Improved Performance of the Basic Array of a Microstrip Adaptive Antenna using a Tree Structure of Patch Fed by Electromagnetic Coupling

T. MAZRI, N. EL AMRANI, F. RIOUCH

***Abstract*—The aim of this investigation is to improve the performance of a basic microstrip antenna array using a tree structure patch supplied by electromagnetic coupling. The developed network which contains two subnets, a distribution subnet and a scanning subnet, 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 realized in the laboratory signals, systems and components of FST-Fes, in colaboration with the Microwave Laboratory of the National Institute of Posts and Telecommunications of Rabat.**

***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].Nevertheless, there is still a strong need to develop and improve the functioning and performance of antennas with minimal impact on the cost and complexity of these systems. Patterns of diversity have been studied for a long time. Among them; the adaptive antennas get all the attention for mobile applications.

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 (2Ghz), geometry and bandwidth" will be considered for an UMTS application. The circuit has been realized with FR4, a commonly used material for the manufacture of printed circuit with the following characteristics (thickness: 1.6 mm εr: 4.5 and $tg\delta$: 0.02).

II. FEEDING BY ELECTROMAGNETIC COUPLING

In Section 2, the electromagnetic coupling will be introduced between radiating elements in a printed antenna array, and the different types of this coupling will be discussed.

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

Manuscript received January 09, 2011.

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microstrip antennas. 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.

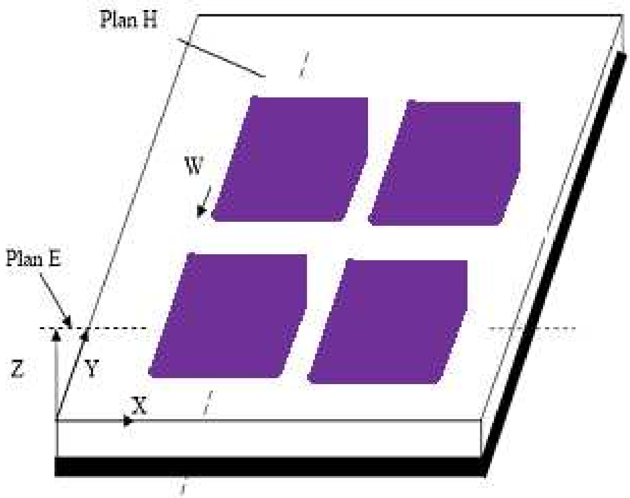

Fig. 1. Electromagnetic coupling between patches antennas in the E plane and H.

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 Sh 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, the basic array results will be presented on first. 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].

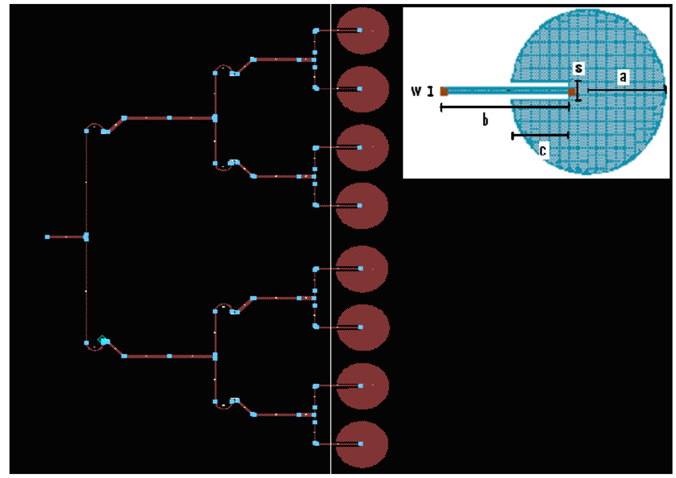

Fig. 2. Microstrip array antenna with eight elements circular.

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.

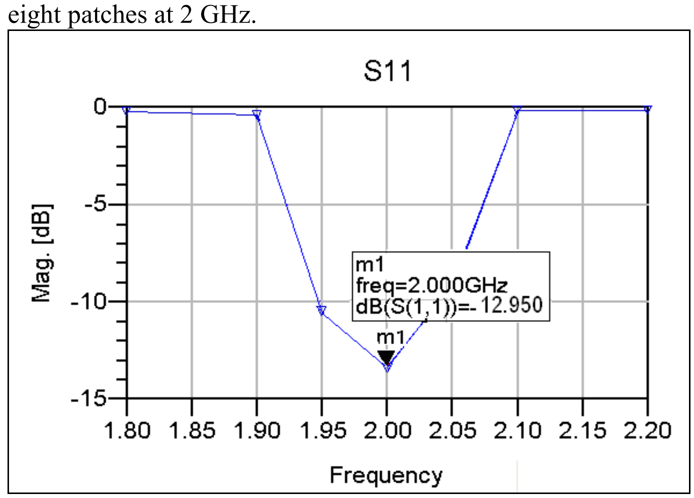

Fig. 3. Reflection coefficient of the microstrip array antenna with eight circular elements (GHz).

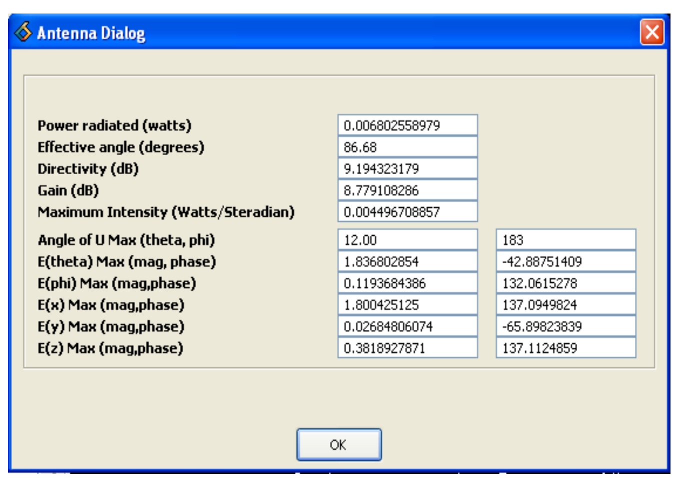

Fig. 4. Characteristics of the microstrip antenna array with eight elements circular.

The simulation results show an adaptation coefficient of -12 dB. Concerning the array characteristics, the directivity is about 9dB, a gain of 8dB and an effective angle of 86 degrees “Fig. 4”. This array allows a bandwidth of 90 MHz. It also presents an electromagnetic coupling in the H plane.

B. The array with a tree structure

This structure has been inspired by the 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.

Our basic network will consist of two separate networks;

- The first subnet will be called the scanning network; its role will be to detect users and memorizing their locations.
- The second subnet will be call distribution network, its role will be to generate the radiation pattern which obey the structure calculated by the first subnet.

The distribution of parasitic patches will be made in order to take into account the future functionality of sub-networks, where the difference between the two structures used: For scanning network, the tree structure is a single branch. However, for the distribution network, the structure is in two branches.

The scanning array

In this simulation our array has been developed by introducing circular patches arranged in a tree structure and supplied by electromagnetic coupling (Figure 6).

This array presents an electromagnetic coupling in the E and H planes.

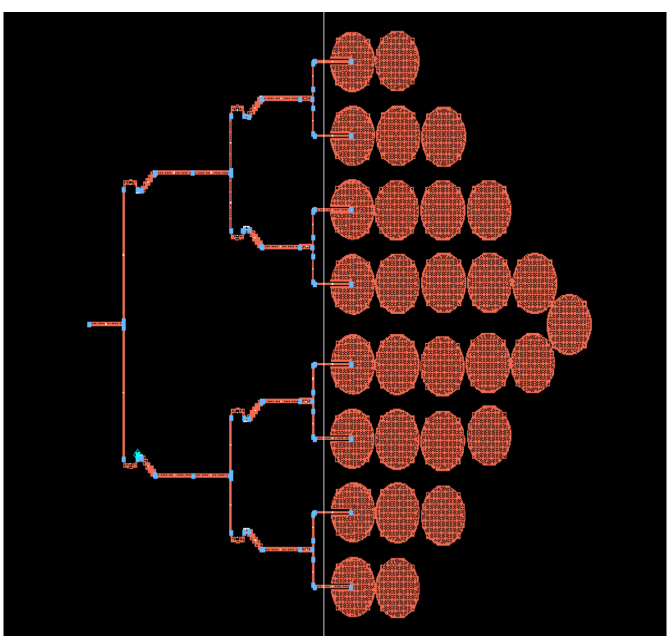

Fig. 5. The scanning microstrip antenna arrays with a tree structure.

The simulation result of the reflection coefficient of this antenna is shown in Figure 6.

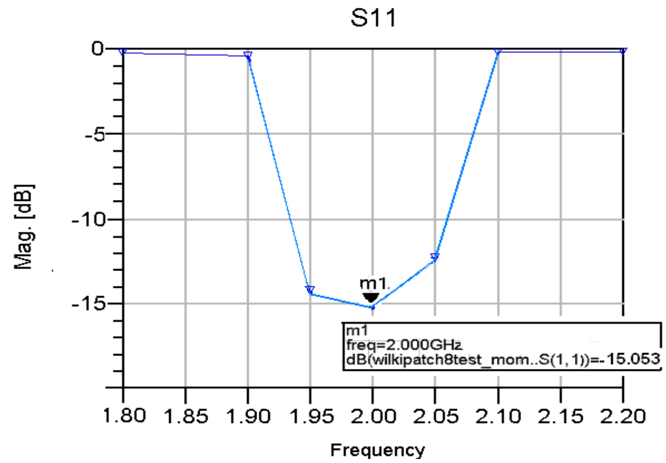

Fig. 6. Reflection coefficient of microstrip antenna arrays with tree structure.

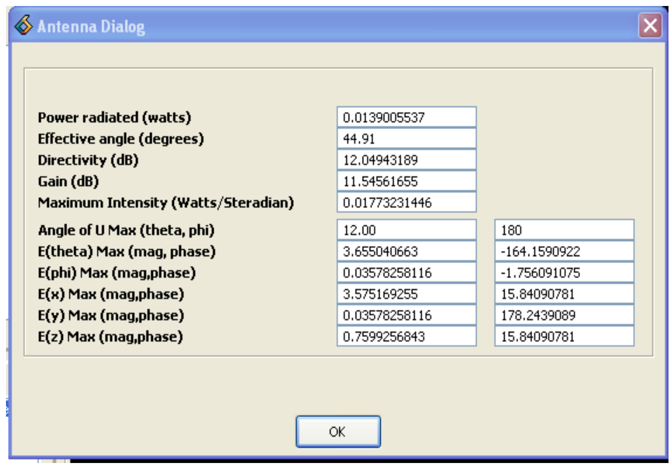

Fig. 7. Characteristics of the microstrip antenna array with a tree structure.

For this structure, the simulation results give an adaptation coefficient of -15 dB (Figure 7), and the array is characterized by a directivity of 12 dB, a gain of 11dB and an effective angle of 44 degrees (Figure 8). This array allows a bandwidth of 140 MHz

The radiation pattern is given by the Figure 8

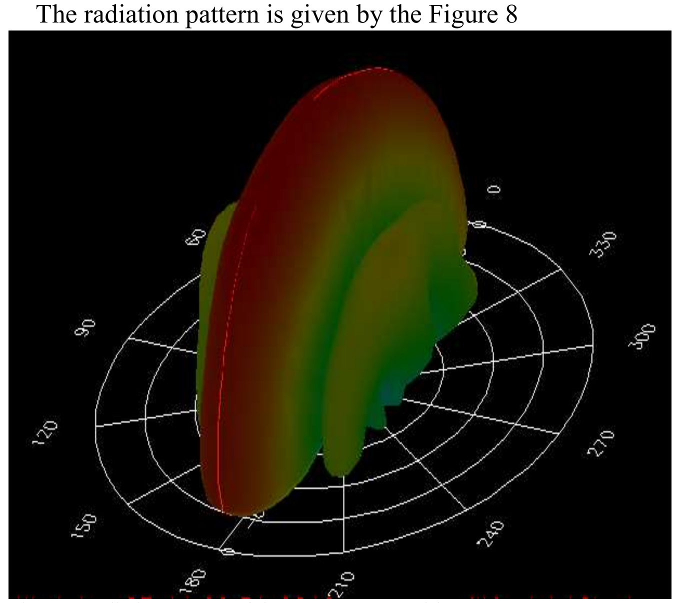

Fig. 8. Radiation pattern of the antenna array with a tree structure.

The 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.They is many algorithms for calculating weights that optimize the following criteria. For example, the method of Dolph-Chebyshev optimizes the weights to achieve maximum gain for a sidelobe level imposed by the application. Also the main lobe is directive and this is consistent with the results given by the computer (Figure 7).

The distribution array

For the distribution network, our array has been developed by introducing circular patches arranged in a tree structure. The difference between this structure and the structure simulated in the last paragraph, is that the distribution of parasitic patches was made in two branches instead of a single branch "Fig. 9". This network presents an electromagnetic coupling in the E and H planes.

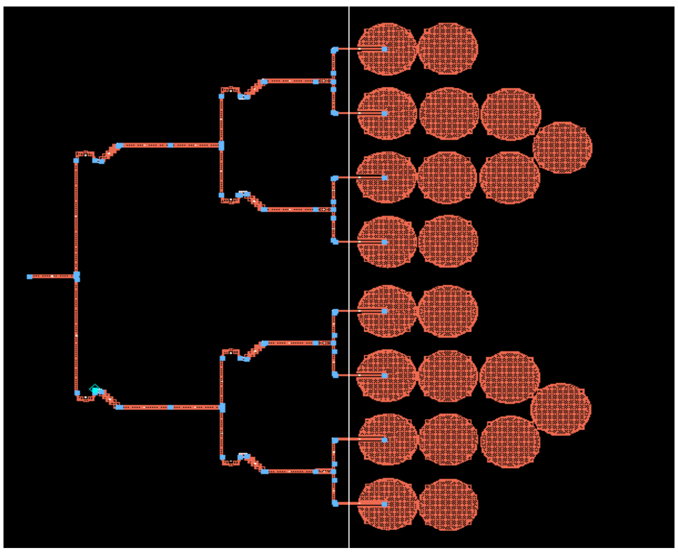

Fig. 9. Microstrip antenna arrays with a tree structure.

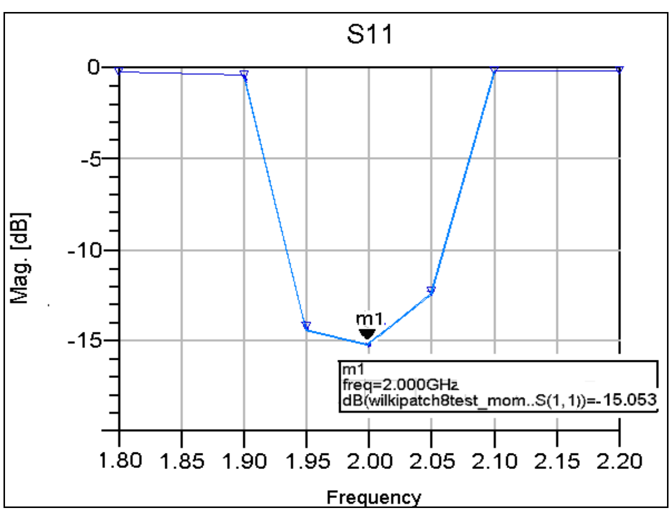

Fig. 10. Reflection coefficient of microstrip antenna arrays with tree structure.

The simulation results of distribution network give an adaptation coefficient of -15 dB "Fig. 10", and the array is characterized by a directivity of 12 dB, a gain of 11.4dB and an effective angle of 46 degrees "Fig. 11". This array allows a bandwidth of 140 MHz.

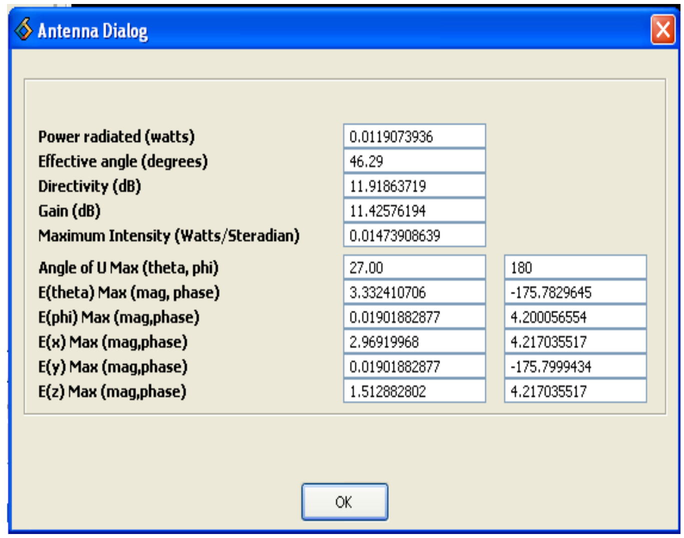

Fig. 11. Characteristics of the microstrip antenna array with a tree structure.

The radiation pattern is given by the Figure 12.

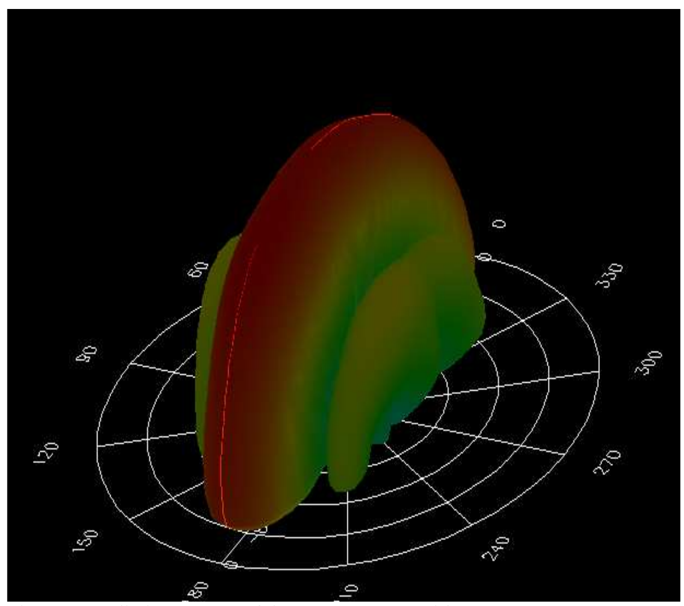

Fig. 12. Radiation pattern of the antenna array with a tree structure.

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, a VSWR about 1.42 and the array is characterized by a directivity of 11.9dB, a good level of gain "11.4dB" for base station antenna [6] and an effective angle of 46 degree for distribution network and 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 44 degree for scanning network.

This network will form the basic network of our application. Indeed it will be developed in order to have the opportunity to change the angle of distribution network depending on demand and geometry gave by scanning network. So as a perspective, the intelligent function of our network will be integrated and the bandwidth will be improved to meet the need for a UMTS application.

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