



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**



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***Note:** This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2011

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(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.

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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 kHz².

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 Recommendation 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 software³ 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

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 $\epsilon = 70$.
2. Sea water, average salinity: conductivity $\sigma = 5$ S/m.
3. Land: relative permittivity $\epsilon = 40$.
4. Land: conductivity $\sigma = 0.03$ S/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(μ V/m)	Receiver height 15 m dB(μ V/m)	Receiver height 20 m dB(μ V/m)	Receiver height 50 m dB(μ V/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(μ V/m))

Distance (km)	Receiver height 10 m dB(μ V/m)	Receiver height 15 m dB(μ V/m)	Receiver height 20 m dB(μ V/m)	Receiver height 50 m dB(μ V/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(μ V/m)	Receiver height 15 m dB(μ V/m)	Receiver height 20 m dB(μ V/m)	Receiver height 50 m dB(μ V/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 (μ V/m) at 10 km and 44.39 dB(μ V/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 band⁴.

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 negligible⁵.

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.

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.