Research Article

A Dual Wideband Planer Inverted-F Antenna using Reactive Impedance Surface and Defective Ground Surface for WLAN/X-band Applications

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Abstract: This paper presents a reactive impedance surface (RIS) and a defective ground surface (DGS) in a dual wideband planer inverted-F antenna (PIFA).DGS is a technique that allows tooptimize the antenna's different parameters, like size reduction and bandwidth. The RIS structure, which consists of $3× 3$ periodic metallic unit cells, aids in increasing the antenna's bandwidth. The RIS PIFA using DGS to design, analyze, and execute antenna a 2.4 and 8.4 GHz. Finally, the complete 3D electromagnetic simulator HFSS used to simulate a prototype. The implemented results -10 dB < S11 impedance bandwidth design has estimated at being 1199 MHz (2.0734-3.26921GHz) 49.95% WLAN bands at 2.4 GHz and 912 MHz (8.0239-8.9321 GHz) 10.03% for X-bands at 8.4GHz.

Keywords: PIFA, Defective ground surface, Reactive Impedance Surface,Gain, Wideband

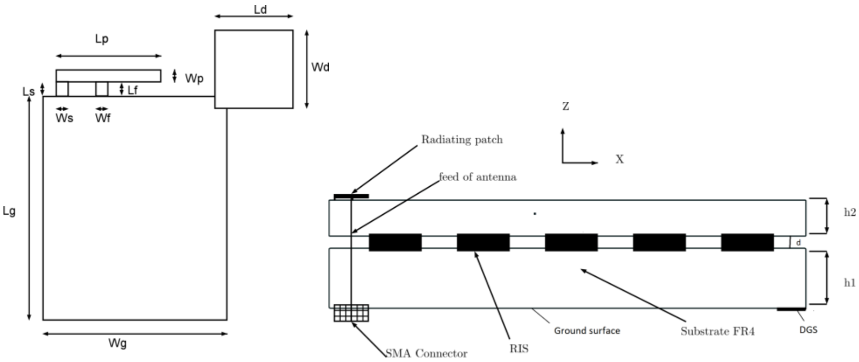
1. Introduction

The fundamental antenna design and function of wireless communication have recently advanced, resulting in an unprecedented increase in cellular users. As a result, service providers more attention to users' demands for lightweight, small-footprint antenna models that are also cost-effective. As a result, mobile users and devices wanted better communication capabilities, such as a wider frequency bandwidth or multiple frequency bands. These implementations, on the other hand, necessitated high-quality signals on both the transmitter and receiver sides. Increased gain and a large bandwidth are the most capable solutions to this issue. A large number of antenna components accommodated in the smaller size of a recent compact handset [1]. For a handheld phone, PIFA is a totally tunable lightweight antenna device with configurable segregation enhancement [2].A basic low-profile PIFA as well as an antenna with a broad tuning range[3]. a printed-IFA with composite right/left-handed (CRLH) unit cells is ideally and experimentally explored using electromagnetic simulators. To achieve multiband behavior, folded slots are CPW-fed with L-loaded PIFA. Capacitive loads are mounted to the open end of the L-loaded printed-IFA to further reduce the antenna size, and seven distinct printed elements are integrated into a small handset [5], [6]. The dual-band, single-layer, U-slot-fed antenna with linear polarization [7]. In a two-planar inverted-F antenna printed on a circuit board device, metamaterial particles based on a split-ring resonator investigates to increase the decoupling speed [8]. The RIS structure's symmetric slotted-slit microstrip patches have been used to miniaturize the antenna while boosting the bandwidth [9]. The metamaterial used for broad bandwidth [10],[11], and DGS eliminates coupling by adding currents in the opposite direction of the initial characteristic modes (CM) currents [12]. The difference between low and high fidelity, as well as the separation between the patch and the radiating patch can be reduced [13]. PIFA's bandwidth, improved by metallic cross branching [14]. PIFA is a rigid and lightweight personal contact antenna with a tunable internal antenna [15]. Smaller antenna sizes in wireless communication systems due to the need for miniaturization gain enhancement. As a result, for PIFA mobile applications, size reduction and bandwidth enhancement have become critical considerations. Small internal antennas for wireless terminals and ease of implementation are two of PIFA's distinguishing features. The PIFA usage in a variety of settings due to its many appealing advantages. However, some of the PIFA's disadvantages will still outweigh the benefits, such as power handling capacity,polarization, smaller bandwidth andlower gain. Precision analysis methods, advanced principles, and optimal design techniques need a PIFA with fewer effects. This paper presents a lightweight, dual, wideband PIFA using RIS and DGS, which has the benefits of compact size and suitability for mobile devices. Mobile communication is more difficult due to PIFA's gain and lower bandwidth.At the height of the radiating patch and substrate increases, the antenna's bandwidth increases. It has also reduced the efficiency factor. To minimize the limitations of PIFA, a new proposed RIS-based PIFA with DGS has been introduced to address the following issues. Defected slots are geometrical slots found in one of the PIFA's corners. A DGS may have a small unit cell and a single defect configuration. The RIS, which consists of a lattice structure of three times three periodic metallic square patches, improves the antenna's bandwidth improvement. The proposed PIFA has modeled using the HFSS simulation method.

2. AntennaDesign

ConventionalPIFA

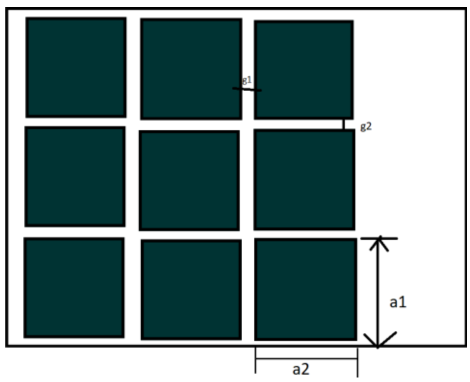
In a typical PIFA, the planar patch area is above the antenna ground plane (top surface), ground plane (bottom surface), short-circuiting pin or plate, microstrip line feeding mechanism, and dielectric constant.The basic antenna function, which is shaped like the letter F in English, is known as an inverted-F antenna. Figure 1 depicts the proposed antenna's schematic structure. The antenna has a total built volume of 24.01 times 1.22 times 2 mm, making it ideal for mobile applications. The PIFA is attached to the antenna ground plane. The PIFA ground surface on the PCB frame has an average dimension of 56.4 mm times 51.3 mm. The antenna having a FR-4 substrate with a dielectric constant of 4.4 and a height of antenna 1.59 mm. Figure 1(a) and (b) shows the PIFA structure with DGS and a cross-section of the PIFA with RIS and DGS.Table.1 shows the detailed dimensions of the PIFA with DGS. Two h1 and h2 dielectric substrates with heights of h2 = 1 mm and h1 = 1.59 mm are used in the proposed PIFA using RIS and DGS.



(a) PIFAwithDGS(b) Cross-sectional view proposedantenna

Fig. 1. Proposed PIFA using RIS and DGS

Fig. 2. Geometrical view of RIS



Defective Ground Surface

A square cell is the basic structure of a defective ground surface. The layout of ground plane the antenna has an attaching square branch with a side corner. As a result, the effective dielectric constant of the antenna's electric circuit's efficient inductive and capacitive components is higher. The slow-wave property of the antenna's defected ground surface affects the surface current distribution in the antenna ground surface. The ground plane has changed transmission line characteristics such as capacitance and line inductance, causing electrical interference. In other terms, a faulted or defected ground plane surface manipulated with RIS and DGS.

Table 1. Dimensions of Geometric parameters of proposed antenna Parameters Size (mm) Parameters Size

(mm) Parameters Size (mm)

g1	0.5	g2	0.3	d	1.0
a1	16	a2	17	εr	4.4
Wf	2.1	Lf	3.8	Ls	3.8
Lp	26.5	Wp	2.88	Ws	2.1
Wg	51.3	Wd	20.63	h1	1.0
Lg	56.4	Ld	20.63	h2	1.59

Reactive ImpedanceSurface

RIS has a PEC or PMC designed to represent total power while stores magnetic or electric energy. A resonant antenna's lattice property is used to tune it below its natural resonance frequency. It's also have demonstrated that RISs can reduce antenna-to-substrate interference, allowing for easier matching and wideband operation.The RIS also enhances the interaction between the antenna substrate (antenna picture on the RIS)and antenna. It also has a front-to-back ratio of antenna similar to that of a PEC surface. The RIS structure is shown in Fig. 2 as a periodic lattice of 3 × 3 array unit cells.

PIFA using RIS and DGS

The antenna geometrical parameters of PIFA using RIS and DGS were determined using various equations derived from the transmission line model. When designing a PIFA with RIS and DGS, the three most important parameters to recognize i) desired resonance frequency (Fr), ii) substrate dielectric constant (ε_r), and iii) dielectric substrate height (h).The geometric radiating patch length (L_p), patch width (W_p), and different slots in the patch were determined. Calculated dimensions have been optimizing with their respective frequency bands. The impedance bandwidth is proportional to the substrate thickness and inversely proportional to the square root of the substrate's dielectric constant (εr). The width of patch

$$Wp = \frac{c}{2f_0\sqrt{\frac{\varepsilon reff+1}{2}}}$$

Inthe fundamental mode, i.e., TM10 mode, is less than λ/4, where λ is the dielectric medium wavelength and is equal to the free space wavelength of λ0.TM10 mode means that the field only varies with the length of λ/4 and does not differ with the patch distance. Where,A is a fixed and,h is the substrate height = 1.59 mm, dielectric constant = 4.4, The effective dielectric constant is measured as follows.

$$A = \frac{ZL}{60}\left(\frac{\varepsilon r+1}{2}\right)^{\frac{1}{2}} + \left(\frac{\varepsilon r-1}{\varepsilon r+1}\right)\left(0.23+\frac{0.11}{\varepsilon r}\right)$$

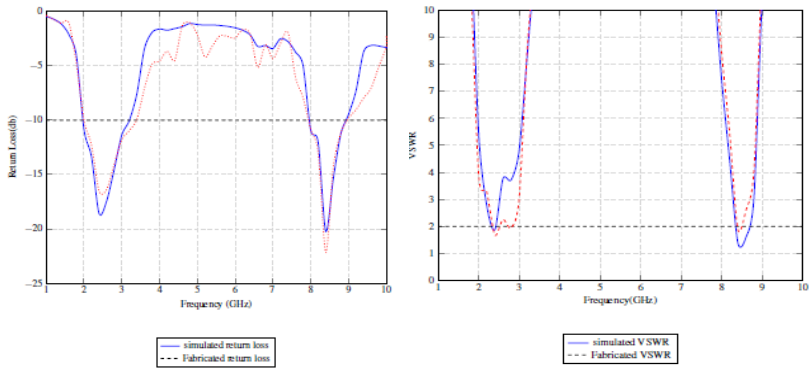
The length of patch

$$Lp = \lambda/4$$

The proposed antenna is 1 mm height and has an FR4 dielectric substrate thickness (ε_r = 4.4, tan δ= 0.02).The proposed antenna is made up of a PIFA design with the ground plane attached to a square slot of DGS in one corner and a RIS structure printed above the ground surface. The antenna dielectric substrate measures 56.4 mm x 51.3 mm. DGS has a slot with a size of less than 0.2 lambda0. DGS has a length and width of 20.63 mm, which is the same as the square slot's length and width. The radiating metalpatch design of the proposed antenna work is illustrated on the top side of the dielectric substrate, the DGS ground surface printed on the lower side, and the RIS structure is above the dielectric substrate. After that, an antenna is designed, built and tested.

3. Experimental Results and Discussion

The various equations derived from the transmission line model are used to design the antenna geometrical parameters of PIFA using RIS and DGS.The S11 antenna design's simulated -10 dB impedance bandwidth is 995 MHz impedance bandwidth (2.0734-3.06921) 13.19 % at 8.4GHz and 41.45% at 2.4 GHz and 1108 MHz bandwidth (7.8239-8.9321 GHz). The measured -10 dB impedance bandwidth estimated is a 1199 MHz impedance bandwidth (2.0734-3.26921GHz) 49.95% WLAN bands at 2.4 GHz and 912 MHz impedance 843 bandwidth (8.0239-8.9321 GHz) 10.03% for X-bands at 8.4GHz. Due to the air slit between the radiation portion and the ground planeprepared during processing, PIFA comprehensive experiments using RIS and DGS slightly improved as compared to the simulated results of the performance parameters. The fabrication antenna is advantageous for a smartphone application.The measured VSWR of the proposed PIFAhas shown in Fig. 3(b). It noted that the VSWR value has almost 1.69 at 2.4 GHz and 1.89 at 8.4 GHz in the manufacturing process. It should be between 1 and 2, indicating better antenna efficiency and a better radiator. It means an antenna input power, as well as good impedance matching transmitted to the patch. The lower value of the VSWR has been transmitting more power from the transmission line to the antenna.



(b) **(b)**

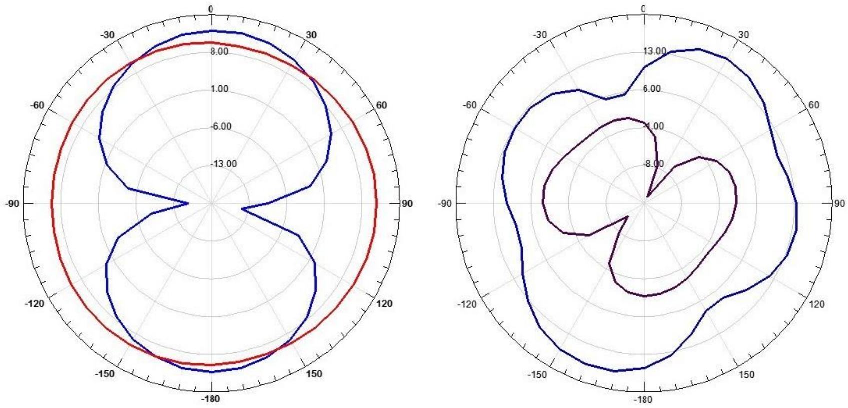
Fig. 3. (a) Return Loss of PIFA is using RIS and DGS (b)VSWR of PIFA using RIS and DGS

The simulated radiation patterns of E-Plane and H-Plane are shown in Fig.4 (a) and (b). The radiation patterns of the PIFA at 2.4 GHz for WLAN applications and 8.4 GHz for X-band applications. The simulated (co-polarized and cross-polarization) radiation pattern in the XY plane at = 0° and = 90°.Thesimulated gain of the PIFA using RIS and DGS for wireless devices, shown in Fig.5, which is acceptable, better dual, wideband antenna. The simulated gain result 4.03 dBi for 2.4 GHz and 2.21 dBi for 8.4GHz as shown in fig.5. Table.2 lists all of the proposed PIFA’s simulated and measured results using RIS and DGS. The High-Frequency Structure Stimulator had been used to simulate the modeled PIFA using RIS and DGS configurations. The term "final designs" refers to an antenna configuration that has been optimized. The feed has a grounding pin and a build with a copper metal on the upper layer of the antenna. In HFSS simulation, the PIFA's microstrip feed point is a single port that is a wave port. The fabricated prototype uses an SMA connector for calculation. Female-type connectors are SMA connectors. The SMA connector has a significant impact on the structure’s electrical properties. An external connector for practical experimental validation has been the EM simulation platform. A elongated probe passes through a hole on the lower surface of the antenna's substrate and attaches to the PIFA element's shorting post to connect the PIFA element's microstrip feed position to the other end of the antenna.

Table 2. Comparison of simulated and measured results of slotted PIFA

Simulated Results				
Frq (GHz)	Return loss (dB)	-10 dB impedance bandwidth (GHz)	% Band width	VSWR
2.4	-18.59.7	2.0734-3.06921	41.49	1.875
8.4	-20.22	7.8239-8.9321	13.19	1.40

Measured Results				
Frq (GHz)	Return loss (dB)	-10 dB impedance bandwidth (GHz)	% Band width	VSWR
2.4	-16.52	2.1873-3.26921	49.95	1.693
8.4	-22.22	8.0239-8.8671	10.03	1.89



(a) Phi=0. (b) Phi =90.

Fig. 4. Radiation pattern of E Plane and H Plane

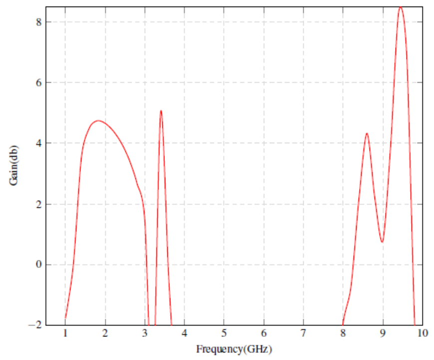


Fig. 5. Gain of proposed PIFA using RIS and DGS

4. Conclusion

A Metasurface-based dual, wideband PIFA using RIS and DGS for WLAN/X-band applications. The proposed antenna's DGS may have a regulated radiation pattern and a wideband. The RIS structure, which consists of a lattice of 3× 3 periodic surface of metallic patches, aids in increasing the antenna's bandwidth. The DGS PIFA with metamaterial creates, analyses, and implements a 2.4 and 8 GHz antenna. The measured -10 dB impedance bandwidth estimated is an 1199 MHz impedance bandwidth (2.0734- 3.26921GHz) 49.95% WLAN bands at 2.4 GHz and 912 MHz impedance bandwidth (8.0239-8.9321 GHz) 10.03% for X-bands at 8.4GHz. PIFA using RIS and DGS showed good radiation pattern, return loss, impedance bandwidth, gain, and VSWR response in both simulated and fabricated results in the WLAN/X-band application..

References

1. Kin-Lu Wong and Kai-Ping Yang. "Modified planar inverted f antenna", Electronics letters, 34(1):7–8, 1998.33
2. IJ Garcia Zuazola and John C Batchelor. "Compact multiband pifa type antenna", Electronics letters, 45(15):768–769, 2009.
3. Nguyen, V.A., Bhatti, R.A.Park, S.O (2008). A simple PIFA-based tunable internal antenna for personal communication handsets. IEEE Antennas and Wireless Propagation Letters, 7, pp.130-133.
4. Soliman, A., Elsheakh, D., Abdallah, E., El-Hennawy, H. : Multiband printed metamaterial inverted-F antenna (IFA) for USB applications. IEEE Antennas and Wireless Propagation Letters, 14, 297-300. (2015).
5. Dalia M Elsheakh and Esmat A Abdallah. "Compact multiband multifolded-slot antenna loaded with printed-ifa", IEEE antennas and wireless propagation letters, 11:1478–1481, 2012.
6. Glogowski, R. Peixeiro, C (2008) Multiple printed antennas for integration into small multistandard handsets. IEEE Antennas and Wireless Propagation Letters, 7, pp.632-635.
7. Liu, S., Qi, S.S., Wu, W. And Fang, D.G (2015) Single-feed dual-band single/dual-beam, Uslot antenna for wireless communication application. IEEE Transactions on Antennas and Propagation, 63(8), pp.3759-3764.

8. Gil, I. Fernandez-Garc ´ ´ıa, R(2016), September. Study of metamaterial resonators for decoupling of a MIMO-PIFA system. In Electromagnetic Compatibility-EMC EUROPE, 2016 International Symposium on (pp. 552-556). IEEE.
9. Agarwal, K. Alphones, A(2013). RIS-based compact circularly polarized microstrip antennas. IEEE Transactions on Antennas and Propagation, 61(2), pp.547-554.
10. Lai, X.Z., Xie, Z.M., Cen, X.L. Zheng, Z (2013). A novel technique for broadband circular polarized PIFA and diversity PIFA systems. Progress In Electromagnetics Research, 142, pp.41-55.
11. Dong, Y., Toyao, H. Itoh, T(2011). Compact circularly-polarized patch antenna loaded with metamaterial structures. IEEE transactions on antennas and propagation, 59(11), pp.4329- 4333.
12. Ghalib, A. Sharawi, M.S(2017). TCM analysis of defected ground structures for MIMO antenna designs in mobile terminals. IEEE Access, 5, pp.19680-19692.DOI: 10.1109/ACCESS.2017.2739419
13. Tejaswi Jadhav and Shraddha Deshpande. "Miniaturized planar inverted-f antenna with metallic cross branch for mobile communication", In 2019 International Conference on Intelligent Computing and Control Systems (ICCS), pages 617–620. IEEE, 2019.
14. Tejaswi Jadhav and Shraddha Deshpande. "Planar inverted-f antenna using defected ground surface for mobile application", In ICDSMLA 2019, pages 611–619. Springer, 2020.
15. Tejaswi Jadhav and Shraddha Deshpande. "Wideband circularly polarized planer invertedf antenna using reactive impedance surface",International Journal of Innovative Technology and Exploring Engineering,2019.