APDs are specific to frequency and bandwidth. Small changes in frequency (<10%) usually have little effect, but changes in the pass-band characteristic may have a significant effect. The conversion of results from one frequency or bandwidth to another is not readily achieved.

2.2 Method of Measurement

An APD is generated from a set of samples of the band-limited noise envelope, recorded over a fixed period of time. The period is chosen so as to be equivalent to a short but significant unit of communications time. 10 minutes has been found to be satisfactory. The number of APDs should be such that all noise conditions on the ship are well represented, whilst the atmospheric component remains relatively stationary.

The detection system uses a 1m monopole antenna connected to a test receiver with a calibrated range of 70 dB. The linearly detected noise envelope is sampled and digitised with logarithmic quantisation, 8 bit precision and a sampling rate of 8 kHz. The samples are accumulated for each amplitude level, from which the exceedence statistics may later be generated.

2.3 Measurements

In the last two years, noise measurements have been obtained from 15 ships of various types, over a wide range of geographical locations and climatic conditions. Sets of 10 minute APDs have been recorded at 2, 4, 8 and 16 MHz, in a 2.4 kHz bandwidth. Measurements were only conducted during daylight hours in periods of stable atmospheric conditions [Rawlins et al., 1986].

An example of these results is given in Figure 2. This shows a mean and an upper decile APD and a plot of standard deviation for the ship noise. Also shown are the mean and upper decile APDs for the expected atmospheric noise. These are derived from the atmospheric noise data and APD model given in Report 322 and provided here for reference in Annex 1 and Figure 3.

The aims of this continuing programme are to determine the significance of the man-made noise component, its statistical nature and the manner in which it may be affected by environmental changes.

2.4 Processing of Results

The APD provides a compact and informative representation of the noise conditions from which the performance of communications systems may be estimated, using methods similar to those suggested in Report 322 for atmospheric noise.

It is desirable to reduce the number of recorded APDs whilst retaining information describing the noise statistics within the APD period, as well as that describing the spread of conditions occurring over all the APDs. Each consistent set of APDs, that is, those recorded under the same conditions (see Section 2.1), is combined to produce a mean APD and an associated plot of standard deviation. This is accomplished by calculating the mean and standard deviation of the scattered APD ordinate values at each point along the probability axis. These have been found to have a distribution that is approximately normal and the procedures for calculating levels of confidence are therefore well defined.

2.5 The Application of Results

The results can be used to estimate the performance of a radio communications system in the noise conditions described by the mean APD and standard deviation, given in Figure 1.

The grade of service of a system is usually given in one of two ways (e.g. in Recommendation 339):-

(a) A signal-to-noise ratio for analogue voice systems.
(b) A bit-error-rate for digital systems.

In either case it is first necessary to determine a median received signal level that will provide the required grade of service, or better, for 50% of the time, that is, for a "time availability" of 50%.

It is generally accepted that the intelligibility of an analogue voice channel is much more seriously degraded by white Gaussian noise than by impulsive noise [Spaulding, 1982]. It is consistent with this that the grade of service signal-to-noise ratio (S) should be offset against the level of the noise APD Rayleigh component (E_R). This provides a value for the required mean received signal level (E_a) and an associated standard deviation (σ_a), shown in Figure 1.

For a digital system, the bit-error-rate must be converted to a probability value, that is, a value for $P(X \geqslant x)$ in Figure 1 (P_d). This is usually determined by the modem in use, for which an example, quoted in Report 322, equates the $P(X \geqslant x)$ value, for a symmetric binary NCFSK system, to twice the bit-error-rate [Montgomery, 1954]. The required mean received signal level (E_d) and an associated standard deviation (σ_d) are then read directly from the APD, as shown in Figure 1.

The standard deviations define the time availability of the required grade of service, or better, as it is effected by the variation in the noise. The analysis is then identical to that recommended in Report 322. The same set of uncertainties must be considered for the calculation of service probability estimates. Additionally it may be necessary to compute standard errors where the number of APDs is small.

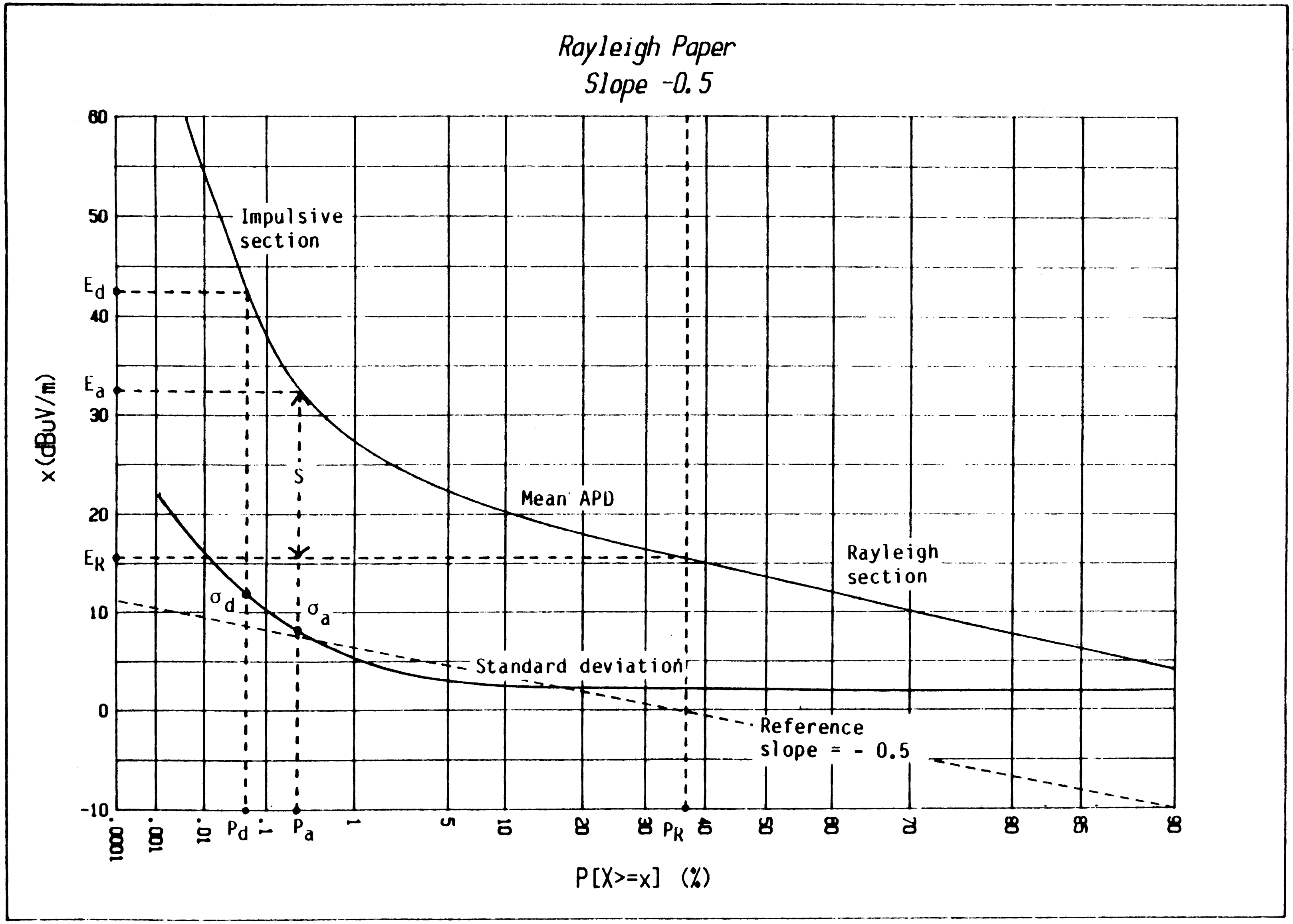

Figure 1. The application of ship noise APDs

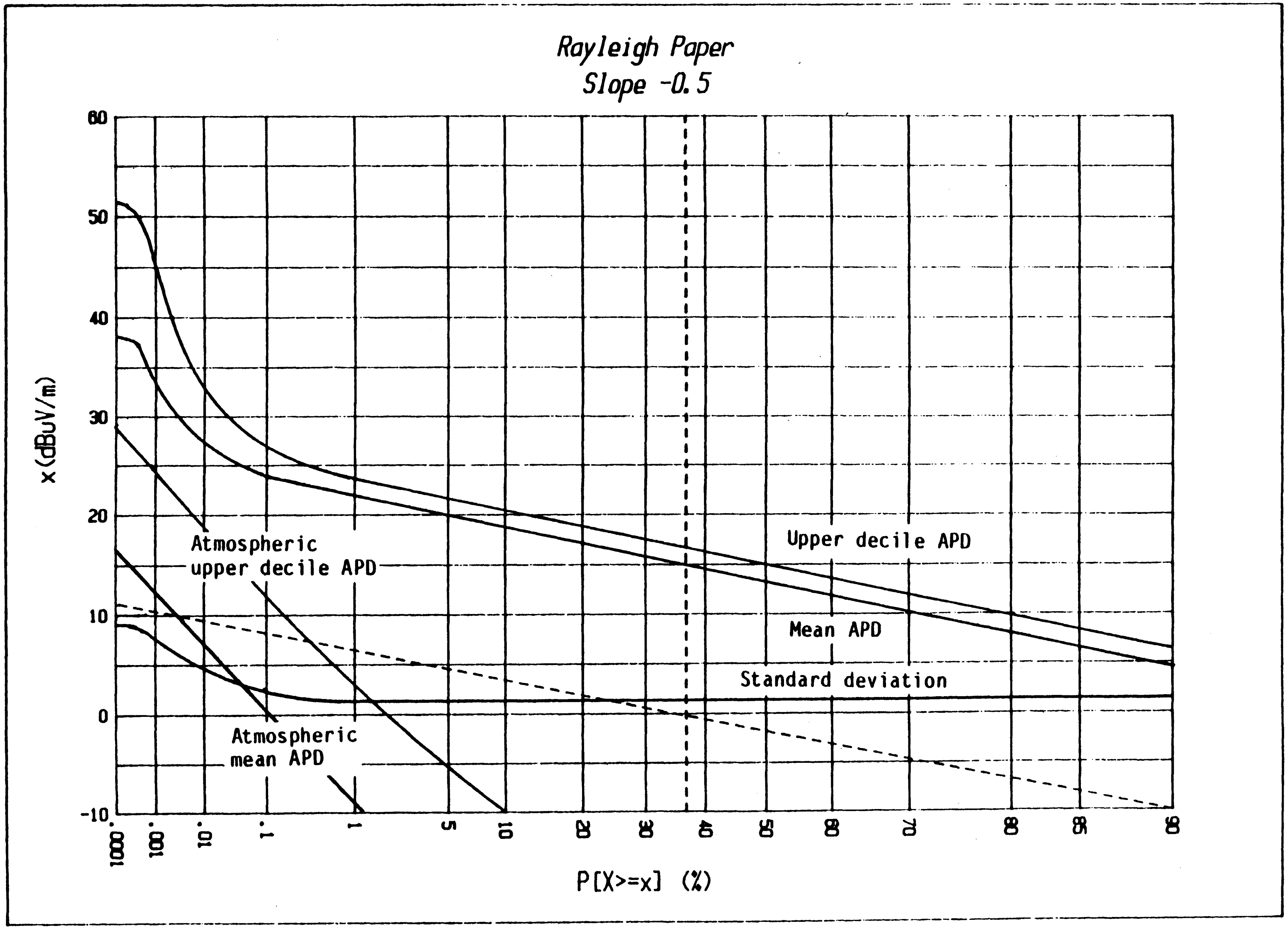

Figure 2. Ship noise APD for passenger ferry Tor Scandinavia, 4 MHz, bandwidth 2.4 kHz, North Sea, July 1985.

3. Identification of sources

It is usually difficult to associate noise events with specific shipboard activity.

A data logging system was developed to produce a real-time recording of 1 s r.m.s. noise field strength and V_d.

This provides rare event detection and enables the correlation of such events with the operation of particular equipment on board. The low data rate facilitates processing, storage and the subsequent analysis of long-term trends.

4. Conclusion

The APD model of noise envelope description is considered the most informative for the measurement of the noise environment on ships.

The results obtained from measurements on board ship can be employed in a similar way to the results given in Report 322.

Recommendation 339 (footnote 4 to Table I) suggests the root-sum-of-squares (rss) method for combining the median value of signal fading power and noise density fluctuation factors, the assumption being that these two mechanisms are statistically independent. Noise in this case is taken as atmospheric noise; however, on ships man-made noise may be significant. Assuming there is no correlation between the long-term fluctuation factors for signal fading, atmospheric noise and man-made noise, then a good estimate of the overall required signal-to-noise ratio should be obtained by using the method given in Recommendation 339 (footnote 4 to Table I).

A set of data similar to that presented in this paper could be produced using the time block structure of Report 322 given sufficient measurement time. With additional data, time series statistics could be produced in a simple format. These could be used with the APD to provide a complete description of the noise environment on board ships.

The use of the V_d monitor mentioned in § 3 could identify the sources and levels of radio noise occurrences on board ship.

REFERENCES

MONTGOMERY, G. F. [1954], A comparison of amplitude and angle modulation for narrow-band communication of binary-coded messages in fluctuation noise, Proc. IRE, Vol. 42, 447.

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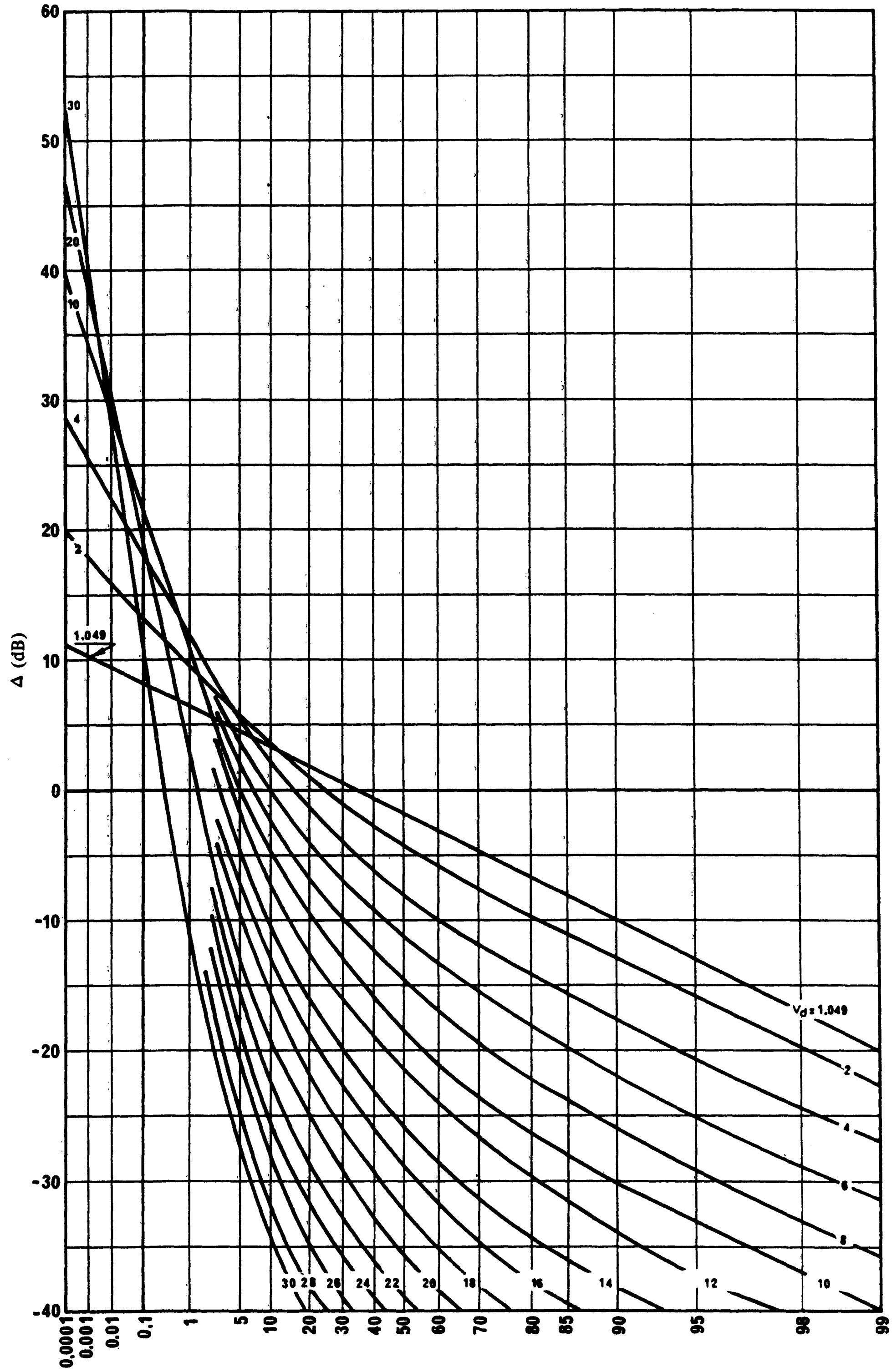

FIGURE 3 – *Atmospheric noise (see Report 322)*

$\Delta = A - A_{rms}$

ANNEX I

EXTERNAL NOISE LEVELS

(calculated using Report 322)

For frequencies below 20 MHz the principal external noise source is atmospheric noise. This Annex summarizes the calculation of external noise levels in European waters during highest noise and lowest noise conditions below 20 MHz.

TABLE I – *Highest noise*

(Between 2000 and 2359 h; Summer; North Sea, Baltic, Adriatic, Black Sea)

Frequency (MHz)		1	2	4	8	16
F_a (1)		80	70	61	50	30
E_n (2) (1 kHz)		14	10	7	3	−11
3 kHz bandwidth		5	5	5	5	5
10% time correction		8	7	5	4	5
5% time correction		10	9	7	5	7
1% time correction		14	13	9	7	9
Field strength (3 kHz bandwidth) (dB(μV/m))	50% time	19	15	12	8	−6
	10% time	27	22	17	12	−1
	5% time	29	24	19	13	1
	1% time	33	28	21	15	3

TABLE II – *Lowest noise*

(Between 0800 and 1200 h; Spring; North Sea)

Frequency (MHz)		1	2	4	8	16
F_a (1)		20	16	20	27	10
E_n (2) (1 kHz)		−45	−43	−33	−21	−31
3 kHz bandwidth		5	5	5	5	5
10% time correction		15.5	14	12	9	5
5% time correction		20	18	15	12	7
1% time correction		28	25	22	17	9
Field strength (3 kHz bandwidth) (dB(μV/m))	50% time	−40	−38	−28	−16	−26
	10% time	−24.5	−24	−16	−7	−21
	5% time	−20	−20	−13	−4	−19
	1% time	−12	−13	−6	1	−17

(1) F_a: effective antenna noise-factor which results from the external noise power available from a loss-free antenna ($F_a = 10 \log f_a$).

(2) E_n: root-mean-square noise field strength for a 1 kHz bandwidth (dB(μV/m)).