Aspects of field penetration through aperture arrays

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Abstract—In this paper we present electric and magnetic fields transmitted through aperture arrays located in an infinite screen and relate these to the corresponding fields transmitted through a single sub-aperture. Both numerical and analytical results are presented.

Keywords- shielding; electric field; magnetic field; polarizability; method of moments; aperture array

I. INTRODUCTION

Modeling of the shielding effectiveness of enclosures with aperture arrays has been treated by several researchers, see e.g. [1] and [2]. In order to evaluate expressions in the literature and to improve our physical understanding of field penetration through aperture arrays we have studied the simple case of the shielding effectiveness of aperture arrays in infinite and perfectly conducting screens illuminated by a normally incident plane wave (E_{inc} = 1 V/m).

II. NUMERICAL CALCULATIONS

The numerical calculations of electric and magnetic fields transmitted through aperture arrays were performed using the Method of Moments solver in FEKO. Since the screens with the aperture arrays were assumed to be perfectly conducting and infinitely thin, simulations were performed for the complementary case of an array of perfectly conducting patches. Thus, transmitted electric and magnetic fields were obtained from numerically calculated scattered magnetic and electric fields, respectively. Simulations were performed for linear and 2D arrays with varying number of elements, *N*, varying sub-aperture sizes and varying sub-aperture separations. Transmitted fields were calculated at varying distances, *r*, behind the centrally located sub-aperture. To simplify the comparison of results for different aperture arrays, simulations were performed over a frequency range such that $\lambda/100 \le L \le \lambda$, where *L* denotes the array length. (In the case of 2D arrays we defined *L* to be the length of the diagonal of the aperture array.)

III. ANALYTICAL CALCULATIONS

Two approaches were used for analytically calculating the fields transmitted through the aperture arrays. In the more rigorous approach the fields were calculated by creating an array of magnetic dipole radiators with electric and magnetic field amplitude determined using the magnetic polarizability of a sub-aperture. Transmitted fields were then obtained by a coherent summation of the contributions from the individual magnetic dipole radiators. In the second approach we started by calculating the fields transmitted through a single sub-aperture, $E_{1\times1}$ and $H_{1\times1}$, using the magnetic polarizability of a sub-aperture. These fields are then multiplied by a factor related to the array, C_{array}, which we found to a good approximation to be equal to *N* if $r \ge L$, while it was heuristically found to be approximately equal to $N \cdot \sqrt{r/L}$ when $0.2L \le r \le L$.

IV. COMPARISONS

An example of numerically and analytically calculated magnetic fields transmitted through an array consisting of 41×5 sub-apertures of size 4×4 mm^2 and a sub-aperture separation of 4 mm are presented in Fig.1. Good agreement is obtained between numerical and analytical results except when being in the reactive near-field (as indicated by the dashed lines).

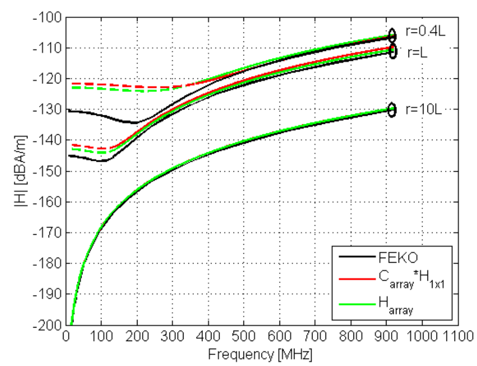

Figure 1. Magnitude of transmitted magnetic field (dBA/m) at various distances, *r*, behind a 41×5 aperture array illuminated by a normally incident plane wave (E_{inc}=1 V/m). FEKO results (black), analytical approximation (red) and analytical results for an array of magnetic dipole radiators. Dashed lines represents results in the reactive near-field (i.e. $r \le \lambda/2\pi$), cf. Table I.

Table I presents approximate relations for the shielding degradation in terms of electric and magnetic fields, ΔSE_E and ΔSE_H, for an array of *N* apertures compared to a single sub-aperture. Note that the presented analytical relation for ΔSE_H for distances $0.2L \le r \le L$ is approximately valid only for $r \ge \lambda/2\pi$, i.e. when outside the reactive near-field.

TABLE I. APPROXIMATE RELATIONS FOR THE SHIELDING DEGRADATION FOR APERTURE ARRAYS

Distance	ΔSE_E ; ΔSE_H
$r \ge L$	N^2
$0.2L \le r \le L$	$N^2 \cdot (r/L)$ *

* For ΔSE_H valid only if $r \ge \lambda/2\pi$.

REFERENCES
[1] Martin Paul Robinson et al., “Analytical formulation for the shielding effectiveness of enclosures with apertures”, IEEE Trans. on EMC, Vol. 40, No. 3, August 1998, pp. 240-248.
[2] M. Li et al., “EMI from airflow aperture arrays in shielding enclosures – Experiments, FDTD, and MoM modeling”, IEEE Trans. on EMC, Vol. 40, No. 3, August 2000, pp.265-274.