A Low Frequency Moment Solution for Electromagnetic Coupling Through an Aperture of Arbitrary Shape

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A three-term moment solution for electromagnetic coupling through an aperture of arbitrary shape is obtained from a low frequency analysis. The results are then corrected to account for the power coupled through the aperture. The moment solution presented constitutes a simple analytic approximation that is likely to yield reasonably accurate solutions for small aperture problems. In addition, guidelines for choosing expansion and testing functions suitable for numerical solutions are pointed out.

Eine Niederfrequenz-Momentenlösung für elektromagnetische Kopplung durch eine Apertur beliebiger Form


1. Introduction

The generalized network formulation for an electrically small aperture in a zero thickness conducting screen has been introduced by Harrington [1] and Mautz and Harrington [2]. They used the equivalence principle to divide the original problem into two parts by replacing the aperture by a perfect conductor and providing for the tangential electric field originally present in the aperture by attaching magnetic current sheets to both sides of the aperture. Then, they formulated a three-term moment solution using reciprocity to find the excitation vector and forcing the moment solution to be equal to the solution predicted by conventional small aperture theory. Further, they accounted for radiation by adding a real part to the aperture admittance matrix. The formulation is applicable in a variety of problems encompassing coupling of electromagnetic energy from one region to another through small apertures. Situations of this nature arise in numerous application areas, e.g., shielding and electromagnetic pulse; electromagnetic penetration into vehicles, aircraft, ships, and missiles; microwave hazards caused by leakage through cracks in shield walls of electronic equipment; radiation from ventilation holes in computer products. Harrington [1] used the three-term moment solution to examine the resonant behavior of a small aperture backed by a conducting object. Leviatan et al. [3] investigated the electromagnetic transmission through apertures in a cavity in a thick conductor. Cheng and Liang [4], [5] applied it to coupling between dissimilar regions.

In this paper, the aperture problem is first investigated in the Rayleigh region, i.e., the range of frequencies for which the maximum dimension of the aperture is much smaller than the wavelength. Quantities of interest are represented by their Taylor series expansion about $\omega = 0$, and subsequently approximated by the first term of their series. The first term is referred to as the quasi-static term. It is shown that the quasi-static electric field scattered by the aperture is due only to the quasi-static equivalent magnetic current which has no surface divergence and hence no associated charge distribution. On the other hand, the quasi-static magnetic field scattered by the aperture is due only to the quasi-static magnetic charge. This charge density is associated with the second term of the Rayleigh series for the magnetic current.

Next, a three-term moment solution is presented. Each expansion function is the current that results from a particular quasi-static excitation. Although the functional forms of these currents are not known in general, the excitation vector and the imaginary parts of the elements of the aperture admittance matrix are evaluated directly using a standard moment method procedure rather than that used in [1] [2] and summarized above. The real parts of the elements of the aperture admittance matrix are subsequently added to account for radiation.

Note that in the range of frequencies for which the maximum dimension of the aperture is of the order of a wavelength, a knowledge of the magnetic current $M$ is sufficient. This is because the magnetic charge density $m$ associated with $M$ can be accurately calculated from the equation of continuity.

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