A Wideband PIFA Loaded with Metamaterial Superstate for 4G LTE & WLAN Devices

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Abstract- In this article a wideband planar inverted F antenna (PIFA) is presented covering 4G LTE (Long Term Evolution) and WLAN (Wireless LAN) bands. RT Duroid 5880 is used as a dielectric substrate with overall dimensions as 44 mm x 20 mm making it suitable for most of the wireless devices. Proposed antenna has wide bandwidth of more than 600 MHz covering 4G LTE from 2.3 to 2.7 GHz and Wireless LAN (2.41 GHz -2.485 GHz) standards. Bandwidth and gain is enhanced significantly by using metamaterial Superstate. It is observed that there is a good match between simulated and measured results.

Index Terms— Duroid, LTE, HFSS, Metamaterial, PIFA, WLAN.

1 INTRODUCTION

LTE is one step towards the (4G) fourth generation mobile technology that commences with current 2G and 3G networks [1]. As mobile telecommunication users are raised, and therefore radio spectrum of particular frequency band is also increased so LTE system is accepted to function in a widespread spectral frequency bands. The spectrum of frequency from 1.4 MHz to 20 MHz is allotted to LTE which has only one carrier and analyze the whole frequency band subjected to (ITU-R). A compact antenna with wideband and multiband characteristics is the need of today. In today's wireless communication an antenna design that has low cost, light weight, compact size, robustness, flexibility and ease of mass production is desired. PIFA's find their advantages in numerous wireless applications particularly in cell phones due to compact size, ease of integration, light weight etc. [2]

PIFA structures produce reduced electromagnetic radiations in the backward direction toward the user's body and hence minimizing the Specific Absorption Rate (SAR). PIFA structures also exhibits moderate to high value gain in both vertical and horizontal states of polarization [3], [4], [5], [6], [7]. Due to its low profile PIFA it is one of the popular antenna structures used in mobile devices such as USB dongles and mobile phones and can work at multiple frequency bands [4]. Narrow bandwidth is one of the disadvantage of PIFA and the remedy for that is to choose optimum size of the ground plane or the antenna height.

As mobile telecommunication users are raised, and therefore the radio spectrum of a particular frequency band is also increased so LTE system is accepted to function in a widespread spectral frequency bands. The frequency spectrum having bandwidth of 1.4 MHz to 20 MHz in various frequency bands is allotted to LTE which has only one carrier and the whole frequency band subjected to (ITU-R) [8], [9], [10]. In LTE technology numerous frequency bands are defined so that various separate carriers can operate effectively.

To simplify the use of multimode terminals and allows a global roaming, LTE supports the operation of FDD, TDD, and half-duplex in a unified design and this provides a great amount of commonality [11], [12].

In this paper, a wideband PIFA is presented which covers WLAN & LTE bands. Coaxial feed technique is used to excite the radiating patch. The software tool used to design and simulate the proposed antenna is Ansoft's High Frequency Structure Simulator (HFSS. The work presented in this paper is an extension to the research work published in [2], the measured results are presented and discussed in this paper.

Materials which are not available naturally are engineered to attain certain properties, such structures are called Metamaterials. Metamaterials with negative permeability or permittivity can be used as a Superstate lens which enhances antenna parameters [11]. Split ring Resonators (SRRs) are mostly used 2D metamaterial structures which provide negative permeability. When such SRRs are arranged periodically in a dielectric substrate, -ve magnetic permeability gets enhanced which further improves antenna performance in terms of gain enhancement, bandwidth enhancement and miniaturization. Usage and analysis of Metamaterial Superstate is presented in this paper. Square shaped ring resonator structure is used as Metamaterial on both sides of FR4 substrate. There are few other techniques also to achieve wideband behaviour and enhancing the bandwidth by using slots on the antenna geometry [13], [14].

Section II confers about the proposed PIFA design. Section III presents and discusses the simulation and measured results. Conclusion of the work presented in the paper is presented in Section IV.

2 DESIGN OF PROPOSED PIFA

The proposed PIFA design is shown in figure 1. The substrate material used is RT Duroid 5880 having loss tangent= 0.0009 and relative permittivity, εr= 2.2. The proposed PIFA consists of the square shape radiating element of size 18.5 mm× 18.5mm placed at the height of 3.8mm above ground plane. In conventional PIFA structure rectangular patch is used most of the times, but here the shape of patch is square and is rarely

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observed in literature. There is a drawback of inadequate bandwidth in conventional PIFA Structures but wide bandwidth from 2.27 GHz – 2.89 GHz is observed in the proposed antenna. Various bands covered by the proposed PIFA are LTE 2300 & 2500 and WLAN (2410 MHz -2485 MHz). The detailed dimensions of the proposed PIFA are presented in Table I.

TABLE 1
DIMENSIONS OF PROPOSED ANTENNA

Variable	Value (mm)
W_g	44
L_g	20
W_p	18.5
L_p	18.5
Shorting Plane Length	3.8
Top Patch Height	3.8
Shorting Plane Width	6.5

The labelled structure of the proposed PIFA design along with dimensions is presented in Figure 1. The fabrication of the proposed antenna is easy as the geometry of the proposed PIFA is simple.

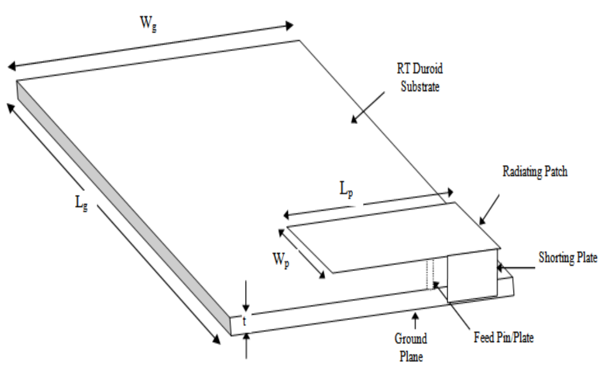

Fig. 1. Proposed PIFA Design (3D View)

Several performance parameters can be improved by using metamaterial Superstate layer above the antenna at a particular height. Various antenna parameters like impedance bandwidth and gain gets enhanced depending on the placement of the superstate layer above the antenna structure. The placement of metamaterial layer is at 15 mm above the ground plane as shown in Figure 2. The size of the metamaterial layer is 56 x 35 mm2 and is designed on FR4 substrate.

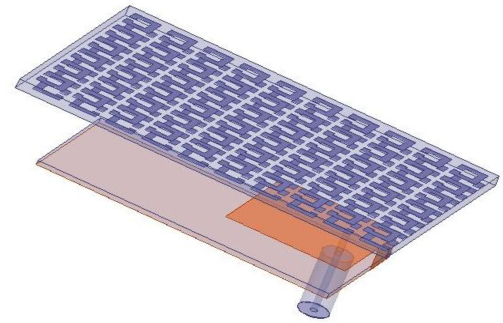

Fig. 2. Proposed PIFA with Metamaterial Superstate

3 SIMULATED & MEASURED RESULTS

Simulated return loss is shown in Figure 3 where -10 dB is considered for measurement of the antenna bandwidth. The proposed antenna resonates at 2.59 GHz and the return loss value is -41.30 dB. The proposed PIFA covers 4G LTE (Band 7, 30, 38, 40, 41, 53, 69), Bluetooth (2400-2480 MHz)/WLAN 802.11 {(2410-2485 MHz) & m-WiMAX (2500 MHz). The bandwidth coverage is from 2.27 GHz to 2.89 GHz which is 620 MHz.

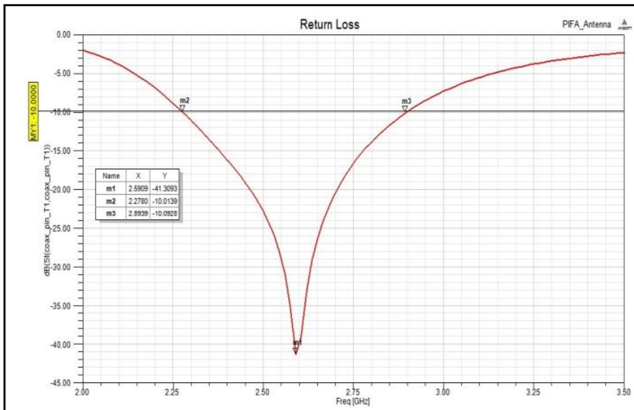

Fig. 3. Simulated Return Loss Curve of Proposed PIFA w/o Meta Layer

Figure 4 presents the simulated return loss curve for PIFA with metamaterial Superstate in which bandwidth enhancement is observed.

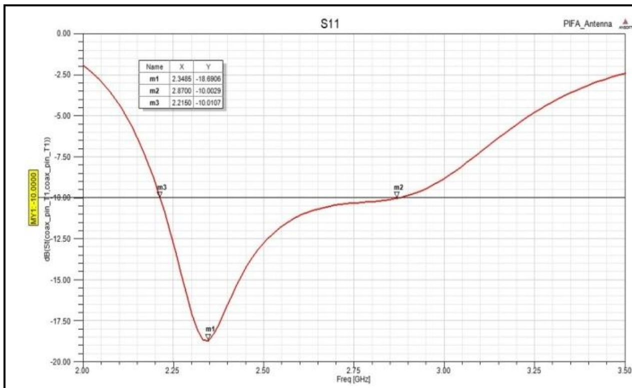

Fig. 4. Simulated Return Loss Curve of Proposed PIFA with Meta Layer

There is a shift in resonant frequency for the proposed PIFA with Meta layer to the lower frequency spectrum because of the miniaturization property of metamaterial. With the use of metmaterial layer the size of the antenna can be reduced further and still resonating on the same frequency with desired bandwidth coverage. The resonance occurred at 2.34 GHz exhibiting the value of -18.69 dB with the enhanced bandwidth of 660 MHz (2.21 GHz to 2.87 GHz). There is approximately 6% increase in the bandwidth coverage.

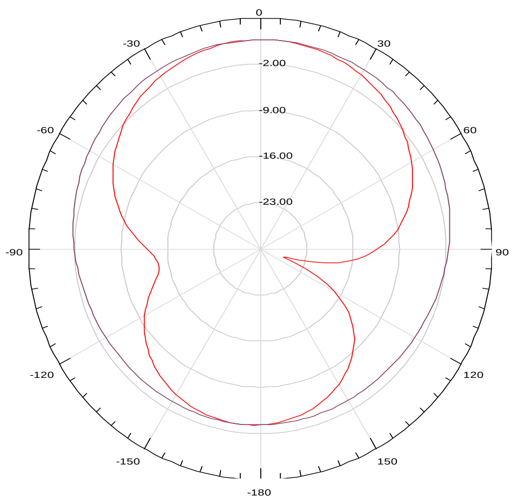

Fig. 5. Simulated Radiation Pattern with Metamaterial layer

The radiation pattern presented in Figure 5 shows that the proposed PIFA exhibits an omnidirectional radiation both in E plane and H plane i.e. for phi = 0^0 and 90^0. Gain is another important figure of merit for an antenna. Figure 6 presents the 3D gain plot of the proposed PIFA at resonant frequency with 4.41 dB as peak gain. The gain is also improved significantly as compared to PIFA without Meta layer which was 3.29 dB.

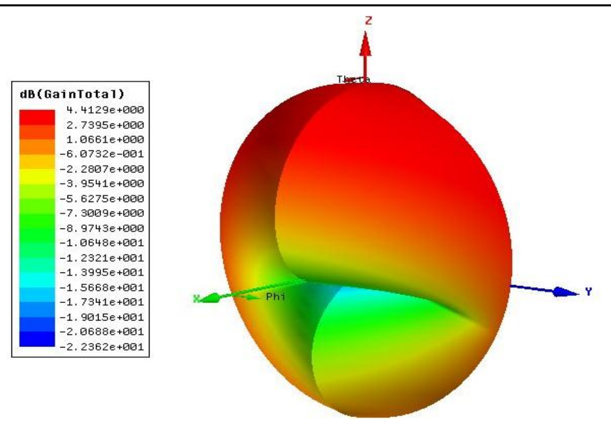

Fig. 6. Simulated 3-D Gain Plot of Proposed PIFA with Metamaterial Superstate

The value of VSWR can be seen in the plot and has to be less than 3 dB which is desirable for most of the wireless applications. The value of VSWR is 2.02 dB at 2.34 GHz as shown in Figure 7. Practically, antenna has been tested using VNA from Anritsu company, model no: MS46322A, having frequency range from 0.01 GHz-20 GHz as shown in figure 8.

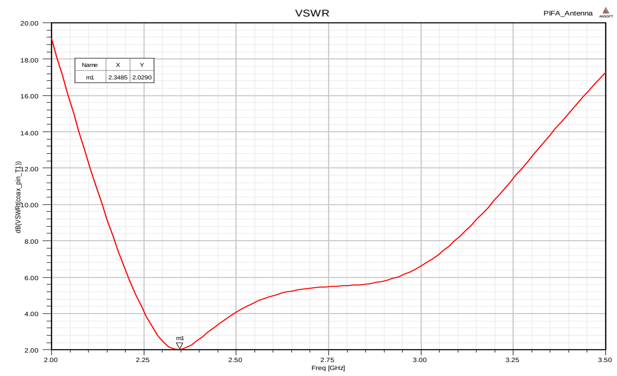

Fig. 7. Simulated VSWR plot of proposed PIFA with Meta Layer

Fig. 8. Testing of Antenna prototype on VNA Anritsu MS46322A

The resonant frequencies have shifted in the magnitude in measured results as compared to simulated results. The root cause of the shift could be due to RT Duroid PCB, which has dielectric constant that varies from 2.0 to 2.4. Practically, a material which is varying along width, length and height will affect resonant frequency and it gets shifted. While During simulation the dielectric constant is assumed to be constant over the whole frequency range.

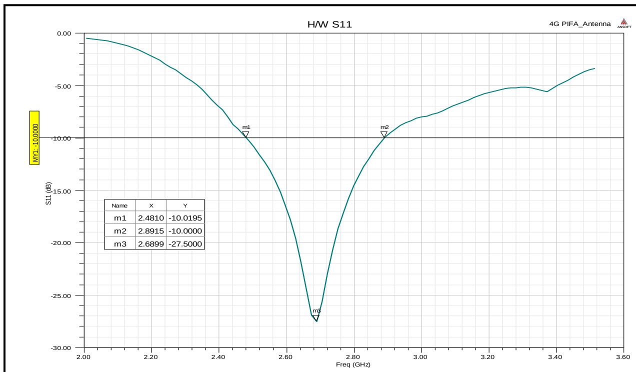

Fig. 9. Measured Return Loss Curve of proposed PIFA w/o meta layer

From the plot shown in Figure 9, it can be seen that the resonant frequency achieved is 2.68 GHz with return loss of -27.50 dB. The bandwidth obtained is from 2.48 GHz to 2.89 GHz which is 410 MHz.

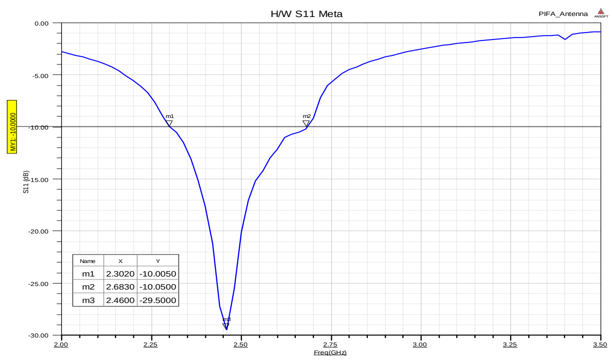

Fig. 10. Measured Return Loss Curve of proposed PIFA with meta layer

From the plot shown in Figure 10, it can be seen that a resonant frequency achieved is 2.46 GHz with return loss of -29.50 dB. The bandwidth obtained is from 2.30 GHz to 2.68 GHz which is 380 MHz. From the results presented above both simulated and measured we can compare and analyse the proposed antenna. It can be observed that resonance obtained after simulation is near to 2.6 GHz LTE band but measured value is at 2.34 GHz which gets shifted to lower side of spectrum due to some practical aspects while measurement. With Metamaterial layer also we can compare both simulated and measured return loss values as it also gets shifted to lower side of spectrum. The overall bandwidths during simulation for antenna without and with metamaterial are 620 MHz & 660 MHz respectively while measured values are 410 MHz & 380 MHz respectively. It can also be observed that measured results doesn't show much variation in return loss value for both the cases of without and with metamaterial Superstate as in the case of simulated results. There is gain enhancement due to metamaterial Superstate. Gain of simulated PIFA without Superstate is 3.29 dB while gain is increased to 4.41 dB with the use of Superstate at a height of 15 mm above the antenna.

4 CONCLUSION

A compact wideband PIFA structure is proposed in this paper for LTE & WLAN standards. Overall volume of the antenna is 44 × 20 × 3.8 mm^3 and can be integrated in any wireless device because of its compact size. With simulated and measured return loss of -41.30 dB and -27.50 dB respectively. Frequency bands covered by the proposed PIFA are LTE 30, 38, 40, 41 and WLAN (2.41 GHz-2.48 GHz). There is 34% enhancement in the value of gain from 3.29 dB to 4.41 dB with the use of metamaterial layer. To evaluate the proposed PIFA, it is fabricated on a RT Duroid 5880 substrate and there is good matching between simulated and measured results.

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