PROBABILISTIC INTERFERENCE DISTRIBUTION ON CABLES DUE TO RANDOMLY DISTRIBUTED MOBILE PHONES

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ABSTRACT

The probability density and exceedance probability functions of the induced currents in a screened cable connecting two enclosures, resulting from the close presence of single and multiple mobile phones working at 900MHz, are investigated. The analysis of the problem is undertaken using the Method of Moments, but due to weak coupling the impedance matrix is modified to reduce the memory and time requirements for the problem, to enable it to be executed multiple times. The PDFs and exceedance probabilities for the induced currents are presented. The form of the PDFs is seen to be quite well approximated by a log-normal distribution.

INTRODUCTION

With increasing numbers and, possibly, increased handset power levels projected for some future generations of personal communication systems, combined with concern over possible radio frequency hazards and the electromagnetic interference (EMI) that may result, it is desirable to predict the probable scale of these effects in real operational scenarios. For example, some theoretical and experimental results on use of mobile handsets next to the human head, or the resulting voltage induced in Ethernet computer cables, plus the underlying mathematical models used, have already appeared in the literature [1-4]. Increasingly, it has been seen that deterministic models do not serve the needs of present-day EMI analyses (e.g. for prediction of BER in digital systems) and probabilistic analyses are needed [5]. In the present paper, a statistical investigation of the EMI problem due to mobile phones is considered, using a numerical technique. The problem studied is a standardised canonical scenario developed by the COST 261 consortium on EMC in complex and distributed systems [6].

The problem posed concerns the EMI induced in a screened cable connecting two conducting enclosures placed above an infinite perfectly conducing ground plane, as shown in Figure 1 [4,6]. The source is a simulated GSM mobile phone working at 900MHz, located at an arbitrary point in a defined volume. The size of the volume corresponding to the geometry given is $32m^3$.

A numerical solution using the frequency-domain Method of Moments (MoM) was adopted [7], using polynomial basis functions in a Galerkin solution. The method is capable of handling wire, strip, conducting surfaces and small regions of inhomogeneous dielectric. Appropriate attachment-mode basis functions were used when connecting wire segments and surface patches. Since repeated runs are required to obtain statistical results, the method was modified by storing the impedance matrix that defines the cable and the two enclosures after the first program execution, for reuse in the rest of the tests. This technique is expected to reduce the computation time by a factor of more than 50, compared with repeated execution of the basic program. Due to the weak coupling of the source to the scatterer, a further reduction in computation time was effected by evaluating the induced voltage on the scatterer from the forward fields of the source. In this case the inverse impedance matrix of the scatterer was stored also and the induced currents were then computed by matrix multiplication only.

Since near-field coupling is negligible, a half wavelength dipole was used to represent the mobile phone throughout the simulation. Due to the symmetrical geometry of the screened cable and enclosures, the possible positions of the dipole were only computed over half of the volume, to reduce the size of the computational task (see Fig. 1). Thus the induced currents in both ends of the screened cable were recorded, to represent two different phone positions in the whole working volume. The probability density and exceedance probability functions of the induced currents at the attachment mode of the cable to the enclosure, due to several sources with different polarisations, were computed. The current values for all sources were normalised to 1 Watt dipole input power.

SUMMARY OF THE METHOD

In the frequency-domain Method of Moments, a standard thin-wire treatment would normally be used for the current basis function on a wire segment [8]. This was adopted in this case, but using the approximated kernel formulation to reduce the computational task. The current basis mode of a wire attached to a surface was represented by a disc of radius 0.16667λ, to conform to the requirement for current continuity. A closed analytical form solution can easily be obtained for this particular radius, and the exact kernel was used in this case, because of the strong coupling to the surface.

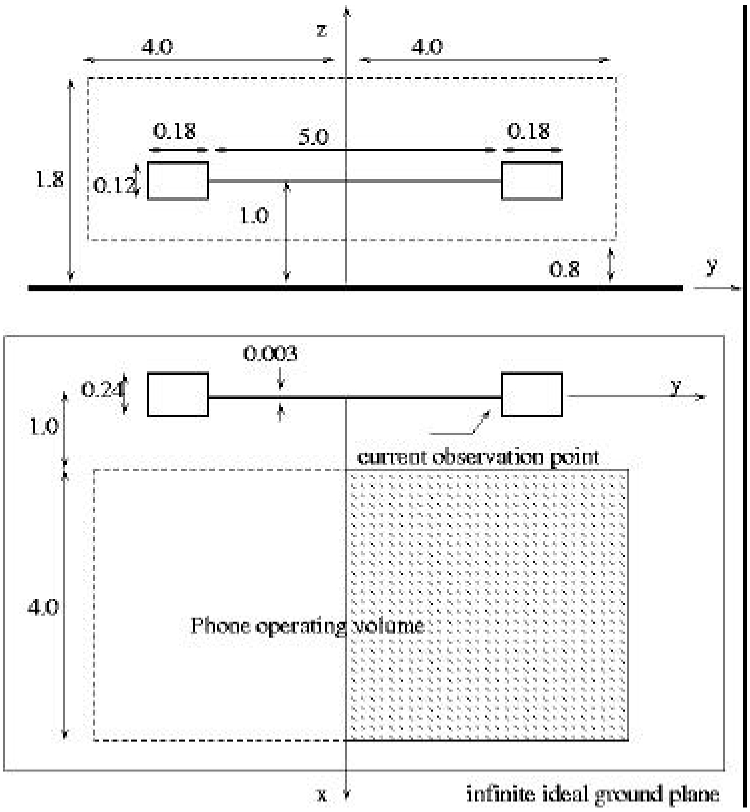

Fig. 1 The basic geometry of the problem

The impedance matrix for the problem shown in Fig. 1 can be evaluated and may be given in the following form:

$$Z = \begin{bmatrix} Z_{ss}(n,n) & Z_{sa}(n,m) \\ Z_{as}(m,n) & Z_{aa}(m,m) \end{bmatrix} \qquad (1)$$

where $Z_{sa} = Z_{as}{}^{T}$

Z_{ss} and Z_{aa} are the self-impedances of the scatterer and the source respectively, whereas Z_{sa} and Z_{as} are their mutual impedances. n and m are the index numbers of the unknowns on the scatterer and the source respectively. Since the scatterer is fixed, the matrix Z_{ss} can be stored and reused from the first execution of the program. Taking account of the weak coupling between the source and the scatterer (and if the current on the source region is known, by running the program without the scatterer), the current induced on the scatterer can be evaluated as follows [9]. The induced currents can be expressed by:

$$J_s = Z^{-1}{}_{ss}(Z_{sa}J_a) \qquad (2)$$

where J_s and J_a are the currents induced in the scatterer and the source respectively. The factor denoted by $(Z_{sa}J_a)$ can be reduced to:

$$(Z_{sa}J_a)_{tp} = \tfrac{1}{2}\hat{a}_s(t).\hat{a}_a(p)J_a(p) \qquad (3)$$

where $\hat{a}_s(t)$ and $\hat{a}_a(p)$ are the unit vectors for the t and p current basis direction for the scatterer and the source respectively. $J_a(p)$ is the current at p on the source region. However, the results obtained from inversion of the total matrices in Eqns (1) and (2) are found to agree very well, since the minimum distance between the scatterer and the source is around 3λ. This implies that the mutual coupling is negligible, and so if the inverse of the Z_{ss} matrix is also stored the computational time can be reduced by a factor of more than 50.

However, since near-field coupling is negligible, and given the symmetrical geometry of the screened cable and enclosures, the possible positions of the source dipole were only computed over half of the volume, to reduce the size of the computational task (see Fig. 1).

SIMULATION AND RESULTS

A program was written which implemented all of the requirements presented in the previous section. The segment length and surface patch width were taken to be less than or equal to 0.1λ. A uniformly spaced set of 196 discrete points was chosen for the source position in the shaded volume in Fig. 1. The induced current at both ends of the cable was computed for a single source located at each position and in three orthogonal polarisations, parallel to the x, y, and z axes, respectively. This gives a total of 392 spatial locations throughout the phone operating volume and 1176 current data values. The relevant statistics were estimated from this finite population using an additional short program written to compute the probability density and exceedance probability of the current in the presence of one or more sources. In obtaining the statistics in cases where more than one source was present a restriction was imposed such that each source was at least one metre distant from its nearest neighbour.

Figure 2 shows the probability density function of the current for one source in the phone operating volume. There are two sets of curves in this figure. Firstly, the computed PDF of the current was derived, using three runs of the computer program used to calculate the statistics. The set of smoother curves shown in Fig. 2 are best-fit log-normal distributions that were used to approximate the computed curves.

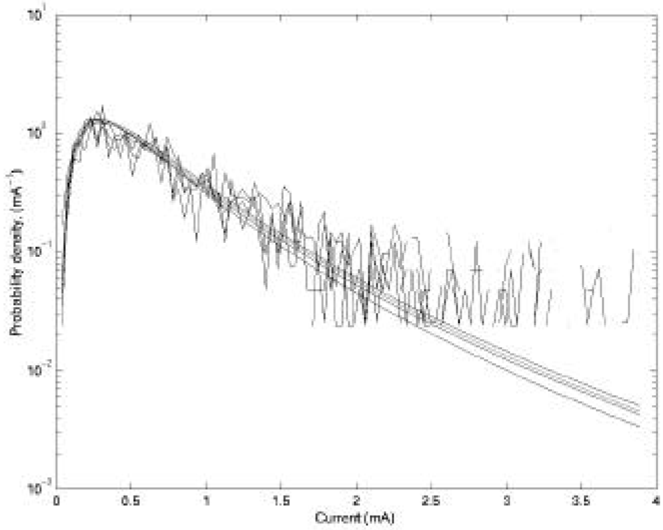

Fig. 2. Probability density function for one source in the operating volume (at three orientations), with best-fit log-normal curves overlaid.

Using the finite population already available, the statistics for the induced current when more than one source is present in the operating volume were computed, using a repeated random selection of the appropriate number of sources. At each selection the one-metre minimum separation distance criterion was checked and those selections that failed were ignored. The magnitude of the total current due to each source was evaluated and the PDF and exceedance probability computed. Fig. 3 shows the exceedance probability of the induced current when the operating volume contains between one and six sources. The trend in these curves is broadly as expected, although the implications of the detailed shapes of the curves merit further consideration.

CONCLUSIONS

A great reduction in memory requirement and computation time of the Moment-Method approach was obtained without losing the required accuracy. Probability density and exceedance probability functions of the induced current on the scatterer were computed. The effect of adding sources to the operating volume was shown. Specific examples of the PDF and exceedance probability were examined and it was shown that at least over a large part of the relevant range a log-normal approximation to the PDF of the current gives a good fit to the data. This is suggestive of a possible theoretical model that could be developed to aid interference analysis in communications cables.

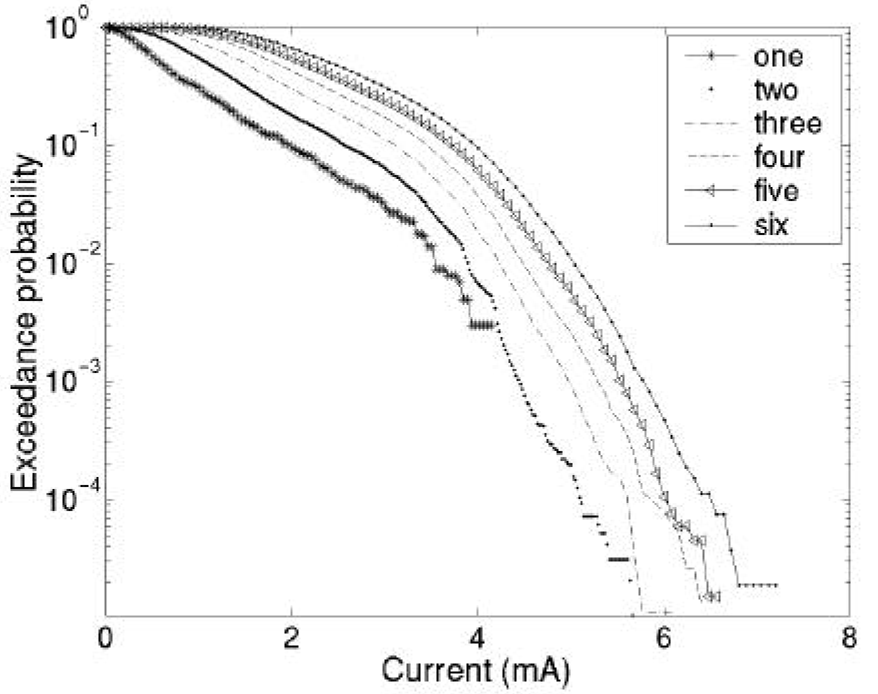

Fig. 3: Exceedance probability of the current with between one and six sources in the operating volume.

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