



Report ITU-R M.2141
(06/2009)

Study of the isolation between VHF land mobile radio antennas in close proximity

M Series

**Mobile, radiodetermination, amateur
and related satellite services**



Documents
Document Sharing Hub

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

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, 2009

© ITU 2009

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

REPORT ITU-R M.2141*

**Study of the isolation between VHF land mobile
radio antennas in close proximity**

(Question ITU-R 7/5)

(2009)

1 Introduction

This Report provides information on calculation and measurement techniques for isolation of VHF land mobile antennas located in close proximity. A major challenge is the management of co-site interference between various radio systems operating in close proximity. In this Report the isolation between antennas are investigated and quantified. The antenna isolation is theoretically analysed, numerically simulated and experimentally verified for the case of separation in the order of 1 to 7.6 m.

2 Scope

This Report provides information on the determination of isolation for mobile radio antennas separated horizontally less than a few wavelengths in the 30 to 108 MHz bands. The study presents analytical and experimental isolation results for two antennas. The impact of isolation to the operation of radio systems and effect of the physical characteristics of the antenna platform are not studied.

3 Related ITU-R Recommendations

Recommendation ITU-R SM.337 – Frequency and distance separations.

4 Abbreviations

NEC	Numerical electromagnetics code
EZNEC	The electromagnetics simulation program based on NEC
USUL	Unmatched source-unmatched load model
MSUL	Matched source-unmatched load model
AWG	American wire gauge
VSWR	Voltage standing wave ratio.

5 Approach used to compute antenna coupling

This study is specifically aimed at investigating the horizontal isolation between a two-vertical-antenna configuration. Of particular interest here is the canonical problem of two antennas separated by a specified distance and how the coupling between the two antennas varies with carrier frequency.

* This Report should be brought to the attention of Radiocommunication Study Group 1.

Mutual impedance between antennas was evaluated on the basis of theoretical techniques used in electromagnetics and applied to the two antenna configuration. Coupled power was computed using standard circuit theory governing voltage, current and power. The theoretical predictions were validated against accepted theoretical results in the literature. Following this first order confirmation, independent calculations using an electromagnetic simulation package based on the numerical electromagnetics code (NEC) was employed to further confirm the validity of the theoretical results. The benefit of using the theoretical techniques over the NEC package is that:

- the expressions are in closed form; and
- relationships between electrical and physical parameters to impedance are seen clearly in the expressions.

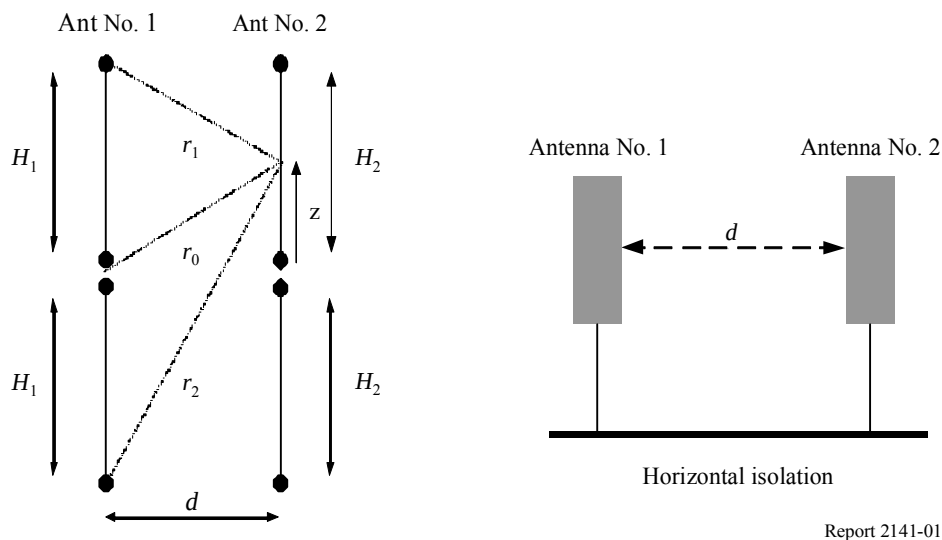
Based on the theoretical and simulation results, experiments were then devised to investigate predictions of coupled power levels.

6 Determination of self and mutual impedance

The problem under consideration is that of evaluating the power coupled between two antennas separated by a distance d , as illustrated in Fig. 1. Fortunately, this problem is addressed in books dealing with electromagnetics and antenna systems [Jordan and Balmain, 1968]. Closed form expressions and simulation of self mutual impedance between antennas are presented in this section.

FIGURE 1

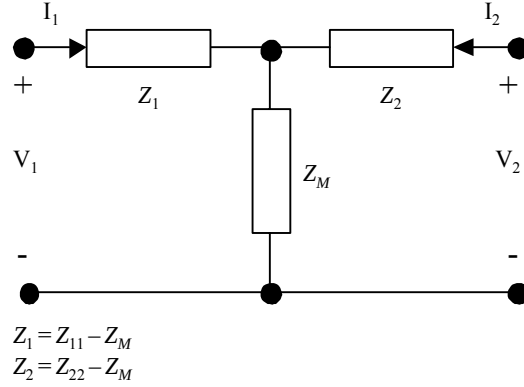
Geometry for fields near the antennas



6.1 Theoretical expressions for mutual impedance

In Fig. 2, with the terminals at antenna 2 open circuit, the impedance seen looking into the terminals at antenna 1 is simply the self-impedance of antenna 1 in isolation, Z_{11} . Similarly, the impedance seen looking into the terminals of antenna 2 with the terminals of antenna 1 open circuit, the impedance seen is simply the self-impedance of antenna 2 in isolation, Z_{22} . By inspection:

FIGURE 2
Definitions of quantities used for derivation of self and mutual impedance



Report 2141-02

The mutual impedance of the pair $Z_M = Z_{12} = Z_{21}$ is computed by solving:

$$Z_M = \frac{Z_2(Z_{1,in} - Z_1)}{(Z_1 + Z_2 - Z_{1,in})}$$

iteratively for Z_M . Here $Z_{1,in}$ is the Norton equivalent impedance at the terminal of antenna 1 when antenna 2 is short circuited:

$$Z_{1,in} = \frac{Z_1 Z_2 + Z_1 Z_M + Z_2 Z_M}{Z_2 + Z_M}$$

and is a non-linear function of Z_M .

Finally, the notation used for resistance and reactance is:

$$Z_M = R_M + jX_M$$

Once these impedances are known, the quantities of interest such as the input impedance, VSWR, and isolation can be computed. What remains for analytical purposes is to determine Z_1 , Z_2 and Z_M for a 2-element monopole antenna using the problem geometry in Fig. 1, which shows two element monopoles, with each element of height $H_1 = H_2 = H$. The general mutual impedance expressions for the two monopole antennas on a perfect reflecting plane and separated by distance d are taken from [Jordan and Balmain, 1968].

Mutual resistance is:

$$R_M = -30 \left(\begin{array}{l} \sin \beta H \cos \beta H \{ Si(u_2) - Si(v_2) - 2Si(v_1) + 2Si(u_1) \} \\ - \frac{\cos 2\beta H}{2} \{ 2Ci(u_1) - 2Ci(u_0) + 2Ci(v_1) - Ci(u_2) - Ci(v_2) \} \\ - \{ Ci(u_1) - 2Ci(u_0) + Ci(v_1) \} \end{array} \right)$$

and mutual reactance is:

$$X_M = -30 \left(\begin{array}{l} \sin \beta H \cos \beta H \{ 2Ci(v_1) - 2Ci(u_1) + Ci(v_2) - Ci(u_2) \} \\ - \frac{\cos \beta H}{2} \{ 2Si(u_1) - 2Si(u_0) + 2Si(v_1) - Si(u_2) - Si(v_2) \} \\ - \{ Si(u_1) - 2Si(u_0) + Si(v_1) \} \end{array} \right)$$

where:

d : distance between antennas

H : height of each antenna element, and half of the total antenna height

λ : carrier wavelength

$\beta = \frac{2\pi}{\lambda}$: wave number (or propagation constant).

Currents and voltages used in X_M are:

$$u_0 = \beta d$$

$$u_1 = \beta \left(\sqrt{d^2 + H^2} - H \right)$$

$$u_2 = \beta \left(\sqrt{d^2 + (2H)^2} + 2H \right)$$

$$v_1 = \beta \left(\sqrt{d^2 + H^2} - H \right)$$

$$v_2 = \beta \left(\sqrt{d^2 + (2H)^2} - 2H \right)$$

$Ci(x)$ is commonly defined as *cosine integral of x* , and has the property:

$$Ci(x) = \ln x + C - S_1(x)$$

where:

$$S_1(x) = \int_0^x \frac{1 - \cos v}{v} dv$$

and

$C = 0.5772157$ is Euler's Constant.

The companion integral $Si(x)$ is $Si(x) = \int_0^x \frac{\sin v}{v} dv$, and is known as *sine integral of x* . The *cosine integral of x* and *sine integral of x* are evaluated from 0 to H .

The self-impedance of a single antenna can be calculated using the formulas used for calculating Z_M , by evaluating the near-field on the surface of a single antenna and setting d equal to antenna radius to obtain Z_{11} and Z_{22} .

6.2 Mutual impedance through calculation

The results in Table 1 through Table 3 contain a comparison of mutual impedances for numerical calculations based on the expressions presented in § 6.1, as well as those obtained from Balmain and Jordan's [1968] (Mutual impedance between monopole antennas of equal height from page 541 Fig. 14-3).