Transmission Cross Section for Apertures and Arrays Calculated Using Time-Domain Simulations

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***Abstract*—Despite continuing advancements regarding computer technology and simulation software, having access to analytical equations that can be used to reduce the computational burden is still desirable. Transmission cross sections are presented for a number of apertures and arrays in perfectly conducting, and infinitely thin, ground planes. Comparisons are made between results obtained from numerical simulations, analytical equations as well as semi-analytical calculations obtained by combining analytical equations with numerical results.**

Keywords-transmission cross section; time-domain simulation; transmission line model; finite-difference time-domain (FDTD); finite integration technique (FIT)

I. INTRODUCTION

Knowledge of the transmission cross section of apertures and arrays constitutes an important factor in the design and analysis of shielding structures. With the continuing advancements regarding computer technology and simulation software, the shielding performance of increasingly complex apertures can today be studied using accurate full-wave simulations. Having access to analytical equations that can be used to calculate the transmission cross section, or at least reduce the computational burden, is, however, still desirable. In this study the transmission cross section of different types of geometrically simple apertures are presented and comparisons are made between results from numerical simulations, analytical equations and semi-analytical calculations obtained by combining analytical equations with numerical results.

II. TRANSMISSION CROSS SECTION

Using antenna theory an analytical equation can be derived describing the ratio between the transmitted power, P_N, from an array of dipoles and the transmitted power, P_1, from a single dipole [1]. This ratio is given by

$$\frac{P_N}{P_1} = N - 6\sum_{n=1}^{N}(N-n)\left[\frac{\cos nkd}{(nkd)^2} - \frac{\sin nkd}{(nkd)^3}\right] \qquad (1)$$

where N is the number of elements in the array, k is the free-space wavenumber and d is the distance between the dipoles. The validity of (1) was tested by comparing results from a FDTD-simulation on an array consisting of four 40×5 mm^2 sub-apertures separated by 3 mm with semi-analytical results obtained by combining (1) with a FDTD-simulation on a single 40×5 mm^2 aperture, see Fig.1. Apart from an overshoot at first resonance, there is excellent agreement between the semi-analytical results and the “correct” numerical results. The discrepancy at resonance is due to a strong aperture coupling, which is not included in (1). The reduction in simulation time using the semi-analytical approach is approximately proportional to N.

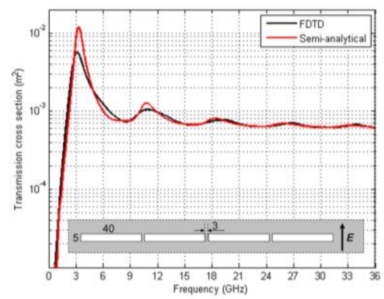

Figure 1. Transmission cross section (m^2) for an array of four sub-apertures of size 40×5 mm^2 and a separation of 3 mm. FDTD-simulation on the entire array (black) and semi-analytical results (red).

The validity of a previously reported transmission line model [2] has been investigated for rectangular apertures with moderately small values on the length-to-width ratio. The transmission line model was found to provide accurate results when the ratio exceeds approximately five. By combining the transmission line model in [2] with (1) an analytical solution is obtained for the transmission cross section. Fig.2 compares the analytical solution with the numerical solution for two linear arrays. Very good agreement is obtained for frequencies up three times the first resonance frequency.

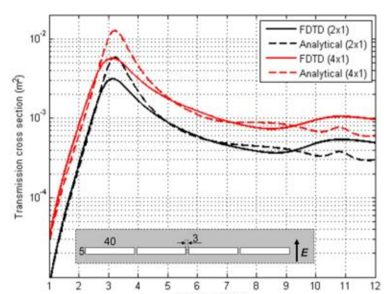

Figure 2. Transmission cross section (m^2) for arrays with two (black) and four sub-apertures (red) of size 40×5 mm^2 and a separation of 3 mm. FDTD-simulations on the entire array (solid) and analytical results (dashed).

REFERENCES

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