International Telecommunication Union

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Radiocommunication Sector of ITU

Report ITU-R M.2203
(11/2010)

Compatibility of amateur service stations with existing services in the range 415-526.5 kHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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REPORT ITU-R M.2203[1]

Compatibility of amateur service stations with existing services in the range 415-526.5 kHz

(2010)

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[1] This Report has been prepared in support of World Radiocommunication Conference 2012 (WRC-12) Agenda Item 1.23. In the event that WRC-12 does not make an allocation to the amateur service in this band, the Report will be suppressed.

Page

1 Introduction

This Report describes the results of ITU-R studies on the compatibility between the amateur service and incumbent services in the range 415-526.5 kHz.

2 Related ITU-R Recommendations, Reports and Handbooks

Recommendation ITU-R M.1732 − Characteristics of systems operating in the amateur and amateur-satellite services for use in sharing studies

Recommendation ITU-R P.525-2 – Calculation of free-space attenuation

Recommendation ITU-R BS.560 – Radio-frequency protection ratios in LF, MF and HF broadcasting

Recommendation ITU-R P.368-9 – Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz

Recommendation ITU-R P.372-10 – Radio noise

Recommendation ITU-R P.832-2 – World Atlas of Ground Conductivities

Recommendation ITU-R P.1147-4 – Prediction of sky-wave field strength at frequencies between about 150 and 1 700 kHz

ITU-R SG 3 Handbook – Ionosphere and its Effects on Radiowave Propagation Handbook, Edition 1998

Recommendation ITU-R F.1610 – Planning, design and implementation of HF fixed service radio systems

Recommendation ITU-R M.476 – Direct-printing telegraph equipment in the maritime mobile service

Recommendation ITU-R M.625-3 – Direct-printing telegraph equipment employing automatic identification in the maritime mobile service

Report ITU-R M.2200 − Characteristics of amateur radio stations in the range 415-526.5 kHz for sharing studies

Report ITU-R M.2201 – Utilization of the 495-505 kHz band by the maritime mobile service for the digital broadcasting of safety and security related information from shore-to-ships

Report ITU-R M.910-1 − Sharing between the maritime mobile service and the aeronautical radionavigation service in the band 415-526.5 kHz.

3 Abbreviations

ADF Automatic direction finding

AMS Aeronautical mobile service

ETSI European Telecommunications Standards Institute

ICAO International Civil Aviation Organization

ILS Instrument landing system

IMO International Maritime Organization

MSI Maritime safety information

NAVTEX Navigational text messages

NDB Non-directional beacons

4 Background

In the three ITU Regions, the band 415-526.5 kHz includes allocations to the maritime mobile and aeronautical radionavigation services. Maritime safety information (MSI) systems operate on 424 kHz, mainly 490 kHz and 518 kHz (NAVTEX), and there is a common primary mobile service allocation across the three Regions in the band 495-505 kHz[2].

Ground-wave radio propagation is primarily used in the LF, MF, and the lower part of the HF spectrum and allows for the long-distance transmission/reception of signals. These signals propagate along the curvature of the Earth, well beyond the optical horizon.

Ground-wave propagation is also dependent on the nature of the surface: signal attenuation is affected by ground conductivity and the dielectric constant of the Earth. Recommendation ITU-R P.832-2, gives the ground conductivities for various areas in the world. This Recommendations states "that for ground-wave field-strength prediction, it is essential to know the electrical characteristics of the ground along the path" and "that the most important electrical characteristic of the Earth for frequencies below 3 MHz is the conductivity".

5 Ground-wave and skywave propagation studies

5.1 Introduction

Ground-wave and skywave propagation studies were undertaken to determine the potential impact of proposed amateur stations in the range 415-526.5 kHz on incumbent services in this range. The first study used GRWAVE software[3] to estimate the field strength received from proposed amateur stations transmitting in this frequency range via ground-wave propagation while the second study uses a propagation model described in Recommendation ITU-R P.1147-4 to calculate the field strength received from proposed amateur stations in this range via skywave propagation. Both studies evaluate the compatibility of these proposed stations with existing services in this frequency range.

For the purposes of this simulation, an e.i.r.p. of 20 W (13 dBW) was chosen for amateur stations. No. 25.7 of the Radio Regulations (RR) states that the maximum power of amateur stations shall be fixed by the administrations concerned. As allowable transmitter power differs from administration to administration, this value may or may not be typical of transmissions in the amateur service; however, an analysis of antenna systems of the type which might be employed in the amateur service in the range 415 to 526.5 kHz which is documented in Report ITU-R M.2200, suggests that

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2 RR No. 5.82A limits the use of the band to radiotelegraphy and RR No. 5.82B requests that authorizations for use other than for the maritime mobile service ensure that no harmful interference is caused to this service.

3 GRWAVE (http://www.itu.int/oth/R0A0400000F/en) calculates ground-wave field strength as a function of frequency, antenna heights and ground constants for the frequency range 10 kHz 10 GHz. See Recommendation ITU-R P.368. GRWAVE was used to generate the propagation curves in § 5.2 of this Report.

such antennas would be relatively inefficient (in the range 4 to 20%). With a transmitter output power of 26.78 dBW and an effective gain of −13.78 dBi, the resulting e.i.r.p. would be 13 dBW.

5.2 Background: Ground-wave propagation

5.2.1 Ground-wave field-strength calculations

GRWAVE was used to simulate the field strength as a function of distance from an amateur station transmitting an e.i.r.p. of 13 dBW. As GRWAVE calculates the field strength emitted by one vertical monopole antenna with an output e.i.r.p. P = 1 kW (30 dBW), the simulated field strength was then adjusted downward by 17 dB to take into account the lower radiated power chosen for the purposes of this study.

5.2.2 Transmit antennas

Representative antenna types that could be deployed by operators in the amateur service are described in Report ITU-R M.2200. These antennas are the following types:

– a short vertical antenna with six ground radials;

– a short vertical antenna in the shape of an inverted L, also using six ground radials;

– an inverted-L antenna of moderate size using sixteen 30-metre radials;

– an inverted-L antenna of moderate size using sixteen 15-metre radials.

Vertically polarized signals are subject to far less ground-wave attenuation than horizontally polarized signals. As such, a vertical monopole antenna would simulate worst-case interference. This type of transmitting antenna is typical of what could be deployed in this frequency range by the amateur service.

5.2.3 Summary of parameters for ground-wave study

Ground-wave propagation over land and sea has been simulated using GRWAVE software. As ground wave propagates better over sea water than over fresh water, sea water of average salinity has been chosen. Similarly, as marshy or wet land is more conducive to propagation than dry or desert land, land with average conductivity has been chosen.

The electrical parameters of the surface of the Earth have been chosen as per Recommendation ITU-R P.368. These are average values for both seawater and land.

1. Sea water, average salinity: relative permittivity ε = 70.
2. Sea water, average salinity: conductivity σ = 5 S/m.
3. Land: relative permittivity ε = 40.
4. Land: conductivity σ = 0.03 σ/m.

5.2.4 Ground-wave simulations

Tables 1 and 2 show the results of the simulations using the permittivity and conductivity values above for land and sea for propagation distances of 10 km to 200 km and for receiver heights of 10, 15, 20 and 50 m. Simulation frequency is 500 kHz. The following sections summarize these simulations.

TABLE 1

Propagation over land transmitter height 15 m adjusted field strength

Distance (km)	Receiver height 5/10 m dB(µV/m)	Receiver height 15 m dB(µV/m)	Receiver height 20 m dB(µV/m)	Receiver height 50 m dB(µV/m)
10	72.17	72.45	72.45	72.1
20	65.9	66.39	66.39	65.83
30	62.13	62.81	62.81	62.06
40	59.38	60.25	60.25	59.31
50	57.22	58.3	58.3	57.15
60	55.39	56.63	56.63	55.31
70	53.79	55.2	55.2	53.71
80	52.37	53.95	53.95	52.29
90	51.07	52.82	52.82	51
100	49.88	51.79	51.79	49.81
110	48.78	50.85	50.85	48.71
120	47.74	49.97	49.97	47.67
130	46.77	49.15	49.15	46.69
140	45.84	48.38	48.39	45.77
150	44.95	47.64	47.63	44.88
160	44.1	46.93	46.93	44.03
170	43.29	46.26	46.26	43.21
180	42.5	45.61	45.61	42.42
190	41.73	44.99	44.99	41.66
200	40.99	44.39	44.39	40.91

TABLE 2

Propagation over sea transmitter height 15 m adjusted field strength (dB(µV/m)

Distance (km)	Receiver height 10 m dB(µV/m)	Receiver height 15 m dB(µV/m)	Receiver height 20 m dB(µV/m)	Receiver height 50 m dB(µV/m)
10	72.45	72.45	72.45	72.45
20	66.39	66.39	66.39	66.39
30	62.81	62.81	62.81	62.81
40	60.25	60.25	60.24	60.24
50	58.3	58.3	58.29	58.29
60	56.63	56.63	56.63	56.63
70	55.21	55.2	55.2	55.2
80	53.95	53.95	53.94	53.94
90	52.82	52.82	52.81	52.81

TABLE 2 (*end*)

Distance (km)	Receiver height 10 m dB(μV/m)	Receiver height 15 m dB(μV/m)	Receiver height 20 m dB(μV/m)	Receiver height 50 m dB(μV/m)
100	51.79	51.79	51.79	51.79
110	50.85	50.85	50.84	50.84
120	49.97	49.97	49.96	49.96
130	49.15	49.15	49.14	49.14
140	48.38	48.38	48.37	48.37
150	47.64	47.63	47.63	47.63
160	46.93	46.93	46.93	46.93
170	46.26	46.26	46.25	46.25
180	45.61	45.61	45.61	45.61
190	45	44.99	44.99	44.99
200	44.39	44.39	44.38	44.38

5.2.5 Ground-wave propagation discussion

5.2.5.1 Land

From the simulations over land, there is no change in field strength when the receive antenna is lower than the transmitting antenna – in other words, for receive antenna heights of 5 m and 10 m, the received field strength did not vary. The received field strength increased when the transmit and receive antennas were at equal heights (15 m) and when the receive antenna was at 20 m. The field strength in both these cases was identical – i.e. 72.45 dB (μV/m) at 10 km and 44.39 dB(μV/m) at 200 km. When the receive antenna height is at 50 m, the field strength at the receiver decreases to the same levels as the cases in which the receive antenna was at heights of 5 m and 10 m.

5.2.5.2 Sea

In contrast with the results obtained from the simulation over the sea the received field strengths remain constant, even when the receive antenna is much higher than the transmit antenna. Thus, for transmission over sea paths, the received field strengths would be constant, whereas for transmission over land paths, the values would diminish when the received antennas are higher than the transmit antennas. In terms of received field strengths for land and sea paths, the values are the same at receive antenna heights of 15 m and 20 m.

5.2.6 Ground-wave propagation conclusions

These simulations were done with conductivity and permittivity values that would render ground-wave propagation optimal. For example salt water and marshy land are more conducive to propagation than fresh water and desert land. If the propagation were to occur over desert land or fresh water, for example, the field strengths generated would be lower at the receive antenna.

Moreover, ground-wave propagation is likely to be continuous for the conditions of the particular propagation case, as opposed to skywave propagation, which varies according to a variety of factors discussed below. Therefore, a determination of compatibility between stations in the amateur service and primary services operating in the same range would have to evaluate received field strengths generated for the conditions of propagation (land vs. sea, for example) and ambient noise levels against the required protection ratios of the incumbent services – i.e. received interference vs. received wanted signal.

5.3 Background: Skywave propagation

Skywave propagation allows for the long-distance transmission of signals. Radio waves travel to the ionosphere, which is a region of charged particles created by the sun above the Earth's surface. Long-range radiocommunication at MF depends on the refractive impact of the ionized layers on radio waves. Radio waves sent towards space are bent back to the Earth by the ionosphere and these waves can be received hundreds or thousands of kilometres away from the transmission site.

Variations in the ionosphere, which affect radiowave transmission, result from changes in the sun's activity or from the rotation of the Earth around the sun. In the latter case, such variations can be fairly accurately predicted as they occur in cycles – i.e. daily (diurnal), seasonal and sunspot. In other cases, variations in the ionosphere cannot be accurately predicted as they result from the abnormal activity of the sun.

Daily variations play a large role in the effectiveness of skywave propagation: at MF, propagation is optimal six hours after sunset, with the hourly loss factor decreasing from 30 dB one hour after sunset to 0 dB six hours after sunset. Seasonal variations are also a large factor: at MF, skywave that propagates in temperate latitudes are strongest in spring and autumn and weakest in summer and winter. The overall variation may be as much as 15 dB at the lowest frequencies of the band[4].

To summarize, skywave transmission depends on a number of factors such as sunspot number, time of day, season of the year, and the latitude of transmission and reception of signals. Recommendation ITU-R P.1147-4 and the ITU-R Handbook [1998] both provide detailed discussions of the factors affecting propagation and variations in the field strength. Moreover, the Handbook proposes several prediction methods for calculating skywave field strengths for different regions in the world.

5.3.1 Skywave field-strength calculations

For the purposes of this study, worst-case factors will be used to derive the field strengths of RF communication around 500 kHz. In other words, when losses are minimal, the field strength should be highest, all other things being equal. It should be noted that all formulas and reference numbers in this section are from Recommendation ITU-R P.1147-4.

5.3.2 Solar activity/geomagnetic latitude L_r

In general, solar activity reduces night-time field strengths of MF transmissions. This reduction is a function of geomagnetic latitude, distance, frequency, and sunspot number. Night-time field strengths decrease rapidly with increasing latitude. Thus, at low latitudes, field strengths are greatest. In low latitudes (less than 40°) this reduction in field strength is believed to be negligible[5].

Thus, calculations were done at a geomagnetic latitude = 0° of the mid-point of the path and the loss factor that incorporates the effect of solar activity L_r = 0 dB.

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4 Recommendation ITU-R P.1147-4 – Prediction of sky-wave field strengths at frequencies between about 150 and 1 700 kHz, Annex 1.

5 ITU-R Handbook [1998] Ionosphere and its effects on radiowave propagation, p. 53.

5.3.3 Excess polarization coupling loss L_p

This loss occurs when waves enter the ionosphere and some of the incident power is absorbed. Further losses occur as only the vertical component of the wave, which is elliptically polarized as it leaves the ionosphere, couples with the receiving antenna. Polarization loss is small in temperate latitudes but larger in tropical latitudes. Such differences must be corrected. At MF, L_p for a single terminal is given by one of two formulas:

$$L_p = 180\,(36 + \theta^2 + I^2)^{-1/2} - 2 \text{ dB} \qquad \text{for} \quad I \leq 45°$$

$$L_p = 0 \qquad \text{for} \quad I > 45°$$

where I is the magnetic dip[6], N or S (degrees) at the terminal and θ is the path azimuth measured in degrees from the magnetic E-W direction, such that $|\theta| \leq 90°$. At the magnetic equator, the magnetic dip is 0°.

Calculations were done for $L_p = 0$ dB as this would give the worst-case value for field strength.

5.3.4 Hourly loss factor L_t

This loss is related to the time t in hours relative to the sunrise or sunset time as appropriate. From Fig. 3 of Recommendation ITU-R P.1147-4, losses are smallest 6 h after sunset and plateau at 0 dB. Conversely, losses start to increase about 1 h before sunrise and are greatest about 1 h after sunrise. Therefore, field strength will be greatest after sunset and for this study, $L_t = 0$ dB.

5.3.5 Slant propagation distance p

For paths longer than 1 000 km, the value of p (km) is approximately equal to the ground distance d (km) between transmitter and receiver. For shorter paths:

$$p = (d^2 + 40\,000)^{1/2}$$

This equation may also be used for paths of any length with negligible error.

5.3.6 Ionospheric loss factor L_a

This loss incorporates the effects of ionospheric absorption, focusing, terminal losses and loss between multi-hop paths.

$$L_a = k\,\sqrt{p/1\,000} \quad \text{dB}$$

and the basic loss coefficient k is given by:

$$k = (2\pi + 4.95 \tan^2 \Phi)$$

where Φ = the geomagnetic latitude of the mid-point of the path under study = 0 at the geomagnetic Equator (worst case).

$$k = 2\pi \text{ for } \Phi = 0°$$

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[6] The magnetic dip occurs as a magnet has a tendency to align itself with the Earth's magnetic lines of force. The magnet or compass will tend to point into the Earth due to the fact that the Earth's magnetic lines of force do not run parallel to the surface of the Earth, with the exception of the magnetic Equator.

5.3.7 Ground losses/sea gain G_s

The sea gain is the additional signal gain when one or both terminals are situated near the sea. This value does not apply to propagation over fresh water.

The following two formulas for G_S are for a single terminal:

$$G_S = G_O - c_1 - c_2 \text{ for } (c_1 + c_2) < G_O$$

$$G_S = 0 \text{ for } (c_1 + c_2) \geq G_O$$

If both terminals are near the sea, G_S is the sum of the values for the individual terminals. G_O is a function of distance and c_1 and c_2 are correction factors. From Fig. 2 in Recommendation ITU-R P.1147-4, the sea gain is approximately 8.5 dB at 2 000 km. For two terminals located near the sea, this value would be double. Again, this is a worst-case assumption.

5.3.8 Skywave calculations

Recommendation ITU-R P.1147-4 provides a prediction procedure to be used for calculating field strength for path lengths between 50-12 000 km. The predicted skywave field strength is given by the following formulae:

$$E = V + G_s - L_p + A - 20 \log(P) - L_a - L_t - L_r$$

The values input for parameters given below were derived in § 9.10. The power (13 dBW) of the amateur station is the same as used in the ground-wave study.

where:

E : annual median field strength dB(μV/m)

V : transmitter (dB above a reference cymomotive force of 300 V)

G_s : sea-gain correction loss (dB) for two terminals

L_p: polarization-coupling loss (dB): 0 dB

A : MF constant 107 dB

P : slant distance $(d^2 + 4h^2)^{½}$ for night-time reflecting layer height h = 100 km

L_a : ionospheric loss factor k* $(p/1\ 000)^{½}$ where $k = (2\pi + 4.95 * (\tan \Phi)^{2})$

L_t : hourly loss factor (dB) = 0 dB for 6 h after sunset

L_r : loss factor incorporating effect of solar activity = 0 dB at MF Φ < 45 worst case is SSN = 0.

The Handbook states that "the annual median value of skywave field strength is generally used to determine a station's skywave services area. Field strength exceeded for small percentages of the time is needed to study interference"[7].

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7 ITU-R Handbook [1998] Ionosphere and its effects on radiowave propagation, § 5.2.5, Fig. 5.6.

Recommendation ITU-R P.1147-4 provides formulas for predicting the day-to-day and short-period variations of night-time field strengths. The difference Δ(*w*), where *w* is typically 10 or 1, at a specific time relative to sunset or sunrise, between the field strength exceeded for *w*% of the time and the annual median value is given by the following equations, respectively:

At MF:

$$\Delta(10) = 0.2\ |\Phi| - 2\ \text{dB}$$

$$\Delta(1) = 0.2\ |\Phi| + 3\ \text{dB}$$

In the first equation, Δ(10) is greater than or equal to 6 dB but less than or equal to 10 dB. In the second equation, Δ(1) is greater than or equal to 11 dB but less than or equal to 15 dB.

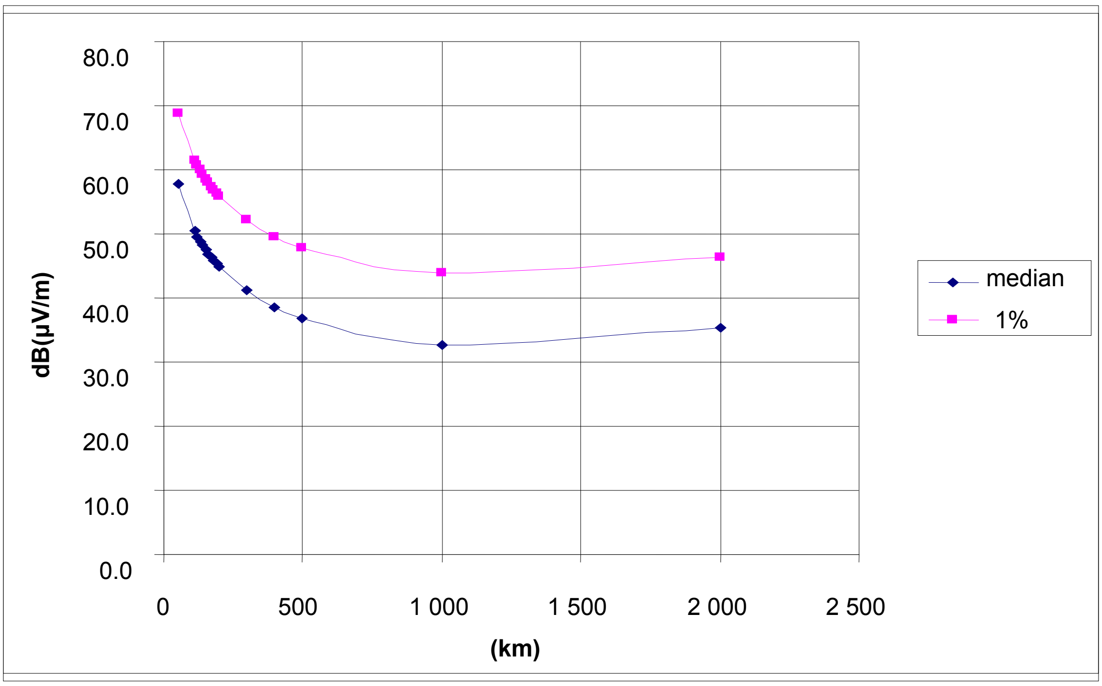
For this study, at low geomagnetic latitudes, field-strength values exceeded for 1% and 10% of the time are about 11 dB and 6 dB, respectively, stronger than the median value.

$$\Delta(10) = 6\ \text{dB and } \Delta(1) = 11\ \text{dB}$$ [8]

Table 3 provides a table of median field strengths and field strengths that are exceeded for 1% and 10% of the time up to 2 000 km for different slant distances. Figure 1 provides an illustration of the field strength up to 2 000 km for both median values and field strengths that exceed the median value for 1% of the time.

FIGURE 1

MF skywave field strength



[8] ITU-R Handbook [1998] Ionosphere and its effects on radiowave propagation, p. 58.

TABLE 3

Skywave field strengths dB(μV/m)

Distance (km)	Slant distance (km)	Median field strength dB(μV/m)	Field strength 1% of time dB(μV/m)	Field strength 10% of time dB(μV/m)
50	206	57.8	68.8	63.8
110	228	50.4	61.4	56.4
120	233	49.6	60.6	55.6
130	239	48.9	59.9	54.9
140	244	48.2	59.2	54.2
150	250	47.5	58.5	53.5
160	256	46.9	57.9	52.9
170	262	46.4	57.4	52.4
180	269	45.8	56.8	51.8
190	276	45.3	56.3	51.3
200	283	44.8	55.8	50.8
300	361	41.1	52.1	47.1
400	447	38.6	49.6	44.6
500	539	36.8	47.8	42.8
1 000	1020	32.8	43.8	38.8
2 000	2010	35.3	46.3	41.3

5.3.9 Skywave propagation summary

This study provides a worst-case analysis for predicting field strengths due to amateur stations using skywave propagation. If any of the following conditions occur:

– losses are not presumed to be zero or minimal;

– the midpoint of the path of propagation is assumed at higher latitudes, away from the geomagnetic Equator;

– path termination points are away from coastal locations;

– sun spot numbers are larger than zero;

– prediction is for local time other than 6 h after sunset;

then predicted field strengths would be lower than those given in Fig. 1. For example, day-time propagation losses could be up to 30 dB lower.

5.4 Discussion of results of ground-wave and skywave studies

A determination of compatibility between stations in the amateur service and those of other services operating in the same frequency range would take into account received noise levels and required protection ratios, i.e. received interference vs. received wanted signal as determined by incumbent services and analysed in subsequent sections of this Report.

5.5 Conclusions for ground-wave and skywave propagation

The ITU-R Handbook [1998] defines (annual median of the field strength) as the annual median (i.e. the value exceeded during 50% of the nights of a year) of the half-hourly medians of the field strength recorded every night of the year during half an hour centred on the hour considered.

Skywave field strength calculations are probabilistic predictions and actual values will change as a function of time of day and sun spot number for a fixed location, whereas the ground-wave field strengths are more likely to be continuous for the conditions of the particular propagation case. In the study undertaken above, worst-case scenarios were assumed, with the result that propagation conditions were optimal. The median field strengths would diminish significantly if any of the above assumptions changed – e.g. daytime as opposed to night-time propagation. Ultimately, each service will have to determine the probabilistic levels of interference that its stations could tolerate – i.e. field strengths that are exceeded 1% or 10% of the days of the year.

ITU-R Working Party 3L confirmed that the propagation studies used the most appropriate texts and that the latest versions are quoted in this Report. In addition it was stated that the empirical method in Recommendation ITU-R P.1147-4 has been primarily of concern to the broadcasting service and the coefficients, etc., have been optimised for the MF and LF broadcast bands. The range 415-526.5 kHz is just below the lower edge of the MF broadcast band but no further information is currently available which might improve the method for this frequency range.

6 Aeronautical radionavigation service

Aeronautical radionavigation in the frequency range under consideration is provided by aeronautical non-directional beacons (NDB) that act as non-precision approach aids and compass-type locators, and are used at ranges up to 160 km. Some NDBs are "stand-alone" types while others are associated with an instrument landing system (ILS). NDBs typically employ a 25 to 100 W transmitter – generally using double-sideband amplitude modulation with a modulating tone, e.g. 400 or 1 024 Hz. The antenna is typically a "T" with a height of 10 to 17 m.

The following sections on NDB systems analysis represent two methods. Section 6.1 describes an analysis where coexistence between amateur stations and NDB systems is not feasible while § 6.2 presents an analysis where co-channel existence is feasible under certain constraints.

While the long-term goal may be to remove NDBs from use, this is unlikely to be achieved in the near future. It is therefore essential to ensure that any new allocation does not adversely affect existing NDB operations.

6.1 Aeronautical non-directional beacons

6.1.1 Background

Amateur stations generally do not operate on assigned frequencies but dynamically select frequencies within an allocation to the amateur service, using listen-before-talk protocols. Many amateur service allocations are shared with other radio services and amateur operators are aware of the sharing conditions. It can therefore be assumed that within the coverage range of an NDB, an amateur operator would detect and be aware of the NDB and would be unlikely to transmit on an NDB frequency. However, in the case of a safety of life service, a worst-case scenario of co-frequency operation must be assumed. In the following analysis it will also be assumed that the aircraft using the NDB is located in the fringe area of the NDB and within line-of-sight (LoS) of the amateur station.

Based on ICAO provisions, the minimum value of field strength in the designated operational coverage area of an NDB should be 70 µV/m. Taking into account a 3 dB allowable degradation in NDB beacon transmit power, minimum field strength of 50 µV/m at the edge of the service area is suggested for the initial studies.

NDB systems are normally designed so that the interfering field strength at an aircraft receiver, caused by the signal from an adjacent NDB transmitter operating on the same frequency, is at least 15 dB below the desired signal strength. In the case of co-frequency interference from transmissions of another service, a safety margin of 6 dB plus a further 6 dB to allow for multiple interfering sources would increase the total required protection ratio to 27 dB. Maximum acceptable co-frequency interfering field strength from an amateur station would therefore be 27 dB below 50, or 2.24 µV/m.

6.1.2 Analysis

Signal strength at an aircraft NDB receiver due to an amateur station transmitter, for LoS propagation, can be determined using the standard formula[9] for free space loss:

$$E = \frac{1}{d}\sqrt{30P}$$

where:

d : the separation distance (m)

E : the field strength (V/m) at the receiving antenna

P : radiated power (e.i.r.p.) (W).

Converting into more useful units gives:

$$d = \frac{5477}{E}\sqrt{GPt}$$

where:

d : the separation distance (km)

E : the field strength (µV/m) at the aircraft antenna

Pt : the output power of the amateur station transmitter (W)

G : numerical gain of amateur station transmitting antenna = antilog (gain in dB)/10.

Table 4 gives minimum separation distances for a range of amateur transmitter power levels necessary to ensure that an interfering signal at the aircraft receiving antenna does not exceed 2.24 µV/m, for a transmitter antenna gain of −10 dB.

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[9] Recommendation ITU-R P.525.

TABLE 4

Calculated minimum separation distance

Pt (W)	d (km)
0.2	346
0.1	245
0.02	110
0.002	35

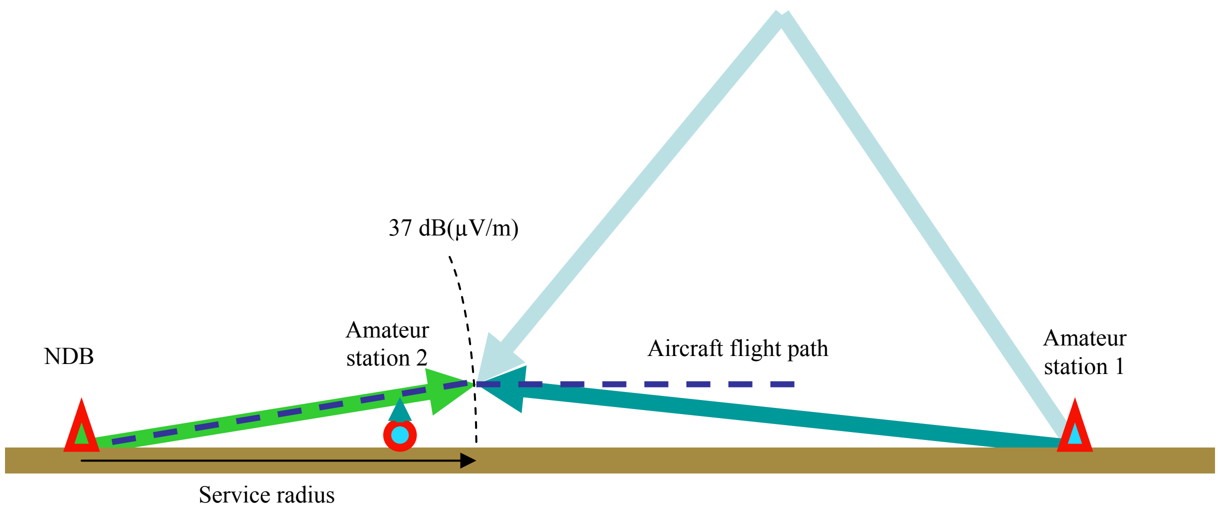
6.1.3 Conclusion – Co-frequency coexistence

In a worst-case scenario of an aircraft in the immediate vicinity of an amateur station located at the edge of an NDB service area, a co-frequency amateur transmitter with an output power level exceeding a few milliwatts would result in unacceptable interfering field strength at the aircraft NDB receiving antenna. Therefore, co-frequency coexistence between amateur stations and NDB systems is unlikely.

6.2 General analysis of protection of NDB/ADF systems

FIGURE 2

NDB service range (40 to 100 km)



6.2.1 Amateur station transmitting at the edge or within the NDB service region

Considering a general scenario where an aircraft that stays above a fictitious cone centred on the NDB, with a height of zero at centre and 300 m at the edge of the NDB's service region. Thus, for a possible over flight above an amateur operating inside the service region, such as the amateur station 2 in Fig. 1, the ratio:

$$\frac{\text{Distance between aircraft and amateur station}}{\text{Distance between the aircraft and NDB}}$$

is always larger than the ratio of the height of the cone at the radius of the edge of the service region (300 m) and the service radius (40-100 km). When considering short distances the ground-wave absorption can be ignored. Since the field strength scales inversely linear with distance the ratio of the field strength of desired (NDB) to undesired (amateur) signals will be worst where the amateur transmitter is located at the edge of the service region. Thus, if the calculations demonstrate that an amateur station can operate at the edge of the service region without the need for a protection zone it follows that the station can also operate anywhere within the service region without causing interference.

6.2.2 Amateur station transmitting far outside of NDB service region

In this case there is a need to consider interference from both ground-wave propagation and night-time skywave propagation to calculate the minimum distance between the amateur station and the edge of the NDB service region in order to protect the latter.

ICAO Annex 10 of volume I, 3.9.1.1 sets a requirement of 37 dB(μV/m) for the minimum usable NDB signal, and defines the following terms:

D : desired NDB signal field strength

U : undesired NDB signal field strength, i.e. a nearby NDB

I : interference signal field strength

df : frequency separation.

– The ICAO reference sets the ratio of D/U as 15 dB for co-channel operation of two NDBs.
– Receiver selectivity data is taken from "Description of NDB and ADF operation and definition of protection requirements"[10].
– The aircraft's altitude is 300 m or more above ground level.
– The interfering transmit antenna (amateur station) is assumed to have a vertical radiation component (e.g. magnetic loop).

The additional safety margin of 12 dB (specified by one administration) is derived from 6 dB for multiple interference sources and an additional 6 dB for modelling uncertainties.

6.2.3 Generation of NDB protection distances using ground-wave and skywave propagation analysis

For distances greater than 10 km one can graphically interpolate the 500 kHz curves in Recommendation ITU-R P.368-9.

For short distances (less than about 3 km) the ground-wave attenuation becomes negligible. Under these conditions the curves on Recommendation ITU-R P.368-9 approach the inverse-distance line for unobstructed free-space propagation. The underlying 1/r formula can also be applied to slant vertical ranges, and thus used to take into account a minimum altitude of an aircraft carrying an ADF receiver.

Skywave calculation should be performed according to the Recommendation ITU-R P.1147 for calculating the maximum field strength, I_{max}:

$$I_{max}\ (\text{dB}(\mu\text{V/m})) = e.r.p.\ (\text{dBW}) + 77 - 20 \log (r'\ (\text{km})) - a\, r' - 3$$

where:

r': is the distance between the aircraft and the amateur service station via the ionosphere signal path and is given by:

$$r' = \sqrt{(r^2 + 4h^2)}$$

[10] Darren Roberts [July, 2000] UK Civil Aviation Authority Report 8AP/88/08/04.

where:

h : is the height of the ionosphere (100 km) and r is the distance between the amateur service station and the aircraft;

a = 10.29 dB/ 1 000 km for average ionospheric conditions.

Table 5 reflects protection distances for different frequency offsets and amateur service station radiated power. The night-time distance is the larger of the groundwave or skywave mode of propagation path that satisfy the protection objective. The minimum distance from amateur station to edge of NDB service range (day/night), including the 12 dB additional safety margin, is as follows: The minimum distance from amateur station to edge of NDB service range (day/night), including the 12 dB additional safety margin, is as follows:

Recommendation ITU-R P.368-9, 500 kHz, ε_r = 30, σ = 10 mS/m, e.i.r.p. (W), e.m.r.p. (dB(kW)).

TABLE 5

NDB protection distances

df	***I/D***	U_{max}	**1.6**	**5.2**	**16.2**	**52.5**	**164**	**Watts**
(kHz)	**(dB)**	**(dB(μV/m))**	**−32.6**	**−27.6**	**−22.6**	**−17.6**	**−12.6**	**dB(kW)**
> 7	58	95	0	0	0.3	0.6	1.2	km
6	50	87	0.1	0.5	0.9	1.7	3.1	km
5	35	72	1.7	3.1	5.4	9.4	16	km
4	20	57	9.4	16	26	41	61	km
3	5	42	41	61	88	125	165	km
2	−10	27	125	165	220/288	270/492	340/758	km
1	−22	15	240/364	300/589	370/888	440/1 284	500/1 799	km
0	−27	10	300/589	370/888	440/1 284	500/1 799	580/2 458	km

Table 5 calculations are based on a ground conductivity of 10 mS/m, a worst-case value. Mountainous areas have values in the order of 1 mS/m. A ground conductivity of 3 mS/m reduces the radius of the protection zone by up to 50%.

From the Table 5 of NDB protection distances, the distances between the aircraft and the amateur station were projected onto the ground. If this minimum distance is less than the assumed altitude (300 m), no protection distance is required and a value of zero km was entered in the table.

Ground conductivity data can be found in Recommendation ITU-R P.832-2.

6.2.4 Example of typical protection zone areas

The following maps show the assessed protection zones for a specific NDB (Zilina, Slovakia, 508 kHz, coverage 25 nm (46 km)) for different frequency separations with constant ground conductivity 10 mS/m (worst case).

FIGURE 3

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

6.2.5 European assignments to NDBs in the frequency range from 200 kHz to 1 000 kHz

Figures 9 and 10 show the frequency assignments to NDBs in Europe as extracted from "Table Com 4 – Frequency assignments of terrestrial navigation aids in the European area", ICAO, European and North Atlantic Office, Edition 2006[11].

EUR FASID, WD, Part IV-CNS, Supplement, Table COM4, #Foreword".

EUR FASID, WD, Part IV-CNS, Supplement, Table COM4, AppA".

EUR FASID, WD, Part IV-CNS, Supplement, Table COM4, AppB".

NDBs are concentrated between approximately 280 kHz and 430 kHz to minimize the negative influence of skywave propagation.

Many of the 2006 listed NDBs have been decommissioned meanwhile and the process of decommissioning of NDBs continues steadily. The remaining NDBs in the upper part of the segment 415-526.5 kHz are situated in the south eastern part of Europe. Some countries in Region 3 have NDB assignments above 511 kHz, and request that these primary radionavigation assignments be protected.

[11] http://www.paris.icao.int/documents_open/files.php?subcategory_id=36.

FIGURE 9

Number of European NDB-assignments per channel (overview)

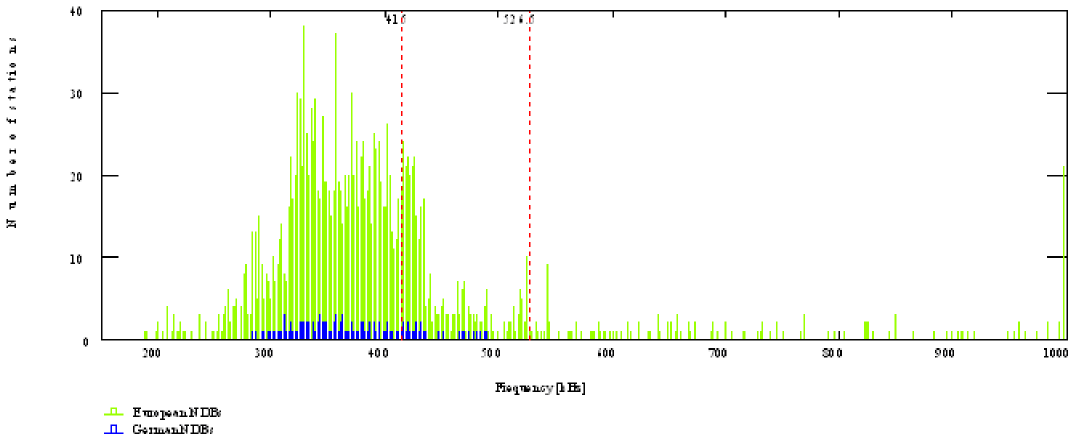
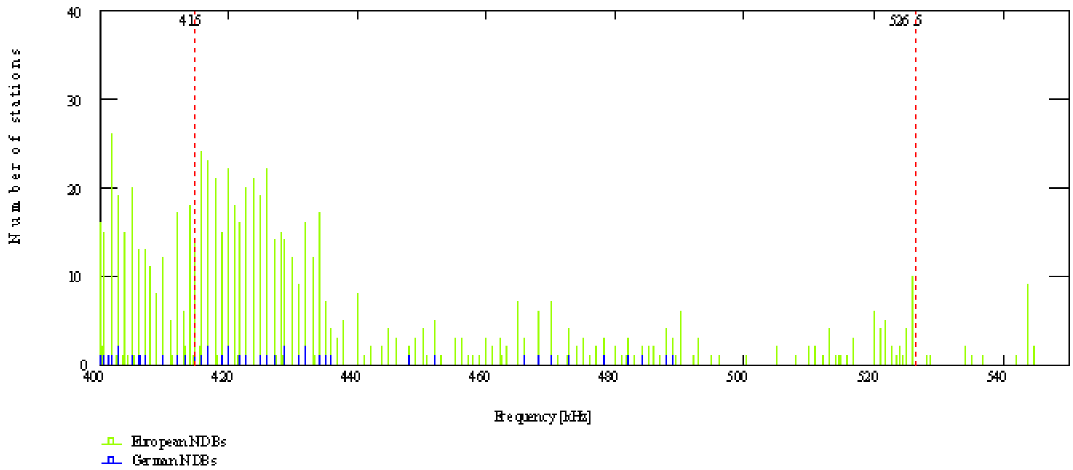


FIGURE 10

Number of European NDB-assignments per channel, near the frequency band under consideration



6.2.6 Conclusion

Protection of applications of the aeronautical radionavigation service could be achieved by appropriate geographical and frequency separation along with restricting the power of the amateur transmissions. As well, depending upon the number of affected NDBs operating within their territory, administrations may choose to effect such protection in different ways. Examples of such locally administered protection could include exclusion zones, restrictions of certain frequencies and limitations on transmitter powers.

7 Maritime mobile service

7.1 NAVTEX

NAVTEX is an international automated direct-printing service defined in Recommendations ITU-R M.476-5 and ITU-R M.625-3 (100-baud FSK 170-Hz shift) for delivery of navigational and meteorological warnings and forecasts as well as urgent marine safety information to ships. Worldwide, MF transmissions are authorized on 424 kHz (local language), mainly 490 kHz (local language), and 518 kHz (English).

7.1.1 Characteristics of NAVTEX system

The NAVTEX system has the following characteristics:

– Class of emission = F1B.

– Modulation = FSK frequency shift 170 Hz with forward error correction.

– Signalling rate = 100 Baud.

– The receiver 6 dB bandwidth is between 270 and 340 Hz[12].

7.1.2 NAVTEX protection criteria

The values of the minimum field strength have been extracted from the ITU Document – Frequency Plans and related procedures for the mobile and radionavigation terrestrial services. Minimum field strength to be protected:

– 31.5 dB(µV/m) north of and on parallel 30° North;

– 51.5 dB(µV/m) south of parallel 30° North,

for F1B emissions in the bands 415-435 kHz and 435-526.5 kHz.

The output power of a NAVTEX station is determined by the need to achieve the required minimum signal strengths of 31.5 dB(µV/m) or 51.5 dB(µV/m) at the fringe of a specified NAVTEX service area.

7.1.3 Selectivity of a NAVTEX receiver

The receiver selectivity may be found in standard ETSI ETS 300 065-1 V1.2.1 (2009-01)[13] by deduction from the test method to ensure a given maximum character error ratio.

7.1.4 Analysis

Calculations of the required geographical separation as a function of frequency separation and power (e.m.r.p.), is based on the minimum field strength of 31.5 dB(µV/m).

This is a worst-case figure as a level of 51.5 dB(µV/m) is required for near tropical areas. For this calculation, in addition to taking the more stringent level of 31.5 dB(µV/m), two arbitrary additional protection levels 14 dB and 20 dB lower than the most stringent level 31.5 dB(µV/m) are used that should be compared with the 8 dB margin requirement by IMO Resolution A.801(19), Annex 4.

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[12] Recommendation ITU-R M 625-3 – Direct-printing telegraph equipment employing automatic identification in the maritime mobile service.

[13] ETSI Standard can be downloaded at www.etsi.org.

The calculation has also used a ground-conductivity value of 5 S/m, the value for sea water. Typically, the path will not be entirely over water causing the ground-wave signal to be attenuated more quickly with distance.

The geographical separation required for these three levels of protection is assessed directly from the relevant graphs, see Fig. 2 taken from Recommendation ITU-R P.368-9, where the frequency has been taken as 500 kHz, permittivity ε_r is 70, and the ground conductivity (ν), as previously mentioned is 5 S/m.

In the MF band the atmospheric noise floor is the limiting factor – not the receiver sensitivity. The definition of the minimum field strengths (31.5 dB(μV/m) respectively 51.5 dB(μV/m)) is based on this atmospheric noise floor.

ε_r: relative permittivity

σ: ground conductivity (S/m)

e.r.p.: effective radiated power

e.m.r.p.: effective monopole radiated power

df: frequency separation

* : interpolated receiver selectivity for 2 kHz offset

D: desired signal

I: interfering signal

U_{max}: maximum field strengths of undesired signal

n/*m*: distance day/night (km).

7.1.5 Results of calculations for different protection criteria

TABLE 6

Protection criteria −6 dB (co-channel rejection from ETSI ETS 300 065-1 V1.2.1 (2009-01)

Recommendation ITU-R P.368-9, 500 kHz, ε_r = 70, σ = 5 S/m

e.i.r.p. (W), e.m.r.p. dB(kW)

df	***I*/*D***	U_{max}	**1.6**	**5.2**	**16.2**	**52.5**	**164**	**Watts**
(kHz)	**(dB)**	**(dB(μV/m))**	**−32.6**	**−27.6**	**−22.6**	**−17.6**	**−12.6**	**dB(kW)**
3	70	101.5	0.06	0.1	0.2	0.3	0.6	km
2*	55	86.5	0.3	0.6	1.1	1.9	3.3	km
1	40	71.5	1.9	3.3	5.8	10	19	km
0.5	20	51.5	19	35	60	100	160	km
0.5	−6	25.5	270	370	490	600	750/900	km

TABLE 7

Protection criteria −8 dB (co-channel rejection from NAVTEX-Manual)

Recommendation ITU-R P.368-9, 500 kHz, ε_r = 70, σ = 5 S/m

e.i.r.p. (W), e.m.r.p. dB(kW)

df	***I/D***	U_{max}	**1.6**	**5.2**	**16.2**	**52.5**	**164**	**Watts**
(kHz)	**(dB)**	**(dB(µV/m))**	**−32.6**	**−27.6**	**−22.6**	**−17.6**	**−12.6**	**dB(kW)**
3	68	99.5	0.07	0.13	0.26	0.42	0.75	km
2*	53	84.5	0.42	0.75	1.3	1.95	2.8	km
1	38	69.5	2.5	4.6	7	13.5	24	km
0.5	18	49.5	24	46	76	130	200	km
0.5	−8	23.5	320	420	540	670/700	800/1 050	km

TABLE 8

Protection criteria −14 dB (co-channel rejection from NAVTEX-Manual + 6 dB extra margin)

Recommendation ITU-R P.368-9, 500 kHz, ε_r = 70, σ = 5 S/m

e.i.r.p. (W), e.m.r.p. dB(kW)

df	***I/D***	U_{max}	**1.6**	**5.2**	**16.2**	**52.5**	**164**	**Watts**
(kHz)	**(dB)**	**(dB(µV/m))**	**−32.6**	**−27.6**	**−22.6**	**−17.6**	**−12.6**	**dB(kW)**
3	62	93.5	0.17	0.27	0.49	0.85	1.6	km
2*	47	78.5	0.77	1.35	2	4.8	8.5	km
1	32	63.5	4.2	8.3	17	27	55	km
0.5	12	43.5	48	80	150	210	320	km
0.5	−14	17.5	440	550	680	820/1 100	950/1 600	km

TABLE 9

Protection criteria –20 dB (co-channel rejection from NAVTEX-Manual + 12 dB extra margin)

Recommendation ITU-R P.368-9, 500 kHz, ε_r = 70, σ = 5 S/m

e.i.r.p. (W), e.m.r.p. dB(kW)

df	***I/D***	U_{max}	**1.6**	**5.2**	**16.2**	**52.5**	**164**	**Watts**
(kHz)	**(dB)**	**(dB(µV/m))**	**−32.6**	**−27.6**	**−22.6**	**−17.6**	**−12.6**	**dB(kW)**
3	56	87.5	0.3	0.5	0.94	1.8	3	km
2	41	72.5	1.6	3	5.2	9.8	16.5	km
1	26	57.5	9.5	18	29.5	52	90	km
0.5	6	37.5	85	130	210	340	450	km
0.5	−20	11.5	590	700/850	850/1 200	1 000/1 700	1 120/2 300	km

It can be noted that with a frequency separation of 3 kHz even with much higher protection criteria (compared with the −8 dB requirement of IMO Resolution A.801(19), Annex 4) the needed geographical separation is only slightly increased.

From ETSI ETS 300 065-1 V1.2.1 (2009-01) *(in italics):*

6.2 Interference rejection and blocking immunity

6.2.2 Method of measurement

The wanted signal shall be the normal test signal at a level of 20 dBµV.

The unwanted signal shall be unmodulated.

For the frequency ranges 517 kHz to 517,5 kHz and 518,5 kHz to 519 kHz, the level shall be 40 dBµV.

For the frequency ranges 515 kHz to 517 kHz and 519 kHz to 521 kHz, the level shall be 60 dBµV.

For the frequency ranges 100 kHz to 515 kHz, 521 kHz to 30 MHz, 156 MHz to 174 MHz and 450 MHz to 470 MHz, the level shall be 90 dBµV.

6.2.3 Limit.

The unwanted signal shall not induce a character error ratio of more than 4 x 10^{-2}.

6.3 Co-channel rejection.

6.3.2 Method of measurement.

The wanted signal shall be the normal test signal at a level of 20 dBµV.

The unwanted signal shall be unmodulated at a level of 14 dBµV at the nominal receiver frequency.

6.3.3 Limit.

The unwanted signal shall not induce a character error ratio of more than 4 × 10^{-2}.

7.1.6 Selectivity curve data

Based on above test specification ETSI 300 065 *(6.2)* and a centre frequency of 518 kHz.

≥ 0.5 kHz: ratio unwanted/wanted signal ≥ 20 dB.

≥ 1 kHz: ratio unwanted/wanted signal ≥ 40 dB.

≥ 3 kHz: ratio unwanted/wanted signal ≥ 70 dB.

By interpolation the value for 2 kHz was estimated.

The receiver test specification ETSI 300 065 *(6.3)* requires to have the signal strength of an unmodulated (undesired) signal on a same frequency 6 dB below of that of a desired signal. According to publications of the United States Coast Guard, the receiver bandwidth (6 dB) is typically between 270 and 340 Hz.

7.1.7 IMO NAVTEX Manual requirements

Quotes from the IMO NAVTEX Manual[14] *(in italics)*:

ANNEX 5

IMO RESOLUTION A.801(19), Annex 4

[14] http://www.imo.org/includes/blastDataOnly.asp/data_id%3D9810/1122.pdf.

The ground-wave coverage may be determined for each coast station by reference to CCIR Recommendation 368 (replaced by Recommendation ITU-R P.368) and CCIR Report 322 (replaced by Recommendation ITU-R P.372) for the performance of a system under the following condition:

Frequency – 518 kHz.

Bandwidth – 500 Hz.

Propagation – ground-wave.

RF S/N in 500 Hz bandwidth – 8 dB.

Percentage of time – 90.

Bit error ratio 1×10^{-2}.

The NAVTEX Manual requires for 90% of time within a bandwidth of 500 Hz a RF *S*/*N* ratio of −8 dB for a maximum bit error rate of 1 x 10^{-2}.

7.1.8 Conclusion

The analysis in § 7.1.4 does not account for frequency roll-off of the amateur transmissions in selecting required geographical/frequency separation distance. When considering antenna roll-off for the amateur antennas the worst case decade value of 3.75 kHz (375 Hz x 10) should be considered and there is potentially enough power at such frequency separation to cause interference into NAVTEX operations. The interference can be mitigated. This can be accounted for through geographical or frequency separation, however given the need to ensure protection of NAVTEX operations it is better to account for this through frequency separation since protection through geographical separation can only be accounted for in Administration regulations.

Taking into account all these factors, a secondary allocation to the amateur service should be separated by more than 3 kHz from a NAVTEX operating frequency.

7.2 Future maritime systems

Maritime data broadcast systems are contemplated for the frequency range 495-505 kHz for the transmission of port safety and security data.

7.2.1 Characteristics of future maritime systems

7.2.1.1 General characteristics of the future maritime systems

The future maritime system should have the following characteristics:

– Class of emission = F1D.

– Modulation = up to 64-QAM.

– Signalling rate = up to 47.4 kbit/s.

– The receiver 6 dB bandwidth should be between 9.5 and 10.5 kHz.

7.2.1.2 Transmitter emissions mask for the data channel using 64-QAM

Transmitter emissions mask requirements for the 10 kHz channel 495 kHz to 505 kHz

For transmitters designed to operate with a 10 kHz channel bandwidth, any emission must be attenuated below the peak envelope power (*P*) of the transmitter as follows (Fig. 11):

1. On any frequency from the centre of the authorized bandwidth f_0 to 4.5 kHz removed from f_0 : 0 dB.

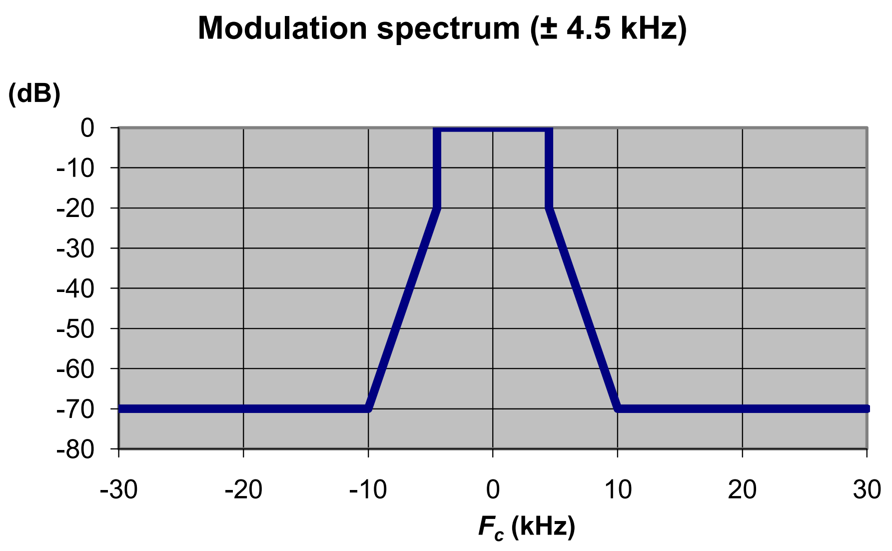
2. On any frequency removed from the centre of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 4.5 kHz but no more than 10 kHz: at least 5.82 (f_d − 2.30 kHz) dB.

3. On any frequency removed from the centre of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 10 kHz: at least 50 + 10 log (P) dB or 70 dB, whichever is the lesser attenuation.

For the 495 kHz to 505 kHz broadcast data channel, a 64-QAM modulation at 47.4 kbit/s would meet these requirements and would fit the transmitter emissions mask shown in Fig. 11.

FIGURE 11

10 kHz channel emissions mask (64-QAM modulation at 47.4 kbit/s)



7.2.1.3 Radio-frequency propagation and noise

For predicting radio-frequency propagation, the technical approach set out in Recommendation ITU-R P.368-9 is used. Radio noise and man-made noise characteristics are provided in Recommendation ITU-R P.372-10.

7.2.1.4 Adjustments to the NAVTEX range predictions based on *C*/*N* requirements

The transmit range for NAVTEX broadcasts is calculated assuming an RF *C*/*N* density figure of 35 dB (Hz) at the ship's antenna. This ensures that the NAVTEX receiver is provided with an RF *S*/*N* of 8 dB in a 300 Hz bandwidth.

Prediction of the 64-QAM broadcast transmission range based on adjustment (horizontal scale, Fig. 5 of Recommendation ITU-R M.1467-1) to the NAVTEX predictions as follows:

Scale *C*/*N* requirements from 8 dB to 26 dB (10^{-5} BER):	+18 dB
Scale bandwidth from 300 Hz to 9 kHz:	+15 dB
Allowance for 5 kW transmitter (Fig. 5 of Recommendation ITU-R M.1467-1):	−7 dB
Assumed baseline value of ships F_a:	62 dB
Assumed value of ship's antenna efficiency:	25%

Net adjusted value for ships F_a (18 + 15 − 7 + 62 = 88 dB):	88 dB
Net adjusted value for a 1 kW transmitter (add 7 dB to 88 dB above):	95 dB
Adjusted range for 64-QAM (5 kW Tx):	400 NM (~741 km)
Adjusted range for 64-QAM (1 kW Tx):	320 NM (~593 km)

7.2.1.5 Ship receiver performance specifications

The assumed ship receiver specifications are set out below. To achieve the desired bit error rate (BER) at the extreme range, the data rate may be adjusted and 16-QAM to 64-QAM may be used.

Ship receiver specifications:

Frequency band:	495 to 505 kHz
Adjacent channel rejection:	−70 dB at ± 10 kHz
Noise factor:	< 20 dB
Usable sensitivity for 10^{-5} BER:	< 100 dBm
Dynamic:	> 80 dB
Receiving antenna efficiency:	> 25%.

7.2.1.6 Summary of the 495-505 kHz digital broadcast service

The 495 kHz to 505 kHz band is available for the new system, and the coverage range is similar to the coverage provided by the current NAVTEX system. New digital technology provides a greatly improved data throughput from that currently provided by the current NAVTEX system.

7.2.2 Analysis

Considering the 10 kHz (± 5 kHz) channel bandwidth design, a 5 kHz minimum channel separation is required to insure compatibility. This design is intended to support adjacent channels on 10 kHz channel centres, each with an occupied bandwidth of 9 kHz.

7.2.3 Conclusions

A secondary allocation to the amateur service should not be closer than 5 kHz to the edges (495-505 kHz) of the future maritime systems described in Report ITU-R M.2201.

8 Broadcasting service

8.1 Background

There is no overlap in Regions 1 and 3 between the frequency range proposed for this allocation to the amateur service and the 526.5 to 1 606.5 kHz allocation to the broadcasting service. In Region 2 the allocation to the broadcasting service (525 to 1 605 kHz) overlaps the spectrum range under study only between 525 and 526.5 kHz.

Therefore, there is no possibility in Regions 1 and 3 of co-channel operation between the proposed amateur service allocation and a station in the broadcasting service. There is likewise little practical possibility of such co-channel operation in Region 2 despite the frequency overlap. (The broadcasting service in Regions 1 and 3 is generally channelized with 531 kHz being the lowest-frequency channel. Similarly in Region 2, 530 kHz is the lowest-frequency channel.)

However, a potential does exist for off-channel interference to reception of MF broadcast signals by amateur service transmissions in a case of collocation of an amateur transmitter and a broadcasting service receiver. Two situations were examined: urban areas where amateur stations may be operated close to broadcast receivers, but where broadcast signal strength is high, and rural areas, where typical separation distances are greater, but broadcast signal strength may be closer to the minimum level recommended in Recommendation ITU-R BS.560.

Recommendation ITU-R BS.560 specifies co-channel protection ratios from 26 to 40 dB depending on location, time of day, and receiver bandwidth. Amateur service operation within a few kHz of the broadcast allocation is neither practical nor desirable, because broadcast transmitter power levels would cause excessive interference to much weaker amateur service signals. Therefore, co-channel operation is not considered an option. Relative protection ratios for off-channel interfering signals depend on the bandwidth of the interfering signal. For amateur service transmissions occupying a bandwidth less than 150 Hz, and a frequency separation greater than 6 kHz, the relative protection ratios can be calculated from the selectivity curve of a standard broadcast receiver.

8.2 Analysis

This study considers the potential interference to an MF broadcast receiver from an amateur station transmitter operated at a nearby frequency, as a function of the frequency separation and distance from the broadcast receiver[15].

For the purposes of this study, several assumptions are made:

1. A broadcast station at 530 kHz, providing an typical signal strength of 10 mV/m for an urban area and minimal acceptable signal strength of 1 mV/m for a rural area.
2. A required co-channel protection ratio of 40 dB.
3. A required off channel protection ratio based on the selectivity curve of an EBU standard receiver.
4. A station in the amateur service transmitting a narrow-band signal with an effective isotropic radiated power of 20 W.
5. Free space propagation (for the distances involved, there is little difference between free space loss and ground loss over average terrain).
6. Typical amateur urban and rural antennas as given in Report ITU-R M.2200.

Table 10 gives the results of calculations giving the minimum allowable distance as a function of frequency, between a broadcast receiver and an interfering transmitter, necessary to meet the required protection ratio.

[15] Recommendation ITU-R BS.560 – Radio-frequency protection ratios in LF, MF and HF broadcasting.

TABLE 10

Calculated minimum acceptable distance as a function of interfering frequency

f	Δf	r	E_u	E_r	d_u	d_r
524	6	−10	32	3.2	0.76	7.6
522	8	−15	56	5.6	0.44*	4.4
520	10	−18	79	7.9	0.31*	3.1
518	12	−20	100	10	0.24*	2.45
516	14	< −20	100	10	< 0.24*	< 2.4
514	16	< −20	100	10	< 0.24*	< 2.4

f: frequency of interfering signal (kHz)

r: required protection ratio (dB) (Recommendation ITU-R BS.560)

E_u: allowable urban interfering signal strength (mV/m)

E_r: allowable rural interfering signal strength (mV/m)

d_u: minimum acceptable distance from an interfering transmitter (km) (urban)

d_r: minimum acceptable distance from an interfering transmitter (km) (rural)

*   indicates that in cases of potential interference, the broadcast receiver would lie within the near field of the interfering transmitter, making precise calculation of distance difficult[16].

For small antennas, the assumed boundary of the near field is taken as λ (0.6 km).

8.3 Conclusion

To ensure compatibility between the amateur service and the broadcasting service, the upper limit of a possible amateur service allocation should not exceed 516 kHz.

9 Land mobile service

Compatibility studies for land mobile service have not been undertaken as no usage was identified.

10 Aeronautical mobile service

The aeronautical mobile service has a secondary allocation in Region 3 in the band 505-526.5 kHz. The aeronautical mobile service comprises:

1. Mobile service between aeronautical stations and aircraft stations, or between aircraft stations in which survival-craft stations may participate. Emergency position-indicating radio beacon stations may also participate in this service on designated distress and emergency frequencies.

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[16] http://www.osha.gov/SLTC/radiofrequencyradiation/electromagnetic_fieldmemo/electromagnetic.html.

2. Aeronautical mobile service intended for communications including those relating to flight coordination, primarily outside national or international civil air routes, e.g. Off Route (OR).

3. Aeronautical mobile service reserved for communications relating to safety and regularity of flight primarily along national or international civil air routes, e.g. on Route (R).

Specific information on the protection requirements of stations in the aeronautical mobile service (AMS) has not been received in WP 5A. It can safely be assumed that the protection requirements for AMS transmissions using NDBs is the same as that for NDBs. The only known AMS assignments below 526.5 kHz are all above 520 kHz. It has been concluded in § 8.3 that to ensure compatibility between the amateur service and the broadcasting service, the upper limit of a possible amateur service allocation should not exceed 516 kHz. Any such allocation would not cause interference to AMS transmissions above 520 kHz.