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Parasitic Dipole Coupled Transverse Slot and its Radiation Characteristic

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I. Introduction

Broad wall transverse slots in wave-guide array may have a potential application in an antenna array with bore-site beam [1] when antenna will have low thickness. However there are disadvantages using transverse slots like, it has high reflection, no phase reversal technique available, and excitation of resonant slot does not change much with offset or by coupling. Since there is no phase reversal technique available for transverse slot, it imposes that the slots have to be spaced at guided wavelength λg to obtain uniform phase and magnitude of excitation coefficients. High efficiency antennas use hollow waveguide. As for the hollow waveguide the guided wavelength λg is always greater than the free space wavelength λo. When the element spacing in an antenna is more than the free space wavelength the radiation suffers from grating lobes, which are undesired as they have the same level of radiated power with that of the main beam. Several methods have been proposed before to suppress the grating lobes. A baffle technique was proposed by Josefsson [2], where radiation takes place between two parallel plates to eliminate the grating lobes. An inhomogeneously loaded waveguide was introduced by Joubert [3] and a capacitive diaphragm was introduced by Shan et.al.[4] to reduce the slot spacing to less than λo. Use of additional materials inside the waveguide will introduce extra losses in the antenna design. The authors proposed a new way of grating lobe suppression recently [5] where a parasitic dipole layer is used to suppress the grating lobes without disturbing the interior design of the waveguide. The problem was solved as a theoretical problem where the consideration was taken only in the external region of the waveguide. In this paper the problem is seem as a complete one by including the interior part of the waveguide. A detail analysis of the S-parameters is done for a transverse slot with and without parasitic dipoles in Method of Moments (MoM). The simulation results are compared with that of the experiments. Very good agreement is obtained between calculated and measured S-parameter results. Radiation patterns are calculated and measured for a simple problem of 3-slot and 5-dipole linear array to explain the grating lobes suppression mechanism. The suppression of grating lobes is about –5dB with some suitable dimensions of the fabricating structure. However optimization shows that the grating lobes can be suppressed down about -14dB.

II. Theory

The geometry to explain a model-coupling configuration between a waveguide transverse slot and a strip dipole is shown in Fig. 1. Integral equations for the excitation coefficients on the slot and dipole are obtained by using the field equivalence and continuity theorems. The integral equations are solved using the Gelarkin's MoM. The slot and dipole are located with reference to global coordinates; however, reactions on slots and dipoles are carried out in local coordinates as shown in Fig. 1. Radiation patterns are calculated based on the far field approximation of Maxwell's equations and Fourier transform method [6], [7].

III. Results

Scattering parameters produced in a rectangular waveguide due to a transverse slot on the waveguide broad wall is calculated in MoM and compared with that of the measured data at 12 GHz band. Two cases have been considered, a slot with a parasitic dipole and the slot alone to see the effect of the presence of the parasitic dipole. Slot and dipole configuration is shown in Fig. 1. The dimensions of the waveguide, slot and dipole are: broad wall width a=19.05mm, narrow wall width b=9.525mm, broad wall thickness t=1.27mm. Both slot and dipole are electrically narrow of width=2.0mm. The length of the slot SL=12.7mm, length of the dipole DL=12.5mm and the height of the dipole Dh=12.5 mm. The dipole is considered as infinitely thin perfectly conducting strip placed in

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quadrature with the slot for a maximum slot-dipole coupling. The magnitude and phase of S-parameter generated due to the slot are presented in Fig. 2 through 5, where the thin lines represent the S-parameter data from slot without parasitic dipole and the thick lines represent the same when the slot is with the parasitic dipole. The MoM simulation results are plotted in dashed lines and the measurements data are plotted in solid lines. The magnitude and phase plot of S11 are shown in Fig. 2 and 3 respectively. It is observed that the reflection is larger at about 11GHz with the presence of the parasitic dipole. However it improves as frequency approaches the design frequency of 12 GHz. It is worth mentioning that a very good agreement is achieved in the comparisons between calculated and measured data that validates the reliability of the calculated data. The S21 plots for magnitude and phase are shown in Fig. 4 and 5, respectively. The plot in thick lines for with-dipole case shows that the S21 at about 11GHz is low, which gives higher power in radiation. On the other hand at about 12 GHz S21 goes higher as compared with the thin lines plot for without-dipole case that gives effect on the radiation power going down. As though the radiation power is reduced due to the presence of the dipole, the suppression of grating lobes is expected to improve the directive gain of the antenna.

To see the radiation charactering as well as the suppression level of grating lobes, a linear array of 3 slots and 5 dipoles is analyzed as shown in Fig. 6. The waveguide dimensions are same as of the S-parameter analysis case above. Slots are numbered as S#1, S#2 and S#3 that have the lengths 12.5mm, 12.7mm, and 12.5 mm respectively. Dipoles are numbered as D#1, D#2,…and D#5. Dipoles positioned right above the slots (1, 3, and 5) have the same length of Ld1=12.5mm. Dipoles in the middle of two slots have the same length of Ld2=13.0mm. The dipoles are mounted on a foam spacer of a height of about 12.5 mm, which represents the dipole height (Dh). The above dimensions of the dipoles are considered for a convenient fabrication point of view. Calculated and measured radiation data are presented in Fig. 7. The thick lines show the radiation pattern for with-dipole case and the thin lines show the without-dipole case i.e. radiation coming only from the slots. The dashed lines plot the MoM data and the measured data are in solid lines. It is noted that the foam height have an approximation in the experiment as there exist an air gap, and taping to put ground plane and spacer. We found very good agreement for without dipole case shown in thin lines. With-dipole case shows that the grating lobes are suppressed about -5dB, which may not look so large. These suppression grating lobes are dependent on dipole length and height. However, it is very sensitive with the dipole height as shown in Fig. 8. Optimized dipole parameter to attain the suppression about -14dB, are carried out at: Ld1=12.47mm, Ld2=12.85mm and Dh=11.5mm. As seen in Fig. 8 that height increasing or decreasing from some critical height deteriorates the suppression of the grating lobes.

IV. Conclusion

Parasitic dipole may have a novel application in a transverse slot linear array to suppress the grating lobes. Analysis of a transverse slot in presence of a parasitic dipole show that the S-parameter inside a rectangular waveguide changes significantly. The far field measurement data confirms that the parasitic dipoles are able to suppress the grating lobes significantly in transverse slot linear array.

References:

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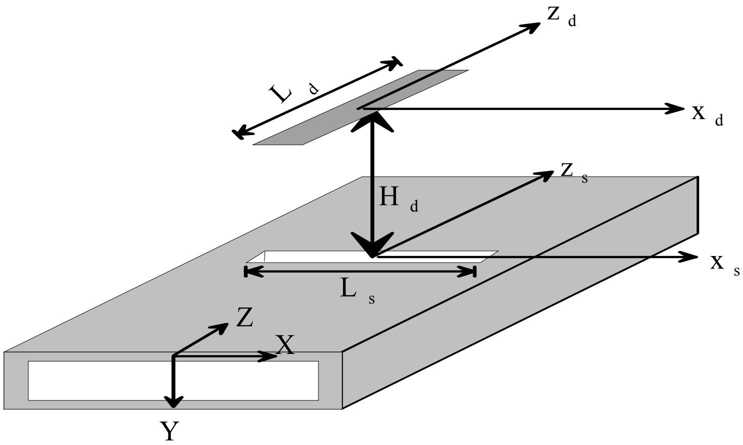

Fig. 1. Parasitic dipole coupled transverse slot on the rectangular waveguide broad wall with coordinate systems.

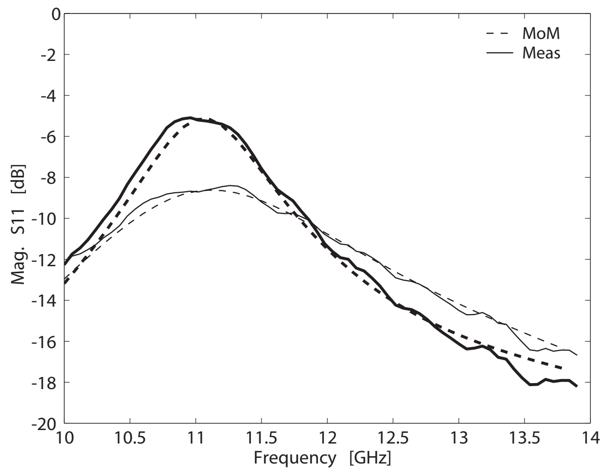

Fig. 2. Magnitude of S11 with and without parasitic dipole.

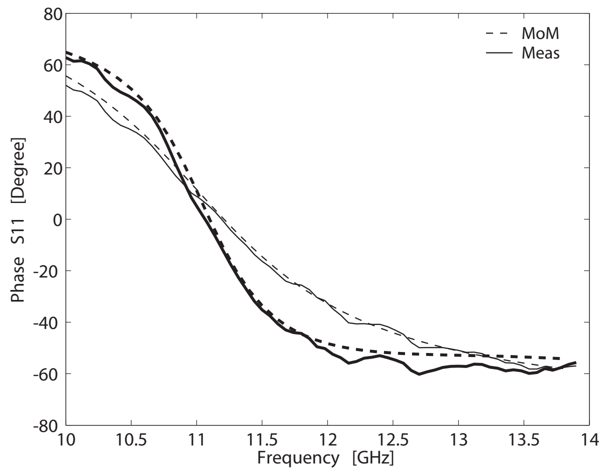

Fig. 3. Phase of S11 with and without parasitic dipole.

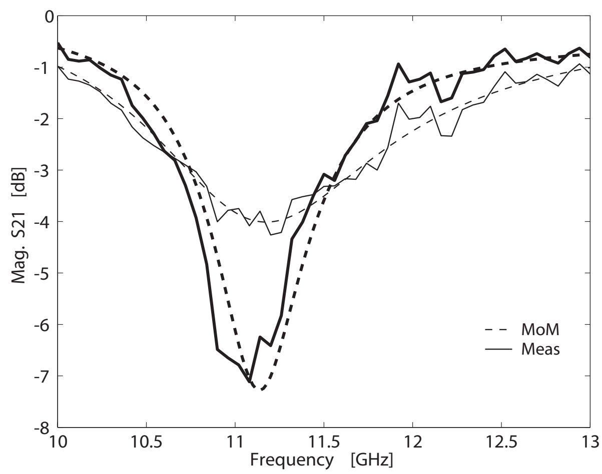

Fig. 4. Magnitude of S21 with and without parasitic dipole.

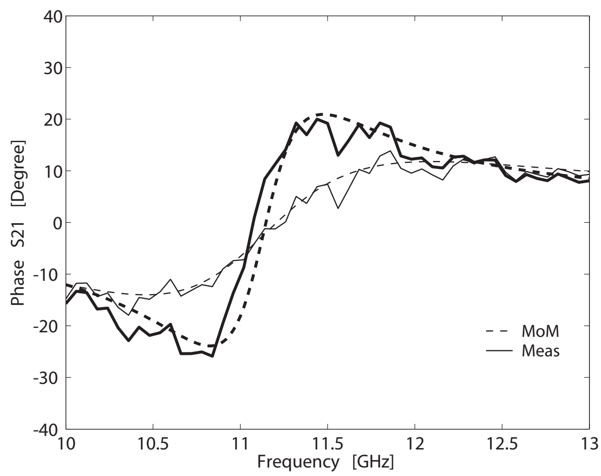

Fig. 5. Phase of S21 with and without parasitic dipole.

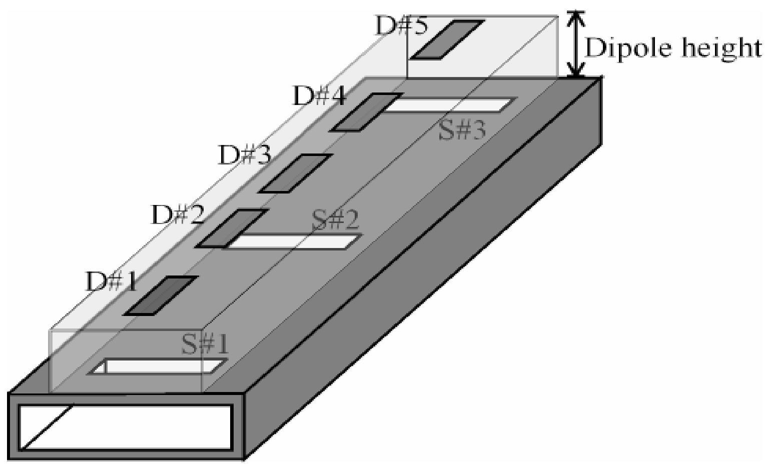

Fig. 6. A linear array of 3 slots and 5dipoles suppress the grating lobes.

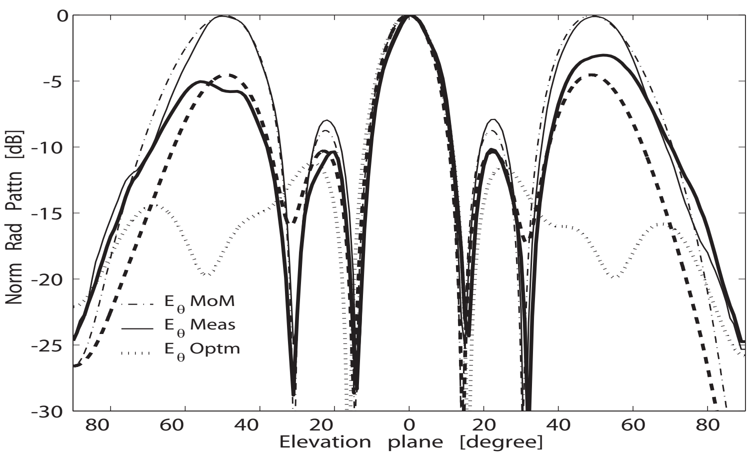

Fig. 7. Far field pattern of 3-slot and 5-dipole linear array.

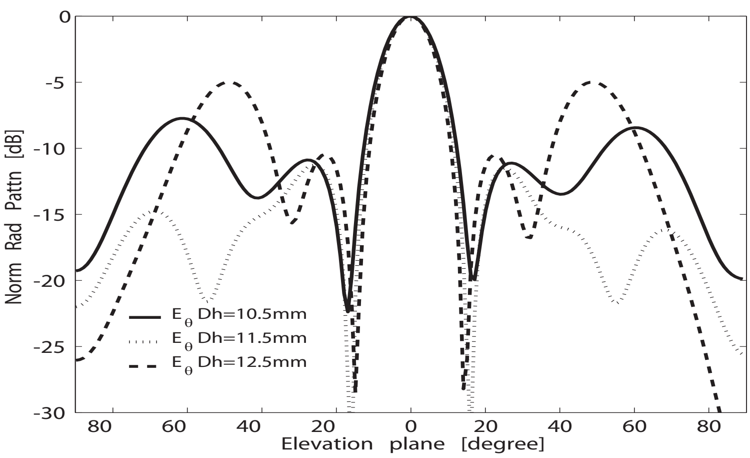

Fig. 8. Far field pattern with different dipole height.