



Report ITU-R M.2200
(11/2010)

**Characteristics of amateur radio stations
in the range 415-526.5 kHz
for sharing studies**

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Foreword

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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.*

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REPORT ITU-R M.2200

**Characteristics of amateur radio stations in the
range 415-526.5 kHz for sharing studies¹**

(2010)

Objective

This Report describes the transmission characteristics of amateur radio systems most likely to be employed in amateur radio operations at frequencies in the 415-526.5 kHz range including analyses of antenna systems likely to be used in the amateur service at these frequencies.

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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

Recommendation ITU-R M.1732 describes the characteristics of systems operating in the amateur and amateur-satellite services for use in sharing studies. This Report provides typical transmission modes and characteristics of stations in the amateur service that could be deployed in the range 415-526.5 kHz. It also provides simulations of radiation patterns of antennas that could be deployed in this range.

2 Related ITU-R Recommendations

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

Recommendation ITU-R M.1798 – Characteristics of HF radio equipment for the exchange of digital data and electronic mail in the maritime mobile service.

Recommendation ITU-R M.1677 – International Morse code.

3 Abbreviations

ADSL	Asymmetric digital subscriber line
DSL	Digital subscriber line.
EZNEC	A simplified antenna simulation program based on NEC
FEC	Forward error correction
NBDP	Narrow-band direct printing
NEC	The numerical electromagnetics code: Antenna modelling software package
PACTOR	Packet teleprinting over radio
PSK31	Phase shift keying 31.25 Hz
QPSK31	Quadrature phase shift keying 31.25 Hz
WSPR	Weak signal propagation reporter

4 General

Amateur stations generally do not have assigned frequencies but dynamically select frequencies within a band allocated to the amateur service using a listen-before-talk protocol. Many bands allocated to the amateur service are shared with other radio services and amateur operators are aware of the sharing conditions. Amateur stations in the range 415-526.5 kHz could perform a variety of functions similar in nature to those performed in other bands allocated to the amateur service, such as training, communication between amateur stations, disaster relief communications and technical investigations in radio techniques for personal as opposed to pecuniary interest.

Given the modest size of the proposed allocation (about 15 kHz), amateur transmissions in the range 415-526.5 kHz would likely make use of radiotelegraphy and a variety of data transmissions.

5 Transmission modes in the range 415-526.5 kHz

5.1 Morse code

Morse code (CW) or continuous-wave, *Emission Mode A1A*, is radiotelegraphy accomplished by keying a carrier on and off in accordance with the international Morse code.

While varying with the keying speed, the necessary bandwidth of conventional CW signals can be taken as 150 Hz or less. An allocation in the range 415-526.5 kHz would likely make considerable use of very-slow-speed CW (Slow Morse), the necessary bandwidth of which may be as small as 1 Hz.

Morse code is defined in more detail in Recommendation ITU-R M.1677.

5.2 Narrow-band direct printing radiotelegraphy

Narrow-band direct printing (NBDP), *Emission Mode F1B*, is the modern amateur radio implementation of traditional commercial narrow-band direct printing and has the following characteristics:

- Frequency-shift keying (FSK) with a spacing of 170 Hz between the lower (SPACE) and the upper (MARK) frequency.
- A transmission capability of 60 words/min².
- Encoding using the five-level Baudot (ITA2) code.

NBDP, which requires a necessary bandwidth of 250 Hz, will fit within the proposed allocation of about 15 kHz. A commercial implementation of NBDP for LF and VLF frequencies using an 85 Hz shift could be used by the amateur service in the range 415-526.5 kHz.

PACTOR is a further enhancement of NBDP utilizing both automatic repeat request (ARQ) and FEC. PACTOR 2, *Emission Mode J2D*, has a necessary bandwidth of 375 Hz and will likely find application in the band 415-526.5 kHz.

The PACTOR mode, specifically the PACTOR-III Protocol, is described in Recommendation ITU-R M.1798.

² Each word assumed to be five characters in length; each character requiring five bits to encode. Allowing for space characters, start and stop bits, etc. the resulting bit rate is 45.45 bit/s – often quoted as 45.45 Bd.

5.3 Narrow-band phase shift keying modes

Phase-shift keying 31.25 Hz (PSK31), also frequently referred to as binary phase shift keying (BPSK), *Emission Mode G1B*, is a data transmission mode involving shifting the phase of a steady carrier by 180° while suppressing most of the undesirable distortion artefacts. In operation, each transmission begins with a carrier that has a continuous sequence of phase reversals at 31.25 Hz. Un-encoded, this would result in a continuous string of binary zeroes. As the operator types text, the bit stream is encoded using a scheme of variable-length bit sequences, whereby the most common characters have the shorter bit sequences.

The necessary bandwidth for PSK31 is 60 Hz, and uses no error-correction; however, a variant called quadrature phase-shift-keying (QPSK31) provides some FEC. This would be more attractive for an amateur service in the range 415-526.5 kHz because of its better performance under fading conditions.

PSK31 is a data mode that is implemented in software. This has allowed narrower-bandwidth variants such as PSK08, PSK02, etc., to be readily implemented. For example, PSK08 operates at one quarter the speed, i.e. approximately 8 symbols/s, with the necessary bandwidth reduced pro rata.

5.4 MFSK and FDM modes

There are a number of digital modes used by stations in the amateur service that employ multiple frequency-shift keying (MFSK), orthogonal multiple phase-shift keying or frequency-division multiplexing (FDM) of multiple carriers. These include modes such as Olivia. Olivia is a recent digital protocol, which has the promise of permitting reception of text transmissions under very adverse receiving conditions such as signals significantly below the noise floor.

Amateurs have studied sky-wave propagation near to 500 kHz through the experience of two-way communications, and also through the use of beacon transmitters. Recently, amateur beacons in several countries using the WSPR operating mode recently developed by amateurs, have been used successfully. WSPR uses a narrow bandwidth (~6 Hz) MFSK signal that can be successfully decoded and quantified under weak signal conditions (-30 dB SNR in 3 kHz bandwidth) making it well suited for use by amateur stations with low e.i.r.p. Each station alternates between transmit and receive time slots, so that signals may be monitored on all paths between the active beacon stations. Received signal data from all stations is automatically logged and uploaded to a publicly accessible online database for further analysis. Apart from WSPR's contribution to analyzing propagation conditions, its use to optimize transmitter antenna performance whilst operating at low transmitter bandwidth and e.i.r.p. is of significant benefit.

6 Characteristics of radiated signal

6.1 Overview

Amateur radio operators will be especially challenged by the large dimensions of antenna structures theoretically required and often employed in commercial installations in the range 415-526.5 kHz.

So as to better understand the characteristics of transmit antennas that might be employed in the amateur service in this frequency range, representative antenna types were analyzed using EZNEC pro/4 software. The antennas studied included two that could be constructed in limited space and two variations of an antenna requiring more substantial space. A detailed analysis of the antenna simulations and the results obtained for each antenna appear in Annex 1.