INVESTIGATION OF MUTUAL COUPLING EFFECTS ON THE RADIATION PATTERN OF RECTANGULAR PATCH ANTENNAS

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I. INTRODUCTION

Microstrip antenna arrays have been studied extensively with respect to both application, e.g. [1], and analysis and/or design. A comprehensive collection of papers on single and coupled microstrip elements can be found in [2]. Techniques such as the transmission line model method, the Sommerfeld integral method, the cavity model method, the method of moments, the vector potential method etc. have been utilized. A rigorous solution to the problem of a rectangular microstrip antenna fed by a microstripline is presented in, e.g., [3]; the currents on the feed line and the patch are expanded in a suitable set of modes, and a moment method solution is formulated in the spectral domain. Similarly, finite phased arrays of rectangular microstrip patches have been treated utilizing the spectral domain moment method [4]; a theory has been developed for the active input impedance as well as the active element pattern of the array. From a practical point of view, however, it is commonly accepted by antenna designers that each and every particular element of the array is affected only by its adjacent neighbors, and impedance influence introduced by other elements of the array can be neglected.

In this paper, it is demonstrated that this assumption in general is not correct. Various scenarios of mutual coupling in a 3x3 array are investigated, it is found that more elements of the array have to be considered in order to obtain a more accurate radiation pattern.

II. MUTUAL COUPLING SCENARIOS

A 3x3 rectangular patch antenna array (c.f. Fig. 1a) is investigated. The dots indicate the locations of feeding points. If the radiation properties of the array are analyzed by a method-of-moments procedure, there are several scenarios of modeling the contribution of mutual coupling effects and some of them are illustrated in Fig. 1.

The simplest approach is to neglect coupling among the array elements completely. This is shown in Fig. 1d where the darker area depicts the part of the array that is covered by the impedance matrix calculation. The array configuration formed by a number of identical patches is introduced only in the characteristic function of the array. On the other hand, Fig. 1a describes the case of completely included coupling effects where all array elements are involved in the computation of the impedance matrix. Since the configuration of the array is symmetrical, so must be the surface current distribution. Taking this into account, it can be assumed that mutual coupling effects are pronounced to a somewhat lesser degree. Therefore, only the upper or lower half of the array is covered by the impedance

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matrix (Fig. 1b). In this scenario, the radiation pattern of the entire structure is calculated by duplicating the related column of the admittance matrix. Finally, there is the case where only adjacent patches are involved in the impedance matrix calculations; Figs. 1c illustrate the arrangements for three particular patches.

For the numerical examples shown, a standard moment-method algorithm is applied. The theoretical formulation basically follows that outlined in [5] and need not be repeated here.

III. FAR-FIELD CHARACTERISTICS

Computed and measured radiation patterns of a single patch radiator are compared in Fig. 2. Good agreement between the calculated results (solid line) and the measured data (dash-dotted line) can be observed in the E-plane within angles up to 70 degrees. For higher angular values, measured and calculated patterns diverge due to the simplicity of the theoretical model, which necessarily leads to a E-plane null at 90 degrees. The computed H-plane pattern (dashed line) is shown for comparison.

Figs. 3 present the calculated H- and E-plane far-field radiation patterns of the 3x3 array for the different scenarios described in Figs. 1. The distance between the feeding points of the individual patches is 3 cm in both directions. As the influence of the contribution of mutual coupling effects on the overall array pattern is increased from no coupling (Fig. 1d) through partial coupling (Figs. 1c, 1b) to full coupling (Fig. 1a), the beamwidth decreases and sidelobe levels increase. These phenomena are well-known consequences of electromagnetic coupling within antenna arrays. Of particular importance, however, are the differences between the patterns with complete mutual coupling on one hand and the patterns obtained by including only coupling effects caused by adjacent elements on the other hand. The differences clearly demonstrate that in order to predict radiation characteristics more accurately, it is not sufficient to take into account only coupling effects introduced by adjacent patches.

IV. CONCLUSIONS

Different scenarios of including mutual coupling effects in the analysis of rectangular patch antenna arrays are investigated. A standard method-of-moments technique is utilized to present three different models of mutual coupling interactions. The corresponding radiation patterns of a 3x3 array are compared with those of neglected mutual coupling. The results illustrate the movement in the radiation patterns as the modeling of the contribution of coupling effects increases from one level to another. It is found that considering only the adjacent patches of the individual elements results in inaccurate radiation pattern predictions.

Acknowledgment: The authors would like to thank the Satellite and Communications Systems Division of Spar Aerospace Ltd., Ste-Anne-de-Bellevue, Québec, Canada for providing the measured data presented in Fig. 2.

REFERENCES

[1] Huang, J., "Microstrip antenna developments at JPL", IEEE Antennas & Propagation Magazine, vol. 33, pp. 33-41, June 1991.

[2] Gupta, K.C. and A. Benalla (ed.), *Microstrip Antenna Design* , Artech House , Norwood, 1988.

[3] Pozar, D.M. and S.M. Voda, "A rigorous analysis of a microstripline fed patch antenna," *IEEE Trans. Antennas Propagat.,* vol. 35 , pp. 1343-1350 , Dec. 1987.

[4] Pozar, D.M. "Finite phased arrays of rectangular microstrip patches," *IEEE Trans. Antennas Propagat.,* vol. 34, pp. 658-665, May 1986.

[5] Harrington, R.F. , *Field Computation by Moment Methods* , The Macmillan Company, New York, 1968, ch. 4.

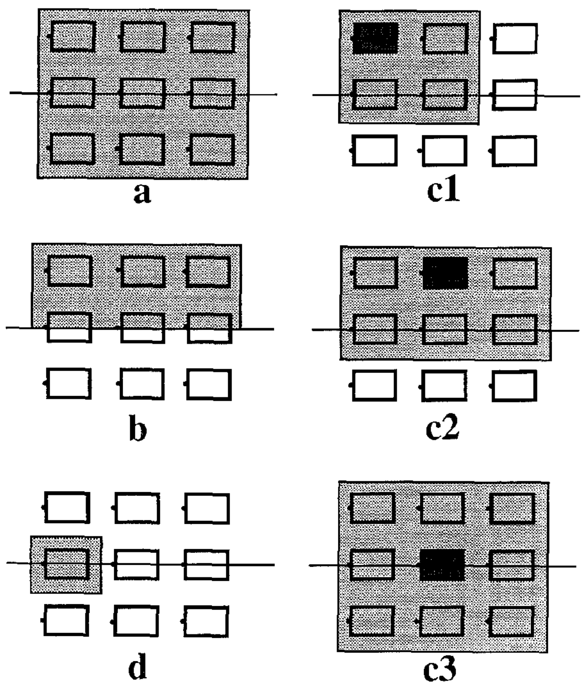

Fig.1 Basic configuration of a 3x3 microstrip antenna array and various scenarios to include the influence of mutual coupling.

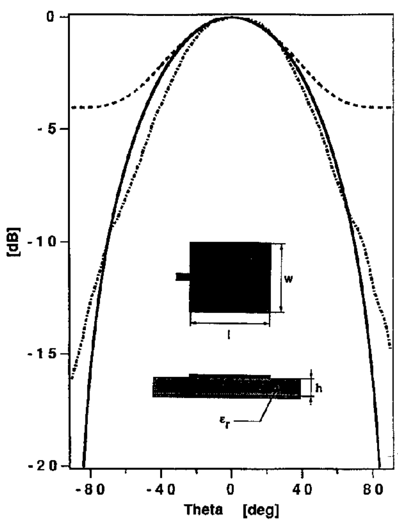

Fig.2
Comparison of the computed pattern with measured data provided by Spar Aerospace Ltd., Quebec , Canada; solid line: computed pattern in the E-plane; dash-dotted line: measured pattern in the E-plane ; dashed line: computed pattern in the H-plane. Dimensions: w = l = 1.712 cm , h =1.575 mm, ε_r = 2.33, f = 5.3 GHz.

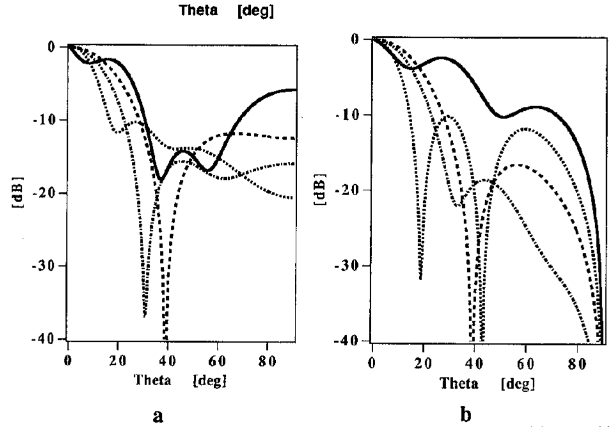

Fig.3 Comparison of the calculated patterns obtained by the scenarios illustrated in Figs.1; frequency and patch parameters as in Fig.2; solid lines: Fig.1a; dotted lines: Fig. 1b; dash-dotted lines: Fig.1c; dashed lines: Fig.1d.
a) H-plane, b) E-plane .