

A comparison the performances of Linear and Planar Array of the Four Patches Antennas by the software Matlab

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Abstract: A linear array is a simple configuration and commonly used, however it is essential to investigate its performances.

There are four basic factors that influence on performances of an array patches antennas: spacing between patches, number of patches in the array, amplitude distribution, and excitation phase, all these parameters will be varied to find the optimal configuration.

This paper is consecrated to the variation of the excitation phase, and the other factors are fixed, what is going to permit us to scanning the radiation pattern of a linear array of four rectangular patches microstrip antennas in the E-plane and in the H-plane,

without resorting to a mechanical displacement of this array [1]. The effect on the direction of the main beam of those arrays (linear and planar) will be studied. We are going to compare our theory used and programmed in MATLAB by one simulations executed in the PCAAAD (Personal Computer Aided Antennas Design) software [2].

However, we are going to explore the radiation pattern by the variation of the excitation phase of patches of a square array for four rectangular microstrip patches antennas array, as we takes the same elements of the previous linear array[3], [4], and we are going to put them under shape of a planar square array.

Keys words: Patch antenna; Liner array antenna; Planar array antenna; Excitation phase; Radiation pattern.

1 – Results and Discussions:

1 – 1 – Linear array of four patches antennas:

1-1-1 effect of the variation of the excitation phase β :

The parameters predefined of our antennas used in the computation are:

| | |
|-----------------------------|----------------------|
| Patch length | L = 4.04 cm |
| Patch width | W=5.94 cm |
| Dielectric thickness | h = 0.127 cm |
| Dielectric permittivity | $\epsilon_r = 2.42$ |
| Antenna resonance frequency | $f_r = 2.31$ GHz |
| Wavelength | $\lambda = 12.98$ cm |

Performances of a linear array of patches microstrip antennas will be examined by the variation of the excitation phase β between patches of the array. The general radiation patterns that formed by the combination of radiation pattern of a patch microstrip

antenna isolated and the linear array factor, will be analyzed.

The general model will be studied using the E-plane and the H-plane. The following assumptions are used for the calculus and simulation:

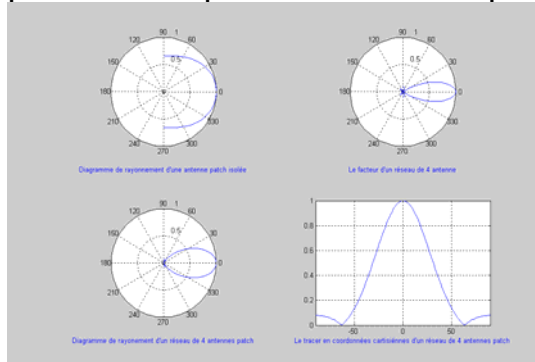
Number of patches = 4
 The amplitude of patches excitation is uniform (=1).
 The spacing between elements is 4.2 cm in the direction of the x axis (this spacing between patches was been found to produce the best radiation pattern after several tests).

The results are given by software MATLAB that we have programming the formulations used as our theory to study this style of antennas, are shown in figures .1 and 2, we fond The radiation pattern of an isolated patch microstrip antenna, the factor of 4 antenna array, the radiation pattern of a 4 patches array antennas in polar coordinates and in Cartesian coordinates. Those results given by simulation using the software PCAAD are found in tables 1 and 2 in the E-plans and H-plane.

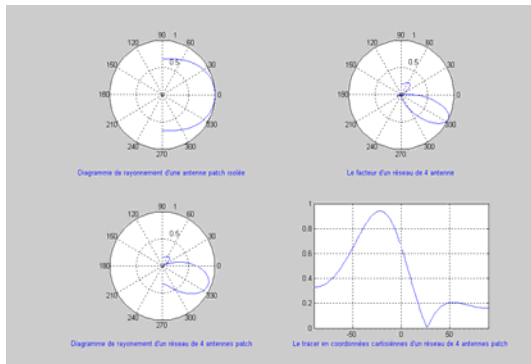
Radiation in the E-plane:

We varied the excitation phase β of the array from 0° to 360° by step 45° , and we observes its

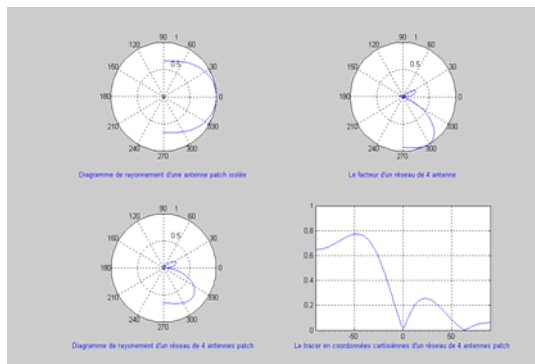
effect on the position, the directivity and the radiation pattern amplitude in the E-plane:



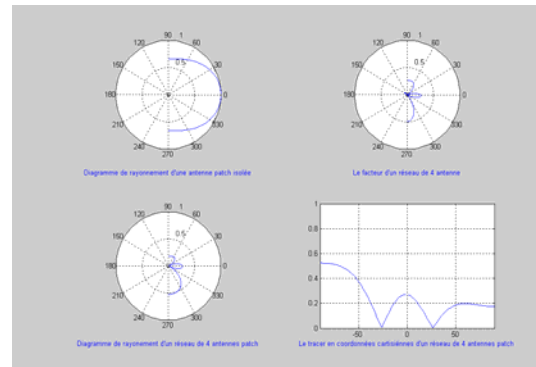
(i) $\beta=0^\circ, 360^\circ$



(ii) $\beta= 45^\circ$

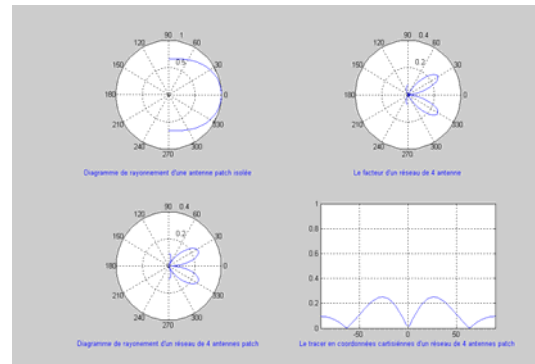


(iii) $\beta=90^\circ$

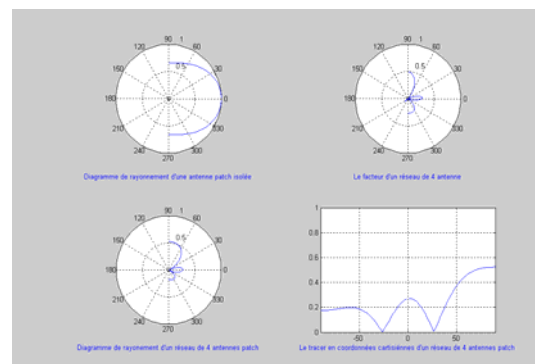


(iv) $\beta=135^\circ$

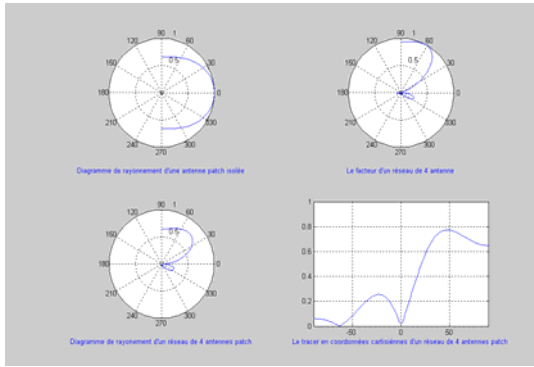
Figure 1: The radiation pattern of a linear array of four patches antennas in the E-plane, for different excitations phases of patches,



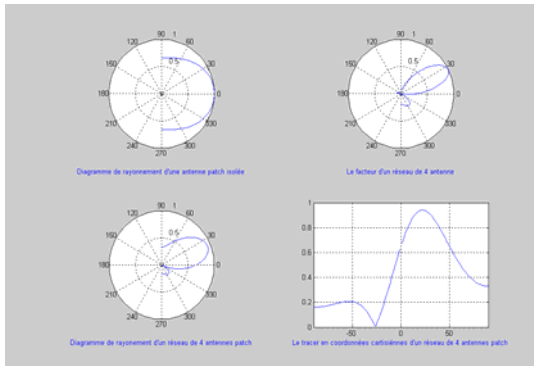
(v) $\beta=180^\circ$



(vi) $\beta=225^\circ$



(vii) $\beta=270^\circ$



(viii) $\beta=315^\circ$

The results given by the software PCAAD for a linear array of 4 patches antennas in the E-plane shown in the table 2-1 are compatible with those given by the software MATLAB in the E-plane.

| β (degrees) | directivity (dB) | Beam width in 3dB (degree) | Angle of the main lobe (degree) |
|----------------------|---------------------|-------------------------------------|---|
| 0, 360 | 11.30 | 19 | 0 |
| 45 | 10.96 | 19 | -19 |
| 90 | 10.60 | 20 | -40 |
| 135 | 11.15 | 27 | -69 |

| | | | |
|-----|-------|----|----|
| 180 | 9.39 | - | - |
| 225 | 11.15 | 27 | 69 |
| 270 | 10.60 | 20 | 40 |
| 315 | 10.96 | 19 | 19 |

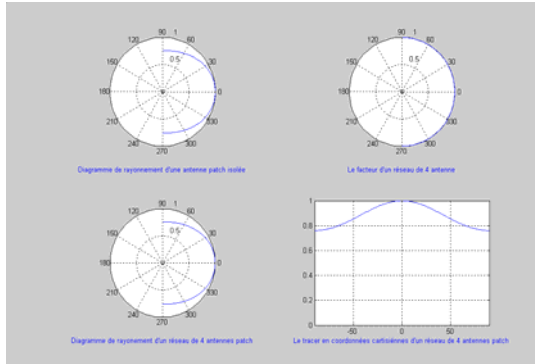
Table 1: The characteristic parameters of the radiation pattern of a linear array of four patches antennas in the E-plane, given by the software PCAAD,

We noted that when the excitation phase varies from 0° to 135° , the angle between the main beam (main lobe) and the z axis of the reference mark array increases, the amplitude of the main lobe decreases to depends of the apparition of the side lobe. At $\beta = 180$, the main lobe disappears, and it's only apparition of several secondary lobes (side, minor and back lobes), the radiation in this case is inside the dielectric. The best directivity of the radiation pattern is at 0° .

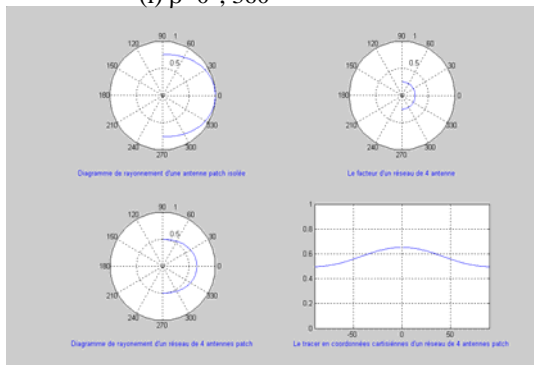
When the excitation phase β varies from 225° to 360° , the directivity, the amplitude and the deviation angle of the radiation pattern presents a symmetry in relation to $\beta = 180^\circ$. Amplitude increase and deviation angle decreases. The best directivity is fond at $\beta = 360^\circ$ (0°).

Radiation in the H-plane:

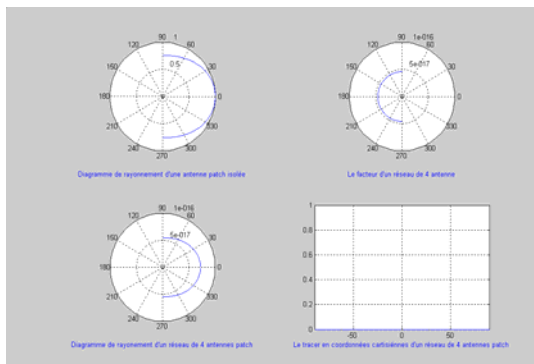
We varied the excitation phase β of the array from 0° to 360° by step 45° , and we observe its effect on the position, the directivity and the radiation pattern amplitude in the H-plane:



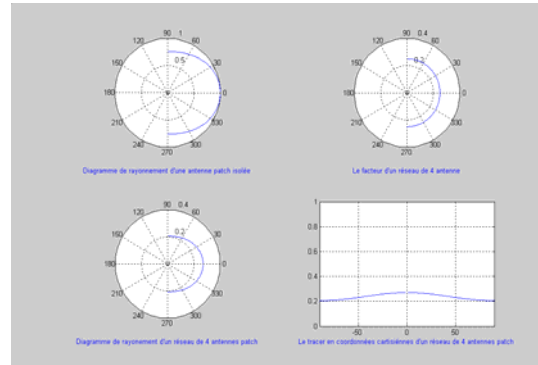
(i) $\beta=0^\circ, 360^\circ$



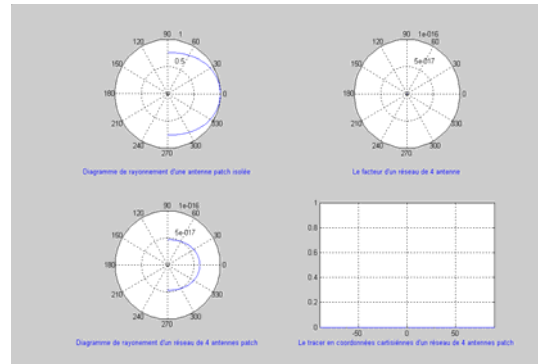
(ii) $\beta=45^\circ$



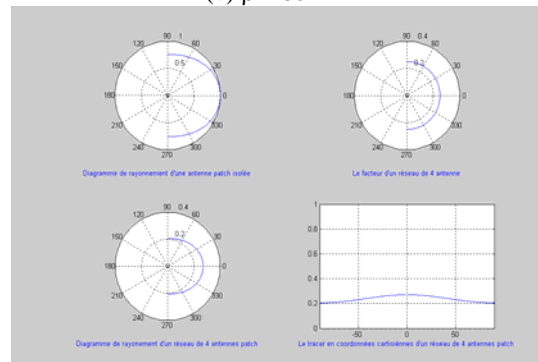
(iii) $\beta=90^\circ$



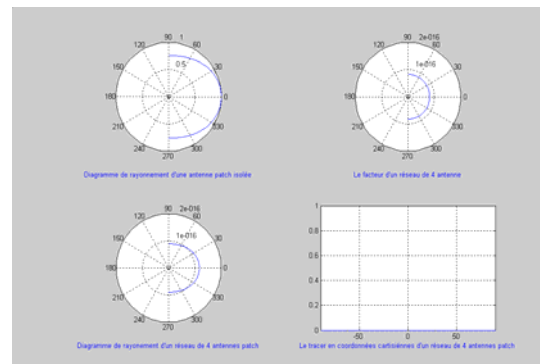
(iv) $\beta=135^\circ$



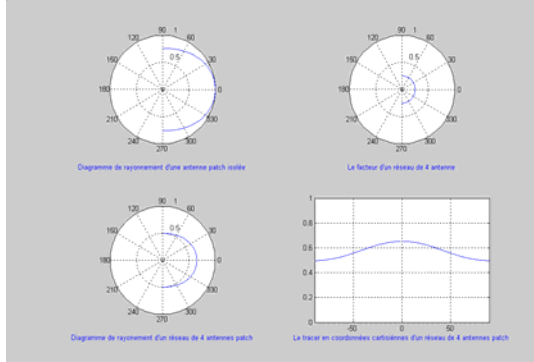
(v) $\beta=180^\circ$



(vi) $\beta=225^\circ$



(vii) $\beta=270^\circ$



(viii) $\beta=315^\circ$

Figure .2: The radiation pattern of a linear array of four patches antennas in the H-plane, for different phases of excitations patches

Results given by the PCAAD software for a linear array of four patches antennas in the H-plane shown in the table 2 are compatible with those given by the calculus doing in MATLAB for the H-plane (figure 2).

| | | | |
|-----|-------|----|---|
| 135 | 11.15 | 37 | 0 |
| 180 | 9.38 | - | - |
| 225 | 11.15 | 37 | 0 |
| 270 | 10.60 | - | - |
| 315 | 10.95 | 37 | 0 |

Table 2: The characteristic parameters of the radiation pattern of a linear array of four patches antennas in the H-plane, given by the PCAAD software

In the H-plane, the variation of the patch's excitation phase influences only on the amplitude and the directivity of the radiation pattern, but the deviation angle of the main beam stay always equal to 0, whatever the value of the phase.

The amplitude decreases when the excitation phase increases between 0° and 180° , except the two exceptional cases 90° and 180° where the amplitude of the radiation pattern is very weak, the best directivity is at the value 0° of the excitation phase.

1 – 2 - Planar array antennas:

1-2-1-Effect of the variation of excitation phases β_x and β_y :

Performances of a square array of four patches microstrip antennas will be examined by the variation of excitation phases β_x and β_y respectively in the x-axis and in the y-axis. The general

| β (degree) | Directivity (dB) | Beam width at 3dB (degree) | Angle of the main lobe (degree) |
|---------------------|---------------------|-------------------------------|------------------------------------|
| 0, 360 | 11.30 | 37 | 0 |
| 45 | 10.95 | 37 | 0 |
| 90 | 10.60 | - | - |

radiation pattern is formed by the combination of this of an isolated patch microstrip antenna and the array factor of a planar array of four beaming elements [6].

The general model will be studied by the theory treated by MATLAB and the simulation by the PCAAD software. The modelling of the antenna chosen is:

Number of patches = 2 x 2

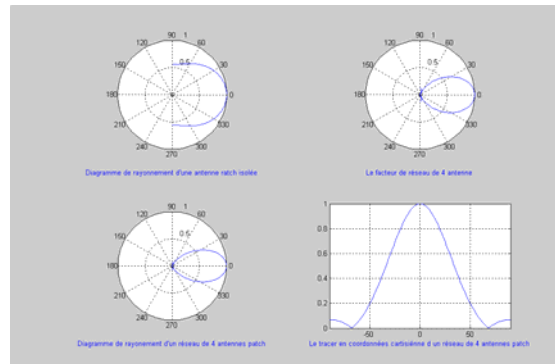
The spacing between patches is 7 cm in the direction of the x-axis, 7.5 cm in the direction of the y-axis (the spacing between patches to be found after several tests to produce the best radiation pattern).

The amplitude of patch's excitation is uniform (=1).

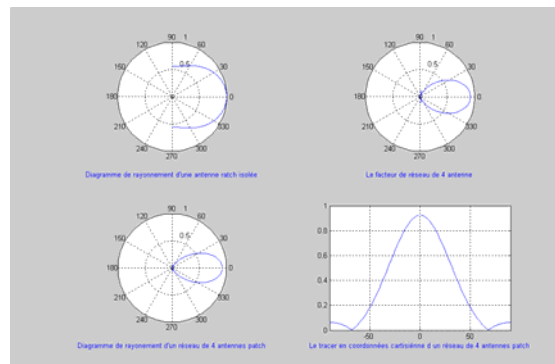
The figures 3, 4, 5 and 6 shown the radiation pattern of an isolated patch antenna, the factor of four antenna arrays, and the radiation pattern of a 4 patches antennas array in polar coordinates and its tracing in Cartesian coordinates given by the theory used and treated by the software MATLAB. The tables 3 and 4 the results simulated with the same array of antennas given by the software PCAAD. Those results are given in the E-plane and H-plane.

Radiation in the E-plane:

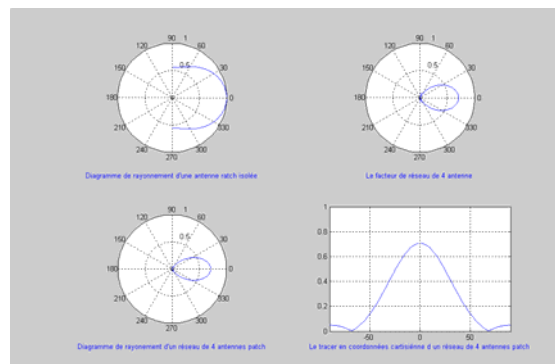
We fixes β_x at the value 0° and we varies β_y from 0° to 180° by step of 45° , we observes its effect on the position, the directivity and the amplitude of the radiation pattern in the E-plane.



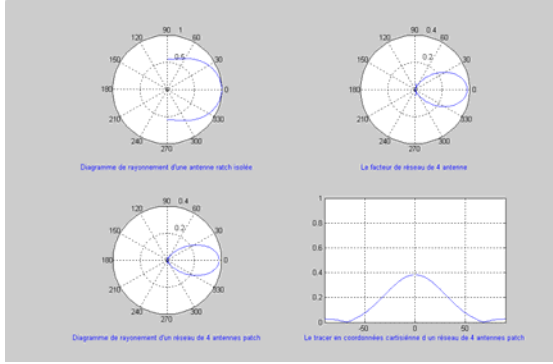
(i) $\beta_x=0^\circ, \beta_y=0^\circ$



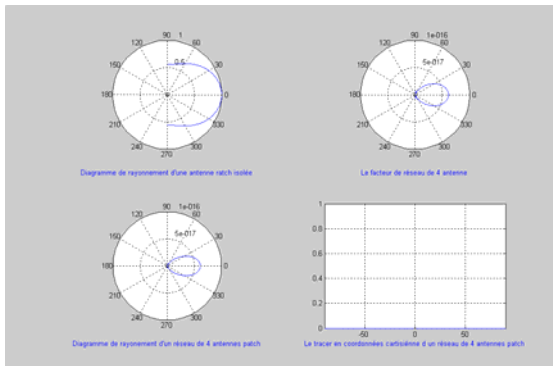
(ii) $\beta_x=0^\circ, \beta_y=45^\circ$



(iii) $\beta_x=0^\circ, \beta_y=90^\circ$



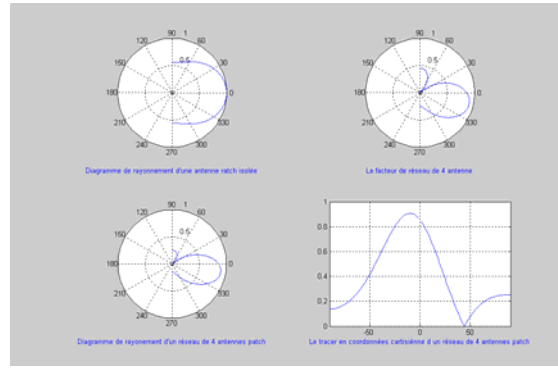
(iv) $\beta_x=0^\circ, \beta_y=135^\circ$



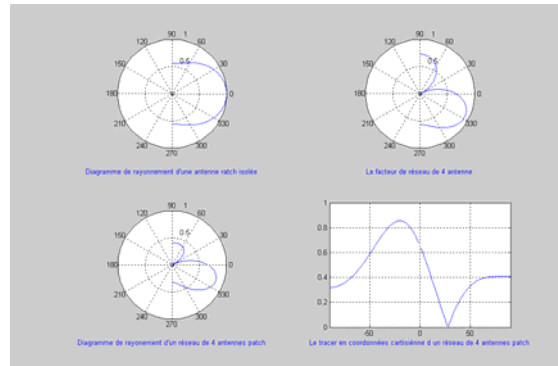
(v) $\beta_x=0^\circ, \beta_y=180^\circ$

Figure .3: The radiation pattern of a square array of 4 patches antennas in the E-plane

Now we fixed β_y at the value 45° and we varied β_x from 45° to 180° by step of 45° . Its effect on the position, the directivity and the amplitude of the radiation pattern in the E-plane are shown in the following figure 4:

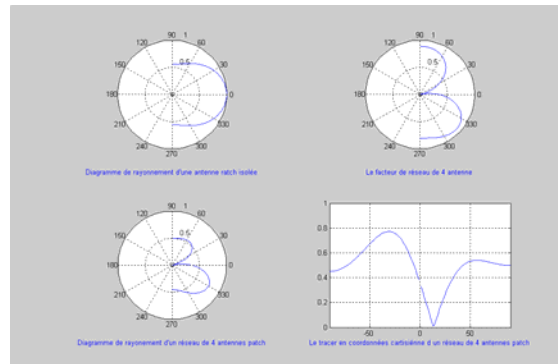


(i) $\beta_x=45^\circ, \beta_y=45^\circ$

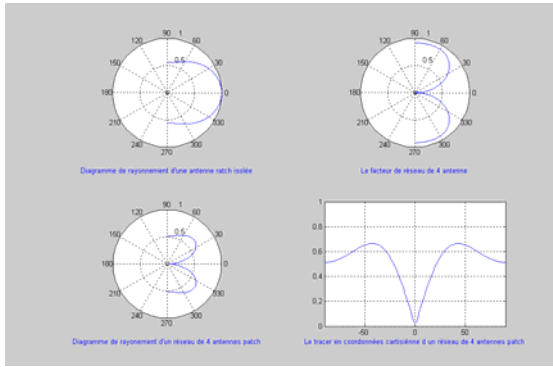


(ii) $\beta_x=90^\circ, \beta_y=45^\circ$

Table .3: The characteristic parameters of the radiation pattern of a square array of 4 patches antennas in the E-plane given by the software PCAAD



(iii) $\beta_x=135^\circ, \beta_y=45^\circ$



(iv) $\beta_x=180^\circ$, $\beta_y=45^\circ$

Figure .4: The radiation pattern of a square array of 4 patches antennas in the E-plane

Results of simulations of the PCAAD software for the same array in the E-plane are resumed in the table .3. We remarks that the values found are compatible with those given by MATLAB.

| β_x (deg ree) | β_y (deg ree) | Direc tivity (dB) | Bea m widt h at 3dB (deg ree) | Main lobe Angl e (deg ree) |
|---------------------------|---------------------------|-------------------------|---|---|
| 0 | 0 | 12.62 | 24 | 0 |
| 0 | 45 | 14.34 | 24 | 0 |
| 0 | 90 | 14.64 | 24 | 0 |
| 0 | 135 | 10.28 | 24 | 0 |
| 0 | 180 | 10.12 | 24 | 0 |

| | | | | |
|-----|----|-------|----|-----|
| 45 | 45 | 14.08 | 23 | -10 |
| 90 | 45 | 13.37 | 23 | -20 |
| 135 | 45 | 12.29 | 23 | -31 |
| 180 | 45 | - | - | - |

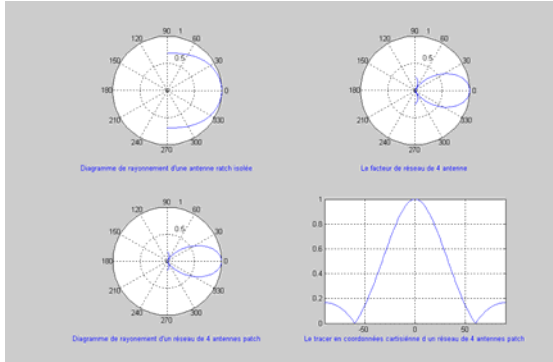
When the excitation phase β_x is fixed and equal to 0° , the excitation phase β_y is variable (Figure 3), we remarks that the influence of β_y is grand on the radiation pattern, the angle of deviation of the main beam stay always equal to 0 (figure 3 and table 3).

On the contrary, if β_y is fixed at 45° and the excitation phase β_x is variable, the radiation pattern changes the direction for every value of β_x , and it is accompanied by a slower reduction of the amplitude of the main beam. At $\beta_x = 180^\circ$ the radiation pattern is divided in two parts, in this case we can say anything on its directivity, its beam width at 3dB and its direction (figure 4, table 3).

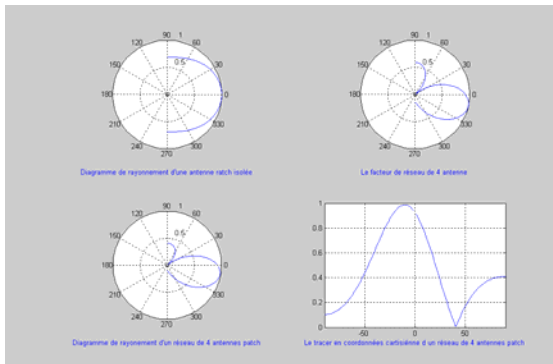
Radiation in the H-plane:

First, we have $\beta_x = 0^\circ$ and β_y varies from 0° to 180° by step 45° . The figure 5 shows the variation of β_y on the position, directivity and the radiation pattern in the H-plane.

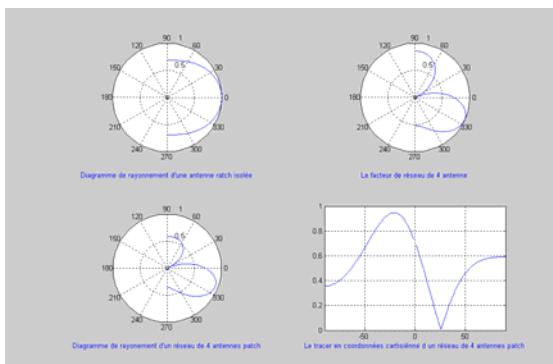
Secondly, we fixed β_y at the value 45° and we varied β_x , the figure 6 show its effect on the same parameters in the H-plane.



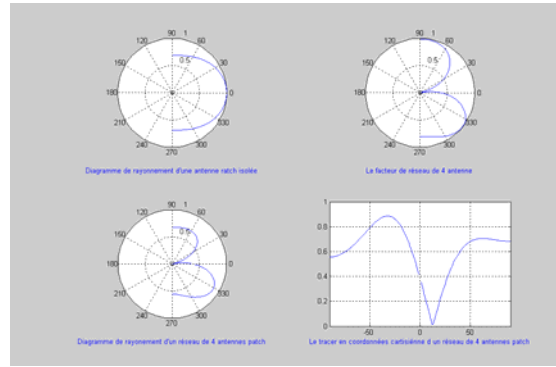
(i) $\beta_x=0^\circ, \beta_y=0^\circ$



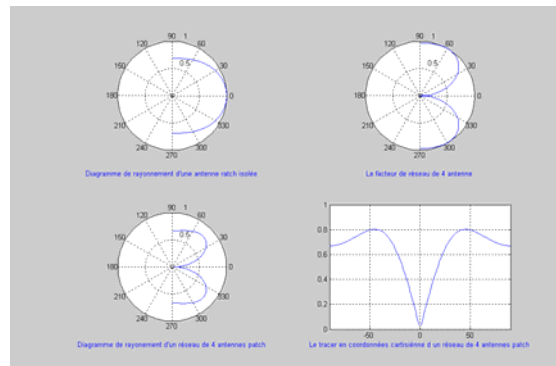
(ii) $\beta_x=0^\circ, \beta_y=45^\circ$



(iii) $\beta_x=0^\circ, \beta_y=90^\circ$

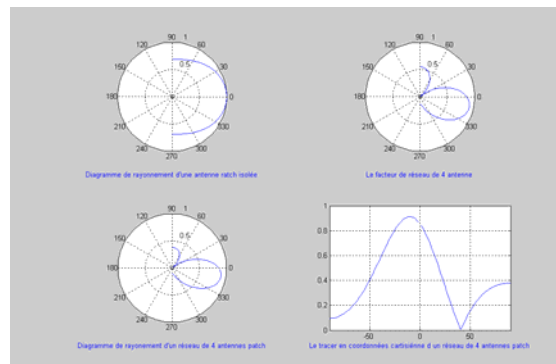


(iv) $\beta_x=0^\circ, \beta_y=135^\circ$

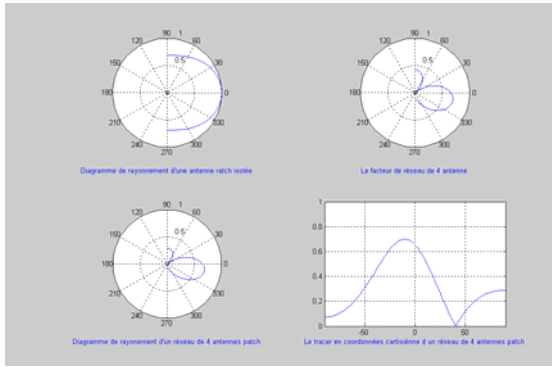


(v) $\beta_x=0^\circ, \beta_y=180^\circ$

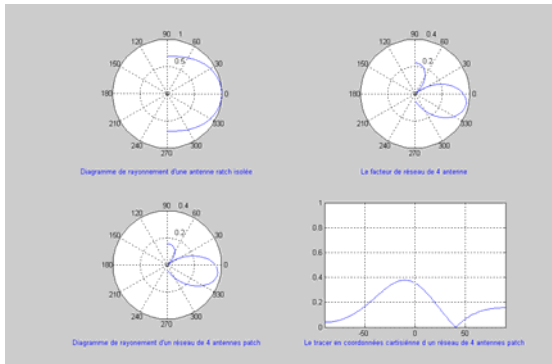
Figure .5: The radiation pattern of a square array of four patches antennas in the H-plane, β_x fixed and β_y variable



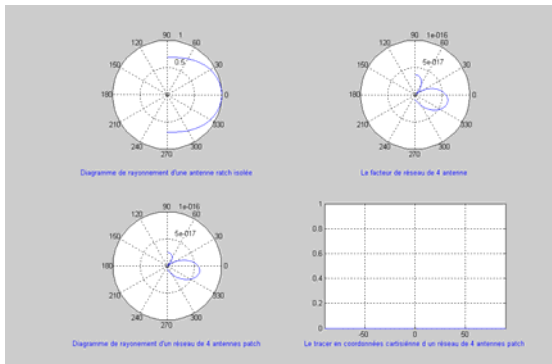
(i) $\beta_x=45^\circ, \beta_y=45^\circ$



(ii) $\beta_x=90^\circ, \beta_y=45^\circ$



(iii) $\beta_x=135^\circ, \beta_y=45^\circ$



(iv) $\beta_x=180^\circ, \beta_y=45^\circ$

Figure 6: The radiation pattern of a square array of four patches antennas in the H-plane, β_y fixed and β_x variable

The same parameters of our antenna that the program doing in MATLAB treats it are used for the simulation on PCAAD (table 4). If we compare the results, we noted that it is compatible and satisfactory.

| β_x (deg ree) | β_y (deg ree) | Direc tivity (dB) | Bea m widt h at 3dB (deg ree) | Main lobe angl e (deg ree) |
|---------------------------|---------------------------|-------------------------|---|---|
| 0 | 0 | 12.62 | 21 | 0 |
| 0 | 45 | 14.80 | 20 | -8 |
| 0 | 90 | 16.72 | 18 | -16 |
| 0 | 135 | 14.80 | 19 | -25 |
| 0 | 180 | 10.12 | - | - |
| 45 | 45 | 14.08 | 20 | -8 |
| 90 | 45 | 13.37 | 20 | -8 |
| 135 | 45 | 12.29 | 20 | -8 |
| 180 | 45 | 10.91 | - | - |

Figure .4: The characteristic parameters of the radiation pattern of a square array of 4 patches antennas in the H-plane, given by the software PCAAD

In the H-plane, the variation of the phase excitation β_y , so that β_x fixed at 0° provoke a rotation of the radiation pattern in the H-plane, with a slow decrease of the amplitude of the main beam. At $\beta_y = 180^\circ$ it's unable to say anything on the directivity of the radiation, the beam width at 3dB and the amplitude of the main lobe, since the diagram divides in two parts (figure 5, table 4).

For $\beta_y = 45^\circ$ and β_x variable we observes a rapid decrease of the amplitude of the main beam, and the angle of rotation of the main

beam in the H-plane stay always constant at -8° . When $\beta_x = 180^\circ$, the radiation pattern is null (figure 6, table 4).

2 - Conclusion:

Linear array: In the E-plane, the main beam does a scanning of an angle of 2π in the E-plane, without necessary to use a mechanical displacement of this antenna array.

In the H-plane, we found a good directivity and a maximum of amplitude at the value 360° of the excitation phase of patches.

Planar array: In the E-plane, the excitation phase β_x permits an electronic scanning of the radiation pattern, that is come with a very slow decrease of the radiation amplitude and the side lobe apparition.

On the other hand, the excitation phase β_y does not participate in the electronic scanning that is assured by β_x , it is only a major inconvenience on the radiation pattern, its amplitude decrease quickly in the E-plane.

In the H-plane, the variation of β_y with β_x fixed encourages the electronic scanning, that is come with a slow decrease of the main beam amplitude and the side lobe apparition, but the variation of β_x in the H-plane has a major inconvenience on the radiation pattern: the quick decrease of

its amplitude until its annulment at 180° .

We can conclude that a planar array present several advantages compared to a linear array: several variables to controlling and modelling the radiation pattern as. It's give a symmetrical radiation pattern with a lower secondary lobes (side, minor and back lobes) [5]. It can be used to browse the main beam of the antenna until some points of the space and miss a minimum of space compared to a linear array.

Acknowledgment:

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