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# MIFA: Modified IFA Radiating Element for Small Handheld Devices

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**Abstract:** In this paper a broadband IFA antenna is presented for WLAN applications in the 5.6 GHz band. An improvement in the design of this IFA antenna is analyzed to achieve a radiating element more stable when changes are done in the input microstrip line or/and in the dimensions of the ground plane. This fact helps to integrate the antenna with the other parts of the transceiver using microstrip line. A comparison between arrays (MIFA array and IFA array) is done too to present the improvements of the new IFA antenna.

**Keywords:** WLAN systems, omnidirectional, broadband, IFA antenna, inset-feed, wireless communication.

## 1. Introduction

In recent years, very demanding high quality services have had a rapid increase for the need of wireless broadband communications, security, handover, and increased throughput for the wireless local area networks (WLANs). The main aim of next generation wireless communication is high speed networking service for multimedia communication. In this case, provided system uses the frequency band 5.470 GHz - 5.725 GHz with omnidirectional antenna. The microwave wireless communication systems require compact and broadband antennas [1], and these are two requirements that the antenna presented in this paper fulfils.

The antennas in portable equipment, which establish a wireless link with a base station, have to be small, compact and cheap. Printed antennas are a very suitable solution for these devices. One antenna with these features that is usually found in literature is the Inverted F Antenna (IFA). The IFA provides an acceptable bandwidth but the ground plane plays an important role in the design of this radiating element [2]. Its size influences the behaviour of the IFA antenna in terms of impedance matching and radiation performance. A variant of the IFA antenna is presented in this paper. The difference with respect to the traditional IFA antenna is that the ground plane is extended creating a "window" through which the element radiates. With this modified antenna it is possible to stabilize the impedance and radiation behaviour even when changes in the ground plane are done. This allows an easy integration of these elements in small portable equipment in which a MIMO system is implemented.

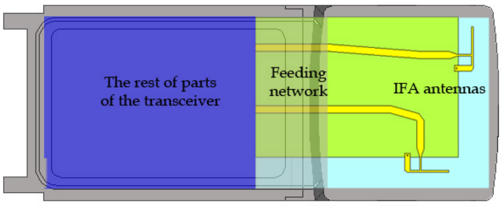


*Figure 1: Array of two IFA antennas in a PCMCIA form factor*

## 2. IFA Antenna Design

The IFA antenna is a variant of the monopole, where the top section has been folded down so as to be parallel with the ground plane. This is done to reduce the height of the antenna, while maintaining a resonant trace length. This parallel section introduces capacitance to the input impedance of the antenna, which is compensated for by implementing a short-circuit stub. The stub's end is connected to the ground plane through a via [3]. The antenna element is placed on a 32 mils-thick FR4 substrate, with $\varepsilon r = 4.05$ and $\tan\delta = 0.014$.

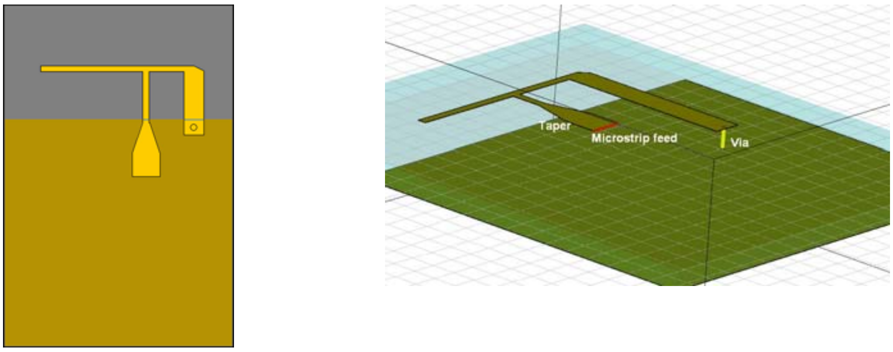


*Figure 2: a) Top View of the antenna IFA. b) 3D layout IFA antenna using FR4*

This radiating element is well-tuned in the 5.6GHz band (5.47 GHz – 5.725 GHz) and an omnidirectional radiation pattern is achieved. However slight changes of the ground plane dimensions can cause considerable alteration on the system's input impedance characteristics. The width of the ground plane seems to be more sensitive to shortening than the length as it can be deduced in the study realized in [2] and this can be attributed to the fact that the induced currents are mainly concentrated along the width of the ground and near to the antenna element.

Besides the study of the ground plane influence, another important characteristic is studied: the feeding network of the radiating element. The position of the feeding network with respect to the edges of the ground plane influences the integration of the radiating element with the rest of parts of the transceiver, especially in small handheld devices where a MIMO implementation is done, and consequently several elements are used. The IFA antenna is terminated to 50-Ω port. Three cases are studied in which the input microstrip line has different lengths and different positions with respect to the ground plane. In general, any change in the length of the microstrip line and in the ground plane dimensions shouldn't affect the matching when the initial design is well-tuned. However this element is sensitive if any modifications are done. In the following figures, only changes in the feeding network and in the ground plane dimension are applied to demonstrate the sensibility of the IFA antenna.

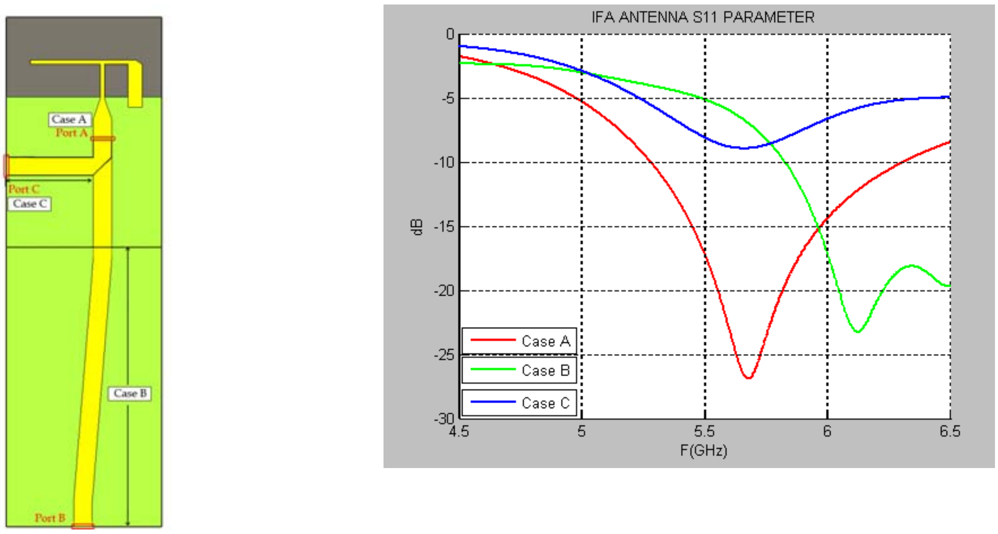


*Figure 3: a) IFA antenna layout for 3 different feeding networks. b) Simulated $S_{11}$ parameter of IFA antenna for case A, case B and case C*

Case A is the first design of IFA antenna. Case C are the same radiating element as case A, only the microstrip line used to feed the antenna is extended to make the integration easy. In case B, two changes are done: the feeding network and the ground plane are extended. The simulated results show that any change in the input microstrip line and / or in the ground plane dimensions will affect to the matching of the IFA antenna.

## 3. Modified IFA Antenna Design

This section describes the novel model of IFA antenna (MIFA) with the same features that the presented in the previous section but more stable when the same changes are done in the size of ground plane and/or in the feeding network. In this new IFA antenna the ground plane is extended creating a "window" through which the element radiates. This "window" helps to isolate the radiating element when some change is done around the element. This modification allows a better matching when the feeding network is altered. In order to demonstrate that "window" IFA antenna improves the IFA antenna results, several configurations of this modified antenna are studied changing the feeding line and the ground plane.

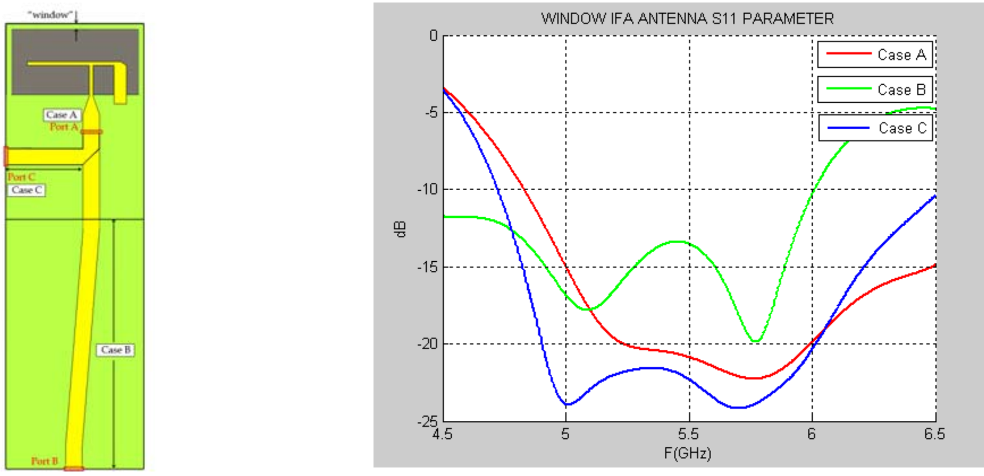


*Figure 4: a) MIFA antenna layout for 3 different feeding networks. b) Simulated $S_{11}$ parameter of MIFA antenna for case A, case B and case C*

Case A is equivalent to case A in the previous section. The difference is in the fact that a window surrounds the antenna in the bottom of the PCB. As a first fact it should be noted that the MIFA radiating element has a higher bandwidth than the IFA one. In this way, it is ensured that the desired bandwidth is covered independently on errors in simulation and manufacturing. The matching result of the case C is even better than in the IFA design. In the case B a long extension of the ground plane and the input microstrip line is implemented. Figure 4 shows a well-tuned antenna in the working frequency band in spite of the changes.

### *3.1 Measurement of the Modified IFA Antenna*

To complete the radiating element study the MIFA antenna has been measured to validate the simulation results. The case B of the MIFA antenna has been manufactured and tested in the laboratory. For these tests an end-launch SMA connector is used to connect the antenna with the network analyzer.

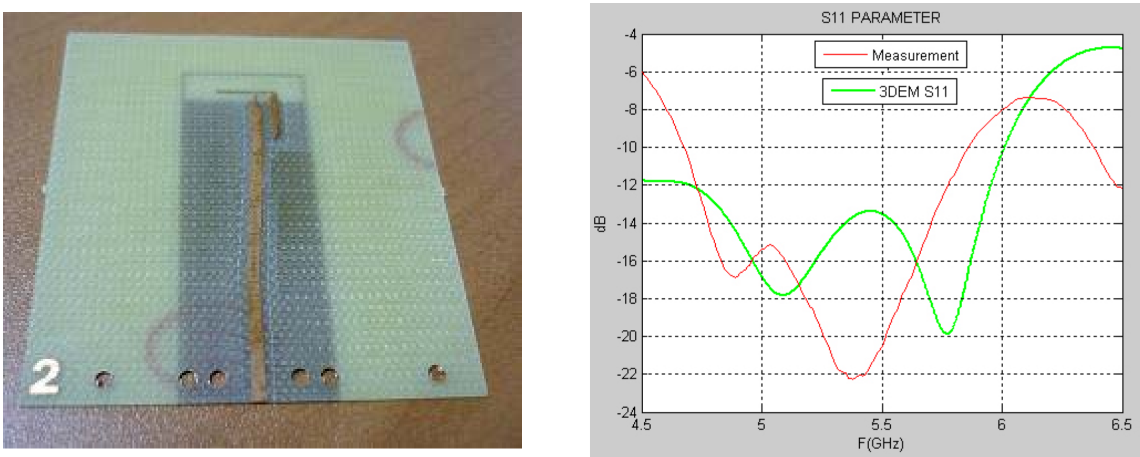


*Figure 5: a) MIFA antenna, case C. b) Comparison between simulated / measured $S_{11}$ parameter of MIFA antenna case C*

The measured result shows a well tuned antenna in the used band and demonstrates the stability of this radiating element when some changes are made in the dimensions of the ground plane and in the input microstrip line.

## 4. IFA and MIFA Arrays

Two arrays with different radiating elements are presented now. The main idea of this array study is to show the benefits of an array using MIFA radiating elements in comparison with an array formed by IFA antennas in the same conditions.

### *4.1 Configuration of the MIFA array and IFA array*

To begin with the array study, an analysis of the different configurations is performed. The first configuration consists of two IFA antennas separated by 10.76 mm. The second configuration formed by two MIFA antennas has the same separation between radiating elements. In this section the ground plane and the microstrip line are extended to achieve an antenna design with a perfect integration using microstrip line. Besides, another important factor will be analyzed: the array behaviour when another radiating element is close.

The distance between antennas is small in order to analyze the influences among radiating elements better.

The fact of having two o more antennas on the same ground plane may degrade the antenna's performance when they are placed close to each another. Albeit, to achieve an integrated design, it is necessary to join the ground planes of all elements in spite of the fact that the antenna properties may be minimized. So the ground plane is extended in the two different arrays.

With this array study, the capacity of isolation of the different radiating elements is also analyzed. The IFA antenna is a radiating element very sensible when other element is close. However, The MIFA antenna improves the mutual coupling results between elements and the return losses in 5.6GHz frequency band. This improvement is due to the small frame around the MIFA element, which isolates the elements to avoid influences between them. The geometry and dimensions of the investigated configurations are depicted in Figure 6.

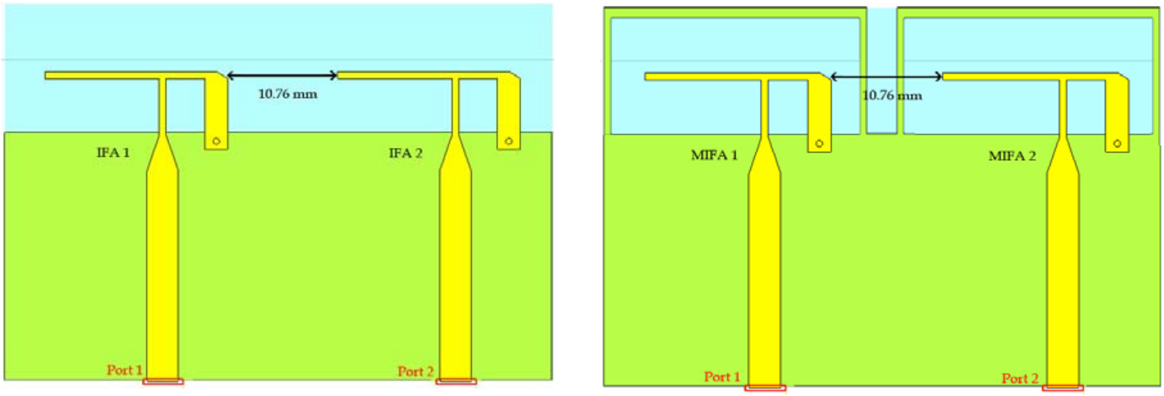


*Figure 6: a) Top view of IFA array b) Top view of MIFA array*

### *4.2 Matching and isolation results for the different configurations*

The S-parameters are studied for both cases. The return loss of IFA configurations doesn't cover the 5.6 GHz band because the extension of the microstrip line and the changes in the ground plane size have a strong impact on the design. The proximity of the elements has influence also in the matching and in the isolation results of the elements. Albeit, the MIFA array shows more stable results: each MIFA antenna exhibits large bandwidth and is well tuned for the 5.6 GHz band. Figure 7 shows the S parameters of the two different configurations (IFA array and MIFA array have been analysed).

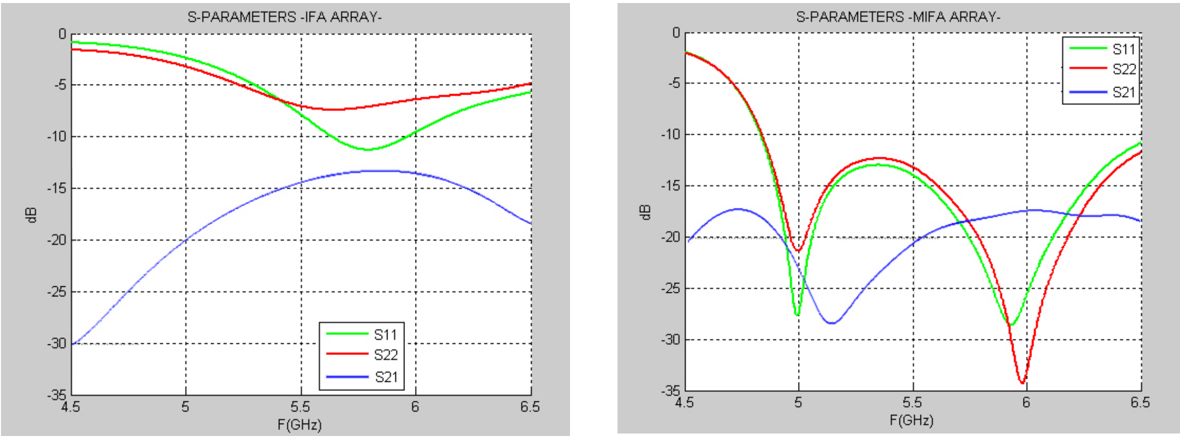


*Figure 7: a) S- Parameters in IFA Array b) S- Parameters in MIFA Array*

The mutual coupling parameter is improved too when the MIFA antennas are used because in this case the isolation always remains below -18 dB in all 5.6 GHz frequency band whereas in the IFA array this value never is better than -15 dB in the same band.

The isolation and the return loss are important factors to avoid the correlation between antennas. A good correlation factor is very important for a MIMO antenna.

Especially in the last decade, MIMO wireless radios, e.g. in 802.11n or in WiMAX, has gained considerable attention due to its potential to significantly increase spectral efficiency and link reliability compared to single-input singleout put (SISO) systems. Low correlation between antennas at transmitter and receiver enables transferring a MIMO channel into several parallel SISO channels. Therefore, higher efficiency, better reliabilities and larger coverage ranges are achieved due to array gain, diversity gain and multiplexing Gain [4].

### *4.3 Radiation patterns*

In spite of the changes done in the first IFA and MIFA designs, the radiation patterns does not undergo important alterations. The quasi-omnidirection pattern is maintained in the two arrays. The radiation patterns of the MIFA array are presented in the following figures:

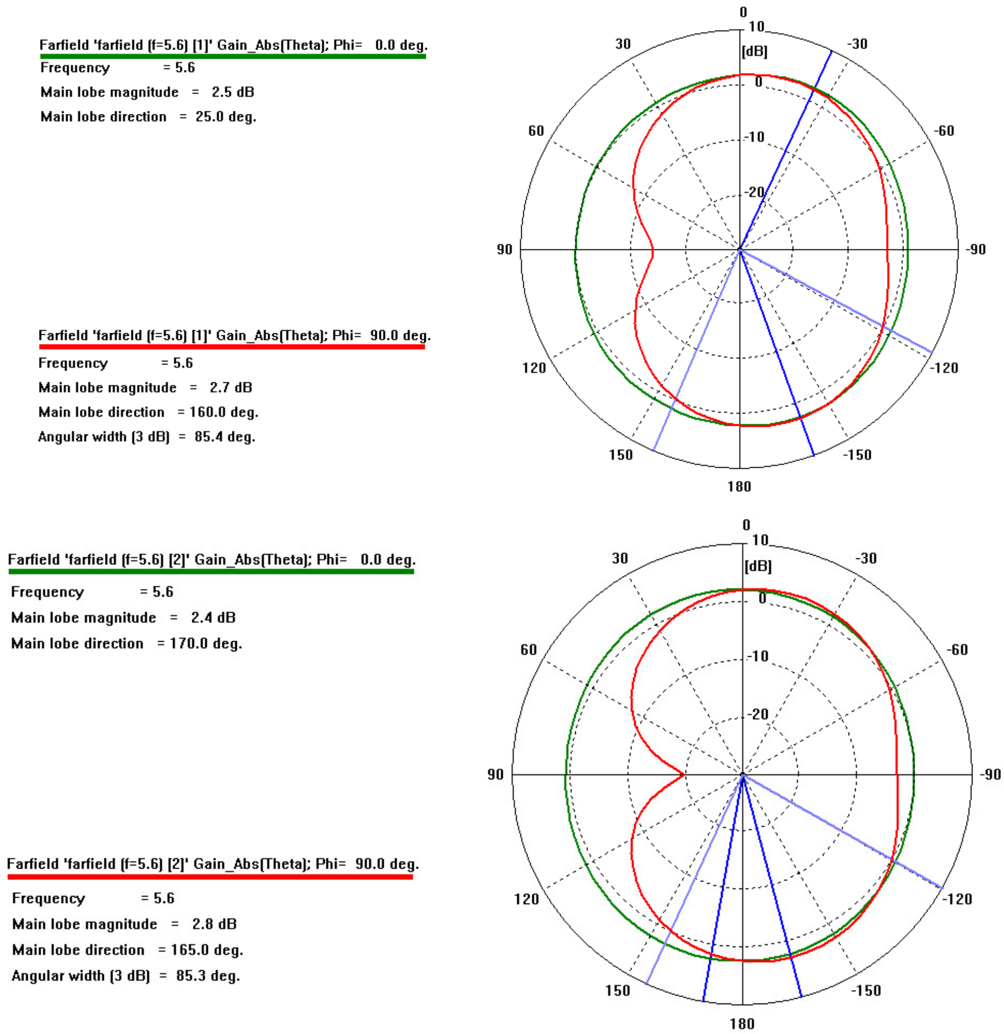


*Figure 8: Radiation pattern (Cut phi=0 and cut phi=90) of the MIFA array .f=5.6GHz. a) MIFA antenna 1 b) MIFA antenna 2*

## 5. Conclusions

In conclusion, IFA radiating element is ideal to allocate in a small device where MIMO techniques are applied due to its versatility in the integration. This element has important advantages: compact size, large bandwidth and ease in manufacturing at no additional cost. The problems of the instability are solved using a window extending the ground plane around the element maintaining the matching in spite of the above mentioned changes (MIFA antenna). The modification in the IFA antenna permits to maintain the well tuned result in the 5.6 GHz band in spite of several alterations in the size of the ground plane and in spite of the microstrip line being extended. Besides, the MIFA antenna has a better behaviour when another radiating element is close because the "window" helps to isolate the elements.

## 6. Future work

Next step is the design of an antenna array using MIFA's elements at a small distance. Small devices like a PDA or a PCMCIA card are a suitable frame where testing these arrays because the available space is small. According to the investigations presented in this paper, MIFAs will solve the problem of correlation and coupling between antennas because besides improving the return loss of each antenna, more isolation between radiating elements is achieved with respect to traditional IFA concept.

IFA antenna is a common radiating element that is ideal for small devices in MIMO systems. However, in many cases, the integration problems and the effects of the coupling among antennas avoid the use of these radiators in an array. A MIFA array may solve this problem maintaining the low cost, small size and easy manufacture of the antenna array.

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