

The NPL calculable standard dipole antenna and 60 m ground plane

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Introduction

This paper reviews the NPL calculable standard dipole antenna whose performance was first published in 1991¹ and also describes for the first time the large ground plane which was brought into use in 1993. The NPL dipole antenna has a measured antenna factor within ± 0.1 dB of the theoretically predicted value. This has been verified over the frequency range 30 MHz to 500 MHz. The two antenna method was used, which involves measuring the insertion loss between two identical antennas. The gain or antenna factor is calculated from the insertion loss using the Friis formula². Dipole antennas are not sufficiently directional to enable ground reflections to be prevented. The method therefore involves measurement over an electromagnetically well defined ground plane. In the calculation of antenna factor the ground reflected signal is allowed for in Smith's formula³. The fact of such good agreement between measurement and theory validates not only the antenna design but also the ground plane and the theory being applied. In the next section two distinct methods for calculating the properties of the dipole are compared. The use of a calculable standard antenna in EMC applications is then described. The final sections deal with the mechanical properties of the ground plane and the undesirable phenomenon of edge diffraction.

Calculation of site insertion loss and antenna factor

The key to the validation of the dipole antenna is the prediction and measurement of site insertion loss. In this context site insertion loss is defined as the ratio of the power reading with the antenna input cables connected together to the reading when the antennas are inserted and positioned apart above a ground plane, Fig 1. The antenna factors can be calculated from the site insertion loss or simply from the properties of the dipole elements. NPL has extensively investigated two independent methods of calculating the properties of linear dipole antennas and the coupling between pair of such dipoles. The first method uses method of moments to solve an integral equation for the current on the dipole using a popular program NEC⁴. The second is the induced emf method which assumes a sinusoidal current distribution on the dipole elements⁵: NPL calls this method SCD. The two methods agree to less than ± 0.05 dB when resonant dipole lengths are used. In the 1991 paper this difference was cited as ± 0.3 dB but it has since been found that SCD requires very thin dipoles. NEC has the advantage that it accurately predicts the measured performance of the dipoles over a bandwidth of the order of 200%. It also copes well with bent dipoles as in the case of 5 m long elements at 30 MHz whose tips droop under their own weights. SCD can only be used for straight elements and it only has limited accuracy away from the resonant frequency.

The uses of a calculable standard antenna

The earliest EMC standards referred to the resonant dipole antenna as the standard to be used for accurate measurements of radiated emissions. To this day it is mandatory to refer the performance of broadband antennas to that of the resonant dipole and to use resonant dipoles to validate open-area test sites⁶. This is because the theory for half-wave and resonant dipole antennas is well established and accurate. The free-space antenna factor can be found

using a simple formula, allowing for the mismatch of the dipole element. In practice emission tests are not made in free-space and if mutual coupling to the ground plane is not allowed for, the result can be in error by several decibels. It is only recently that rigorous calculations have been brought to the attention of the EMC community which allow for the effect of the ground plane⁷, but this still assumes that the tuned dipole is being used. In the last decade, with the increasing complexity of emission measurements, broadband antennas have been used in preference to the time consuming tuned dipole.

It is possible to substantially reduce the uncertainty of measurement of E-fields by using antennas whose properties are calculable over a broad bandwidth. This has been achieved for the NPL calculable dipole antenna. Four lengths of dipole are used to cover the frequency range 30 MHz to 1 GHz. The antenna factors at the band edges are kept reasonably low by restricting the bandwidth of each dipole to less than 100%. In this form the dipole antenna can be used to accurately calibrate other types of antennas without restriction on the frequency interval. Likewise a pair can be used to accurately measure site attenuation, a property which indicates the quality of an EMC open-area site.

The antenna calibration facility at NPL

Measurements on EMC antennas started at NPL in 1989. A wire mesh ground plane was used. This had dimensions of 30 m by 10 m and was laid on plywood at ground level. Agreements between predicted and measured antenna factor of ± 0.2 dB were obtained on this site. In 1993 the ground plane was enlarged to 60 m x 30 m. Continuously welded steel plate with a specified flatness of ± 5 mm was laid on a concrete platform. It is possibly the largest sheet steel antenna range in the world designed for the calibration of EMC antennas and is regarded as a standard site in Europe. Measurements of site insertion loss between horizontally polarised standard dipole antennas agreed with theoretical prediction to within ± 0.2 dB in the frequency range 30 MHz to 500 MHz. Over the frequency range 10 MHz to 100 MHz the coupling between monopole antennas agreed with theoretical prediction to within ± 0.3 dB. Techniques have been developed at NPL for measuring the free-space antenna factor of a full range of EMC antennas⁸. The work at NPL has been used to help CISPR/A to decide on methods of antenna calibration and evaluation of test sites for inclusion in international standards.

Measurements of insertion loss between vertically polarised antennas were affected by a significant contribution from edge diffraction. The coupling between two biconical antennas is shown in Fig. 2, the ripple being caused by the signal reflected from the edges of the ground plane. When the surrounding soil was wet the edge currents were better grounded and the ripple of ± 1 dB reduced to ± 0.3 dB. There is no noticeable edge effect for horizontal polarisation.

Level survey

When construction of the ground plane was completed in May 1993 a survey of its flatness and level showed it to be within ± 8 mm over its working area. A more thorough survey was made in June 1995. The ground plane was marked with a 1 m grid. The heights at 63% of the intersections were measured omitting peripheral areas where antennas are not normally placed. Of these 95% were within ± 6 mm of a datum level. All the points were within ± 11 mm if one ignores the rises of up to 25 mm at the very edge ground plane. The spread of the 1891 measurement points is shown in the bar chart in Fig. 3. This survey shows that the ground plane has remained very stable over two years. The construction allows the steel plate to expand. It is painted white which very effectively restricts the temperature rise in direct sunlight.

References:

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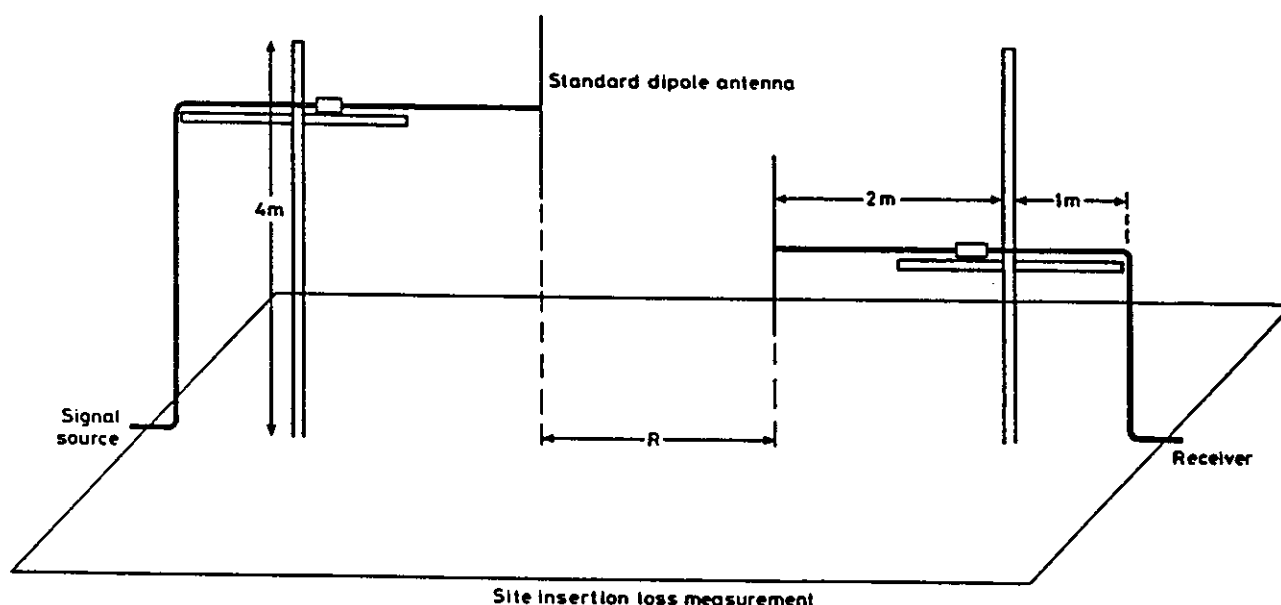


Figure 1. Antenna set-up for site insertion loss measurement.

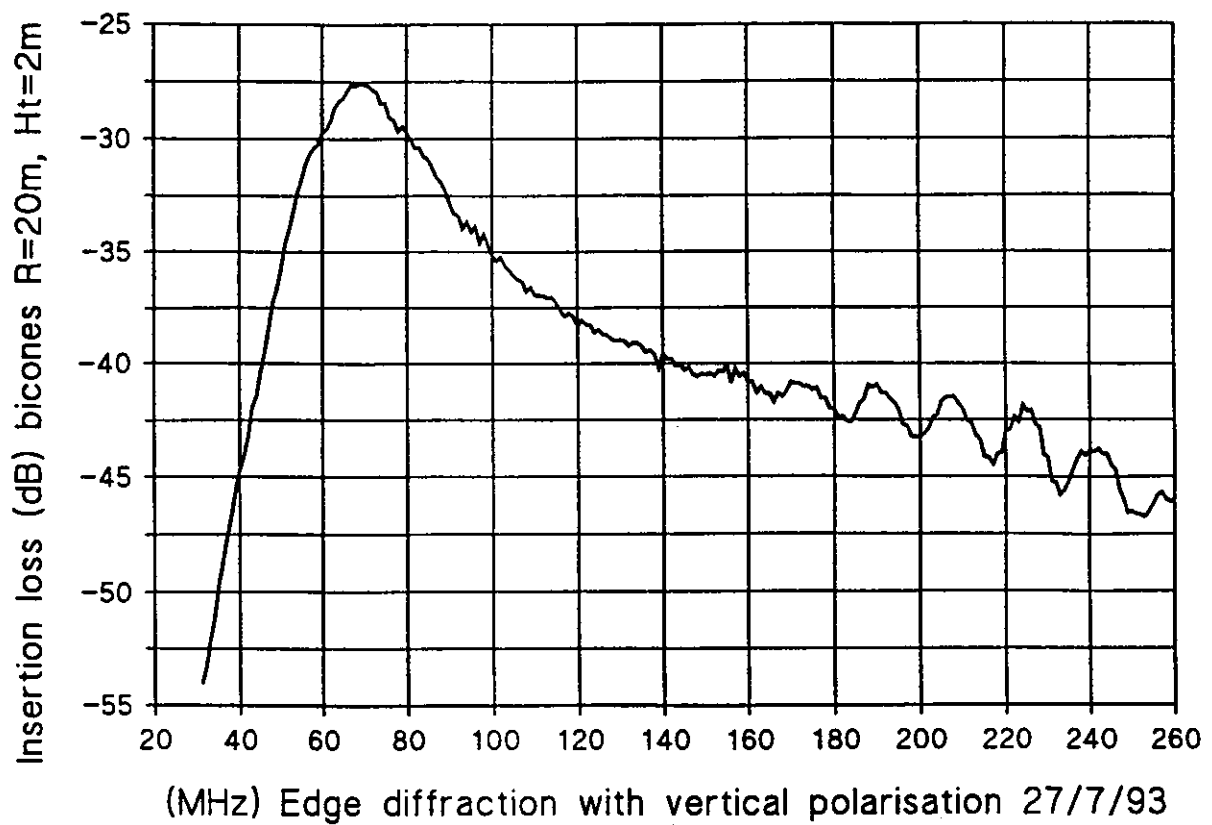


Figure 2. Insertion loss between two biconical antennas affected by edge diffraction

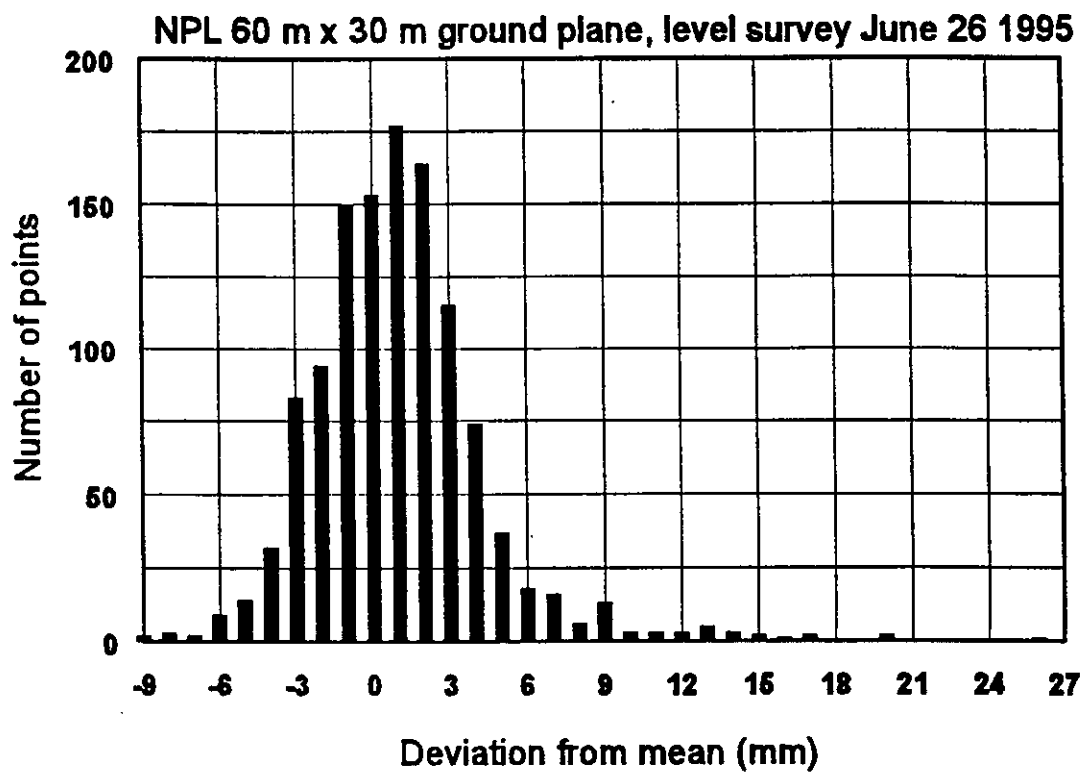


Figure 3. Height of ground plane above mean value, points on 1 m grid.