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ARRAY TRADE-OFF STUDY USING MULTILAYER PARASITIC SUBARRAYS

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ABSTRACT:

The use of multilayer parasitic patch subarrays in a microstrip phased array offer many potential advantages. In this paper an analytical study of microstrip arrays with high gain multilayer parasitic patch subarrays and conventional patch antennas is presented. It is indicated that a thinned array of half as many multilayer parasitic patch subarrays (per row and column) at twice the spacing will perform as well as the full array of ordinary patch antennas. The criterion for comparison was array gain, 3 dB beamwidth and sidelobe level. The attendant reduction in the required number of patch antennas and consequently, MMIC phase shifters is very significant in terms of array complexity, cost and power loss.

INTRODUCTION:

It has been reported in the literature that the presence of parasitic patch elements adjacent to excited ones enhances the gain of the patch antenna [1-3]. Recent experimental studies have established that parasitic patch subarrays with overlaying stack of parasitic patches above an excited one can produce gain several dB higher than that of the single excited patch itself [4]. Using these higher gain multilayer patch subarrays as tne basic radiating unit for a large array with MMIC (Monolithic Microwave Integrated Circuits) phase and amplitude control offer many advantages. For beam pointing and sidelobe level control in a large array of patch antennas, the number of MMIC's required is proportional to the number of patches comprising the array. The resulting beam forming network introduces complex feed architecture, high power loss, spurious radiation in the feed network and high cost due to MMIC's. To alleviate these problems, higher gain parasitic patch subarrays can instead be employed that will meet the array design criterion with fewer number of elements and hence fewer number of MMIC devices.

The aim of this paper is to study the feasibility of using a reduced numnber of such high gain elements to maintain the design performance in large MMIC phased array. The result of this study will serve as a reference performance basis in large array design where array architecture is modified, addressing critical configuration and performance issues.

ARRAY TRADE-OFF ANALYSIS:

In the simulation, the trade-off performance of a (16 x 16) array of microstrip patch elements in the broadside direction was studied. The 34 dB array gain was realized with the above array of 256 patch elements with 10 dB individual gain and aperture dimension of (7.5λ x 7.5λ). Figure 3 shows such an array. If instead, the multilayer parasitic patch subarrays with 15 dB individual gain were chosen as the basic radiating unit then the array performance goal (i.e. gain, sidelobe level, beamwidth) is achieveable with only 81 elements; resulting in a substantial reduction in the number of MMIC required.

Figures 1 and 2 show the far-field patterns of a single patch and a multilayer parasitic patch subarray respectively. For analysis; the element patterns were approximated by appropriate cosine powered functions. Then two-dimensional array patterns were computed using generalized array theory.

Figures 5 through 10 show the H-plane cut of the far-field plots for different array configurations. For comparison, only the H-plane plots have been displayed. Gain for each array was computed by integrating the total radiated power.

RESULT AND DISCUSSION:

The trade-off comparison for a planar array of mentioned gain, sidelobe level, beamwidth is displayed in Table 1. The first three columns in Table 1 correspond to the array configurations with 34 dB array gain. The next three columns give an alternate look at the array if element savings are not taken into consideration. The resulting increase in array gain of 39 dB is associated with higher gain elements at the expense of a larger number of MMIC devices or with a large number of standard gain elements and proportional number of MMIC devices. The study results indicate that an array of standard gain patch elements reconstructed with reduced number of higher gain parasitic elements within the same array aperture and consequently at increased element spacing will produce same directivity, 3 dB beamwidth and lower sidelobe envelope. Hence for a large array, an improvement of 5 dB in element gain will reduce the number of MMIC required by 66% to operate at the design performance level.

The above study does not take into consideration the effect of mutual coupling or radiation from the feed lines which would likely degrade the anticipated performance and lower the array gain.

The performance degradation can be recovered somewhat without additional MMIC devices by an array of (16 x 16) multilayer parasitic subarrays and connecting the subarrays into groups of two. Each such group can be controlled by an MMIC device as indicated in Figure 4. Though the resulting array has the same number of radiating elements as its conventional counterpart but requires fewer number of MMIC devices. Such an array produces even higher overall gain and lower sidelobe envelope with identical 3 dB beamwidth and null location.

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1. Entschladen, H. and Nagel, U. (1984) Microstrip Patch Array Antenns, Electron. Lett., 20: 931-933.

2. Lee, K. F., Acosta, R. J. and Lee, R. Q. (1987) Microstrip Antenna Array with Parasitic Elements, IEEE/AP-5 International Symposium, Blacksburg, VA.

3. Lee, R. Q. Acosta, R. J. and Lee, K. F. (1987) An Experimental Investigation of Parasitic Microstrip Arrays (1987) Symposium on Antenna Application, Monticello, IL.

4. Lee, R. Q. and Lee, K. F. (1988) Gain Enhancement of Microstrip Antennas with Overlaying Parasitic Directors, Electron. Lett., 24: 656-658.

Gain: Array	34 dB			39 dB		
Element	10 dB	15 dB	15 dB	15 dB	10 dB	10 dB
Array: Number Aperture Spacing	 (16 x 16) (7.5λ x 7.5λ) 0.5λ	 (9 x 9) (7.5λ x 7.5λ) 0.94λ	 (9 x 9) (4λ x 4λ) 0.5λ	 (16 x 16) (7.5λ x 7.5λ) 0.5λ	 (29 x29) (7.5λ x 7.5λ) 0.27λ	 (29 x 29) (14λ x 14λ) 0.5λ
Feature	Reference Array	Aperture Constant	Spacing Constant	Spacing Aperture Constant	Aperture Constant	Spacing Constant
θ_{3H}	6.2°	6.2	10.5°	6.2°	6.36°	3.4°
1st Zero	7.05°	6.8°	12.3°	6.8°	7.27°	9.1°
S.L.L.: 3rd 5th	 -23 dB -31.5 dB	 -24.5 dB -36 dB	 -27.5 dB 	 -26 dB -41 dB	-24 dB -34.5 dB	-22 dB -25.5 dB

TABLE I

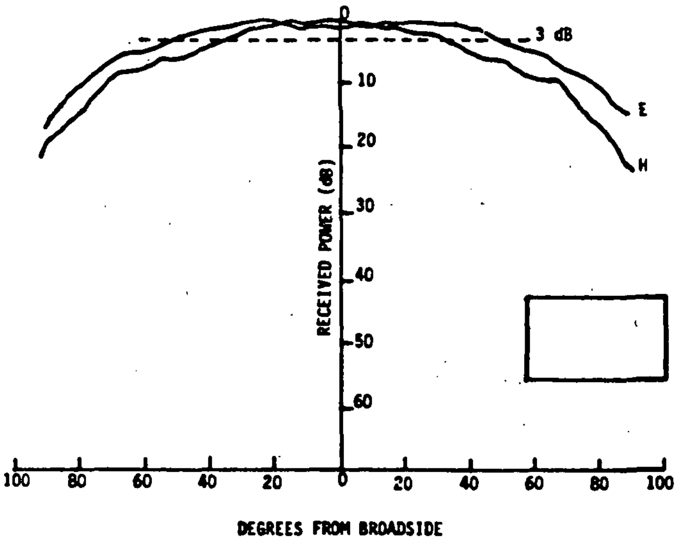

FIGURE 1: E AND H-PLANE PATTERNS FOR A SINGLE PATCH ELEMENT.

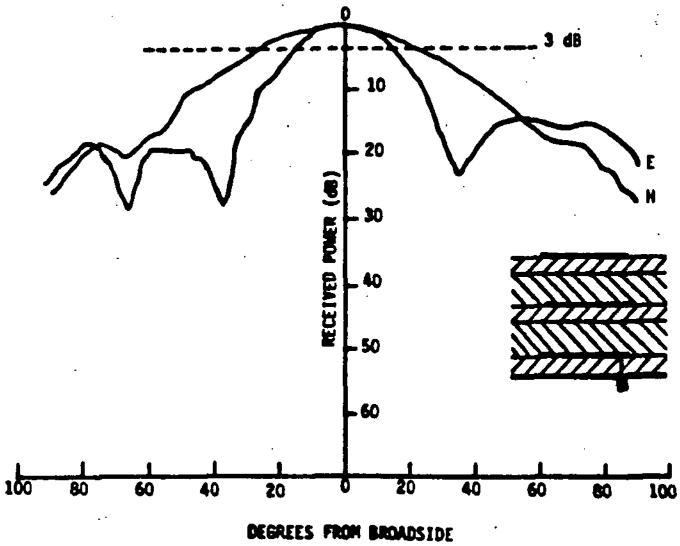

FIGURE 2: E AND H-PLANE PATTERNS FOR A MULTILAYER PARASITIC SUBARRAY ELEMENT.

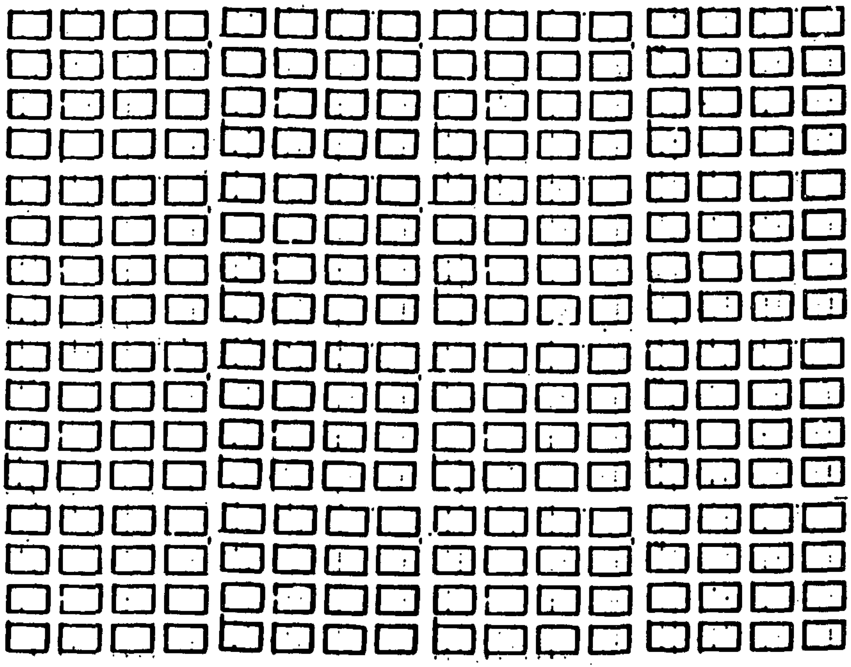

FIGURE 3: (16 x 16) ARRAY OF SINGLE PATCHES.

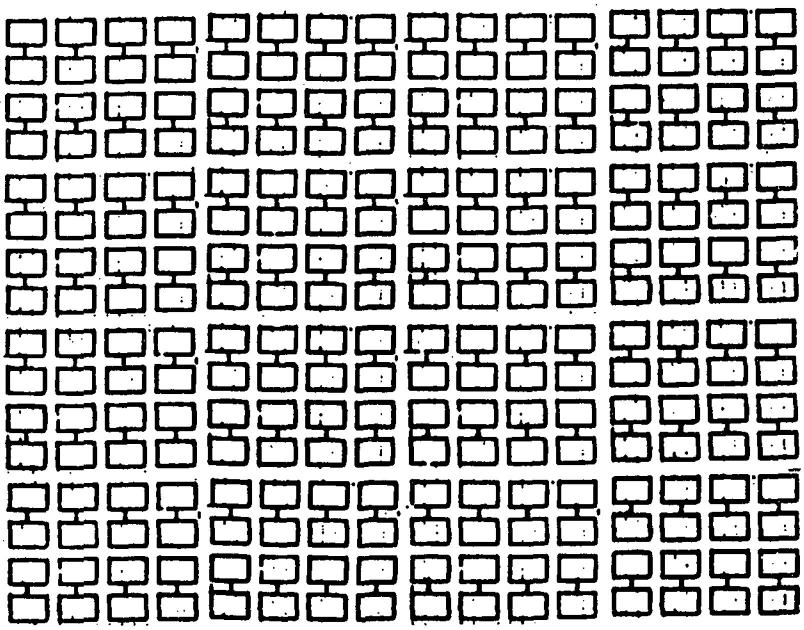

FIGURE 4: (16 x 16) ARRAY OF MULTILAYER PARASITIC SUBARRAYS. SUBARRAYS CONNECTED INTO GROUPS OF TWO.

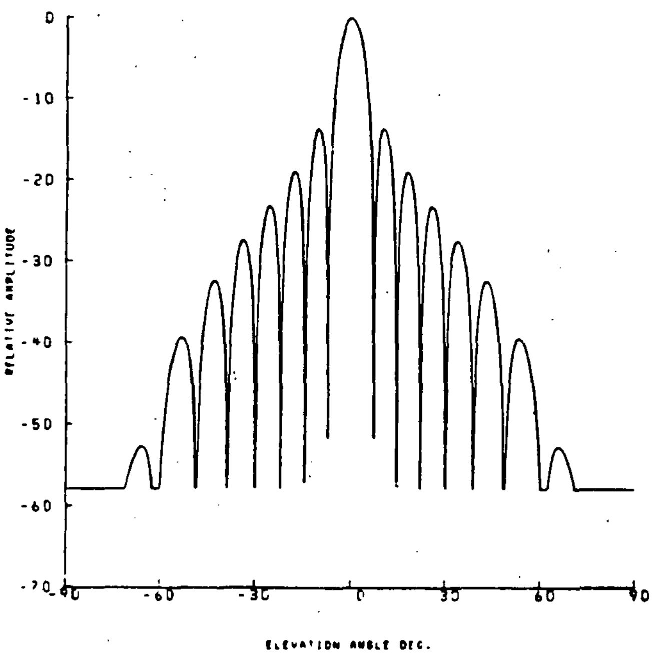

FIGURE 5: H-PLANE PATTERN FOR A (16 x 16) ARRAY OF SINGLE PATCHES AT 0.5λ ELEMENT SPACING.

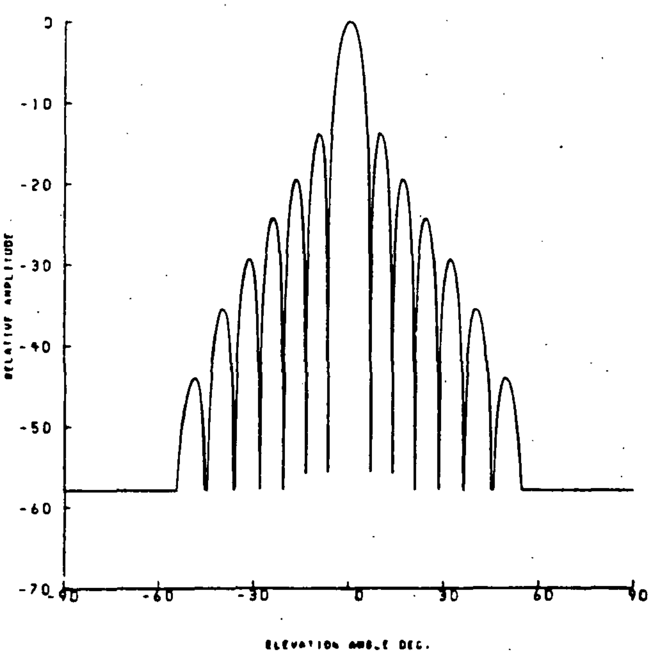

FIGURE 6: H-PLANE FOR A (9 x 9) ARRAY OF MULTILAYER PARASITIC SUBARRAYS AT 0.94λ ELEMENT SPACING.

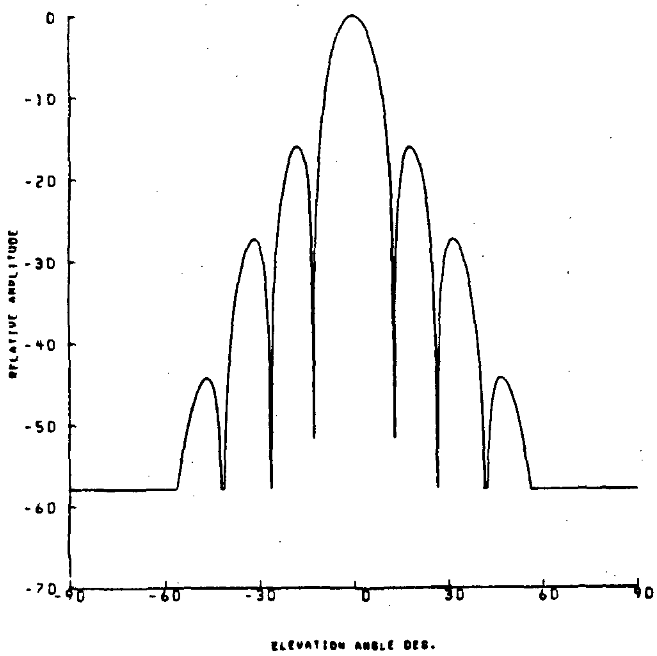

FIGURE 7: H-PLANE PATTERN FOR A (9 x 9) ARRAY OF MULTILAYER PARASITIC SUBARRAYS AT 0.5λ ELEMENT SPACING.

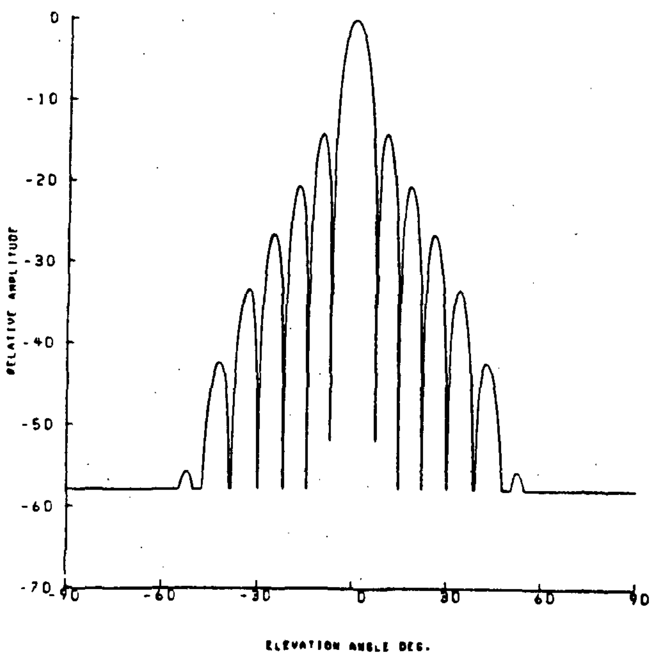

FIGURE 8: H-PLANE PATTERN FOR A (16 x 16) ARRAY OF MULTILAYER PARASITIC SUBARRAYS AT 0.5λ ELEMENT SPACING.

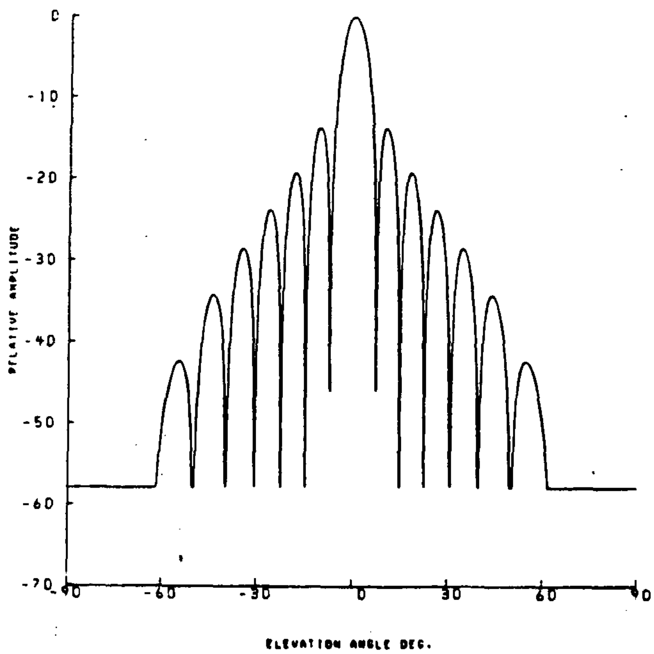

FIGURE 9: H-PLANE PATTERN FOR A (29 x 29) ARRAY OF SINGLE PATCHES AT 0.27λ ELEMENT SPACING

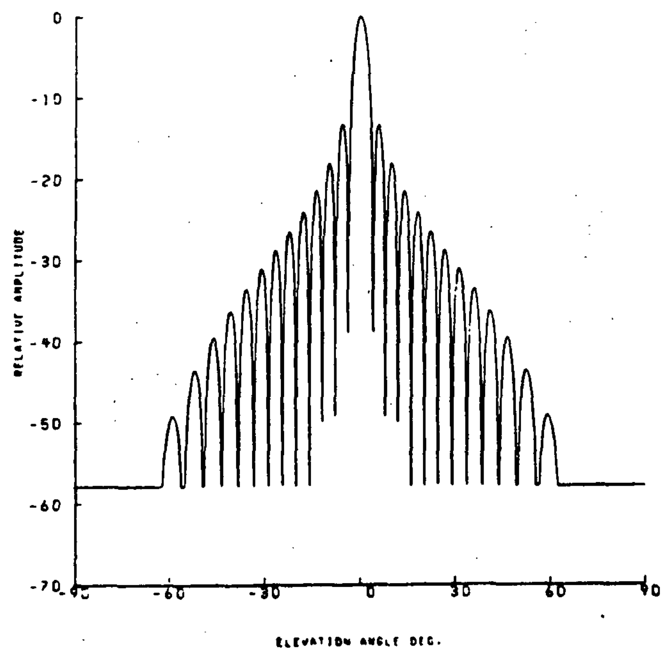

FIGURE 10: H-PLANE PATTERN FOR A (29 x 29) ARRAY OF SINGLE PATCHES AT 0.5λ ELEMENT SPACING.

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