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Measuring the radiation pattern of on-board antennas at sea

A. Valles Castro[a], F.J. Calviño Dopazo[a], L.F. Sánchez Álvarez[a], S. García Fernández[a], J.E. Antoranz Álvaro[a], F. Torrecilla Orte[a], M. García Sánchez[b], A.V. Alejos[b], I. Cuiñas[b], P. Gómez-Pérez[c,*]

[a] *Centro de Medidas Electromagnéticas de la Armada (CEMEDEM), Ministry of Defense, Marín, Spain*
[b] *Dept. of Signal Theory and Communications, Universidade de Vigo, Avda. Maxwell s/n, 36310 Vigo, Spain*
[c] *Centro Universitario de la Defensa, Escuela Naval Militar (Defense University Centre, Spanish Naval Academy), Pza. de España s/n, 36920 Marín, Spain*

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ABSTRACT

Measuring the radiation pattern from antennas operating on ships is costly in terms of time and money. Due to the reflections on the sea surface, multipath influences measurement results. The standard procedures recommend repeating the measurement process several times and then applying a statistical analysis to suppress the multipath effect and obtain the correct antenna radiation pattern. However, a close analysis of the multipath problem using a two-ray model may help to find a measurement setup that minimizes the multipath effect and reduces the need for measurement repetitions. This would dramatically reduce the time and cost of measurements and improve the efficiency of the process.

1. Introduction

The performance of communication and navigation antennas mounted on metal ships may be seriously affected by the ship structure. Blind areas may appear at some azimuth angles of the antenna radiation pattern due to scattering by the metal poles and surfaces on the ship. Thus, the results of measuring the antenna performance, considering it as an isolated element, would not correspond its real-world behavior. Under these conditions, a precise evaluation of the antenna performance requires on-site measurements of the radiation pattern. The problem arises as on-site experiments involve the complete floating ship and its environment: sea and coast.

Then, these measurements will not be full open-range, as the sea surface will give rise to multipath propagation. This is a well-known problem. In fact, there are measurement procedures specifically designed [1,2] to cope with multipath effect. These procedures provide a result that approaches the antenna pattern as it would be obtained if using an anechoic chamber. However, these methods are very time consuming, as they require repeating the measurements several times at different locations to gather enough data to perform some ulterior statistical analysis. Then, finding a way to reduce the repetition of measurement events becomes an important improvement in the experimental characterization of on-board antenna patterns. This paper focuses on such improvement based on a detailed analysis of radio wave propagation conditions.

We have used a two-ray model to describe the measurement scenario, then validated the model with measurements at different frequencies and finally used it to provide some insight on the effect of the sea reflection on the antenna measurement results [3]. This propagation model allows us to determine the most adequate measurement setup to mitigate the multipath effect and reduce the amount of measurements needed. Thus, the overall measurement cost would be reduced.

In Section 2 we describe the antenna pattern measurement procedure. In Section 3 we define and validate the two-ray model and analyze the characteristic behavior of oversea radio channel. Finally, in Section 4 we use that two-ray model to analyze the effect of multipath on the antenna pattern measurement and we show how the results can be improved if the measurement setup is adequately defined.

2. Procedure for measuring radiation patterns of on-board antennas

In Fig. 1 we present the general scheme of the measurement setup. The antenna under test at the ship should be in transmission mode. A receiver is placed on a static location, on a tower, on land and near the coastline. It consists of a spectrum analyzer and a constant-aperture receiving antenna with gain on the order of 20–30 dBi. The antenna has to be carefully pointed toward the ship to maximize the received power.

For radar antenna measurements, the spectrum analyzer should

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[*] Corresponding author.
E-mail address: paula@cud.uvigo.es (P. Gómez-Pérez).

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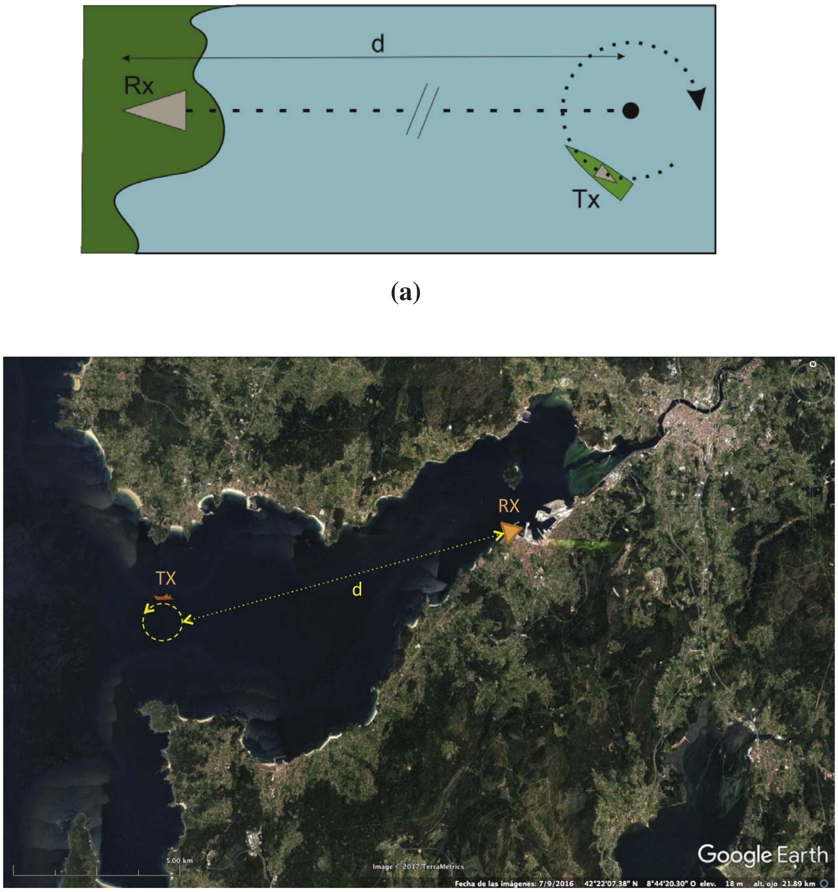

(a)

(b)

Fig. 1. (a) Scheme of radiation pattern measurement procedure and (b) real scale procedure and environment. Picture from Google, TerraMetrics.

meet the capabilities described in [2]. It has to be tuned to the radar fundamental frequency in a zero-hertz span. The sweep time should be set slightly longer than the radar's beam scanning interval because a single complete rotation (or scan) of the radar has to be recorded. The bandwidth should be set to provide the maximum dynamic range (signal-to-noise ratio).

The ship should be at enough distance from the receiver to guarantee that it is in the far field region of the ship antenna. The ship will have to navigate in circles to complete the 360° azimuth pattern measurement. The radius of the circle depends on the ship characteristics, but may vary from 400 yards (366 m) to 500 yards (457 m). As the ship moves, the distance to the actual receiver varies.

Ref. [2] specifies performing the following procedures to mostly eliminate the multipath effect:

1. Measure the antenna pattern several times at one location, [using the previous procedure], and cross-correlate the results to eliminate temporal multipath effects at that location.
2. Then, move the measurement system to another location and repeat the procedure to eliminate temporal variation at the second location.
3. Find the median of the patterns from these first two separate locations.
4. If desired or necessary, repeat this procedure at a third measurement system location, and find the median of the three patterns.

This will require the ship to navigate several circles before the pattern could be properly determined, increasing the cost of the measurement procedure.

3. Radio propagation model

Recommendations provided by ITU work properly under standard conditions for handling out most of oversea radio propagation cases. For instance, diffraction on Earth's surface or refraction by the atmosphere can be studied using recommendations ITU-R P.526 [4] and ITU-R P.834 [5].

However, for short propagation distances, as the ones we are dealing with, such effects are negligible and the propagation mechanism can be described by to a two-ray model: a direct line-of-sight contribution and a contribution reflected from the sea surface. The two-ray model leads to a received power p_{rx} as in (1) [6,7]:

$$p_{rx}(d) = 4\cdot p_{LOS}\cdot \sin^2(\Delta\varphi/2) \tag{1}$$

being p_{LOS} the power received under free space conditions, as Friis propagation equation estimates, and Δφ the phase difference between the two rays, the direct and the reflected. This phase difference Δφ is expressed as in (2) if the antenna heights h_T and h_R are small compared to the distance, d, between transmitter at ship and receiver on land.

$$\Delta\varphi = (2\pi/\lambda)\cdot(2h_T h_R/d) \tag{2}$$

To check the validity of this model we performed several measurement campaigns transmitting from a ship and measuring the received power at a station on coast, while the ship approached the coast, as can be seen in Fig. 2. The received power was measured using two spectrum analyzers with two antennas at different heights and at four different frequencies at UHF, L, C and X bands. Measurements conditions are summarized in Table 1.

The antennas on the ships were: