Design and Analysis of PIFA Antenna based on Embedded Metamaterial for Communication Devices

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ABSTRACT

Antenna and its feed system in wireless communications require to be multi-functional for increasing flexibility and feasibility of devices, such as possibility to integrate, smaller-footprints, cost effective and low effort on fabrication, and it should be wideband frequency operating. The objective of this paper is to design and analyze a PIFA based on metamaterial resonators for wideband operation. The antenna has frequency notch function since the composite Co-Planar Waveguide metamaterial planar inverted F antenna that is embedded on the planar substrate that resonates for different frequency bands. The antenna resonates for the frequency of UMTS 1.91 to 2.18 GHz, Wi-MAX 3.42 to 3.51 GHz, W-LAN 5.73 to 5.86 GHz that has excellent impedance matching and radiation performance.

Keywords
PIFA, Antenna, Communication Devices, Co-planar waveguide, wideband antenna.

1. INTRODUCTION

The multiband or wideband antennas have increased high interest in recent years for application to different communication systems. Because of low cost and process simplicity, printed monopole antennas are very popular candidates for these applications. The currently popular designs suitable for wireless local area network (WLAN) operation 5.2/5.8 GHz (5.15–5.35 GHz/ 5.725–5.825 GHz) and Universal Mobile Telecommunications System (UMTS) bands have been reported. The key design configurations in order to meet this multi-band operation include a monopole antenna fed with a meandered coplanar waveguide (CPW), a CPW-fed monopole antenna with two resonant paths, a CPW-fed tapered bent folded monopole antenna, a microstrip-fed double-T monopole antenna, a meander-line monopole antenna with a backed microstrip line, a C-shaped monopole antenna with a shorted parasitic element, and a branched monopole antenna with a truncated ground plane. However, to further support the worldwide interoperability for microwave access (WiMAX) applications, none of the above available designs can achieve a dual-band response with sufficiently large bandwidth to additionally cover the 3.5/5.5 GHz (3400–3500/5725–5850 MHz) Wi-MAX and Hiper-LAN bands.

In [8], the authors presented a CPW-fed split ring monopole antenna with a square conductor-backed plane for dual-band WLAN applications. This design generally needs to consider many dimension parameters and the resulting bandwidth is still not sufficient to cover the 3.5 GHz WiMAX bands. In this letter, a new antenna is proposed for the purpose of WiMAX and HiperLAN mode operations.

One of the most common elements of metamaterials, which was introduced by Pendry et al. in 1999, is the split ring resonator (SRR). SRR is an nonmagnetic conducting unit, in which and its periodic array yields negative effective magnetic permeability with an enhanced magnitude when the frequency of the incident electromagnetic field is close to the SRR resonance frequency. The resonance frequency of the SRR depends on its geometrical parameters. The structure can show resonant behavior at frequencies that are much larger than its size. Many groups have achieved experimental demonstration of this structure at microwave frequencies. The application of metamaterials to increase antenna performance is of great interest. It was shown that introducing metamaterials could enhance the radiated power of the antenna. Moreover, negative magnetic permeability materials are a candidate for obtaining properties such as an electrically small antenna size, high directivity, and tunable operational frequency. Furthermore, by utilizing a combination of right handed (RH) and left handed (LH) materials in a composite (CRLH) transmission line, a backward to forward scanning capability is obtained. Antennas composed of single negative materials that resonantly couple to external radiation was invented by Isaacs. Even if the radiation wavelength is much larger than the antenna size, the antenna is sensitive to radiation due to the resonant coupling. By feeding such a resonator one can obtain an electrically small antenna when operating at microwave frequencies.

2. DESIGN / PRINCIPLE OF OPERATION

A. Antenna Design

Fig. 1 illustrates the geometry of the proposed PIFA antenna for WiMAX operation. The antenna was implemented on an inexpensive FR4 substrate with thickness of 1.6 mm and relative permittivity of 4.6. It can be seen from Fig. 1 that the rectangular substrate and feedline are printed on the side of substrate of the antenna.

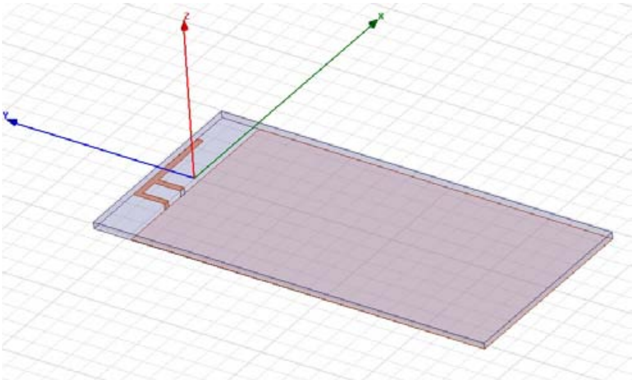

Fig. 1. PIFA Antenna designed in Ansys HFSS®

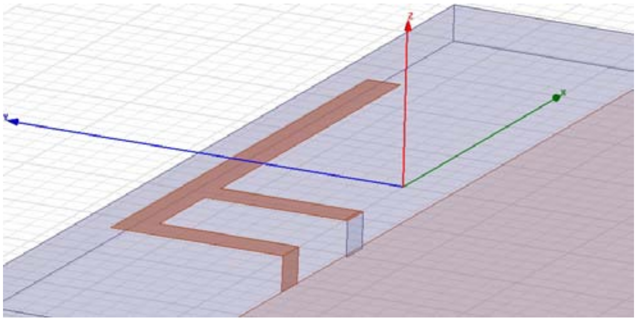

Fig. 2. Inverted F connected to Metamaterial Substrate

In the proposed antenna configuration, the rectangular strip can provide the fundamental band and next higher resonant band at 5.7 GHz is obtained by embedding the PIFA structure in the antenna respectively, This PIFA plane resonates based on electrically coupled to the rectangular monopole. By properly tuning the dimensions and spacing to semi-ground plane PIFA embedded plate, the antenna can create the second resonant frequency in individual resonant radiation band based on an over-coupling condition. This mechanism can remarkably increase the resonant radiation bandwidth.

B. Design Analysis

The dimension of the slot antenna is referred to the guide wavelength (• g) which is given in [2],

Where •eff is an effective constant •eff• (•r +1)/2. In this case, •eff • (4.4+1)/2 • 2.7 and •g= 33.16 mm (for f= 5.5 GHz) antenna which can be optimized with choosing the dimensions

3. ANALYSIS OF GROUND STRUCTURES

The antenna is shown in Figure 1 and 2 have the same dimensions as that of Figure 1, except that they have demonstrate the closer perspective.

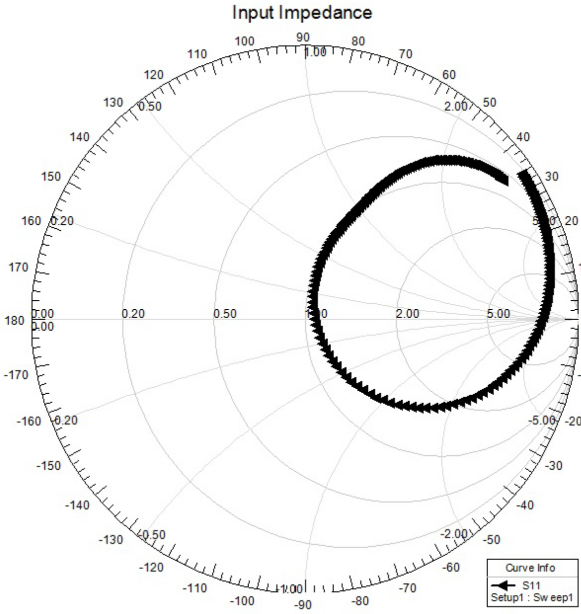

Fig. 3. Input Impedance of PIFA Antenna

From Figure 5 it is clear that designed antenna and equivalent ground places are giving better performances than the rest of the patch antennas.

4. RADIATION PATTERN

The 3-D and 2-D radiation patterns shows as in Figure 4 that the proposed PIFA antenna has high directivity, gain and radiation efficiency in Figure 6.

5. RESULTS AND DISCUSSIONS

The simulated return loss for the proposed antenna with the conventional and the proposed PIFA embedded antenna on the plane are shown in Fig. 5 and 6. The resemble result between the conventional and proposed is shown in Table - 1. The antenna gain across the 2.4 GHz and 3.725 – 3.875 GHz dual band of the proposed antenna comparison with convention patch are also studied. It is clearly seen that the PIFA metamaterial antenna, the antenna gain is merely high. In the proposed methodology, the antenna with PIFA metamaterial embedded on the substrate increases the gain to 4.0 dBi.

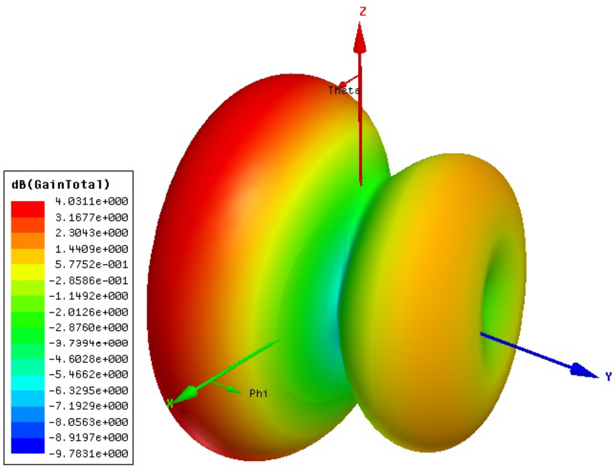

Fig. 4. Radiation Pattern (dB)

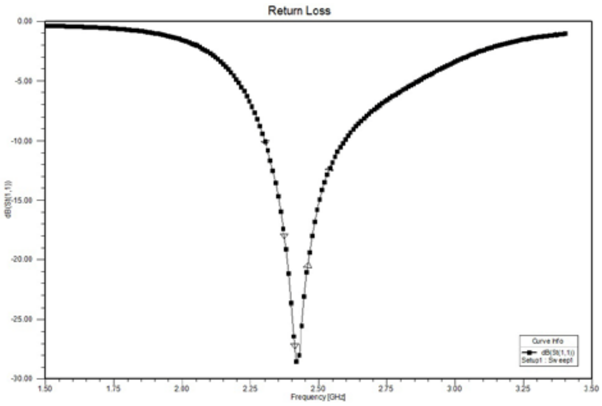

Fig. 5. Return Loss of 28 dB at 2.4 GHz Frequency

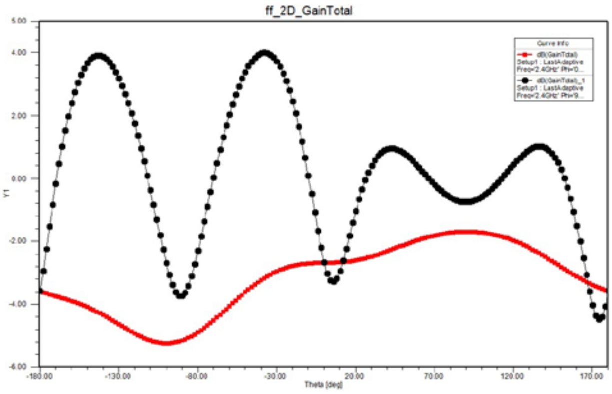

Fig. 6. Gain dB Plot of PIFA Antenna

Table1. Comparison of Conventional and Proposed Antenna based on Metamaterial

Parameter	Patch Antenna	PIFA Embedded Metamaterial
Gain (dB)	1.73	2.5299
Directivity	1.415	2.536
Efficiency (%age)	68.5%	99.76%

The radiation efficiency of the conventional antenna is about 68%. But, the proposed antenna increases the radiation efficiency to 99.76%. More specifically, the antenna gain of proposed PIFA embedded metamaterial antenna is equivalently high when compared to a Patch antenna.

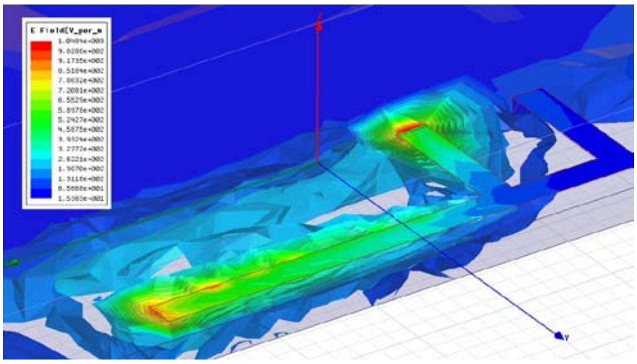

Fig. 7. Electrical Field Distribution in an PIFA Antenna

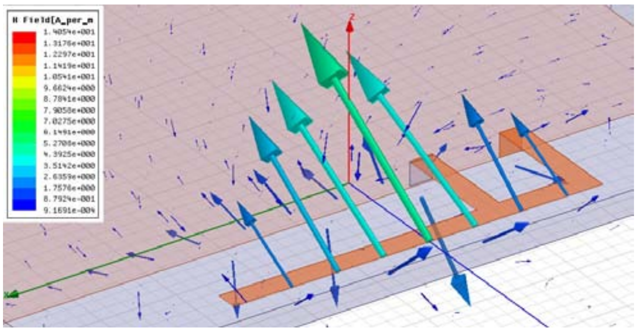

Fig. 8. Vector Magnetic Field Distribution in an Planar Inverted F Antenna.

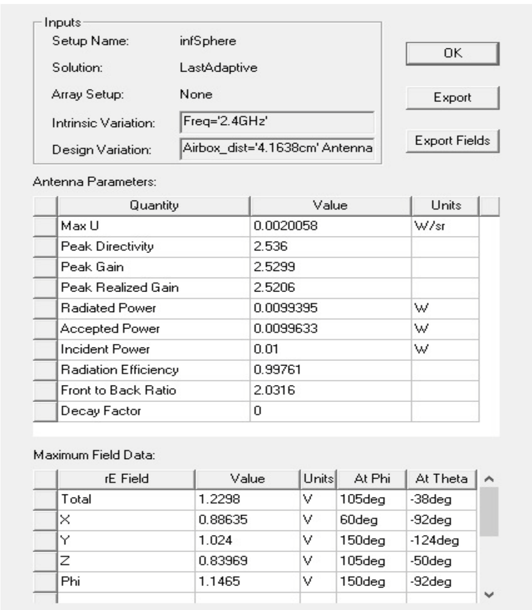

Fig. 9. Antenna parameters extracted using EM Solver.

4. CONCLUSION

A simple printed antenna with a PIFA metamaterial embedded on the substrate and ground plane for UMTS, Wi-MAX and Hiper-LAN mode operation has been proposed. The use of PIFA metamaterial structure produces the different band has increased impedance bandwidth very remarkably to sufficiently covers the (1.92 – 2.17, 3.4 – 3.5 & 5.725 to 5.875) GHz bands. The final results show satisfactory performance and good agreement with the simulated results. In future using optimization in structure the antenna size is further being reduced.

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