# DESIGN OF LOW COST PRINTED ANTENNA ARRAYS

*J. P. DANIEL, Professor, Université de Rennes I, 35042 RENNES CEDEX, FRANCE*
*E. PENARD, Engineer* | *CNET LANNION B*
*M. NEDELEC, Tint* | *Department MER/STA*
*J. P. MUTZIG, Engineer* | *22301 LANNION, FRANCE*

## INTRODUCTION

Microstrip antenna arrays are often presented as low-cost elements for small communication or radar systems when narrow bandwith (less than 5 %) and medium gain (15 to 25 dB) are needed.

In fact to main conditions must be kept in mind when cheap antennas are required :

- first high frequency bands (20-30 GHz for instance) are well suited, because they require a rather small surface of usual printed circuit such as PTFE,
- secondly simple radiating structures and corporate feed, printed on the same side, are highly desirable.

Following the previous requirements some arrays have been investigated and tested in the 20/30 GHz band. Some of them have been already described [1]. Here two new aspects are considered : reduction of cross polarization using an alternate location of the elements on the feeding line and reduction of side lobe level using simple taper for linear serie's array. Moreover to avoid tapered distribution on two dimensional array, cross-fed structure including only four quarter wavelength matching sections lead to low side lobes in E and H planes.

## 1 - *RADIATION OF CORNER FED SQUARE PATCHES*

### *1.1 - Theory*

The corner fed square patches have been choosen because they provide a high input impedance well suited for serie's array. When the patch is excited at one corner (fig. 1.1), the cavity model [2] shows that the main part of the internal field is the sum of two degenerated modes with equal amplitudes i.e. modes (0,1) and (1,0). If the higher modes are neglected the $E_x$ and $E_y$ fields along the edges exhibit the variations shown on (fig. 1.2). The far field is linearly polarized either in the E plane ($\phi$ = 0) or in the H plane ($\phi$ = 90°). For instance in the H plane, only the $E_\phi$ component arises.

As far as we want to know the cross polarization level, higher modes must be considered. The next mode (1,1) adds a contribution with a magnetic line distribution plotted on fig. 1.3. It must be noticed that $M_1$ is much more smaller than $M_0$ but gives the $E_\theta$ component. $E_\theta$ exhibits a null for $\theta$ = 0 and increases with $\theta$.

### *1.2 - Example of linear arrays ($A_1$ and $A_2$)*

When the spacing along the feeding line equals one guided wavelength, the different elements are uniformly excited (fig. 2.1). Here the ten elements array is printed on a usual PTFE substrate ($\varepsilon_r$ = 2.17 and thickness = 0.38 mm). The quarter wavelength transformer enables a good matching to the 50 Ω coaxial output.

As expected the H plane diagram exhibits the well known -13 dB first side lobe ; the cross polarization component is very low at $\theta$ = 0 and then quickly increases with $\theta$ to -17 dB (fig. 2.2).

In order to reduce the cross-polarization level a new design has been investigated. Element spacing is now half wavelength but each two patches is fed on the out of phase part so equiphase excitation can be kept (fig. 3.1).

As a result copolar components ($E_{\phi_0}$ for the H-plane) add in phase when cross polar components ($E_{\theta_1}$) add out of phase, and then the cross polarization level is lowered. The diagram plotted on fig. 3.2 shows that the cross polarization is reduced to -28 dB instead of the -17 dB. Due to the smaller length of the array the half-power beam width is increased and twenty elements with $\lambda/2$ spacing would give the same directivity.

## 2 - *TAPERED LINEAR SERIE'S ARRAY.*

### 2.1 - *Theory*

The previous arrays were uniformly excited. High side lobes are the consequences of this illumination. The idea was to design a non uniform amplitude distribution while keeping the simplicity of the previous serie's feeding.

Let us consider a linear array with one guided wavelength spacing ; as the radiating elements are identical, impedance transformers are necessary to get the given amplitude current. To do so a two step quarter wave transformer can be used in each cell (fig. 4.1). The transformed admittance $Y_i$ in the $\pi'_i$ plane is given by

$$Y_i = \left(\frac{Y_{L_2}}{Y_{L_1}}\right)^2 Y_{i+1} = n_i^2 Y_{i+1} \qquad (1)$$

where $Y_{i+1}$ is the admittance at node i+1

$Y_{L_2}$ and $Y_{L_1}$ are the characteristic admittance of each quarter-wavelength transformer.

If the inputvoltage leads to a unit current in the first element, then the current distribution is readily obtained with the following relations :

$$I_o = 1 \ ; \ I_1 = n_1 \ ; \ I_i = n_i \, n_{i-1} \dots n_1 \qquad (2)$$

one can deduce step by step the various ratio $n_i$ from the known $I_o$, $I_1$, $I_i$ weight.

### 2.2 - *Results (array $A_3$)*

A ten elements array have been built (fig. 4.2). The requirement was to get side lobe level lower than -20 dB. Only eight transformers were used because $Y_{L_2}$ was choosen equal to the characteristic admittance of the half wavelength following line. Taking a characteristic impedance of the main line near 100 Ω, the various transformers exhibit impedance value between 75 to 95 Ω which are easily realized with microstrip lines. On fig. 4.3 the experimental H plane diagram is plotted ; it shows that the side lobe level is lower that -20 dB while the gain and the input impedance matching remain very similar to the uniform array.

## 3 - *CROSS-FED ARRAY ($A_4$).*

A square array of uniform excited elements would give -13 dB side lobes in the E and H planes. The cross-fed array is very attractive because, first its geometry gives a low side lobe level and secondly the corporate feed is very simple [1].

An array of 50 elements was designed at 20 GHz (figure 5.1). Quarter wave length transformer on each branch of the cross are calculated in such a way that the input power is equally devided between each patch and that the input impedance is matched to the 50 Ω coaxial connector. Because the width of the line for one section transformer was too wide we had to use a three section transformer for the vertical branch.

The radiation pattern is given fig. 5.2 for the H plane and one can note the very low side lobes (lower than -25 dB in both E and H plane). The measured gain is 23 dB, VSWR lower than 1.8 between 19.5 and 20.4 GHz.

## CONCLUSION

Microstrip antenna arrays are very attractive for low cost communication system with medium gain (15 to 25 dB). High frequency band (20/30 GHz) seems to be well suited because rather small surfaces are needed and technical processes (photo etching) remain fairly simple. Reduction of cost requires also a simple design of one side printed antenna ; either for cross polarization and low side lobes performances it has been shown that the serie's structure brings a simple and feasible solution in the 20/30 GHz.

REFERENCES


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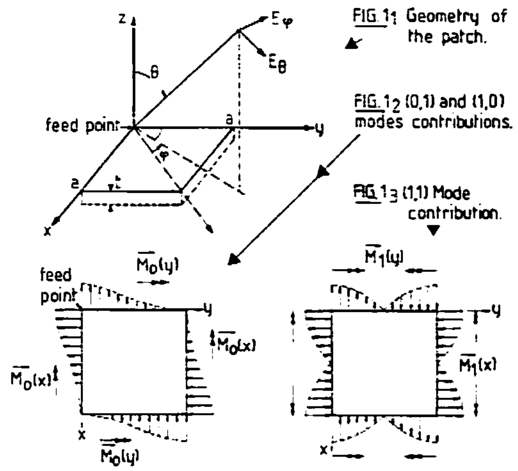



GEOMETRY AND MAGNETIC CURRENTS OF THE CORNER FED PATCH.

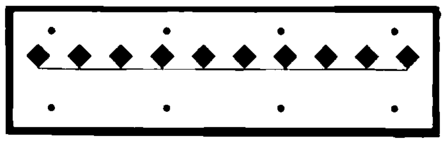
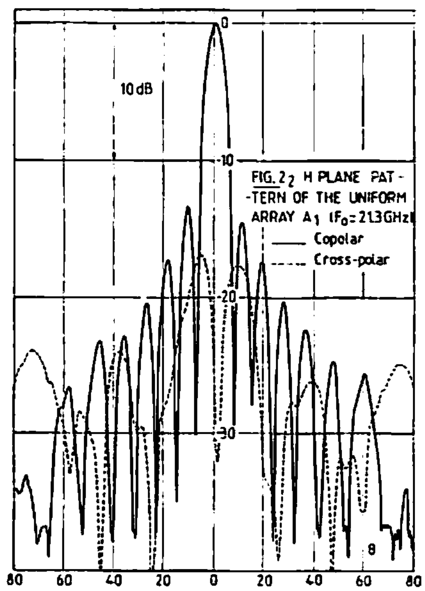


FIG. $2_1$ Uniform linear array $A_1$ ($F_o$ = 21.3 GHz)



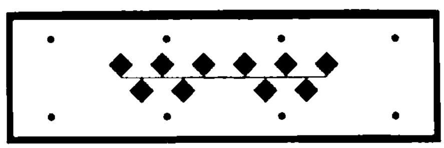



FIG. $3_1$ Uniform array $A_2$ with alternate elements

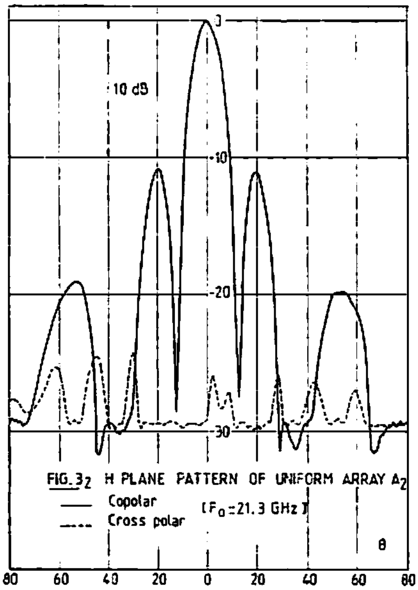



FIG. $3_2$ H PLANE PATTERN OF UNIFORM ARRAY $A_2$ ($F_0$=21.3 GHz)
—— Copolar
---- Cross polar

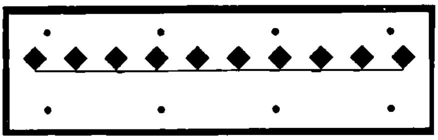


FIG. $4_2$ Tapered array $A_3$

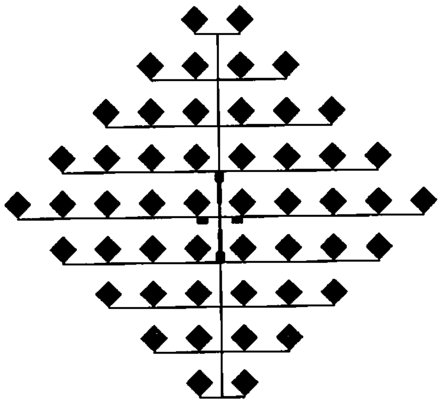


FIG. $5_1$ Cross fed array with coaxial output $A_4$

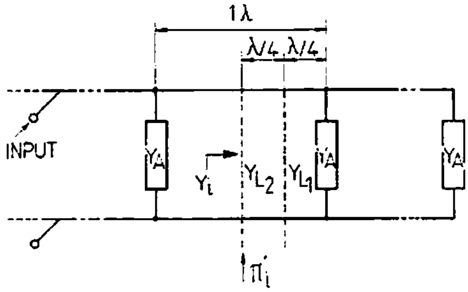



FIG. $4_1$ STRUCTURE OF A TAPERED SERIE'S FED ARRAY.

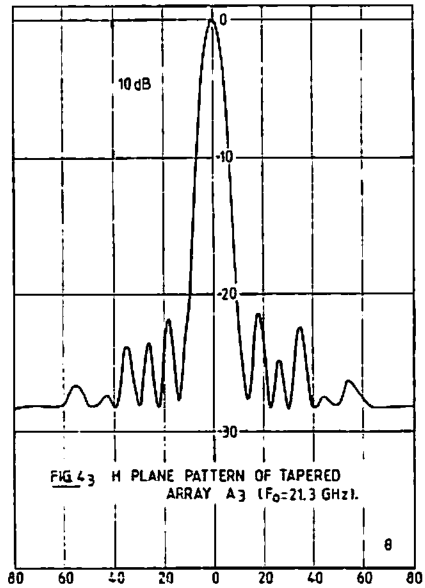



FIG. $4_3$ H PLANE PATTERN OF TAPERED ARRAY $A_3$ ($F_0$=21.3 GHz).

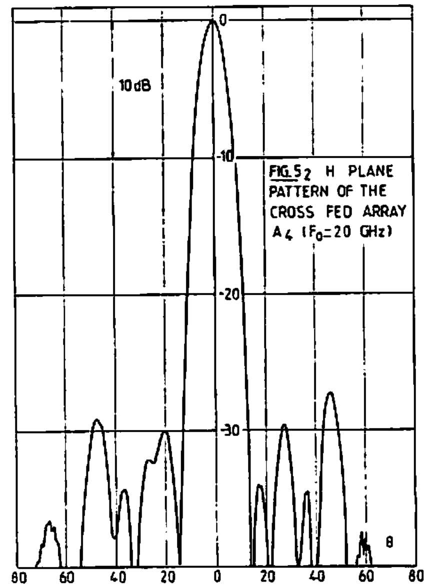



FIG. $5_2$ H PLANE PATTERN OF THE CROSS FED ARRAY $A_4$ ($F_0$=20 GHz)