Semicircular Multiband ACS Feed Antenna for IoT

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Abstract— **In this communication, design and analysis of a semicircular multiband asymmetrical coplanar strip (ACS) feed antenna operating over the frequency range of GSM 1800, Bluetooth (2.4-2.484 GHz)/Wi-Fi (2.4 GHz) for IoT (Internet of Things) has been investigated. The proposed antenna consists of two semicircular arcs which provide services in the GSM 1800, Bluetooth and Wi-Fi in ISM frequency band facilitating the multiband behavior. The antenna is fabricated on a low cost FR4 substrate of thickness 1mm and has the most compact dimension of 24 × 10 mm^2. The fabricated prototype yields a measured impedance bandwidth of 1.725 - 1.9115 GHz, 2.25 – 2.6555 GHz covering operating frequencies of GSM, Bluetooth and Wi-Fi frequency bands respectively. Good electrical characteristics in frequency domain makes the antenna suitable for IoT application deployment.**

Keywords—Multiband antenna, GSM 1800, Bluetooth, Asymmetrical Coplanar Strip

I. INTRODUCTION

Internet of Things(IoT), a network that interlinks objects which can exchange and access data using network connectivity has been extensively promoted over last few years. The interconnectivity between objects such as Television sets, air conditioners, digital lockers, automotive such as car, etc. provides direct integration of physical world into computer based systems thereby providing improved efficiency and economic benefits. Interconnectivity between different objects will provide interaction and exchange data with each other through wireless network connectivity using wireless network adapters. The wireless network interconnectivity across different technology platforms such as Bluetooth IEEE 802.11 b/g (2.4–2.484GHz), 3.5GHz WiMAX IEEE 802.16 (3.4–3.6GHz), 5.2/5.8GHz WLAN IEEE 802.11 a (5.15–5.35GHz and 5.725–5.825GHz) and 5.5GHz HIPERLAN2 (5.47–5.725GHz) can be achieved by integrating these technologies on a common SoC using network adapters. These wireless network adapters will be embedded with antennas and System on Chip (SoC) for wireless data exchange. Integrating several such technologies will require deploying multiple antennas to provide operation across these platforms. Multiple antennas, independent for each of these technologies will accumulate more space as well as increase the power requirement of the SoC. Antennas explicitly required to be deployed for IoT applications must meet specifications such as light weight, compact structure, low profile, robustness and conformability and are expected to grab as much spectrum as possible to provide multiband or broadband operation. Multiband antennas provide multiband or broadband operation will eliminate the requirement of additional space as well as increased power consumption [1-4].

TABLE I. COMPARATIVE STUDY OF THE EXISTING ACS FEED MULTIBAND ANTENNA WITH PROPOSED WORK

Ref. No.	Antenna size (mm^2)	Operating frequency band	Antenna type
[11]	37.5 × 24	2.4 GHz	Single band
[12]	28 × 30	2.4/ 3.5/ 5.5 GHz	Tri band
[13]	21 × 19	2.4 / 5.2 GHz	Dual band
[14]	10 × 24	2.4/3.5/5.5 GHz	Tri band
[15]	18 × 22	2.4/ 3.5/ 5.5 GHz	Tri band
[16]	17 × 17.5	3.5/ 5.5 GHz	Dual band
Proposed Work	10 × 24	1.8/2.4GHz	Dual band

The design of several multiband antennas with microstrip feedline have been reported in [5–10]. However, integrating microstrip feedline antenna with existing SoC technology is perplexing as the feedline and ground plane lie on two separate planes. An alternative approach consists of using coplanar waveguide (CPW) feed have been elaborated in [6–9]. Design of Asymmetrical Coplanar Strip (ACS) antenna, a modified CPW feed that provide approximately 50% size reduction have been explored in [11–14]. Table 1 shows the comparison of existing ACS feed multiband antenna with proposed work. In this communication, a very compact multiband antenna operating over the GSM 1800MHz and Bluetooth and Wi-Fi in the ISM frequency band is presented. The multiband frequency operation of the proposed antenna makes it suitable for IoT device communication.

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II. ANTENNA DESIGN

A. *Geometrical Configuration of the proposed antenna*

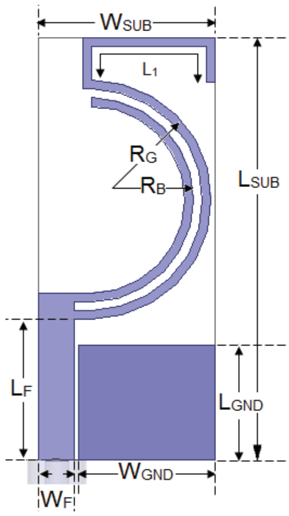

Fig.1 Geometrical configuration of the proposed antenna

Fig.2 Evolution of dual band ACS feed antenna (a) Single band antenna operating at 1.8GHz (b) Dual band antenna operating at 1.8GHz /2.4 GHz

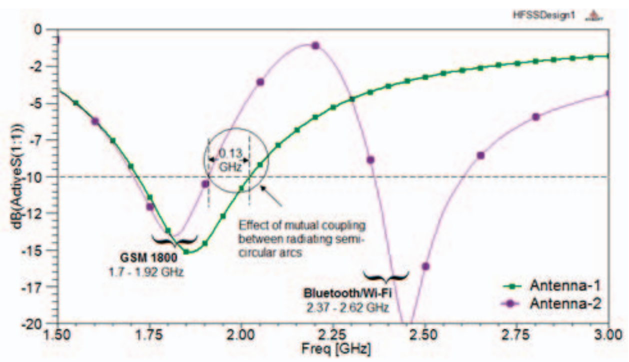

Fig.3 Simulated return loss at various stages of evolution

The geometrical configuration of the proposed dual band GSM 1800MHz and Bluetooth /Wi-Fi antenna is as shown in Fig.1. The antenna is designed and analyzed using CEM software Ansys HFSS. The antenna exhibits a very compact substrate dimension of 0.144 × 0.06λ with respect to fundamental frequency of 1.8 GHz and is printed on a single-sided low-cost FR-4 substrate having thickness of 1mm with dielectric constant of 4.4, loss tangent of 0.02. The antenna is designed and analyzed in two stages as shown in Fig.2. Antenna -1 is optimized to operate over the GSM 1800MHz frequency band (1.7-2.02GHz) which comprises of a '5' shaped radiating monopole connected to a 50Ω feedline. The length of the radiating monopole is calculated using (1), as follows:

$$\pi R_G + L_1 = C0/(f_G * \mathrm{sqrt}(\varepsilon_{reff})) = L_G \qquad (1)$$

$$\varepsilon_{reff} = (\varepsilon_r + 1)/2 \qquad (2)$$

Where C_0 stands for velocity of light in free space, ε_{reff} is the effective relative permittivity of the substrate and f_G = GSM resonance frequency. Theoretically, L_G = 25.04mm while practical optimized value of L_G = 29mm.

Further, the Bluetooth/Wi-Fi (Antenna-2) operation in the ISM frequency band is achieved by integrating a semi-circular radiating monopole in the vicinity of the 5-shaped monopole as shown in Fig.2. The length of the radiating monopole is calculated following [14],

$$C_B = \pi R_B \qquad (3)$$

Where $C_B = C_0/(4fB * \mathrm{sqrt}(\varepsilon_{reff}))$, ε_{reff} follows (2) and f_B = Bluetooth resonance frequency. Practically, optimized value of C_B is 18.22mm, which follows the theoretical bound of C_B = 18.70mm

B. *Frequency domain specifications*

Fig.3 shows the simulated return loss of proposed antenna at various stages of evolution. As observed in Fig.3, integrating the new monopole in the vicinity of the 5-shaped monopole has significantly reduced the bandwidth of GSM band due to mutual coupling. However, the proposed antenna still provides the GSM 1800MHz frequency operation.

Furthermore, to validate the fore mentioned equations, parametric study of the antenna is carried out by changing the length of the radiating monopoles as shown in Fig.4 and Fig.5 respectively. As observed in Fig.4, when the L_G is increased, the resonance frequency f_G decreases which validates the inverse proportionality of L_G and f_G in (1). Similarly, increasing the radius R_B decreases the resonance frequency f_B, thus validates the results given by (3). The optimized dimension of the proposed antenna is:

W_{SUB} = 10mm, L_{SUB} = 24mm, W_{GND}= 7.75mm, L_{GND}=6.5mm, W_F = 2mm, L_F= 8mm, R_B=5.8mm, R_G= 6.8mm.

III. RESULTS AND DISCUSSION

Furthermore, to get more physical insights of the dual band operational antenna, the surface current distribution is observed at sampling resonance frequencies of 1.8 GHz and 2.4GHz.

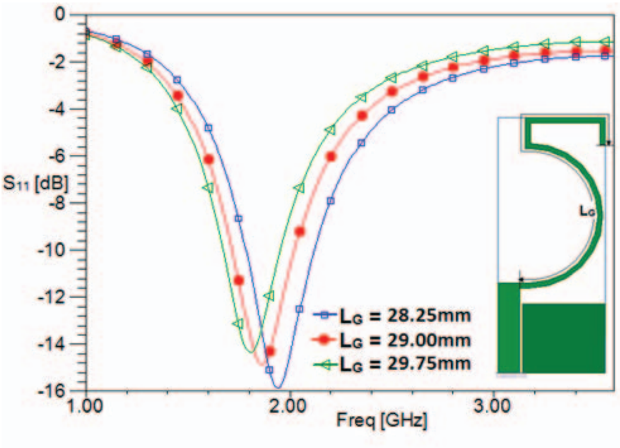

Fig.4 Simulated return loss for varied L_G

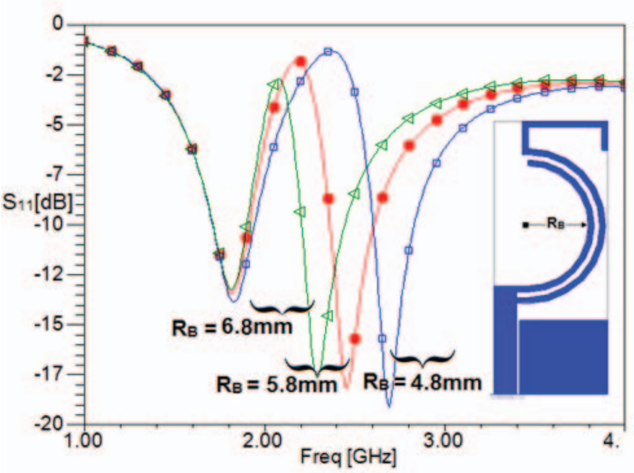

Fig.5 Simulated return loss for varied R_B

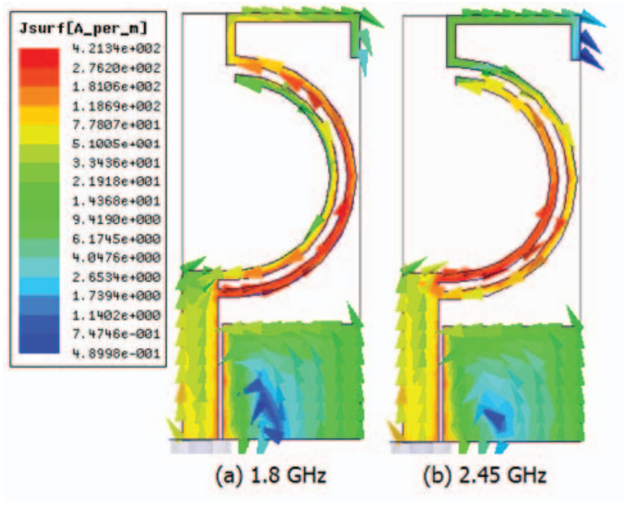

Fig.6 Surface current distribution of the dual band ACS feed antenna

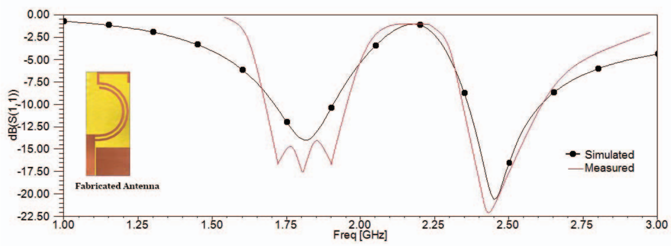

Fig. 7. Simulated and measured return loss characteristics of the proposed ACS feed multiband antenna (With Fabricated prototype in inset)

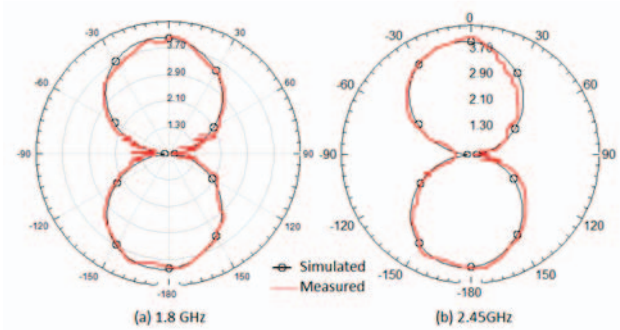

Fig. 8. Simulated and measured radiation pattern along E plane at sampling frequencies of 1.8 GHz and 2.45 GHz respectively

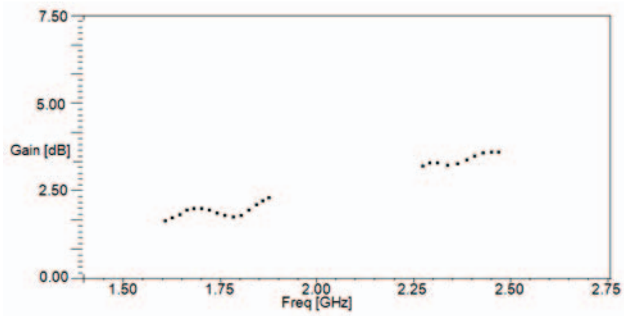

Fig. 9. Measured gain of the proposed dual band ACS feed multiband antenna

As observed in Fig.6 (a), at the resonance frequency of 1.85GHz, maximum current is concentrated along the 5-shaped radiating monopole which indicates the first resonance frequency at 1.8 GHz, while in Fig.6 (b), current is localized in the semi-circular radiating arc which facilitates the second resonance at 2.4GHz. The return loss characteristics are measured in-house by using Agilent Field-Fox Vector Network Analyzer (VNA: N9916A) in an open area test site. The measured -10dB impedance bandwidths are: 1.725 - 1.9115 GHz, 2.25 – 2.6555 GHz covering operating frequencies of GSM, Bluetooth and Wi-Fi frequency bands. A very small discrepancy is observed in simulated and measured return loss which arouses due to def ciency in fabrication process of the prototype, uncertainty of thickness and/or the dielectric constant ε_r of the FR-4 substrate, quality of SMA connectors and losses incurred by cables connecting the prototype and VNA can be observed in Fig.7 [14]. Fabricated antenna prototype along with simulated and measured return loss characteristics are shown in Fig. 7.

The simulated and measured far field radiation pattern of the proposed dual band ACS feed antenna along E-plane at sampling frequencies of 1.8GHz and 2.45GHz is shown in

Fig.8. The simulated and measured radiation pattern shows stable dumbbell shaped structure, which makes the antenna a suitable candidate for wireless communication application. Absence of side lobes in radiation pattern shows that there is no loss in radiation energy which makes the antenna more efficient, thus providing a theoretical efficiency of 94 %. The antenna provides a stable gain of about 2.5dB as shown in Fig.9. The radiation characteristics are measured in anechoic chamber using a standard double ridged horn antenna (used as reference antenna; Model No: 3115) and antenna measurement system (Turning table, 40GHz Anritsu RF Source Generator, 40GHz Anritsu Spectrum Analyzer, connecting cable, L-connectors and radiation pattern plotting software installed on a PC).

IV. Conclusion

A highly compact ACS feed dual band antenna has been proposed and investigated. The antenna consists of a '5' shaped radiating monopole operating over the GSM 1800MHz frequency band and a semicircular monopole that facilitates the Bluetooth/Wi-Fi operation in the 2.4 GHz ISM band. The proposed antenna exhibits nearly symmetrical dumbbell shaped radiation pattern along E plane, while stable gain of 2.5dB. The electrical characteristics in frequency and time domain makes the proposed antenna a suitable candidate for wireless adapters in IoT device communication.

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