Mutual Coupling between the Resonators in the Planar Microstrip Antennas
Part II. Antenna Arrays

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Abstract – In Part two of this paper the basic structures are presented which are investigated in part one and on their basic analysis is extended to antenna arrays with finite size. The gain, radiation pattern, and directivity of antenna array with different number of resonators depending on scan angle had been shown. This result can be use for designing of finite size antenna arrays.

I. Introduction

In the resent years the planar microstrip antenna arrays are widely known, as well as their increasing number of applications [1], [2]. In addition to conformability, microstrip antennas have desirable features such as low cost and light weight which makes them extremely attractive for use in a variety of applications. The principal disadvantage of microstrip patch antennas is their narrow impedance bandwidth, which results from the small separations between the resonators and the ground plane [2]. The most straightforward way to improve the bandwidth is to use a thicker substrate. Unfortunately, the grounded dielectric slab supports tightly bound surface wave modes, which represent a loss mechanism. As the substrate becomes thicker, the bandwidth of the antenna increases. Recently, it has been demonstrated that the metal walls placed between the elements of printed phased arrays prevent mismatch and blindness as the array is scanned. A similar concept can be used to improve performance of microstrip patch face arrays. By placing metal walls between the patch elements, the guided wave modes in the substrate can be suppressed. Thus, the substrate thickness can be increased substantially to improve the bandwidth without corresponding decrease in scan coverage.

In this part of the paper the analysis of the structure that are described in Part I is developed, but emphasis is upon the variation that can be seen in the radiation pattern of the antenna arrays. The variation of the parameters of the antenna arrays with different number of resonators are investigated because of the models that were described in Part I. In particular, the variation of the directivity and the great side lobes are investigated.

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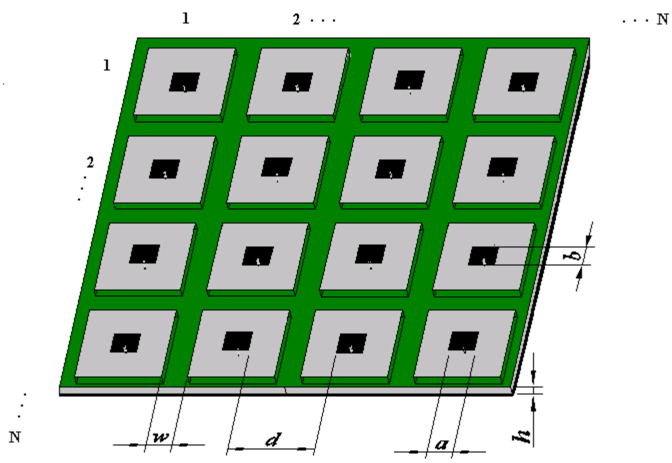

Fig. 1 Antenna array

The objective of this paper is to make an estimation of the performance of the various practical methods used for decreasing of the mutual coupling between the patches.

On the other hand, decreasing of the mutual coupling between the patches can give unlike variations of the radiation pattern and scanning possibilities of the antenna. Also the mutual coupling between the patches has dependence of the number of the resonators that constitute the antenna. This is the other problem that is partly investigated.

Another problem with the scanning antenna arrays is that when the scanning angle increases then the width of the main lobe is changed, the mutual coupling between the patches is increased etc.

The antenna arrays described in this paper are periodical and equidistant. As a result of that the theorems for the periodical structures can be used.

II. Analysis Method

Because microstrip antenna problems are not amenable to closed-form solution, some degree of modeling must be used in their design and analysis. While simple approaches such as the transmission line and cavity models are often used to design microstrip antennas, the deficiencies of these models become increasingly serious, as greater performance is demanded from the antenna.

The most accurate solutions for printed antennas utilize fully electromagnetic techniques such as the finite-difference time-domain (FDTD) method, finite element method (FEM) or integral equation (IE) approach. In this paper, the finite element method is used. This method cannot be used for large structures because of the consumed great computer memory. This requires a settlement by compromise such as dividing the arrays of subarrays, using of symmetric plain and etc. This method can lessen the accuracy of computations, but allows the dedicated computer memory to decrease and larger structures to be estimated [3], [4]. Here, the dividing of the array of subarrays is used to be estimated an NxN antenna array.

For the estimation of the radiation pattern of the antenna arrays is used estimated before radiation pattern of particular radiator. The analytical expression of the radiation pattern is

$$F_A(\phi,\theta)=S(\phi,\theta)F_e(\phi,\theta),$$

where

$S(\phi,\theta)=\sum_{n=1}^{N} W_n e^{jk\vec{r}_n\vec{r}_s}$ is the factor of the arrays

and $F_e(\phi,\theta)$ is the radiation pattern of particular radiator.

(ϕ,θ) are angular coordinates of the current point in spherical co-ordinates

$k=2\pi/\lambda_0$ – wave number in the free space

r_n is the vector determined by the current point and the position of the element *n*,

$W_n = A_n e^{j\psi_n}$ is complex weight of element *n*.

The scanning of a regular antenna array with a step of phase variation per an element ψ_n is defined by

$$\psi_n = -k\vec{r}_n\vec{r}_j$$

r_j is the vector that defined the direction of scanning.

The basic cell used in this investigations is shown on Fig. 2.

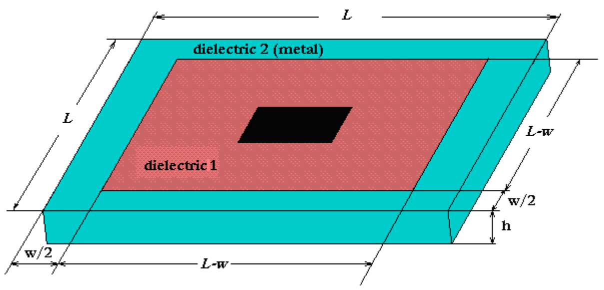

Fig. 2 The isolated microstrip radiator (cell)

It can be seen that the substrate is composed of two parts - dielectric 1 and dielectric 2 (metal). A special case, when the width *w/2*=0mm (without dielectric 2/metal) then this result in the conventional microstrip resonator. This model is used as a template for the other models. The dimensions of dielectric 1 decreases significantly when the values of the width *w/2* is great and this can result in mismatch or undesirable resonances can appear. In this paper are not represented the cases when these effects occur.

The shape of the cell is quadratic with dimensions LxL.

As in part I different cases are described:

1. The barrier between cells is entirely constituted of dielectric;
2. The vertical walls of the barrier are metal-coated;
3. The upper side of barrier is metal-coated;
4. The barrier is entirely constituted of metal.

Also, in the first three cases permittivity is changed $\varepsilon r = 1$; 10; 20. These great differences of ε_r give an idea of the differences in the particular cases. The distance between the patches in this paper is $d=const=0{,}55\lambda_0$. The thickness of barrier between different cells is changed in the interval *W=0, 2…10mm*, the height of the substrate is h=1,5mm, permittivity of the substrate in the area of the resonators is $\varepsilon_r=10{,}2$.

About the structure of the antenna arrays is performed comparison between the two cases for the antenna arrays with sizes: 1x1; 5x5 patches.

III. Results of the Calculations

Electromagnetic simulations are made with the help of high-frequency electromagnetic simulator working by the moment method. All of the investigations are for the same resonance frequency (10,9GHz).

On the next figures is represented the gain of the patch *G* [dBi] versus the width *w* of dielectric2/metal.

First, for the permittivity ε_r of the substrate is assigned the values 1, 11 and 20. The gain significantly decreases for great values of ε_r and *w*. It can be seen that the gain for $\varepsilon=1$ (in air) slightly increases when the area of dielectric 1 become smaller. Variation of the gain when $\varepsilon_r=11$ is negligible due to the permittivity of dielectric 2 that become quite close to that of dielectric 1.

When the permittivity is $\varepsilon_r=20$, *w* has high values and the border area between dielectric 1 and dielectric 2 is metal-coated, it is obvious that the gain decreasing is significantly greater in comparison to the case when the border is not metal-coated (Fig.3 and Fig.4).

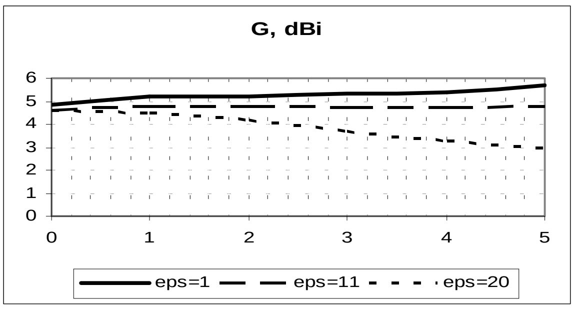

Fig. 3 Gain versus the width w[mm] for different values of the permittivity of the dielectric 2

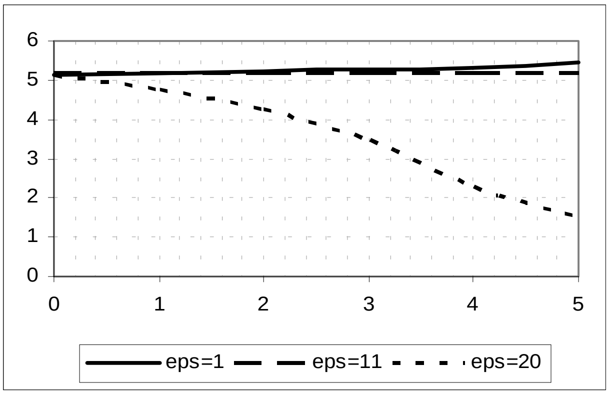

Fig. 4 Gain versus the width w[mm] for different values of the permittivity of the dielectric 2 with metallization between dielectric 1 and dielectric 2

The next simulation is performed with metallization of the top side of dielectric 2. The results are shown on Fig.5. There is not remarkable change of the gain. As the previous cases one can observe greatest gain for εr=1 and smallest for ε_r=20.

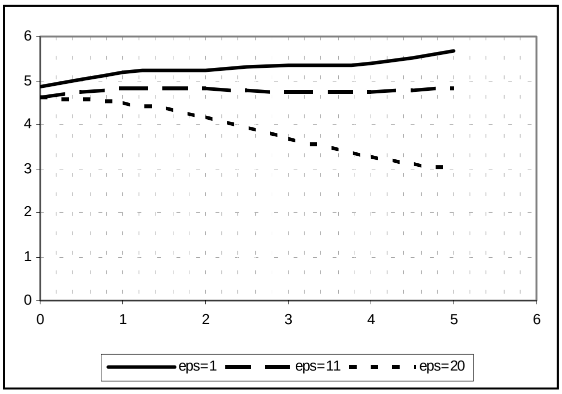

Fig. 5 Gain versus the width w[mm] for different values of the permittivity of the dielectric 2 with metallization on the top of dielectric 2

In the cases described above the parameter that is used for comparison is ε_r. On Fig. 6 are shown four curves for ε_r=1: the dielectric 1 is not metalized; there is a metallization between dielectric 1 and dielectric 2 (vertical strips); the top side of dielectric 2 is metalized (horizontal strips); instead of dielectric a perfect conductor is used. The curve of gain is smoother when the top side of dielectric 2 is metalized. Further, the gain is smaller than this one in the other cases when the values of width *w* are great. It is deeply impressed that the gain significantly increases for all values of *w* when the metal is used instead of dielectric 2. Other special feature is that the gain has resonance (G_{max} =5,78 when *w*=2mm).

The variation of the width of the main lobe of the radiation pattern is also investigated. Because of the same nature of the variations in all investigated structures only the simulation results for the cases with dielectric (without metallization)

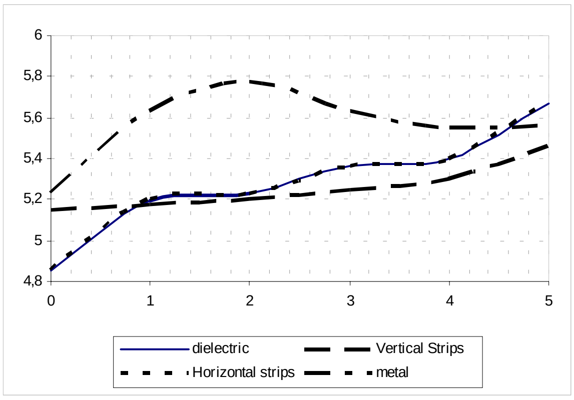

Fig. 6 Gain versus the width w [mm]

and perfect conductor (metal) used instead of dielectric 2 are shown (фиг.7).

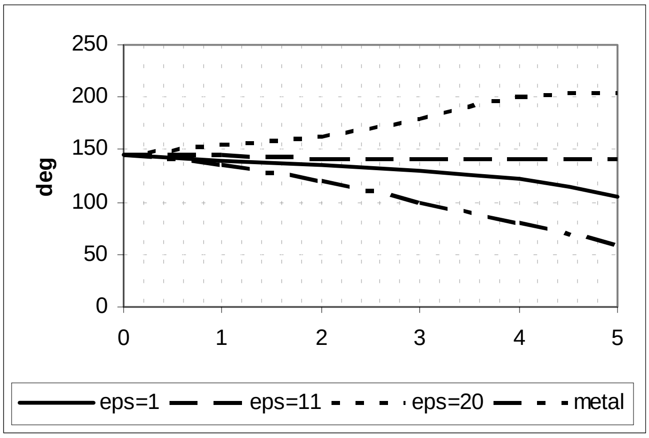

Fig. 7 Main lobe width versus the width of dielectric 2

It is obvious that the increasing of the value of permittivity results in widening of the radiation pattern; despite the inherent low directivity of the isolated radiator, (the main lobe is wide). The use of a metal box can significantly narrow the main lobe and to increase the directivity. This effect can be used in design of microstrip antennas when the main requirement is high directivity.

On the next drawings are represented the simulation results for an 5x5 antenna array in order to get an idea about the variation of the gain and the radiation pattern (Fig.8, Fig.9).

The level of the first side lobe is -13dB that is standard value for the microstrip antennas. When the permittivity of dielectric 2 increases then the backside lobe level decreases. For example, for the great values of width *w* and the permittivity ε=20 the backside lobe is suppressed about 25dB.

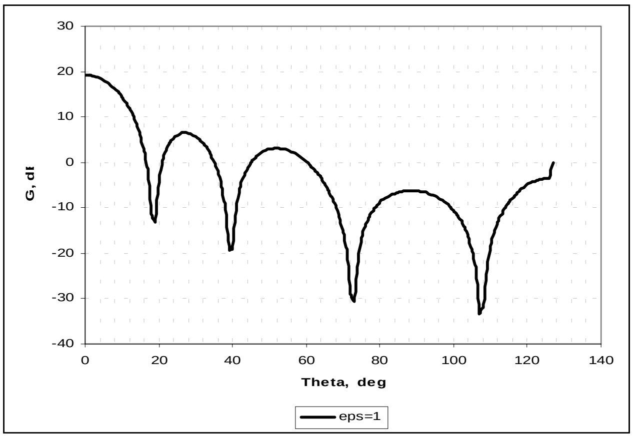

Fig. 8 The radiation pattern for the permittivity of dielectric 2 ε=1

The curves of the gain are similar to these of the isolated radiator (Fig.9). As in the previous simulations on the axes X is the width *w* [mm]. It is noticeable that the difference between the curves is greater for the higher values of the width *w* (more than 2 .5 dB for ε=1 and ε=20).

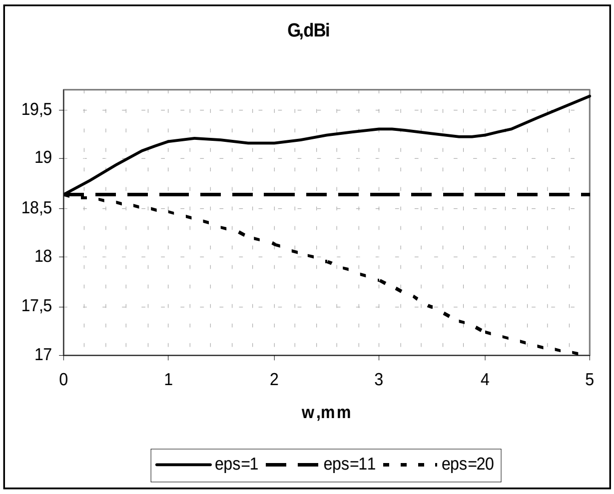

Fig. 9 The gain of a 5x5-antenna array versus the width of dielectric 2

IV. Conclusions

In this paper were represented the gain and main lobe width of the isolated radiator. The computed radiation pattern of isolated radiator is used for the simulation of radiation pattern of an 5x5-antenna array. A comparison between gains for different values of the permittivity ε_r was performed.

When the permittivity of dielectric 2 increases then the backside lobe level decreases. Putting the radiator in a metal box can increase the gain.

Reference

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