Triangle PIFA Antenna Array Prototype for Wireless System Applications

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Abstract— **With the exponential development of wireless communication and miniaturization of RF transceivers, the need for small and low profile antennas has been growing. Besides that, the Third Generation wireless communication system, 3G, will be more focused and driven largely by advances in the antennas array performance. The PIFA, Planar inverted-F antenna, has been recognized as a most promising candidate to satisfy these new requirements. This work describes a triangle PIFA antenna array, that was designed and optimized at 1.9GHz, by the simulation software ZELAND IE3D. Its radiation pattern is steerable, then it can be adapted and updated in accordance with the environment.**

Keywords—**PIFA, Antenna Array, Wireless, 3G, Radiation pattern, Steering, triangle**

I. Introduction

THE antenna arrays have been shown as the fundamental factor in the new technologies development and improvement, toward the 3G and 4G Wireless Communication System, because they provide adaptive radiation patterns. These arrays use the spatial diversity to improve the signal reliability.

With the antenna arrays the system performance is improved. This is ensured by the increase of the channel capacity and spectrum efficiency, by the range extension, by the beams width reduction and by the tracking and location of the users in the cells. Then we can reduce the fading due the multipath, the co-channel interference, the complexity and the cost of the system and the bit error rate. Therefore the radiation pattern is optimized in accordance with the environment, which the array is embedded.

The PIFA antenna satisfies the terminals design needs of mobile communications systems, such as a reduced size, cost and power consumption. Moreover it has others advantages, as high gain and directivity in comparison of commonly used normal-mode helical antennas and reduce the radiation to the human body [1].

The radiation effect on human body has been considered in order to design such an antenna structure which has less radiation power in this direction. The ground plane of planar antennas has this feature in contrast of the helical antennas that have omnidirectional radiation pattern.

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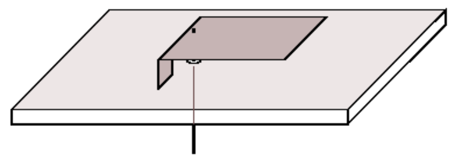
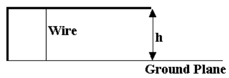
As the rapid development of wearable computer, other wearable system are coming up, including portable communication system and the associated antenna arrangement. The triangle PIFA antenna array is a serious candidate to be incorporated into these systems [2].

II. Antenna array description and design

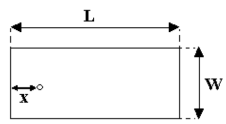
The planar inverted-F antennas, PIFAs, are like quarter-wave monopole antennas, but they are folded coplanar with the ground plane and stretched to form a plate, as shown in figure 1(a). The side profile looks like an inverted F figure, as shown in figure 1(b).



(a) PIFA general view.



(b) PIFA side view.



(c) PIFA top view.

Fig. 1. PIFA Antenna Geometry. Dimensions: L=34.0mm, W=12.0mm, h=7.0mm, X= 5.6mm

The width W and the length L of the PIFA determine the resonance frequency, which is approximately given by [3]:

$$f_r = \frac{c_o}{4\alpha(W+L)} \quad (1)$$

where c_o is the velocity of light and α is a constant approximately equal to 0.9. The antenna matching can be controlled by the feed line distance from the shorted edge of the PIFA [4]. This matching can be analyzed by VSWR, Voltage Standing Wave Ratio, that should be less or equal than 2 in the operation bandwidth, because in these cases 90% of the antenna input power will be radiated. This situation is represented by the return loss, S_{11}, less or equal than -10dB, as shown in the figure 2.

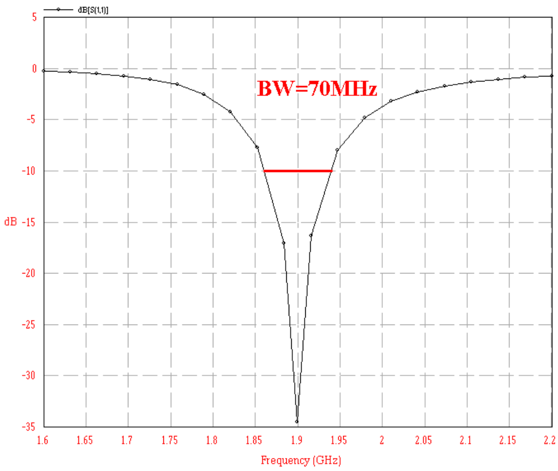


Fig. 2. Simulated Return Loss of PIFA.

The PIFA element of triangle array has directivity D=3.99dB, 3dB Beam Width equal 83.48°, efficiency η = 60.78% and radiation pattern, as shown in the figure 3

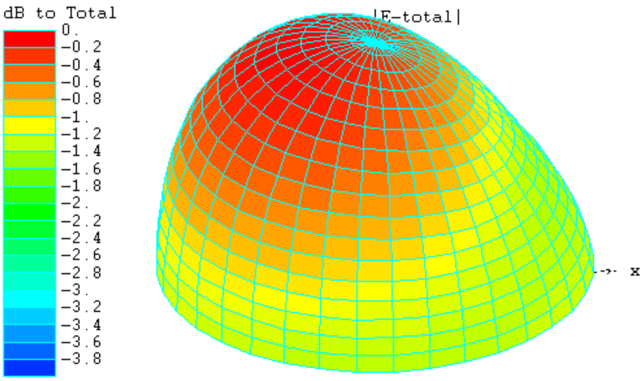


Fig. 3. Radiation pattern of PIFA element.

The antenna array is formed by three identical elements, forming a triangle geometry, as shown in the figure 4. The spacing between the elements was chosen $\lambda/2$, because grating lobes appear in the antenna radiation pattern if the spacing between the elements is greater that $\lambda/2$, where λ is signal wavelength [5]. Another effect that limits the spacing between the elements is the mutual coupling, because as more close are the elements, bigger will be the influence of the coupling.

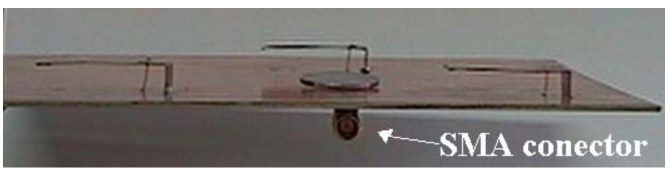


Fig. 4. Triangle PIFA Antenna Array Layout.

This array can digitally controlled by SPDT, Single-Pole Double-Throw, switch, which can commute between transmission and reception, through FDD, Frequency Duplex Domain, or TDD, Time Duplex Domain, methods.

The antenna arrays consider that the desired and interference signals arrive from different directions. The radiation pattern is configured to match the signals from different elements, as shown in the figure 5. To reduce the fading and cochannel interference, a diversity system processes three inputs signals, $X_1(t)$, $X_2(t)$ and $X_3(t)$, to create an improved signal $X_c(t)$. The signal improvement is dependent on the cross correlation and relative signal strength levels between the three received signals [6].

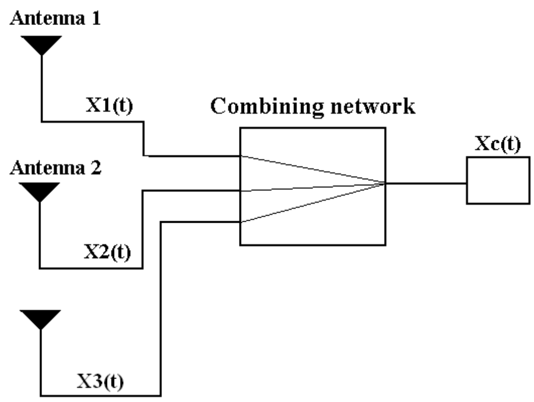


Fig. 5. Adaptive Array for 03 elements.

In the combining network are attributed weights for each array element in accordance with the environment, then the feed intensity and phase can be changed. With theses different feed schemes the radiation pattern can be configured in real time, with help of control algorithms, which are able to determine the direction of arrival(DOA) of electromagnetic wave and suppress the interference, thus the beam is optimized only at the subscriber direction. Therefore the reuse cell is improved and the signal-to-noise ratio, SNR, is maximized.

In optimized adaptive beam techniques, the vector weight is determined as a function of the "cost function" minimization. Typically this function is inversely proportional to the signal quality in the array output [7].

III. Simulation and experimental Results

The array element is optimized with the software Zeland IE3D, through Genetic Algorithms(GA). This software uses as calculation method the Method of Moments(MoM). The project was simulated for an infinite ground plane, on a fiber glass substrate, with dielectric constant ϵ_r=4.8 and thickness of 1.6mm. The return loss measurements were done on Network Analyzer, HP 8714ET. The figure 6 shows the comparison between the parameter S_{11} simulated and measured of PIFA triangle array.

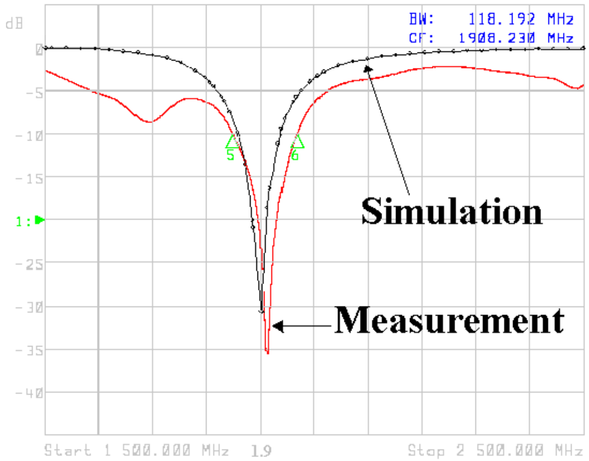
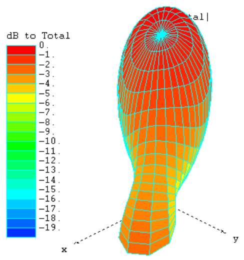


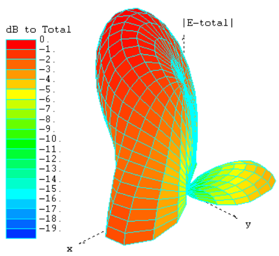
Fig. 6. Measurements and simulated return loss.

The analysis of scattering parameter S_{11}, simulated and measured, shows that the prototype are turned in the design frequency, 1.9GHz, with discrepancy of 0.4%, and bandwidth BW= 118.192MHZ, which represents a improvement of 68.85% in comparison with a PIFA element.

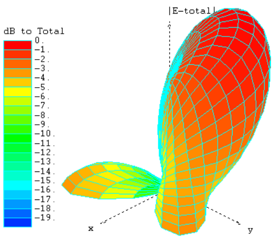
To update the desired radiation pattern, besides feeding different elements number of the array, also it can be fed with different phase delays. The Figure 7 shows the influence of the feed phase(α_i), when the elements 1 and 2 kept fed and the delay phase is changed, resulting in different 3D radiation patterns. Then the array can steer the main lobe without varying the fed elements.



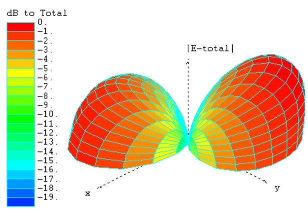
(a) α_1=α_2=0°



(b) α_i=0°and α_2=90°.



(c) α_1=90°and α_2=0°.



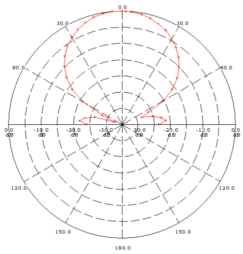
(d) α_1=0°and α_2=180°.

Fig. 7. 3D Radiation pattern elements 1 and 2 fed with different phase.

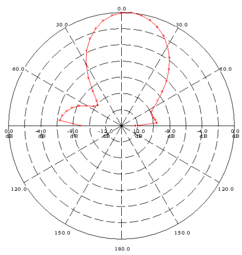
The radiation pattern of the figure 7(a) has the beam more concentrate beam, with directivity D = 8.24 dB at the direction θ = 210°of the azimuth plane. The figure 7(b) and figure 7(c) pattern has similar electric features, but the beam directions are approximately opposite. Finally, the figure 7(d) pattern shows a symmetry in relation to plan YZ, with two identical lobes, directed toward the angles θ=135°and θ=315°. In this pattern the directivity down to D = 6.29dB. This situation can be analogous to a practical situation in which the BTS needs to radiate of a symmetrical form at the two tower sides, because in the both sides there are the same number of subscribers and in similar positions.

The adaptive array processing is necessary for this capacity and the range improvement [5], because is very important to find the users in the cell and to direct the main beam in its direction. This technique is called SDMA, Space Multiple Division Access. By means this technique, the same channel can be used more than a time inside of the same cell. The bias diversity can be used to differentiate two very close users in a cell.

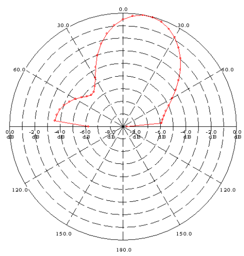
Different configurations of feed schemes were simulated to demonstrate the steerable characteristic of this array. The figure 8 shows the beam steering in some directions of elevation plane.



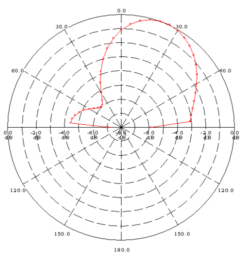
(a) ϕ=0°.



(b) ϕ=5°



(c) ϕ=15°

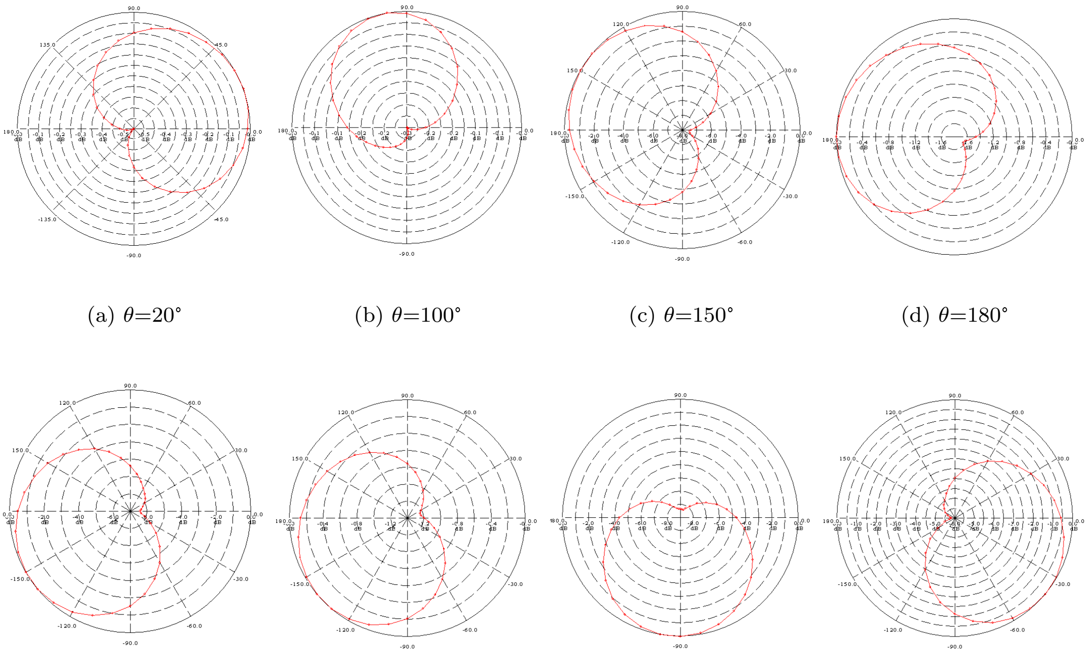


(d) ϕ=25°

Fig. 8. 2D Radiation pattern in different directions of Elevation plane

To ensure the users tracking, some configurations were simulated on the azimuth directions, in steps of 10°, with a high directivity, without the presence of secondary lobes, as shown in some examples in the figure 9.

Besides of the radiation pattern characteristics, it is nec-



(a) θ=20° (b) θ=100° (c) θ=150° (d) θ=180°

(e) θ=210° (f) θ=220° (g) θ=270° (h) θ=320°

Fig. 9. 2D Radiation pattern in different directions of Azimuth plane

essary to evaluate the array main parameters, so many feed schemes had been simulated and summarized in the table I.

TABLE I

Resume of the Triangle array main parameters for frequency f=1.9GHz.

Fed elements	Peak Elevation	Peak Azimuth	Directivity	Efficiency	Gain
	()	()	(dB)	(%)	(dB)
1	15	190	6.05	69.19	4.18
1,2	20	150	7.75	70.70	5.48
1,2	15	240	8.09	73.79	5.97
1,3	5	330	7.24	68.98	4.99
1,3	5	260	7.39	69.74	5.15
2,3	5	20	8.18	73.03	5.97
2,3	10	270	8.06	74.03	5.96
1,2,3	5	30	9.59	78.25	7.50
1,2,3	20	150	9.02	74.54	6.72
1,2,3	10	260	9.55	78.30	7.48
1,2,3	5	310	9.53	77.93	7.42

IV. Conclusion

The PIFA Triangle Array Prototype was proposed and analyzed. This array can be applied in the next generations wireless communications systems, because it provides steerable beams and additional beam patterns to control and shape the overall radiation pattern. Then it radiation pattern can be configured in accordance with the environment in real time, with the aid of control algorithms.

The results demonstrate a great improvement in comparison with a PIFA element. The simulation results show a excellent radiation structure with high efficiency and gain, when compared to helical antenna or a single PIFA. These parameters increase with the number of feed elements. The S_{11} measurements show that at 1.9GHz, this triangle array has a suitable bandwidth and excellent dip of -35.672 dB.

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