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REGULAR ARTICLE

Microstrip Patch Antenna with Parasitic Elements and Slots for Narrow Bandwidth for Modern Wireless Applications

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The present research compares two innovative patches with microstrip topologies using slot with parasitic strips, that are primarily utilized in modern wireless networks involving WiMAX, Wi-Fi or WLAN, along with forthcoming 5G smartphones and tablets. The pair of antennas have been replicated using a FR-4 substrate with a relative permittivity of 4.3 and copper having a diameter outside of 0.035 mm spanning the transmission and grounding planes. A narrow bandwidth of 140 MHz at 3.4 GHz and 350 MHz at 5.88 GHz is accomplished by the suggested Antenna-1. An extra resonant has been achieved in antenna-2 by adding five slots at the top, bottom, and sides of Antenna-1, resulting in Antenna-2 being shaped like a teddy bear. Having return inefficiencies of – 20 dB, – 23 dB, and – 16 dB, accordingly, Antenna-2 exhibits 3 harmonics at 3.25 GHz, 3.7 GHz, and 5.37 GHz. At resonance frequencies of 3.4 GHz and 5.88 GHz, antenna-1 achieved return losses of – 31 and – 16 dB. The greatest surface current densities are 180 A/m and 74 A/m, correspondingly, and the electrical current distribution is consistent throughout the patch area, particularly antennas 1 and 2 having the highest values of 108 A/m and 52.5 A/m, respectively.

Keywords: Defected ground antenna, Teddy bear shape radiating elements, Return loss, Current distribution, Mobile phones, 5G mobile applications.

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1. INTRODUCTION

Throughout the years, 5G networks for mobile phones have evolved significantly and have become in widespread use because they offer many benefits, including decreased latency, an elevated data rate, and large bandwidth for data [1]. A microstrip patch antenna is a created architecture for 5G cell phone services due to its advantages, which include minimal weight, small dimensions, cheap, discreet, minimized size, and ease of fabrication [4]. Traditional microstrip antennae's poor gain along with limited bandwidth are their primary disadvantages [5]. Patch antennas can now function in many bands, attain higher strength, have a wider bandwidth, and be more compact thanks to new concepts created by scientists [6-12]. A Teflon substrate-mounted patch design having a total size of 50 × 80 mm^2 [6] that functions in three distinct bands in fifth Generation (5G) sub-6 GHz was reported for tri band applications .

In reference [7], a Rogers platform patch antenna made having a slot addition form that operates during 3.12 GHz leveraging the Defected Ground Structure technique was suggested. The RO5880 substrate, which has a total size of 77 mm × 70.11 mm, is used in [8]. However, the antenna's frequency band is not disclosed. The effectiveness about 5G wireless networks operating above frequencies below 6 GHz has significantly improved as a result of recent developments in microstrip patch antenna design. Reference [9] presented a 1-band, powerful antennas having a frequency range about 135 MHz having a total power for 7.15 dBi that uses suitable material and operates at 5.65 GHz. The airgap approach was described in [10] as a way to raise the gain of microstrip patch antennas at 2.4 GHz. Using a reflective layer, as suggested in [11], which uses four spacers spread across the patch antenna's four corners, is another way to boost antenna gain. Similarly, a broad printed antenna featuring a total size of twenty-eight × twenty millimeters was created within [12] using FR-4 material for operation within the n77 as well as n78 range that comprise 5G New Radio network (NR). A

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multichannel coplanar plane prism (CPW)-driven monopoly antenna about an entire dimension of 20 × 8.7 mm² was proposed by the investigators in [13] employing FR-4 base with an outer diameter of 0.4 mm when a permittivity coefficient of 4.3. However, the model's gain were 2.6 dBi, while the observed gain for 6.2 GHz remained 2.25 dBi. In order to function in four distinct wavelength categories – Wireless LAN 6E (5925 regarding 7125 MHz), five-GHz n77 (3300 through 4200 MHz), n78 (3300 towards 3800 MHz) – the scientists created four-band circle polarized antennas [14]. The dish antenna achieved increased bandwidth plus moderate gain for each of the four frequency bands. Zelong Hu et al. constructed a graphene-based flexible antenna that can function in two bands [15].

2. PROPOSED STRUCTURE DESIGN

The current study offers a thorough examination for both antennas patch to confirm the effectiveness of the suggested approach. Antennas-1 is a traditional antenna patch with slots, but Antenna-2 is a unique antenna patch with parasitic components with slots. Incorporating parasitic components into a traditional patching antenna may improve spectrum and antenna efficiency. The calculated and manufactured front views of the two antennas are shown in Figure 1. The devices, that depend by the notion of a microstrip patching antenna, are constructed using FR-4 substrates, having an absolute permittivity about 4.3 as well as an overall thickness about 1.6 mm, in addition copper, that includes a thick from 0.035 mm to make the radiate while grounding surfaces. The idea is that the microstrip- for improved impedance correlation, a feeding approach is employed whereas slots are made across the area that radiates to allow the design to be used at different two bands. The proposed antenna was designed using formulae (1) by means of (7). The radiating patch dimension were calculated using the subsequent formulas.

$$W_P = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

in this case, $C = 3 \times 10^8$ meters per second (m/s), r = permittivity of material as well as f_0 = frequency of resonance (GHz).

$$L_P = L_{reff} - 2\Delta L \tag{2}$$

where L_{reff} is located utilizing

$$L_{reff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \tag{3}$$

Following that, base dimensions and length were computed using

$$W_g = 6h + W_P \tag{4}$$

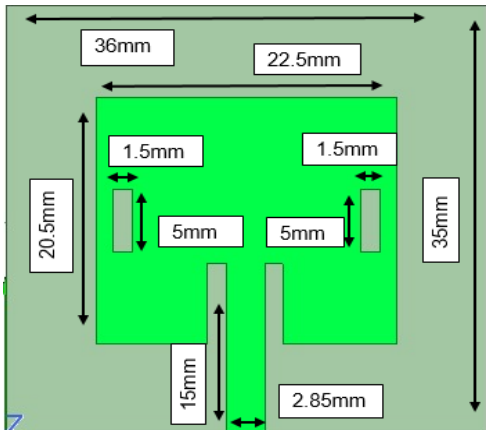
$$L_g = 6h + L_P \tag{5}$$

Here, h represents the substrate's height.
The breadth of the feeding line,

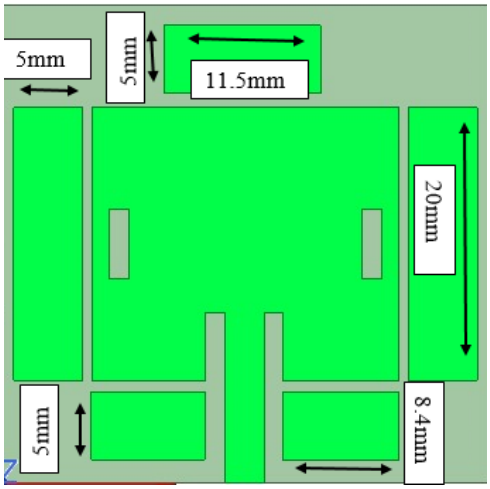
$$Z_0 = \left[\frac{87}{\sqrt{(\varepsilon_r + 1.141)}}\right] \ln\left(\frac{5.98h}{0.8W_f}\right) \tag{6}$$

Considering feedline's length,

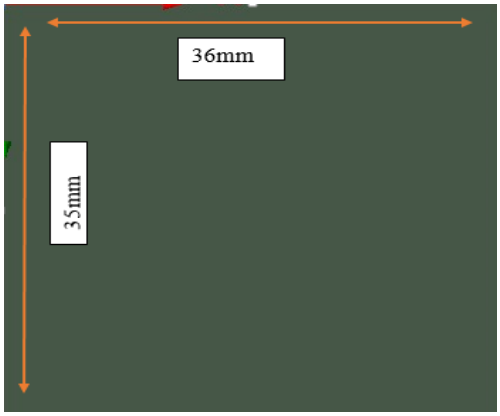
$$L_f = \frac{L_g - L_p}{2} \tag{7}$$



(a)



(b)



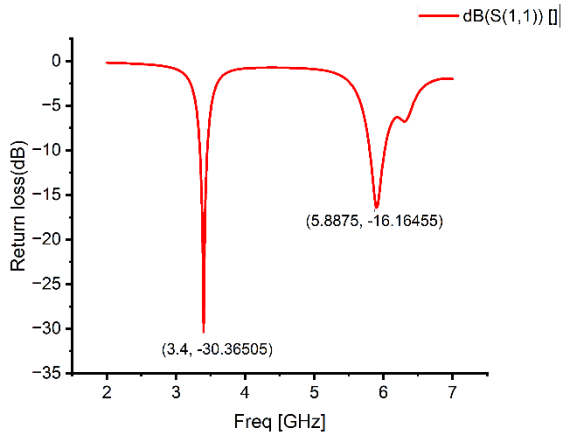
(c)

Fig. 1 – The proposed DGS based antenna with dimension (a) Front view – Anetnna-1 (b) Front view – Anetnna-2 (c) Back view for both with all dimensions as mentioned

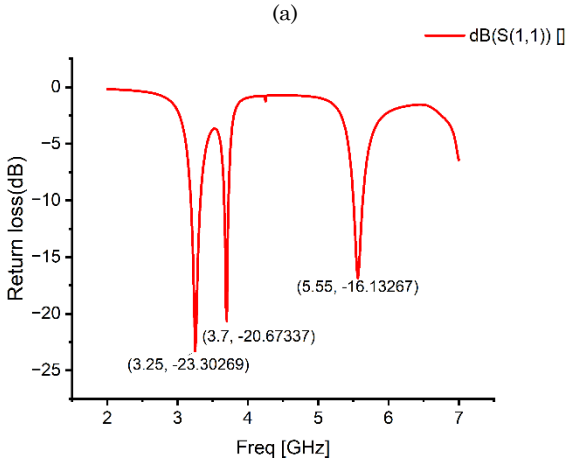
The sum of total antenna lengths (unit in mm) for the two antennas have the same value as shown in Figure 1 (a) and (b). There are no parasite strips on Antenna-1.

3. RESULTS & DISCUSSIONS

The Computer Simulation Tools (CST) of the Electromagnetic Studio (MWS) program version 2022 was used to model the reflecting Coefficient ($|S_{11}|$) along with Capacity of the planned antenna. Figure 2 displays the reflection coefficient graph for the two modeled designs. Antenna-1 resonated at 3.4 GHz with a bandwidth of 140 MHz (3.31 to 3.45 GHz), whereas the $|S_{11}|$ ratio at the targeted frequency bands was less than 10 dB. Furthermore, the antenna resonated at 5.88 GHz and achieved a frequency range of 350 MHz (corresponding to 6.1 GHz). The simulations for the second antenna at 3.25 GHz, 3.7 GHz, and 5.55 GHz showed less than – 10 dB. Despite having three bands, it barely spans a small bandwidth for impedance of less than 100 MHz across all frequencies. The return on loss for the following frequencies consists of – 23 dB, – 21 dB and – 16 dB accordingly at 3.25 GHz, 3.7 GHz and 5.55 GHz.



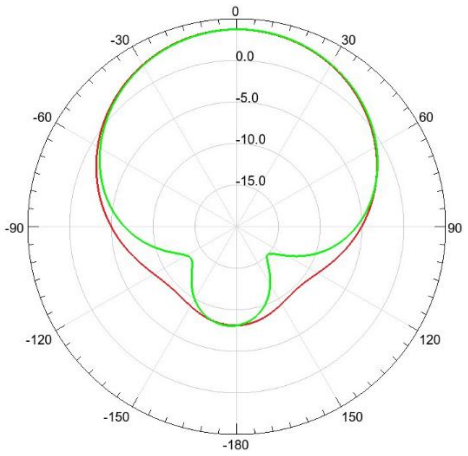
(a)



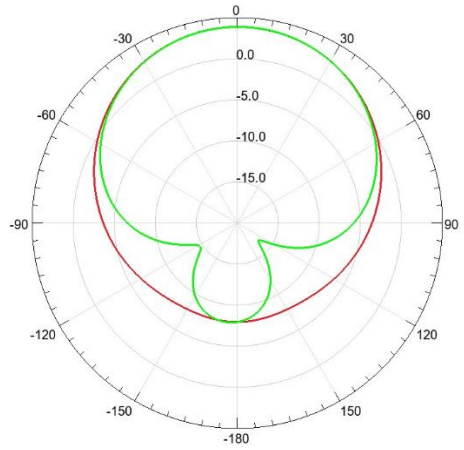
(b)

Fig. 2 – Simulated results of the designed antenna – Reflection coefficient (a) Antenna-1 (b) Antenna-2

Our 2D polarization radiation fields that result from the suggested structure are visible in the following illustration (Fig. 3). As shown in Fig. 3 (a), the simulated radiation distributions at 3.4 GHz indicate that both antennas exhibit a higher radiation spectrum above downward direction, representing a notable degree of concentration as well as gain. The development of great-performance wireless networks that need antennas that are directional with significant gain as well as effectiveness can benefit from these findings. Around 5.88 GHz, nevertheless, the simulated pattern of radiation is practically omnidirectional, because it is diffused across a broader area. As seen in Fig. 3 (b), Antenna-2 at 3.25 GHZ displays identical radiation performance with comparable gain values.

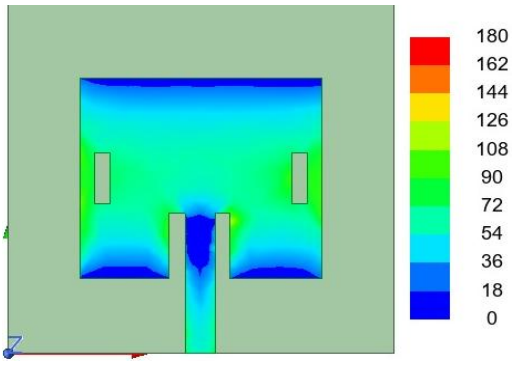


(a)

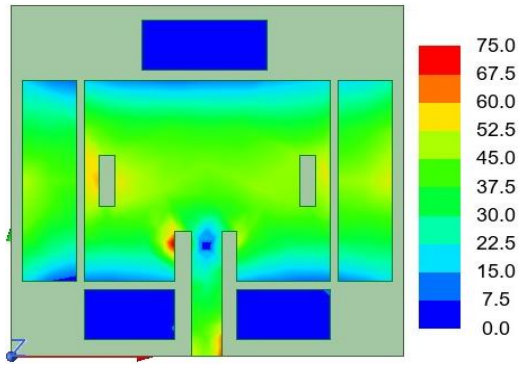


(b)

Fig. 3 – Radiation pattern of proposesd structure (a) Anetnna-1 at 3.4 GHz (b) Antenna-2 at 3.25 GHz



(a)



(b)

Fig. 4 – Density of surface current (a) Antenna-1 in 3.4 GHz (b) Antenna-2, currently 3.25 GHz

The exterior electrical current concentrations of the suggested antenna configurations at 3.4 GHz using Antenna-1 and 3.25 GHz alongside Antenna-2 are displayed in Diagram (Fig. 4). To determine which parts or areas of the antenna are in charge of the multi-band frequencies, a current distribution study is essential. Similar to Fig. 4(a), the two-sided parasitic strips and the antenna length's edges are where the current radio intensity is focused at 3.4 GHz. These regions are what allow the antenna's resonance to produce resonance at the desired range of frequencies. As seen in the illustration – Fig 4(b), the current intensity at Antennae-2 for 3.25 GHz is greater across the antenna's width but upper parasitic strips and less concentrated at the antenna length's edges.

Table 1 – Simulated outcomes of Antenna-1and 2 at various resonant (GHz)

Parameters	Antenna-1		Antenna-2		
Frequency (GHz)	3.4	5.88	3.25	3.7	5.37
Return Loss (dB)	– 31	– 16	– 20	– 23	– 16
Gain (dBi)	1.9	0.2	3.21	2.2	1.6
Bandwidth (MHz)	140	350	< 100		
Dimension (mm²)	35 × 36		35 × 36		

Table 2 – Comparison of results of this work with related works (NR: Not Reported & BW: Bandwidth)

Ref.	f (GHz)	Size (mm²)	BW (MHz)	Gain (dBi)
[6]	2.55, 3.5 & 4.75	50 × 80	2920	2.52, 3.05 & 4.31
[7]	3.12	20 × 35	2560	2.44
[8]	4.53 & 4.97	77 × 70.11	NR	2.44
[9]	5.65	52.92 × 55.56	135	7.15
[10]	2.4	80 × 80	72.837	7.91
[11]	2.392	60 × 55	44.7	5.2
[12]	3.65	28 × 20	700	2.5
This work	3.4 & 5.88	3 5 × 36	140 &350	1.9 & 0.23
	3.25, 3.7 & 5.37		< 100	3.21, 2.2 & 1.6

Table 1 describes an assessment of Antennae-1 along with the proposed antenna, Antennae-2, demonstrating that the suggested design is superior to Antenna-1 in terms of significant operating characteristics. Additionally, the proposed 3-band parasitic strip antennas are considerably reduced by size, has a greater spectrum, along with has a suitable gain across every band of frequencies when in comparison with previous reported research, as shown in Table 2.

4. CONCLUSION

The present paper describes the development and construction two separate FR-4-powered dual and three bands rectangle patch antennas made of microstrip that operate across 3.4 GHz along with 5.88 GHz, as well as 3.4 GHz, 3.27 GHz, in addition 5.37.4 GHz using microstrip-driven techniques. Antenna-1 is a standard two-band patches with slots; however, Antenna-2 is a parasite strip-supported antenna that is suggested in the present investigation. We demonstrated how Antenna-2 outperforms standard two-band patch antennas by contrasting Antenna-1 in addition Antenna-2 with regard to frequency and gain. The use of parasite strips is a key component of better antenna functioning.

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Мікросмужкова антена з паразитними елементами та щілинами для вузької смуги пропускання в сучасних бездротових системах

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У роботі порівнюються дві інноваційні мікросмужкові антени, що використовують щілини та паразитні смужки. Такі антени застосовуються переважно в сучасних бездротових мережах (WiMAX, Wi-Fi, WLAN), а також у перспективних смартфонах і планшетах стандарту 5G. Обидві антени реалізовані на підкладці з матеріалу FR-4 (відносна діелектрична проникність – 4,3) з мідним покриттям товщиною 0,035 мм, яке формує площини передачі сигналу та заземлення. Запропонована «Антена-1» забезпечує вузькі смуги пропускання: 140 МГц на частоті 3,4 ГГц та 350 МГц на частоті 5,88 ГГц. В «Антені-2» реалізовано додатковий резонанс шляхом додавання п'яти щілин (зверху, знизу та з боків «Антени-1»), через що за формою вона нагадує плюшевого ведмедика. «Антена-2» демонструє три резонансні гармоніки – на частотах 3,25 ГГц, 3,7 ГГц та 5,37 ГГц – із відповідними рівнями відбитих сигналів (return loss) – 20 дБ, – 23 дБ та – 16 дБ. Для «Антени-1» на резонансних частотах 3,4 ГГц і 5,88 ГГц рівні відбитих сигналів становлять – 31 дБ та – 16 дБ відповідно. Максимальні значення густини поверхневого струму дорівнюють 180 А/м та 74 А/м; розподіл електричного струму по всій площі випромінювача є рівномірним, причому для антен 1 та 2 максимальні значення становлять 108 А/м та 52,5 А/м відповідно.

Ключові слова: Антена з дефектованим екраном, Випромінювальні елементи, Зворотні втрати, Розподіл струму, Мобільні телефони, Мобільні застосунки 5G.