CPW-Fed Quad-Band Antenna for Compact Wireless Application

Sujith R, Deepu V, Laila D, S Mridula and P. Mohanan.
Centre for Research in Electro Magnetics and Antennas (CREMA)
Department of Electronics
Cochin University of Science And Technology, Cochin, Kerala, India.
e-mail: drmohan@gmail.com

Abstract- **This paper presents the design and development of a compact CPW fed quad band antenna. This low profile antenna has a dimension of 32mmx31mm when printed on a substrate of dielectric constant 4.4 and height 1.6mm. The antenna covers GSM 900, DCS 1800, IEEE802.11.a, IEEE802.11.b and HiperLAN2 bands. The antenna exhibits good radiation characteristics with moderate gain.**

I. Introduction

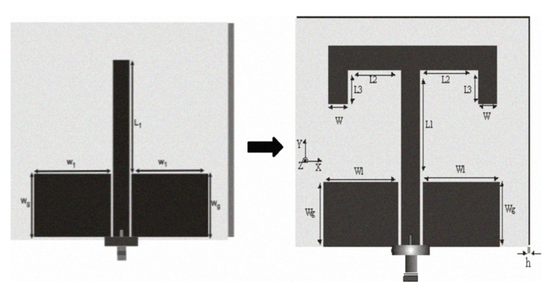
The introduction of a large number of wireless communication channels has intensified the need for multiband antenna. Planar antennas, especially coplanar waveguide fed antennas have received great attention in recent years due to ease of integration, low cost, wide bandwidth, flexibility towards multiband operation, low radiation leakage and less dispersion.

Researches have been carried out on monopole antennas for achieving dual band operations [1]. The dual frequency monopole antenna presented in [2] uses a coplanar waveguide feed while the one proposed in [3] uses a microstrip feed to excite two operating modes associated with various resonating lengths of monopoles. The low profile dual frequency planar antenna presented in [4] uses S-strip and T-strip on either sides of substrate forming double strip monopole to provide the required bandwidth. Triple band slotted monopole antenna in [5] uses CPW feeding structure comprising of rectangular and inverted L-shaped grounds. The required bands are achieved by embedding different shapes of slots into the patch. The quad-band Planar Inverted F Antenna (PIFA) with foam substrate [6] uses three U-shaped slots of different dimension for achieving three bands in addition to the one due to the fundamental rectangular PIFA. However, all of the above cited antennas are either complex or have large dimensions.

The requirement of frequency bands corresponding to system applications such as IEEE 802.11.a, IEEE 802.11.b along with GSM and DCS, arouses the urge for multiband especially Quad-band antenna with same polarization. The CPW-Fed Quad-band antenna proposed in this paper is suitable for applications corresponding to GSM-900 (870-960MHz), DCS-1800 (1710-1880MHz), IEEE802.11.b (2400-2484MHz), IEEE802.11.a (5150-5350MHz) and HiperLAN2 (5470-5725MHz) bands. An appreciable size reduction of 60% compared to a normal CPW–Fed monopole is achieved.

II. Antenna Design

Evolution of the quad band antenna is demonstrated in Fig 1. The basic monopole structure (antenna 1) shown in Fig.1(a) resonates at 3.6GHz when the length L_1 is equal to its quarter wavelength ($L_1 = \lambda_g/4$, λ_g is the wavelength in the substrate). Top loading this monopole as in Fig.1 (b) results in a T-shaped monopole (antenna 2), resonating in two bands centered at 1.77GHz and 5.54GHz. The first resonance occurs when $L_1+L_2+L_3$ is nearly equal to $\lambda_g/4$ and second resonance occurs when L_1 is nearly equal to $\lambda_g/2$. It is found that addition of strip L_3 parallel to L_1 will add a capacitance to the input impedance. The quarter wavelength resonance corresponding to length L_1 is suppressed due to this large capacitive impedance.



(a) (b)

Fig. 1 (a) Monopole (b) Modified T-shaped structure

(L_1=18mm, L_2=11.5mm, L_3=7mm, W=3mm, W_l=14mm, W_g=10mm, h=1.6mm, ε_r=4.4)

The return loss characteristics of antenna 1 and antenna 2 are shown in Fig.2. Any of the symmetrical length (L_3) of antenna 2 can be adjusted by the addition of stub L_4, resulting in antenna 3, to create an additional resonance at 2.4GHz, as shown in Fig.3. However, the antenna is poorly matched at this frequency because of the high inductive reactance created by the addition of stub (L_4). The three resonances at 1.61GHz (due to L_1+L_2+L_3+L_4), 2.4GHz (due to L_1+L_2+L_3) and 5.8GHz (due to L_1) are due to various current paths in antenna 3. The antenna is compact with an overall dimension of 32x31x1.6mm^3.

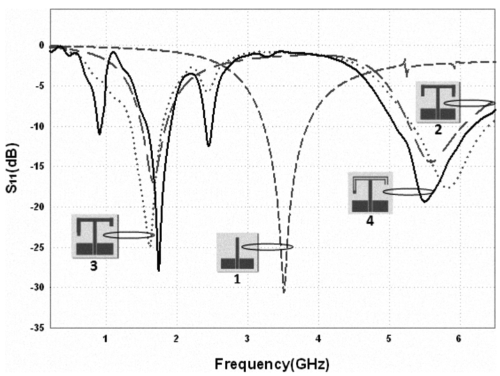


Fig. 2. Return Loss Characteristics

To develop a quad-band antenna (antenna 4), an additional resonant length is introduced without affecting the antenna performance and compactness. This is achieved by introducing a slot *abcdefgh***,** thereby forcing the current to flow around the slot through a longer path and produce an additional lower resonance (Fig 3). This also provides matching for the resonance at 2.44GHz by compensating for the inductive reactance of antenna 3. The geometry of the evolved quad band antenna is shown in Fig.3 and its return loss characteristics is shown in Fig.2.

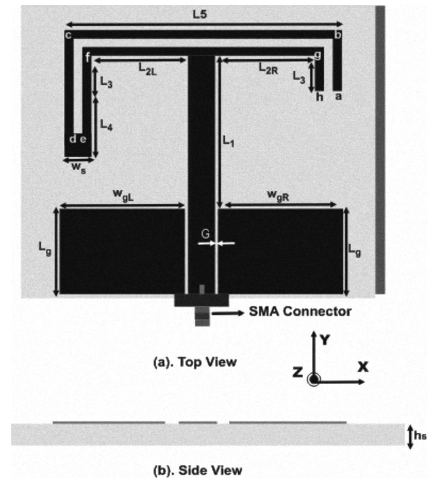


Fig.3. Geometry of the proposed Quad band antenna (L_1=18mm, L_{2R}= L_{2L}= 11mm, L_3=4mm, L_4=8mm, L_5=31mm, W_{gR}=14mm, W_{gL}=14mm, L_g=10mm, W_s=3mm, cd=10mm, bc=29mm, de=ha=1mm, h_S=1.6mm and G=0.35mm)

The prototype is fabricated on a substrate of dielectric constant (ε_r) 4.4 and thickness (h_s) 1.6mm. The strip width (w) and gap (G) of the Coplanar Waveguide (CPW) feed are derived using standard design equations for 50Ω input impedance [7]. The antenna offers a 2.5:1 VSWR bandwidth from 840MHz-970MHz, 1.46GHz-1.95GHz, 2.36GHz-2.52GHz and 4.9GHz-6.4GHz covering GSM-900, DCS-1800, ISM-2.4/5.2/5.8 WLAN and HiperLAN2 bands.

III. RESULTS AND DISCUSSION

The return loss variation in the antenna with slot length *abcdefgh*, by varying the length cd is shown in Fig.4. By increasing the slot length the lower resonance at 900MHz can be shifted to a lower frequency as expected. The lower resonance occurs when the slot perimeter is nearly $0.4\lambda_g$.

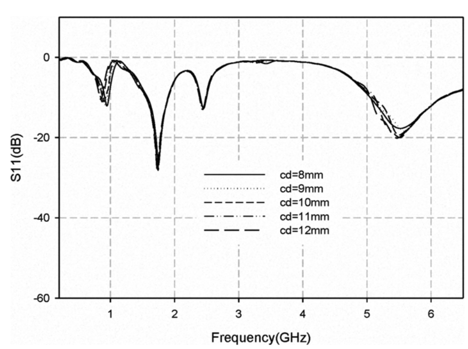


Fig. 4. Variation with Slot length cd (L_1=18mm, L_{2R}= L_{2L}= 11mm, L_3=4mm, L_4=8mm, L_5=31mm, W_{gR}=14mm, W_{gL}=14mm, L_g=10mm, W_s=3mm, bc=29mm, de=ha=1mm, h_s=1.6mm and G=0.35mm)

The variation of return loss characteristics with strip length L_3+L_4 is shown in Fig.5. By increasing the length of the strip the resonant frequency decreases. It is found that the second resonance is mainly due to the total length (L_1+L_2+L_3+L_4) which is nearly equal to $0.35\lambda_g$.

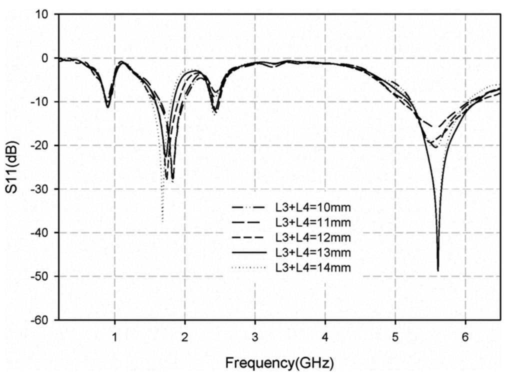


Fig. 5. Variation with Strip length L_3+L_4 (L_1=18mm, L_{2R}= L_{2L}= 11mm, L_3=4mm, L_5=31mm, W_{gR}=14mm, W_{gL}=14mm, L_g=10mm, W_s=3mm, cd=10mm, bc=29mm, de=ha=1mm, h_s=1.6mm and G=0.35mm)

The strip length L_3 mainly affects the third resonance centered at 2.44GHz. The parallel capacitance with L_1 varies as L_3 changes, and hence the fourth resonance is also affected slightly owing to its coupling with the strip L_1. The return loss variation of the antenna with the strip length L_3 is shown in Fig.6. The optimized length (L_1+L_{2R}+L_3) is $0.40\lambda_g$ corresponding to the third resonance at 2.44GHz.

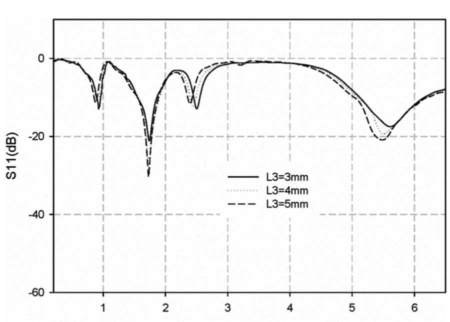


Fig. 6. Variation with strip length L_3 (L_1=18mm, L_{2R}= L_{2L}= 11mm, L_3+L_4=12mm, L_5=31mm, W_{gR}=14mm, W_{gL}=14mm, L_g=10mm, W_s=3mm, cd=10mm, bc=29mm, de=ha=1mm, h_s =1.6mm and G=0.35mm)

The variation of the return loss characteristics of the antenna with strip length L_1 is shown in Fig.7. The fourth resonance which is contributed by the length L_1 is affected severely. The optimized length (L_1) corresponding to the resonant frequency centered at 5.54GHz is found to be $0.49\lambda_g$.

In the performance of compact antennas the effect of the ground plane is also very crucial. Considering the compactness the ground length and width are optimized as $0.061\lambda_g$ and $0.044\lambda_g$ corresponding to the lower resonant frequency. Since the Y-component dominates the X-component in all the operating band, the antenna is polarized along the Y direction. Good polarization purity is exhibited in the first and fourth band and moderately on the second and third band.

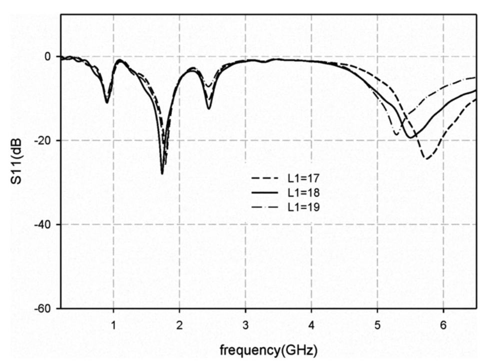


Fig. 7. Variation with strip length L_1 (L_{2R}= L_{2L}= 11mm, L_3+L_4=12mm, L_5=31mm, W_{gR}=14mm, W_{gL}=14mm, L_g=10mm, W_s=3mm, cd=10mm, bc=29mm, de=ha=1mm, h_s =1.6mm and G=0.35mm)

Typical radiation patterns of the antenna in the four different bands are shown in Fig.8. Antenna is showing good radiation characteristics in the entire band. The average gains of the antenna in the four bands are 3.6dBi, 1.94dBi, 1.11dBi and 3.71dBi respectively.

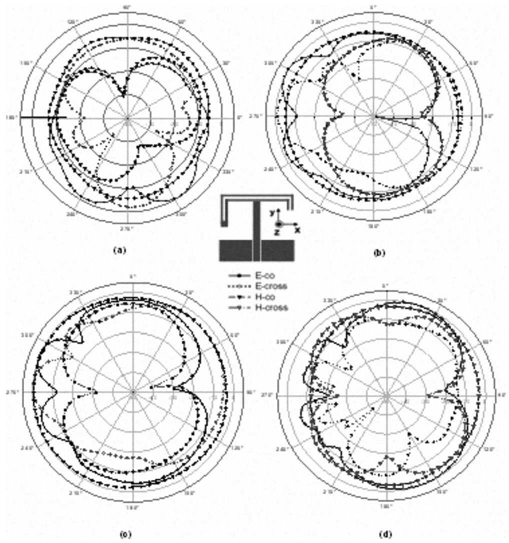


Fig.8. Radiation Pattern at a)900MHz b)1.74GHz c)2.44GHz and d)5.5GHz

IV. CONCLUSION

A compact quad band printed antenna having dimension 32x31x1.6mm^3 is presented. This uniplanar antenna resonates at four bands and is suitable for GSM,DCS,IEEE 802.11.a, IEEE 802.11.b and HiperLAN-2 bands. The presented quad band antenna has good radiation characteristics with a gain of 3.6dBi, 1.94dBi, 1.11dBi and 3.71dBi in the respective bands.

ACKNOWLEDGEMENT

The authors acknowledge Department of Science and Technology (DST), Defence Research and Development Organisation (DRDO) for financial assistance.

REFERENCES

[1] Chien-Jen Wang, Jin-Jei Lee, Rey-Bin Huang, "Experimental Studies of a Miniaturized CPW-Fed Slot Antenna With the Dual-Frequency Operation," IEEE Antennas wireless Propagat. Lett., vol. 2, pp.151-154, 2003.

[2] Horng-Dean Chen, Hong-Twu Chen, "A CPW-Fed Dual-Frequency Monopole Antenna," IEEE Trans. Antennas Propag., vol. 52, no. 4, pp. 978-982, 2004.

[3] R.K. Raj, M. Joseph, B. Paul, P.Mohanan, "Compact planar multiband antenna for GPS,DCS,2.4/5.8 GHz WLAN application," Electron. Lett., vol. 41, no. 6, pp. 290-291, 2005.

[4] RongLin Li, Bo Pan, Joy Laskar, Manos M. Tentzeris "A Novel Low-Profile Broadband Dual-Frequency Planar Antenna for Wireless Handsets," IEEE Trans. Antennas Propag., vol. 56, No. 4, pp. 1155-1162, 2008.

[5] W.C. Liu, H.J.Liu, "Compact triple-band slotted monopole antenna with asymmetrical CPW grounds," Electron. Lett., vol. 42, no. 15, pp. 840-842, 2006.

[6] Dalia Mohammed Nashaat, Hala A. Elsadek, Hani Ghali "Single Feed Compact Quad-Band PIFA Antenna for Wireless Communication Applications," IEEE Trans. Antennas Propag., vol.53,no.8, pp.2631-2635, 2005.

[7] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*. Norwood, MA: Artech House, 2001