Improved Performance of a Microstrip Antenna Array

Using a tree structure patch fed by electromagnetic coupling

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***Abstract*—The aim of this investigation is to improve the performance of a microstrip antenna array using a tree structure patch supplied by electromagnetic coupling. This array is considered as a first step to design an adaptive microstrip antenna for UMTS use. The patch distribution structure used in this experiment allowed a great improvement of gain, directivity as well as the adaptation level of the studied array. The following work was done between the signals, systems and components laboratory of FST-Fez and the microwave laboratory of the National Institute of Posts and Telecommunications.**

***Keywords*—microstrip antenna array; electromagnetic coupling; adaptive microstrip antenna; tree patch distribution structure.**

I. INTRODUCTION

The UMTS (Universal Mobile Telecommunications System) is the cellular standard for mobile telecommunication systems of the third generation [1]. It has been adopted worldwide by 1998 but its service has been delayed due to the implementation costs.

Its special feature is the simultaneous transmission of voice and data with higher rates than those permitted by previous generations.

The development of these systems requires technological advances in electronic components, computer software, coding techniques and antennas.

Indeed, the antenna is one of the key points of wireless network since it represents the last link in the chain that allows emission, transmission and reception of the signal and therefore the information contained in it [1].

The ultimate goal of this work is designing an adaptive microstrip antenna for base stations of UMTS telecommunication networks, to improve the cover.

To reach this purpose, the parameters of our antenna (resonant-frequency, geometry and bandwidth) will be considered for an UMTS application.

The circuit will be made with FR4, a commonly used material for the manufacture of printed circuit with the following characteristics (thickness: 1.6 mm ε_r: 4.5 and tgδ: 0.02).

II. FEEDING BY ELECTROMAGNETIC COUPLING

In Section 2, we will introduce the electromagnetic coupling between radiating elements in a printed antenna array, and we will discuss the different types of this coupling.

A. Introduction to electromagnetic coupling between radiating elements

The electromagnetic interferences between radiating elements in a printed antenna array, is expressed by the modification of the surface currents distribution. This phenomenon, called coupling, depends on the antenna type and the distance between its elements. The coupling between two printed periodical antennas has a great importance in the design of antennas arrays, because it may cause a change in the radiation pattern.

The current flowing in each antenna induces currents in the all other antennas, whatever they are supplied or not.

The mutual coupling is due to the simultaneous effects of radiation in free space and the propagation of surface waves. This is an important criterion which should be considered while calculating array characteristics.

The theoretical calculation of mutual coupling depends on the antenna type and the distance between its elements. Jedlicka and Carver have studied experimentally the effect of coupling between patch antennas for circular and rectangular geometries [2]. Different methods have been presented to calculate the coupling coefficient between microstrip antennas.

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They were proposed by various authors such as Sindora, Pénard, Pozar, et al. [3].

B. *Coupling in the E plan and the H plan*

The radiation patterns are usually represented in two orthogonal planes "E plane and H plane", in relation to the principal direction:

- E Plan: location of space points where the radiated electric field is contained in this plan.
- H Plan: location of space points where the radiated magnetic field is contained in this plan.

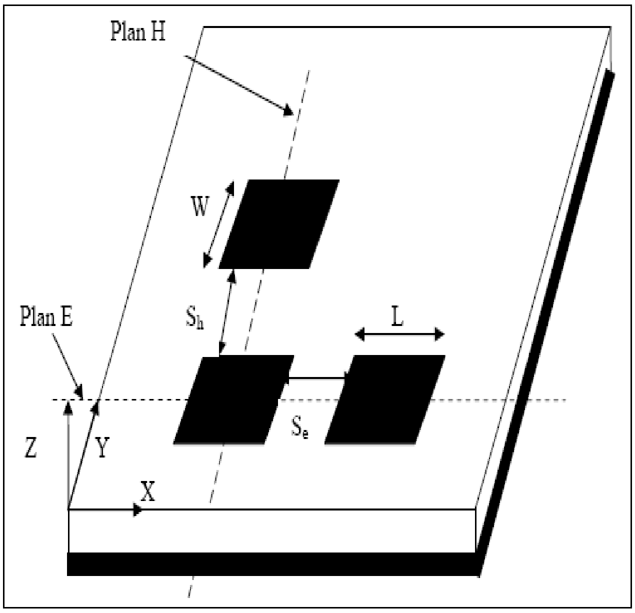

Figure 1. Electromagnetic coupling between patches antennas in the E plane and H.

Furthermore, two coupling types are distinguished:

- Horizontal coupling or coupling in the E plan: This means coupling between two elements in the same substrate, along the x direction with a Se coupling separation. All the W widths of the patches (in the Y direction) have the same size.
- Vertical coupling or coupling in the H plan, along the y direction with a S_h coupling separation. The L lengths of patches (in the direction of x) are identical.

III. TREE STRUCTURE AND IMPROVEMENT OF THE ARRAY PERFORMANCES

The aim of this work is to improve the performances of a microstrip antenna array of a circular shape by choosing a tree patch distribution structure. To illustrate the improvement through the comparison of findings, we will present first the basic array results.

The simulation will be performed using the ADS tool “Advanced Design System”. The substrate used for this simulation is FR4 for a resonant frequency of 2GHz.

A. *The studied array*

Our studied array *“Fig. 2”* consists of eight circular patches supplied by microstrip lines and adapted using coplanar notches [4].

The connecting lines should be sized to be adapted to 50 Ohms at the input of the array. Wilkinson dividers were integrated in order to obtain an impedance of 100 Ohm at the entrance of the patches [5].

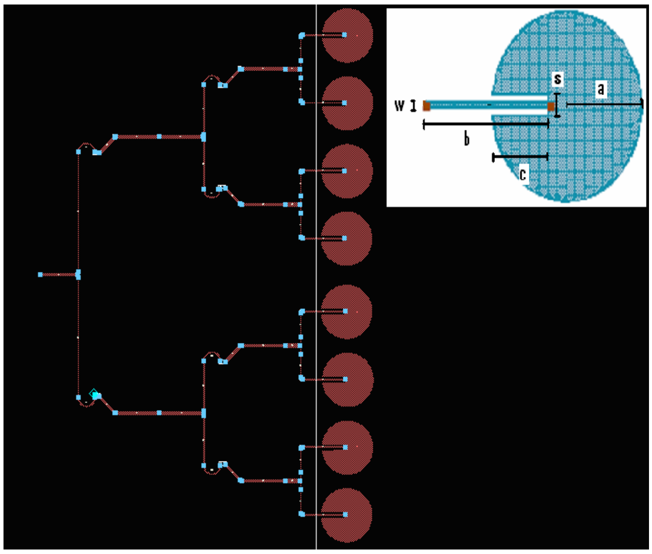

Figure 2. Microstrip array antenna with eight elements circular.

The values of the different parts of the patch and the connecting lines are:

a = 20.70mm.
b = 34.00mm.
c = 15.40mm.
w = 1.25mm.
s = 4.40mm.

The adaptation quality of an antenna is defined by giving either its characteristic impedance (usually 50 ohms) or its reflection coefficient; Figure 3 shows its value for our array of eight patches at 2 GHz.

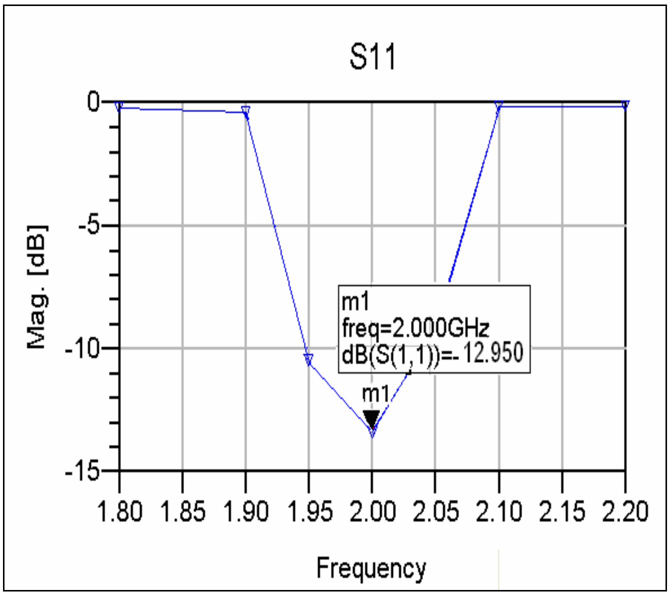

Figure 3. Reflection coefficient of the microstrip array antenna with eight circular elements (GHz).

The simulation results show an adaptation coefficient of -12 dB. Concerning the array characteristics, we can see 9dB directivity, a gain of 8dB and an effective angle of 86 degrees

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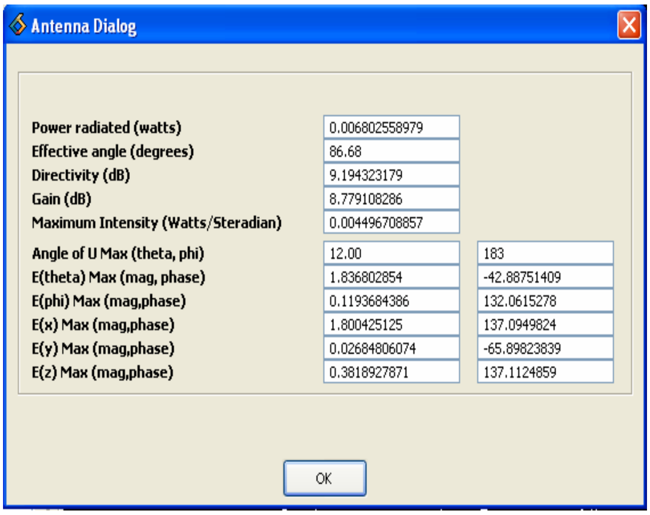
"Fig. 4". This array allows a bandwidth of 90 MHz. It also presents an electromagnetic coupling in the H plane.


Antenna Dialog

Power radiated (watts)	0.006802558979	
Effective angle (degrees)	86.68	
Directivity (dB)	9.194323179	
Gain (dB)	8.779108286	
Maximum Intensity (Watts/Steradian)	0.004496708857	
Angle of U Max (theta, phi)	12.00	183
E(theta) Max (mag, phase)	1.836802854	-42.88751409
E(phi) Max (mag,phase)	0.1193684386	132.0615278
E(x) Max (mag,phase)	1.800425125	137.0949824
E(y) Max (mag,phase)	0.02684806074	-65.89823839
E(z) Max (mag,phase)	0.3818927871	137.1124859

OK

Figure 4. Characteristics of the microstrip antenna array with eight elements circular.

B. *The array with a tree structure*

We have been inspired for this structure by YAGUI-UDA antenna. The eight patches supplied by microstrip lines represent the radiator element, and the patches supplied by electromagnetic coupling represent the director element of the antenna.

In this simulation our array has been developed by introducing circular patches arranged in a tree structure and supplied by electromagnetic coupling *"Fig. 5"*. This array presents an electromagnetic coupling in the E and H planes.

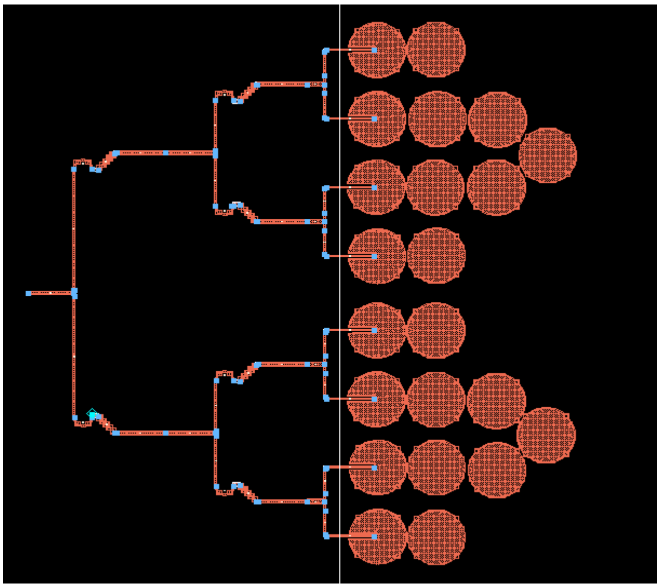


Figure 5. Microstrip antenna arrays with a tree structure.

For this structure, the simulation results give an adaptation coefficient of -15 dB "Fig. 6", and the array is characterized by a directivity of 12 dB, a gain of 11.4dB and an effective angle of 46 degrees "Fig. 7". This array allows a bandwidth of 140 MHz.

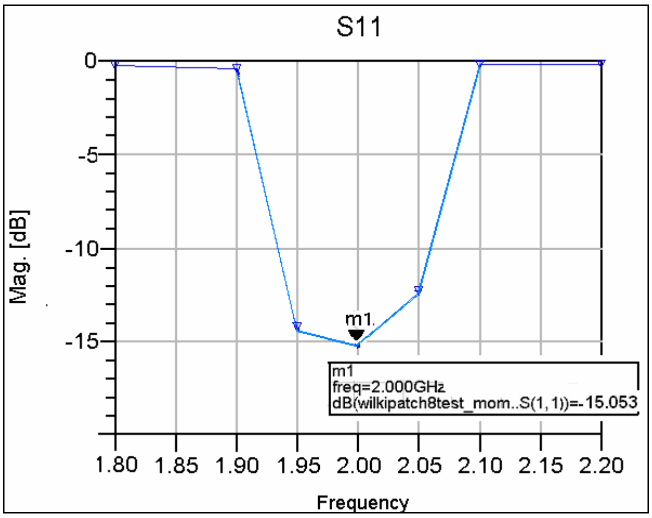
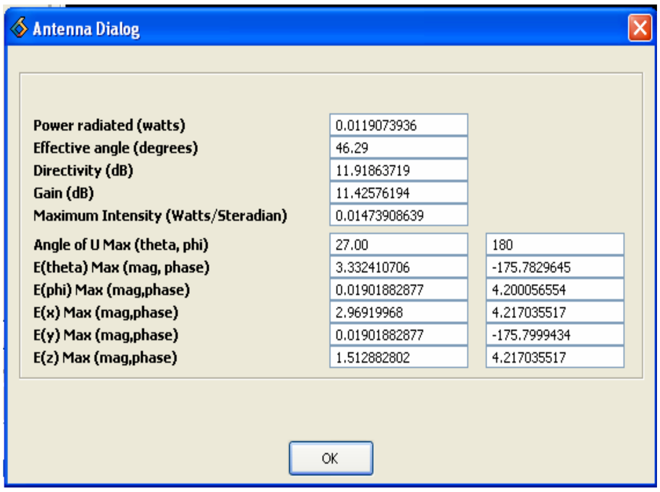


Figure 6. Reflection coefficient of microstrip antenna arrays with tree structure.


Antenna Dialog

Power radiated (watts)	0.0119073936	
Effective angle (degrees)	46.29	
Directivity (dB)	11.91863719	
Gain (dB)	11.42576194	
Maximum Intensity (Watts/Steradian)	0.01473908639	
Angle of U Max (theta, phi)	27.00	180
E(theta) Max (mag, phase)	3.332410706	-175.7829645
E(phi) Max (mag,phase)	0.01901882877	4.200056554
E(x) Max (mag,phase)	2.96919968	4.217035517
E(y) Max (mag,phase)	0.01901882877	-175.7999434
E(z) Max (mag,phase)	1.512882802	4.217035517

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Figure 7. Characteristics of the microstrip antenna array with a tree structure.

The radiation pattern is given by the Figure 8.

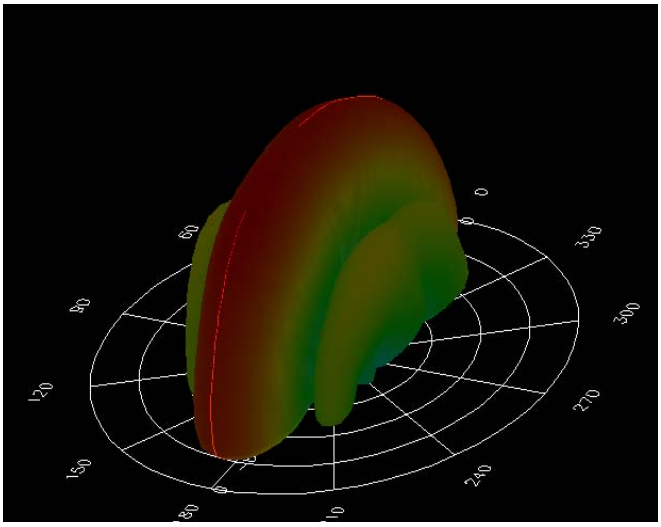

Figure 8. Radiation pattern of the antenna array with a tree structure.

Our network consists of a linear distribution of patches where the appearance of side lobes that have the same level. If these lobes hamper the application, the solution is simply to apply a law of amplitude weighting to reduce their levels. We also note that we have a directive main lobe and this is consistent with the results given by the computer (Figure 7).

IV. CONCLUSION

The experiments performed until now have allowed an improvement of performances of our microstrip array antenna by using a tree structure patch supplied by an electromagnetic coupling. The simulation results show an adaptation coefficient of -15 dB, and the array is characterized by a directivity of 12dB, a gain of 11.4dB and an effective angle of 46 degree. This network will form the basic network of our application; more precisely it will be the pointing network of users. Indeed it will be developed in order to have the opportunity to change its angle depending on demand. So as a perspective, we will integrate the intelligent function of our network and improving the bandwidth to meet the need for a UMTS application.

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