Miniaturization of TEM Horn Antenna Using Spherical Modes Analysis

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***Abstract*— An approach to miniaturize a TEM horn antenna while maintaining and even improving its frequency/time performance is presented. The proposed approach is based on combining a TEM horn with a rectangular loop antenna in order to excite the two fundamental spherical modes (TE_{m1} and TM_{m1}) which improves the antenna's performance at the low frequency end. The spherical modes expansion technique is used to investigate the characteristics of the excited modes and a simple current perturbation approach is utilized to achieve the desired combination of fundamental modes as well the higher order modes to lower the antenna's turn-on frequency and improve its radiation characteristics.**

Keywords- Miniaturization; Spherical modes; TEM horn

I. Introduction

TEM horn antenna (see Fig.1(a)) can operate over very wide bandwidth with low dispersion characteristics and high (CW and Pulsed) power handling capability which makes it an excellent candidate for directed energy weapons and electronic attack systems. However, a persistent issue is its size especially for UHF and VHF operation. Different techniques have been considered to miniaturize TEM horns including material, resistive and ferrite loading. Material-based miniaturizations need to be very carefully executed due to the excess loss and weight. Resistive and ferrite loading approaches reduce the antenna's efficiency due to the power losses. Another interesting miniaturization approach is to combine a TEM horn with dissimilar antennas that operate over different frequency bands like in the case of K-antenna [1]. By adding a configuration that radiates the fundamental spherical TE mode (i.e. loop antenna) to TEM horn, then the combination of the two modes (horn has fundamental TM mode) below the horn's turn-on frequency will not only miniaturize the antenna (lower turn-on frequency) but also improve its gain. The main challenge is to excite the desired modes' with certain magnitude and phase values. In this paper, a combined loop and TEM horn antenna is studied and spherical modes expansion approach [2] is used to analyze the radiated fields in terms of the spherical mode spectrum. The tuning of the desired modes (magnitude, phase, and turn-on frequency) is achieved by adding the perturbation slots to the combined antenna.

II. Results and Discussion

Shown in Fig. 1(b) is an exponential TEM horn combined with a loop. The 5×5.5×2.5cm^3 combined antenna is modeled over an infinite ground plane using method of moments (MoM) and finite elements method (FEM) implemented in FEKO and HFSS; respectively. As seen in Fig. 2(a), the two different full wave models predict that the combined aperture has better match over significantly wider bandwidth compared to a conventional TEM horn. The turn-on frequency for VSWR < 2 reduced from 3GHz almost down to 1.1GHz. Improved VSWR and gain is observed at the low end and around 2GHz for the slotted topology shown in the inset of Fig. 2(b). To understand the physics of the observed performance and possibly even improve its reach, the spherical mode analysis is used. The relative power levels of the combined antenna's fundamental modes are shown in Fig.3. TE_{11}/ TE_{-11} modes are tuned at low frequencies due to the slots leading to a desired combination with TM_{01} and TM_{02} modes. The destructive interference between modes TM_{01} and TM_{02} (due to the phase difference) around 2 GHz is causing the observed drop in the gain of the combined antenna. As seen, the perturbation of the currents due to the slotting also tunes the phase difference between these two modes and improves the performance. The shape and size of the used slots are obtained after detailed numerical studies of the antenna's current distributions.

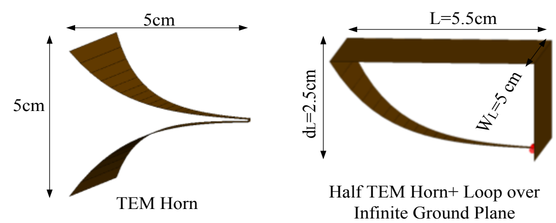

Figure 1. (a-left) TEM horn and (b-right) combined TEM horn-loop.

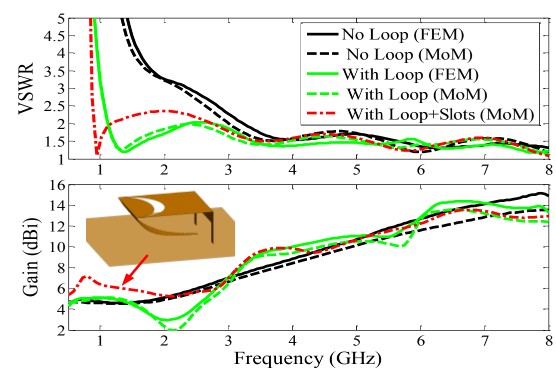

Figure 2. (a-top) VSWR and (b-bottom) gain performances.

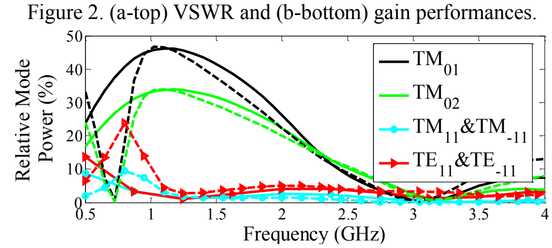

Figure 3. Spherical modes spectrum (solid) no slots (dashed) with slots.

References

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