Mutual Coupling between the Elements of a MIMO Antenna Array for GSM/UMTS/PCS Applications

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ABSTRACT
A compact planar inverted-F multi-band antenna array located on an infinite ground plane for multiple inputs multiple output (MIMO) systems is proposed in this paper. And the study of the suppression of the mutual coupling between the radiating elements of the antenna array is also presented. An identical two PIFA elements are placed uniquely without any distance to each other however; the mutual coupling reduction is achieved by maximizing the separation between them. The multi-band antenna array is designed to operate at GSM [880-960 MHz], UMTS [1920-2170 MHz] and PCS [1880-1950 MHz] frequencies bands for MIMO application, and studied numerically regarding mutual coupling suppression. The simulation analysis was performed using the Ansoft High Frequency Structure Simulator (HFSS).

Keywords
PIFA antenna; Antenna Array; Multi-band; MIMO; Mutual Coupling; GSM; UMTS; PCS.

1. INTRODUCTION
The wireless multimedia technology has increased the capacity and reliability requirements of wireless communication systems. Therefore, the multiple input multiple output (MIMO) system has been one of the most suitable and promising technology for this, because it is well suited for high capacity, high data rate and high reliability requirements. One main advantage of the MIMO system is it can improve capacity and reliability requirements, without increasing transmitted power or bandwidth. However multiple antennas bring drawbacks in the increasing size of the system and worsen the isolation between them, therefore cause distorted radiation pattern and decrease channel capacity.

Several works have been conducted to reduce the mutual coupling effect between antenna elements in MIMO systems. [1]. In some works the authors present a method consists of increasing the distance between the resonators [1] [2] [3]. Others add slits in the ground plane [4] or a ground plane divided by slots [5]. The mutual coupling can be also reduced by changing the positioning of radiating elements (parallel, orthogonal) [6], or by changing both the positioning and spacing between resonators [7] [8].

In this paper a compact MIMO antenna without using any spacing between the elements, operating in GSM/UMTS/PCS bands is proposed. We want to achieve the distance between the two identical PIFA that allows not only the maximal suppression of mutual coupling, but also to have good values at the level of other characteristics of the array antenna (S11 <-10dB, omnidirectional radiation, high gain).As pointed before, all simulations are performed using the Ansoft HFSS software.

2. THEORY OF THE PIFA ANTENNA
The inverted-F antenna is evolved from a quarter-wavelength monopole antenna. It is basically a modification of the inverted F antenna IFA which is consisting of a short vertical monopole wire. To increase the bandwidth of the IFA a modification is made by replacing the wires with a horizontal plate and a vertical short circuit plate to obtain a PIFA antenna. The conventional PIFA is constituted by a top patch, a shorting pin and a feeding pin. The top patch is mounted above the ground plane, which is connected also to the shorting pin and feeding pin at proper positions. They have the same length as the distance between the top patch and the ground plane.

The standard design formula for a PIFA is:

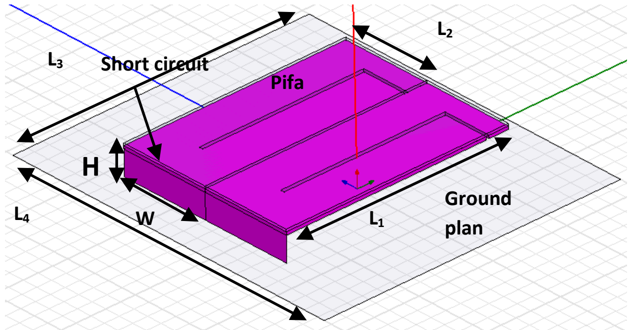
$$f= \frac{C}{4(L+H)} \qquad (1)$$

Where f is the resonant frequency of the main mode, C is the speed of light in the free space; H and L are high and length of the radiation patch, respectively. [9]

In this paper we will increase the distance of 10mm to 40mm in order to have a maximal suppression of mutual coupling. and observe the effect on the characteristics of the array antenna (S11, gain, …).

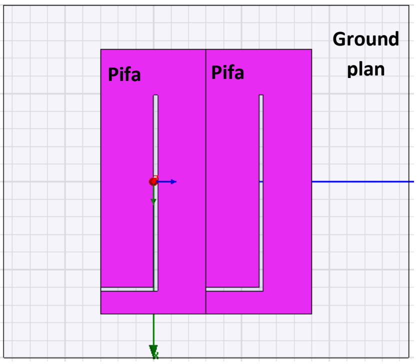
3. ANTENNA CONFIGURATION
3.1 Conventionel PIFA Antenna Array Configuration

The identical rectangular elements (two PIFA with a L-shaped slit) with L1×L2 dimensions are placed in the center of the ground plane whose the dimension are L3×L4, and these

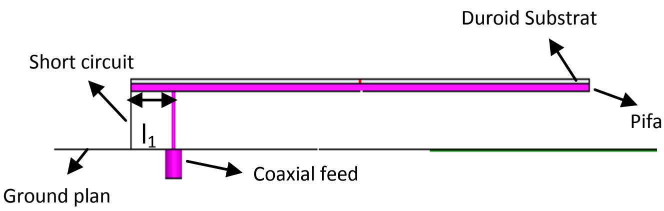


elements are printed below a thin Rogers Duroid Substrat with a thickness h=0.76 mm, relative permittivity εr=1 and tanδ= 0.001.The horizontal and the vertical distances of the coaxial feed probe from the PIFA borders are l1 and l2 respectively whereas the dimensions of the short circuit plate are W×H.

(a)



(b)

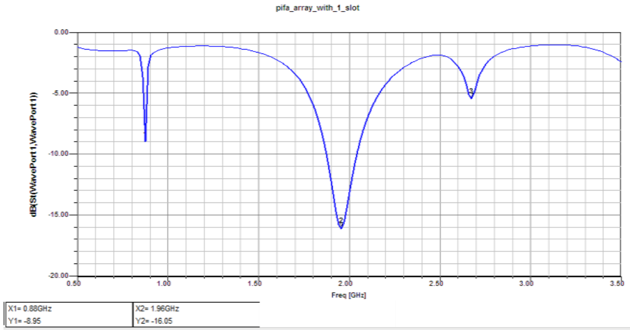


(c)

Fig.1 Geometry of the conventionel Pifa Array (a) Perspective view (b) Top view (c) Font view

Table I. Dimensions of the conventional pifa antenna array parameters

Parameters	Values
L1	75 mm
L2	30 mm
L3	100 mm
L4	115 mm
W	30 mm
H	8 mm

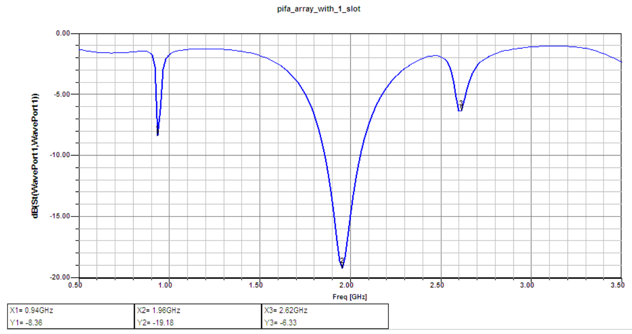


3.2 Results and Discussions

3.2.1 Return loss

The obtained result of the return loss is illustrated in Figure 2.

(a)



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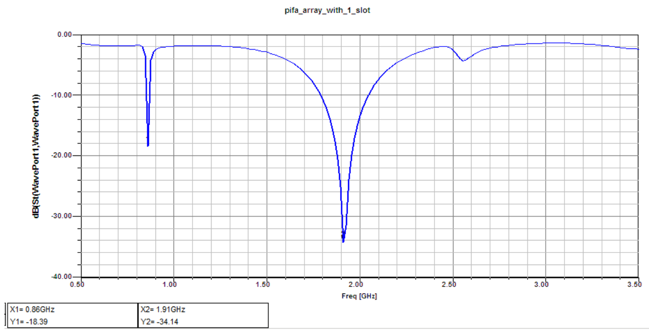
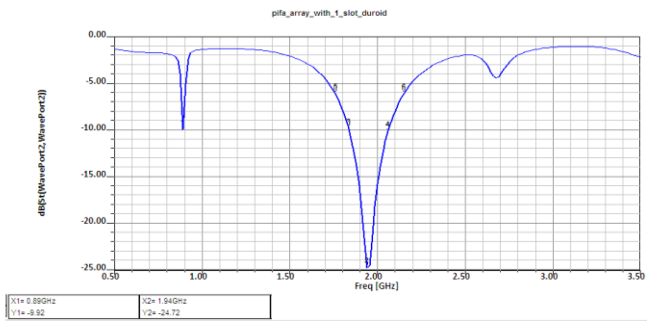


(c)



(d)

Fig.2 The simulated return loss for the PIFA antenna array (a) for d=10mm (b) for d=20mm (c) for d=30mm (b) for d=40mm

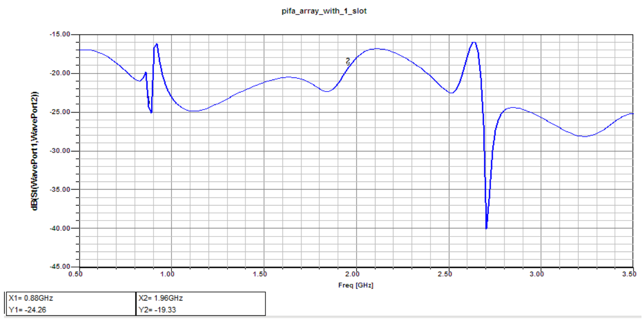
Table II. Antenna performance in terms of the return loss and the resoant frequency

Distance (mm)	Resonant frequency (GHz)	Return loss (dB)	Standards
10	0.88	-8.95	GSM
	1.96	-16.05	UMTS/PCS
20	0.94	-8.36	GSM
	1.96	-19.18	UMTS/PCS
30	0.89	**-9.92**	GSM
	1.94	**-24.72**	UMTS/PCS
40	0.86	-18.39	GSM
	1.91	-34.14	*PCS*

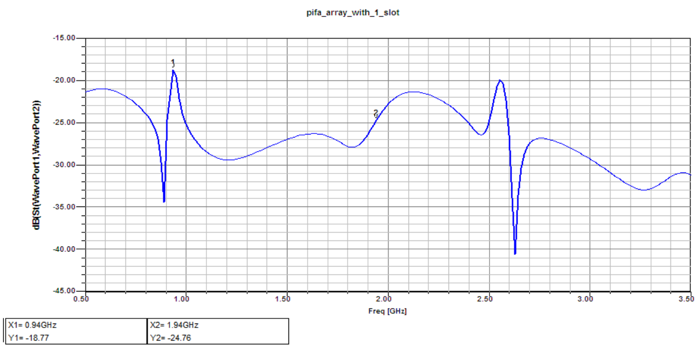
Antenna performance in terms of the Return Loss is summarized in Table II. It result that the value of Return Loss at the operating frequency bands GSM, UMTS and PCS varies relatively with the distance. And the minimal values of the return loss for all the operating bands are given at d=30mm.

3.2.2 The transmission coefficient

The obtained result of the transmission coefficient is illustrated in Figure 3.



(a)



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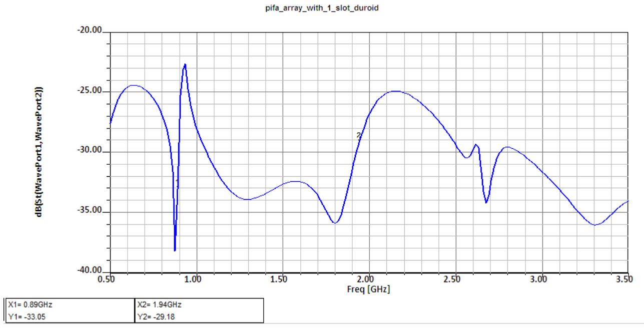
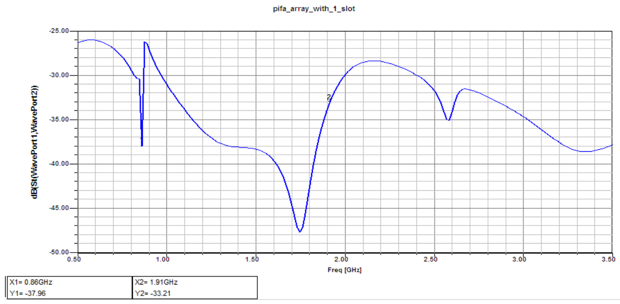


(c)



(d)

Fig.3 The simulated transmission coefficient for the PIFA antenna array
(a) for d=10mm (b) for d=20mm (c) for d=30mm (b) for d=40mm

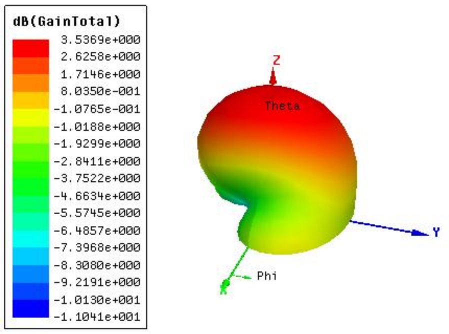
Table III
Antenna performance in terms of Transmission coefficient

Distance (mm)	Transmission coefficient (dB)	Standards	
10	-24.26	GSM	
	-19.33	UMTS/PCS	
20	-18.77	GSM	
	-24.76	UMTS/PCS	
30	**-33.05**	GSM	
	-29.18	UMTS/PCS	
40		-37.96	GSM
		-33.21	*PCS*

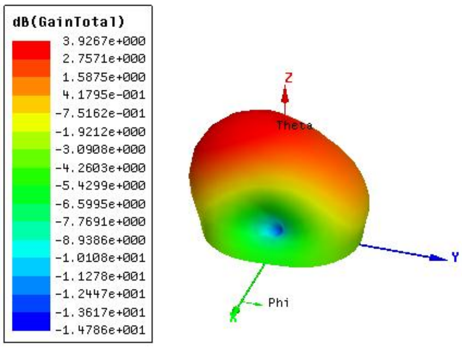
Antenna performance in terms of the Transmission coefficient is summarized in Table III. And we note that the maximal values of that parameter at the operating frequency bands are given at d=30mm.

3.2.3 The radiation pattern

The radiation patterns simulated cuts of the studied PIFA antenna array is shown in Figure 4, Figure 5, Figure 6 and Figure 7.

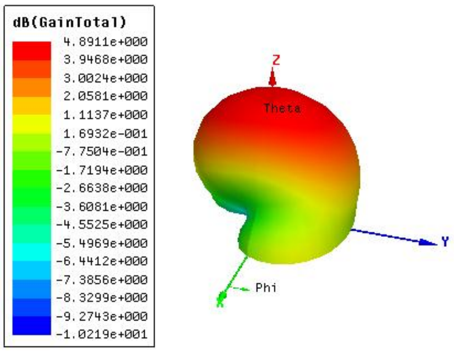


(a)



(b)

Fig.4. 3*D* radiation pattern for the PIFA antenna array for d=10mm at the operating bands (a) GSM (b) UMTS/PCS



(a)

(b)

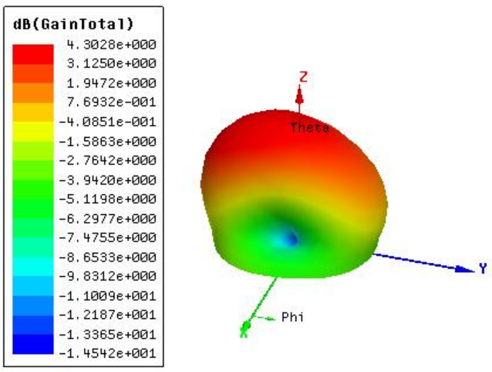
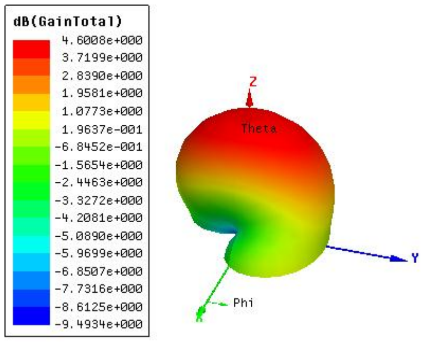
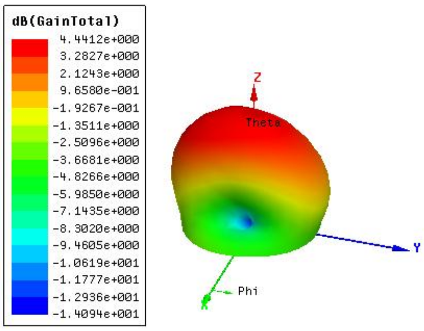


Fig.5. 3*D* radiation pattern for the PIFA antenna array for d=20mm at the operating bands (a) GSM (b) UMTS/PCS

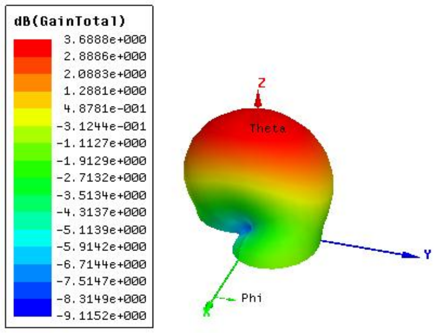


(a)

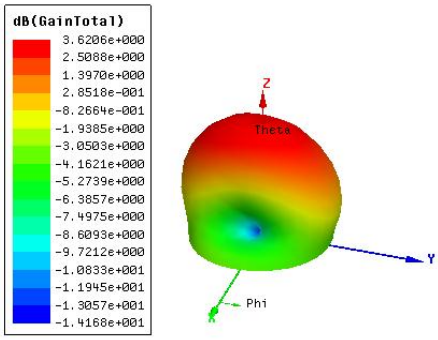


(b)

Fig.6. 3*D* radiation pattern for the PIFA antenna array for d=30mm at the operating bands (a) GSM (b) UMTS/PCS



(a)



(b)

Fig.7. 3*D* radiation pattern for the PIFA antenna array for d=40mm at the operating bands (a) GSM (b) UMTS/PCS

Table IV. Antenna performance in terms of gain

Distance (mm)	Gain (dB)	Standards
10	3.5	GSM
	3.9	UMTS/PCS
20	4.89	GSM
	4.3	UMTS/PCS
30	**4.6**	GSM
	4.44	UMTS/PCS
40	3.68	GSM
	3.62	*PCS*

From this curves, we can see the radiation patterns of the PIFA antenna array in the E-plane (Phi = 0deg) and the H-plane (Phi = 90deg) at the GSM frequency band and the UMTS/PCS band.
Table IV summarized the antenna performance in terms of the Gain. And we note that the maximal values of that parameter at the operating frequency bands are given at d=30mm.

4. CONCLUSIONS

A compact PIFA multi-band antenna array for MIMO application was proposed.
From the study of mutual coupling between the identical radiating elements of the antenna array we can conclude that maximum suppression of mutual coupling (S12 =- 33.05dB;-29.18dB) the minimum reflection loss (S11=-9.92 dB;-24.72dB), and the high Gain (4.6dB; 4.44dB) of the proposed antenna array operating at the GSM frequency band and UMTS/PCS frequency band for MIMO application are obtained when the distance between the identical PIFA is equal to 30mm.
So we succeeded to make a compromise between achieving maximal suppression of mutual coupling and good antenna characteristics. Then the antenna meets the terms of reference.

5. REFERENCES

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