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Mitigating Antennas Proliferation of 2.4 GHz Coaxial fed Microstrip Patch Configuration designed for Bluetooth Connectivity

S. KUMAR[++], R. A. SOOMRO, M. R. ANJUM[*],T. MEHMOOD

Institute of Information & Communication Technologies, Mehran UET- Jamshoro, Pakistan.

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Abstract: This paper personifies the design and insight of Microstrip Patch Antenna using coaxial feed for Bluetooth assimilation. The Bluetooth Technology elicits over short range communication to compliance data for static and mobile nexus. Nevertheless, radio communication has progressed over the years with fostering leading-edge areas from Wireless Body Area Networks (WBANs) to Internet of Things (IoT) with smart home, wearables and beacon ventures. Correspondingly, Bluetooth SIG networks also endures its repute by unveiling advanced power control and pairing contrivances to gripmultifarious vulnerabilities of Blue Borne along with intensifying Enhanced Data Rate (EDR) competency. The bluetooth antenna endeavor has been vindicated with outcomes of1.81VSWR, 6.95dB directivity, 6.13dB gain and return loss of 0.02amid FR4 substrate of 4.4 dielectric permitivity. The procured directivity connotes antenna's effectiveness for bluetooth data transmission outfit over short distances.

Keywords: Bluetooth, Patch Antenna, Voltage Standing Wave Ratio, Internet of Things,Directivity, Return Loss.

1. INTRODUCTION

Bluetooth is the short-range wireless technology using Ultra High Frequency (UHF) radio channels and encompasses widely in cellular phones, iPads, wearables, automotive, beaconing and supervisory IoT grids by maneuvering thermostats, electric lights, door locks and appendage household appliances (Peter,*et al.*, 2017) (McDermott-Wells, *et al.*, 2005) (Sairam, *et al.*, 2002). To gratify constraints of contemporary IoT, Bluetooth SIG disseminated the Bluetooth 5 specifications recently with 2 Mbps PHY through put, low-power ingesting, prompt data transfers for over-the-air (OTA) firmware upgrades and receptivity progression for medical expedients and security practices (Henrik,*et al.*, 2018). The size constrictions, coalesced with larger bandwidth and higher efficiency conscriptions, perceive the antenna configuration an exigent pursuit. Microstrip Antennas are plausibly effortless to assemble due to its planar-archetype simplicity, lightness in weight and volume with milli meter circuits integration proficiency (Jayasinghe, *et al.*, 2012) such as Planar Inverted-F Antenna (PIFA), transmission lines, microstrip coupled filters, resonators, microwave bridges and waveguides are designed with microstrip circuits (Chinig and Bennis, 2017).Several antenna design techniques such as 2-D transmission-line metamaterial (TL-MTM) exhibition entailing two-turns Complementary Spiral Resonators (CSRs) with mushroom symmetry at 2.4 GHz Bluetooth and 3.5 GHz WiMAX with good impedance feed matches using two-annular-rings slot and corresponding radiation gains of 2.45 and 7.65 dB has been investigated (Chinigand Bennis, 2017). The Multiband MPA Antenna with proximity-coupled feed exhibits LTE4, Bluetooth, WiMAX, Wireless LAN, UMTS demeanor in chorus (Bakariya, *et al.*, 2015) with corner-truncated rectangular patch, meandered microstrip feed and defected ground plane has been explored. Analogously, double-negative metamaterial loaded antenna for cellular compact multi-frequency scheme succeeded 66.47% and 66.52% of 10g Specific Absorption Rate (SAR) reduction (Alam, *et al.*, 2015) at 1.8 and 2.4 GHz respectively to shield human bodies from hazardous electromagnetic provokes. Among various scenarios to impede packet loss in a suburban surroundings centered on the Bluetooth Low Energy (BLE) standard, two orthogonally polarised antennas (Evgeny, *et al.*, 2015) at the receiver enriched energy efficiency by 10% fall off of Packet Error Rate (PER). A multifarious diversity bouquet of Bluetooth, WLAN and WiMAX antenna incorporating Log-Periodic Dipole Array (LPDA) with subsectional tapered feedline (Bozdag and Kustepeli, 2016), multi-band grounded coplanar waveguide fed printed planar monopole antenna (GCPW-PPMA) (Bozdag and Kustepeli, 2017), multi-band coplanar waveguide (CPW) fed MIMO antenna (Irem, *et al.*, 2016) has been fostered recently. In this paper, optimized antenna parameters of patch, strip and substrate has been executed for bandwidth efficient bluetooth systems with feed matching erection, substrate thickness and probing directional radiations with effective dimensional appraisal.

[++]Corresponding Author Email: thesateeshkumar@gmail.com;

[*]Department of Electronic Engineering, Islamia University Bahawalpur, Pakistan.

2. ANTENNA RAMIFICATIONS AND DESIGN ALLUSIONS

Antenna design technologies for impending communiqués entails high gain, high-efficiency Antenna-MMIC alliance to empower massive data propagation in lieu of cellular systems and beam-scanning antennas heading for satellite communications. The development survey of the microstrip antennas concerning bandwidth enrichment techniques as photonic bandgap (PBG) substrates, parasitic coupling, active integrated antennas, dual-frequency circularly polarized and loaded microstrip structures has been fathomed (Ramesh 2001). This paper grasps rectangular patch antenna design with FR4 dielectric substrate of permittivity $\varepsilon_r = 4.4$, loss tangent δ of 0.02 and substrate thickness of 6.7 mm. Several stabs were instigated to accumulate the divergent weights of patch antenna such as antenna dimensions, VSWR, return loss with bolstering outcomes. The simulated antenna has revealed expansion in band width with 60 MHz frequencies contrasting to fork shaped antenna with 36 MHz bandwidth from 2.439 GHz to 2.475 GHz band (Mishra, *et al.*, 2014)across VSWR and return loss chase recommended spans. Pondering the antenna compactness of Bluetooth technology, length and width are squeezed to 33.95% and 47.63% of antenna size with 80*80 mm^2 optimal dimensions respectively (Govardhani, *et al*., 2011).

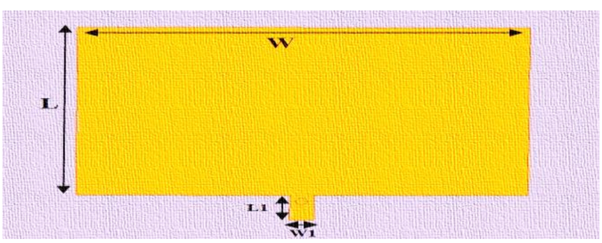

Fig.1. Metamorphosis of rectangular MPA across dimensional sprawling (LxW) with front elevation.

The substrate genus with transfiguration in current design mechanics are exercised to condense the antenna mass and multiplication of the bandwidth correspondingly. Various bluetooth antenna designs are surged such as diversity measurements of slot loaded CPW-fed printed monopole antenna with isolation more than 15 dB, envelope correlation coefficient ρ_e lesser than 0.02 and apparent diversity gain G_{app} superior than 9.9 dB are endorsed recently(Irem, *et al.*, 2016). In the context to billet the electrical field, coaxial feed has been positioned at axis (x,y,z)= (0,-14,0) from the center owing to exuberant electric field distribution, upshots in swelling of gain, directivity and bandwidth of the antenna. **(Fig. 1 and 2)** epitomizes the antenna geometrical vista and design specifications are itemized in **(Table 1).**

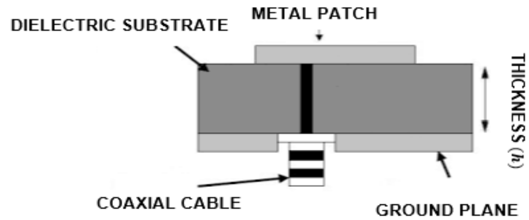

Fig.2. Side view of rectangular MPA fringing patch and co-axial feed with FR4 substrate.

Table 1.Patch Antenna Venture Stipulations

#	RUDIMENTS	PREROGATIVES
1.	PATCH LENGTH (L)	27.16 mm
2.	PATCH WIDTH (W)	38.10 mm
3.	STRIP LENTH (L1)	2 mm
4.	STRIP WIDTH (W1)	4 mm
5.	SUBSTRATETHICNESS (H)	6.7mm
6.	SUBSTRATE LENGTH	68mm
7.	SUBSTRATE WIDTH	78.3mm

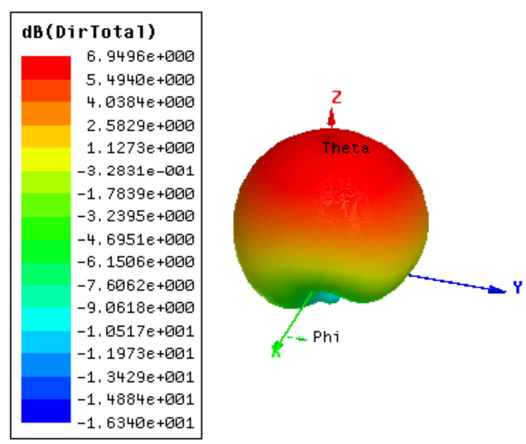

Fig.3.Unswerving directivity alludes antenna dexterity pro-data allocation suit over squatter ranges.

3. MODELING IMPRESSIONS AND DISSERTATION

The dimensions are remedied with the entailed feat involving VSWR, return loss and band width. Congruently, VSWR ≤ 2 enunciates the band width through which feed matching depicts antenna fidelity whilst return loss directs the power forfeiture of the reflected wave of antenna. Sequentially, reflection coefficient (Γ) interprets the transmitted signal dwindling due to transmission line discontinuities amidst impedance disparities with estimation as :

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S} \quad (1)$$

While Z_L suggests impedance to wards load and Z_S denotes impedance contiguous to the source. Successively, $VSWR$ and Return loss (RL) can be weighed by benefiting (2) and (3) respectively,

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \qquad (2)$$

$$RL = 20log|\Gamma| \qquad (3)$$

Consecutively, microstrip ground dimensions can be assessed as:

$$L_g = 6h + L \qquad (4)$$

$$W_g = 6h + W \qquad (5)$$

Where L and W are the length and the width of the patch respectively estimated through substrate thickness (h), dielectric constant (ε_r) and operating frequency (f_o). The antenna directivity has been assessed as 6.9496 dB at 2.4 GHz as indicated in **(Fig. 3)**. The procured directivity ensures data outfit dispersal in the protruded direction to capture short range Bluetooth signaling efficiency.

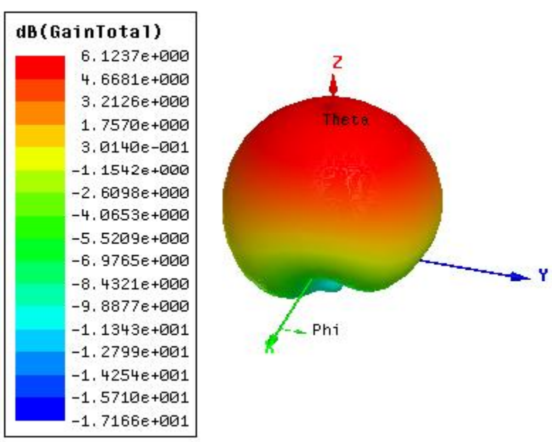

Fig.4.Eloquent gain of 6.1237 dB owing to the patch protruded around substrate thickness and ground-tuning at 2.4GHz resonance.

The locus alteration of the coaxial feed instigates gain declining as succumbed by electric field distribution. However, patch bulging with substrate thickness and ground fine-tuning, enthused gain has been perceived at the expense of undesirable side lobe level (SLL) radiations. **(Fig. 4)** elucidates polar plot of solid meditation of antenna beam with 6.1237 dB gain in solitary direction at operational frequency of 2.4 GHz. **(Fig. 5)** scans the pragmatic gain from 6.10841 dB to 6.12534 dB bordering the bluetooth bandwidth span progression.

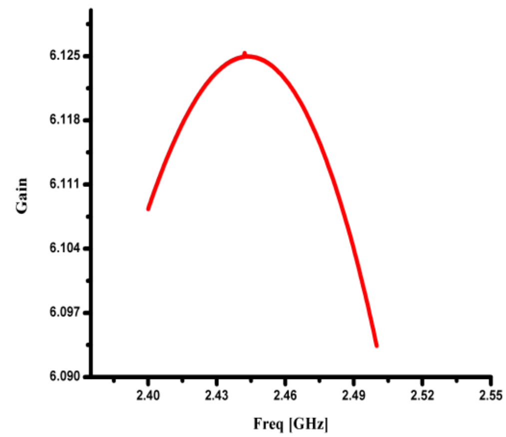

Fig.5. Antenna beam gain squinting from 2.402GHz to 2.485GHz adjoining the bluetooth bandwidth sequel.

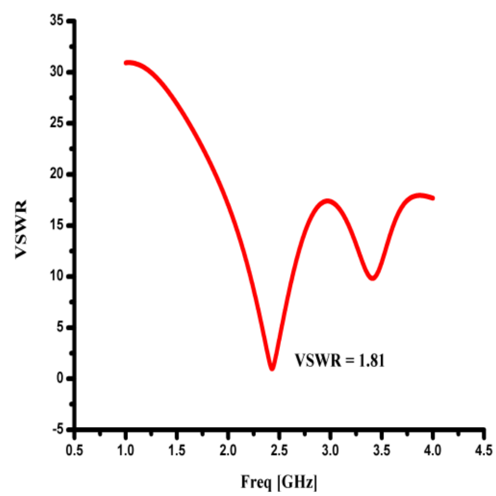

Fig.6.VSWR ≤ 2 mollifies Impedance conflicts to intercede antenna fidelity.

The physique enrichment of the patch and substrate upsurges VSWR in consort with mismatch losses. Analogously, proximity-coupled microstrip antenna gain parades steady manifestation across the constrained wireless bands (Bakariya, *et al.*, 2015), though slender mismatch above5 GHz has been digested to the small returning ground current flaunted on the exterior of the SMA feeding (Bakariya, *et al.*, 2015).

On ground plane, heightening the copper thickness equanimities VSWR of 1.81 at the 2.4GHz frequency as revealed in **(Fig. 6)**, allocating good matching muscles of antenna. During the sequence of the inception numerical scrutiny, subsectional tapered fed (SsTF) PLPDA antenna 2< VSWR< 2.28 in the narrow band between 9.1 and 9.4 GHz deteriorates for UWB and X-band; ascertains recuperation of bandwidth with SsTFwP amid feeding point patch between 1.1 and 13.8 GHz (12.5:1) with VSWR<2 at targeted bands (Bozdag and Kustepeli, 2016). Similarly, bidding the first iteration stage of proposed structure, broadening of patch mass and substrate thickness upswings the return loss, though multiplying the ground depth exhibits -19.7 dB return loss legitimacy at beloved 2.4 GHz frequency as confessed in **(Fig. 7)** by affirming the antenna meticulousness with bluetooth applicability.

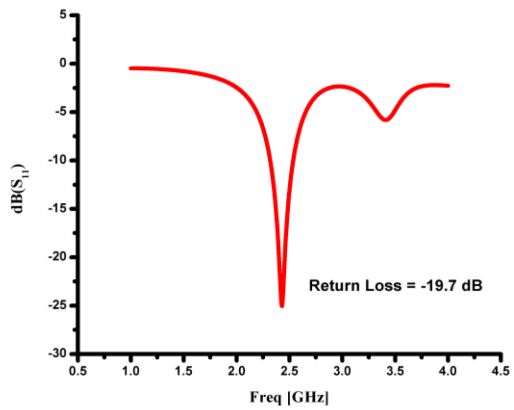

Fig.7.Simulated Return Loss $|S_{11}|$ with ground depth multiplication excavated for ISM band engrossing.

(Fig. 8) exhibits the electric field distribution of the antenna at 2.4 GHz with fringing effects of substrate and patch for contrived antenna modelling. With the elaboration of millimeter design practices (Lee and Tong, 2012) modes of broadbanding, dualistic and multiband goals, size-compression schemes and circular polarizations, electric and magnetic excitations of a microstrip antennas to grip the beloved radiation pattern by maneuvering the main beam posture and the sidelobes levels are the strategic physiognomies of Microstrip Patch Antenna Modelling.

4. CONCLUSION

The microstrip patch antenna has been successfully modeled at 2.4GHz with VSWR≤2 within ISM band stipulating courteous matching, return loss of -19.7dB, 6.9496 dB directivity with gain stability, overall ISM bandwidth 60MHz. The optimization of antenna has been grasped with swarm of parameters as positional stance of coaxial feeding,patch facet acclimatization, substrate thickness and deployment of FR4 with permittivity of 4.4.3D antenna modelling recommends the edifice competence for the bluetooth applicability lying with bidirectional swaping of tidings.

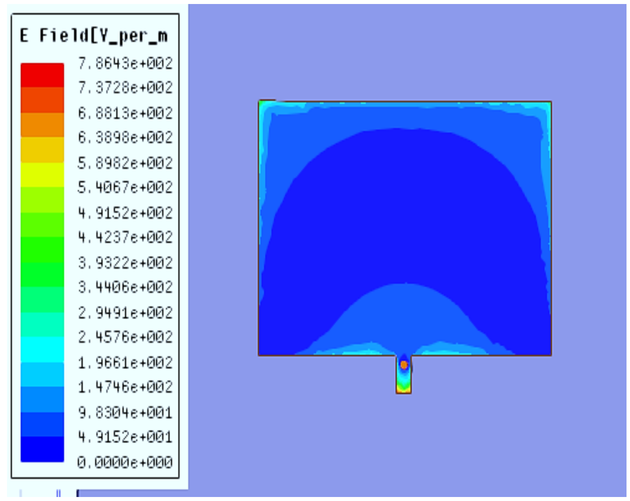

Fig. 8. Adjudicating to lodge the electrical field distribution ensuing esteemed beam, coaxial feed locates at axis (x,y,z) = (0,-14,0) instigating the optimize parameters of gain, directivity and bandwidth of the antenna.

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