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Tunable Monopole Circular Microstrip Antenna for GSM, GPS and FCC ID Applications With Wi-Fi Band Rejection

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Abstract: This paper presents a design and development of tunable monopole circular microstrip antenna for different microwave communication applications. A low cost modified glass epoxy material of substrate dimensions of 30x25x1.6 mm with dielectric constant of 4.2 is used to construct the antenna. The U-slot and J- slot is added over the patch to achieve notch band. This notch band can be tuned by adding simple stub on the right side of the patch in which J-slot is added. By changing the dimensions of J-slot, the antenna rejects Wi-Fi band of frequency range 2.40-2.48 GHz. This band can be tuned 2.4175 GHz to 1.7425 GHz towards lower frequency side by an amount of 675 MHz and having an impedance bandwidth of 23.97% with peak gain of 1.4526 dBi. It can also avoid interference between two other tunable operating bands, one at 1.8325 GHz (2.1909-1.4764 =0.714 GHz) and other at 2.6425 GHz (3.6796-2.4887=1.19 GHz). From these two tunable bands, first band covers an applications of GSM 1800/1900 MHz and GPS 1575 MHz) with peak gain of 3.07 dBi with an impedance bandwidth of 38.9% and the second band covers FCC ID applications. This FCC ID covers broad band radio service (BRS) and educational broad band service (EBS) in which the operation of unlicensed part 15 devices is permitted. The frequency range FCC ID 2.63 to 2.68 GHz lies in operating range of second band having the peak gain of 3.28 dBi with an impedance bandwidth of 45%. Thus, the proposed antenna shows wide bandwidth of 2.2 GHz (1.4934-3.6966 GHz) with impedance bandwidth of 83.3% can cover maximum number of applications except the Wi-Fi frequency range.

Keywords: FCC ID, GPS, GSM, J-slot, Notch Band, TMCMSABR, U-slot stub and Wi-Fi.

Introduction

In the literature it is found that, many researchers designed an antenna in UWB range for rejecting certain bands like WLAN/WiMAX etc., but in the lower frequency wireless communication there is less work for rejecting certain bands like Wi-Fi /GSM/GPS etc. However, in this context it is necessary to reject frequency band of 2.40-2.48 GHz because this band is designated 14 wireless networks channels by just spacing of 5 MHz apart. This Wi-Fi may have lot of interference among all channels and hence it is better to reject to avoid intra and adjacent channel interferences among them. In order to obtain notch band characteristics, there are numerous methods available. From past few years it is seen that, there are many methods for designing notch band antenna that is to add an electromagnetic perturbation in the surface current flowing in the radiating patch or by adding a slot of different geometry like U-slot or J-slot etc. on a patch which gives a notch band with tuning characteristics. Thus in the proposed antenna I have added a U-slot perpendicular to the patch and J-slot along the axis of patch inside the right stub. Here, the stub enclosing a J-type slot creates a single notch band at low frequency side and it can be used for tuning by changing its dimensions. Thus it shows better tunability in lower frequency wireless communications and thus it is resonating at 2.4175 GHz with band width of 579MHz (2.4887-2.1909 GHz) and covers a complete Wi-Fi band. This band can be tuned to lower side up to 1.7425 GHz by shifting to left by 675 MHz. This obtained notch band is in between two useful bands that is one at left side resonating at frequency of 1.8325 GHz and is shifted to lower side by 382.5 MHz of frequency 1.45 GHz. On the right side it resonates at 2.6425 GHz and shifts to lower side by 630 MHz of frequency 2.0125 GHz. Thus, the proposed antenna is useful for GSM 1800/1900 MHz, GPS 1575 MHz and FCC ID applications of frequency range 2.63-2.68 GHz. The peak gain obtained for GSM 1800/1900 MHz is 3.07 dBi , GPS 1562 MHz is 2.45 dBi and FCC ID frequency range (2.63-2.68 GHz) is 3.28 dBi. The radiation patterns are broad side and are linearly polarized in both E and H plane.

Description of Antenna Geometry

The conventional monopole circular microstrip antenna (CMCMSA) is designed using low cost modified glass epoxy of thickness h=1.6mm with relative permittivity $\varepsilon_r = 4.2$. The antenna is fed using microstripline feeding because of its simplicity and it can be simultaneously fabricated along with the antenna element. The radius of this antenna can calculated using equation (1) [1-2].

$$a = \frac{K}{[1+(2h/\pi\epsilon_r k)\{ln(\pi k/2h)+1.7726\}]^{-1/2}} \qquad \text{.....(1)}$$

where $k = \frac{8.794}{f \times \epsilon_r{}^{1/2}}$,

$$a_e = a\left\{1 + 2h/\pi \in_r a\left[ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2}$$

Figure 1 shows top view geometry of CMCMSA in which W_f, and L_f are width and length of microstrip feed line respectively.

Figure 2 shows return loss verses frequency of monopole CMCMSA and it resonates at 1.99 GHz.

Figure 3 shows top view geometry of tunable monopole circular microstrip antenna for WIFI band rejection (TMCMSABR) and this antenna is having the same basic design as that of conventional monopole CMSA as shown in Figure 1. The radius of the patch and dimensions of microstripline feed are remains same. The monopole CMSA has been modified into TMCMSABR by adding a U-slot perpendicular of patch and J-slot inside the outward stub on right side of the patch. The dimensions of the U-slot and stub remain same. The length of long arm of J-slots L_4 and L_5 remains same. Whereas the length of small arm of J-slot L_6 is varied from 0.2cm to 1.0cm to the proposed TMCMSABR [3-4]. The design parameters of proposed antenna are given in Table 1.

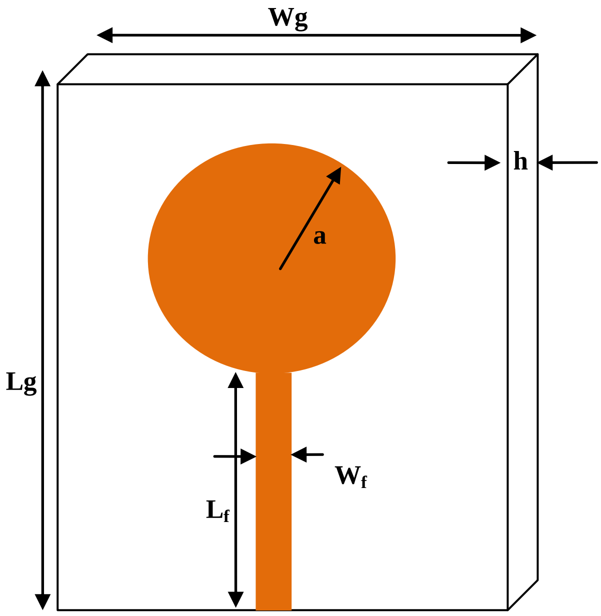

Figure 1. Geometry of CMCMSA

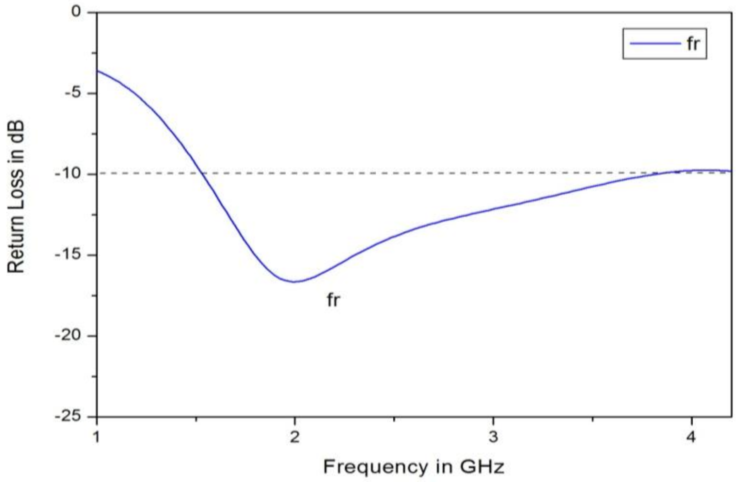

Figure 2. Variation of return loss verses frequency of CMCMSA

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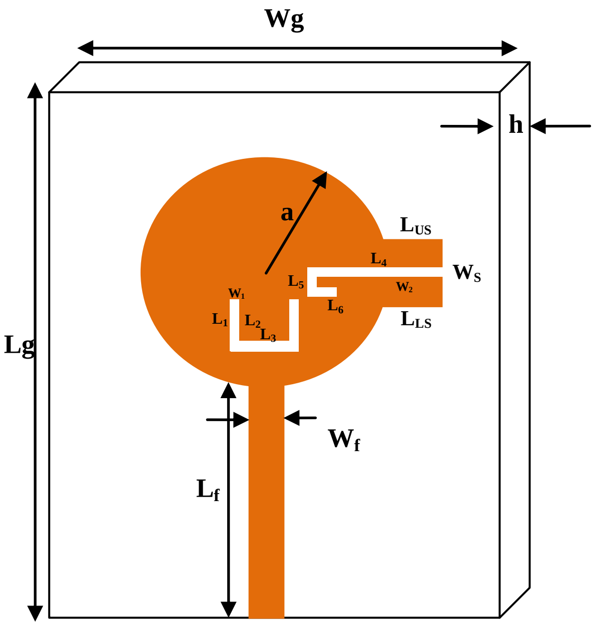

Figure 3. Geometry of TMCMSABR

Table 1. Design parameter of Tunable monopole circular microstrip antenna with Wi-Fi rejection

For constant stub width Ws=0.7cm and lengths of stub L_{US}=0.926cm and L_{LS} =0.857cm with fixed dimensions of U-slot that is L_1=0.8cm, L_2=0.7cm, L_3=0.6cm and W_1=0.1cm and for Constant length of J-slot L_4 =0.8 cm and L_5 1.7cm									
Variation of length of small arm of J-slot in cm.	Left band resonant frequencies in GHz	Return loss in dB	Impedance bandwidth in %	Notch band resonant frequencies in GHz	Return loss in dB	Impedance bandwidth in %	Right band resonant frequencies in GHz	Return loss in dB	Impedance bandwidth in %
L_6= 0.2	$f_{l1=}$1.8325	16.76	38.9	$f_{n1=}$2.4175	6.92	23.97	$f_{r1=}$2.6425	26.94	45.0
L_6 = 0.4	$f_{l2=}$1.6750	17.18	42.1	$f_{n2=}$2.26	7.90	12.0	$f_{r2=}$2.53	20.42	56.48
L_6= 0.6	$f_{l3=}$1.6075	16.96	43.9	$f_{n3=}$2.215	7.50	10.75	$f_{r3=}$2.395	29.22	41.19
L_6= 0.8	$f_{l4=}$1.6890	18.64	33.7	$f_{n4=}$2.08	7.90	8.18	$f_{r4=}$2.2675	22.87	68.59
L_6= 1.0	$f_{l5=}$1.45	20.67	29.8	$f_{n5=}$1.7425	8.78	5.84	$f_{r5=}$2.0125	16.89	84.72

Results and Discussion

Figure 4 shows the variation of return loss verses frequency of TMCMSABR**.** The antenna is constructed with variation of length of small arm of J-slot L_6=0.2 to 1.0 cm, then the resonant frequency of left band changes from f_{l1} to $f_{l5,}$ that is from 1.8325 to 1.45 GHz. The notch band changes from f_{n1} to f_{n5} that is from 2.4175 to 1.7425 GHz and right band changes from f_{r1} to f_{r5} that is from 2.6425 to 2.0125 GHz respectively as shown in Table 1. The tuning range of left band is 26.3% and for right band it is 31.3% [5]. As the length of J-slot, L_6 increases, the resonant frequency decreases because its reactance increases [6]. The impedance bandwidths in percentages are 38.9, 42.1, 43.9, 33.7 and 29.8 for left band 23.97, 12.0, 10.75, 8.18 and 5.84 for notch band but for right band 45.0, 56.48, 41.19, 68.59 and 84.72 respectively as shown in Table 1 [7-10]. The left band can be used for GSM 1900MHz, GSM 1800 MHz and GPS 1575 MHz in available bandwidth of 714 MHz which lies in the frequency range of 2.1909 to 1.4764 GHz where as right side band cover an application like FCC ID of frequency range 2.63 to 2.68 GHz which covers in the bandwidth of 1.19 GHz which lies in the frequency range of 3.6796 to 2.4887 GHz. In spite of these two useful applications, this antenna is also rejecting frequencies of Wi-Fi range 2.40 to 2.48 GHz which lies in the bandwidth of 579 MHz (2.4887 to 2.1909 GHz). Among all the operating bands, the optimum impedance bandwidth is 45% which is quite high and gives a peak gain of 3.07dBi, 1.45dBi and 3.28 dBi for left, notch and right band of the TMCMSABR respectively. The gain of the notch band decreases in comparison with two operating bands due to the antenna misalignment and surrounding environment and the gain remains almost stable over entire range of frequency of two operating bands as shown in Figure 5 [11]. The impedance band with is calculated using equation (2).

$$\text{Impedance bandwidth (\%)} = \frac{f_H - f_L}{f_c} x100 \text{ ....(2)}$$

Figure 5, 6 and 7 shows typical radiation pattern for TMCMSABR measured at 1.8325GHz, 2.4175GHz and 2.6425 GHz respectively. The patterns are broadside and linearly polarized in both E and H plane. [12-15]

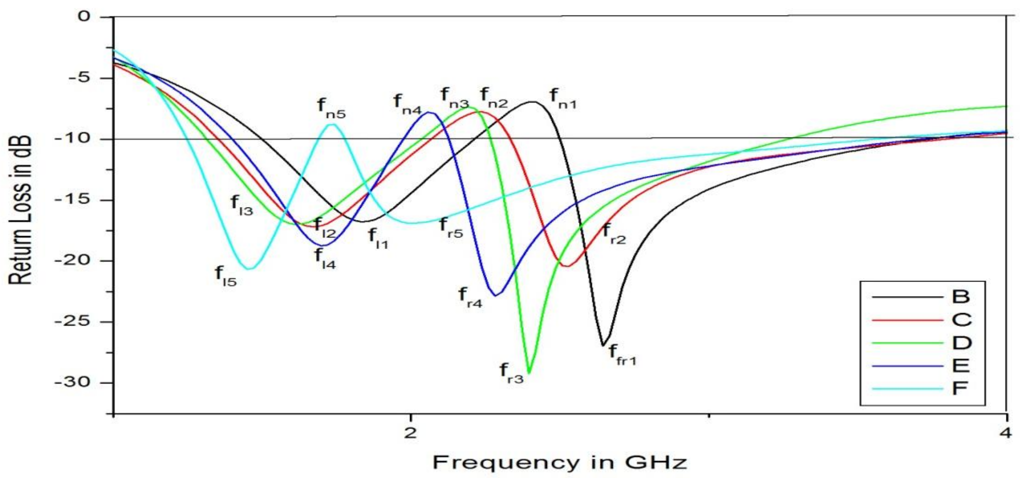

Figure 4. Variation of return loss verses frequency of TMCMSABR

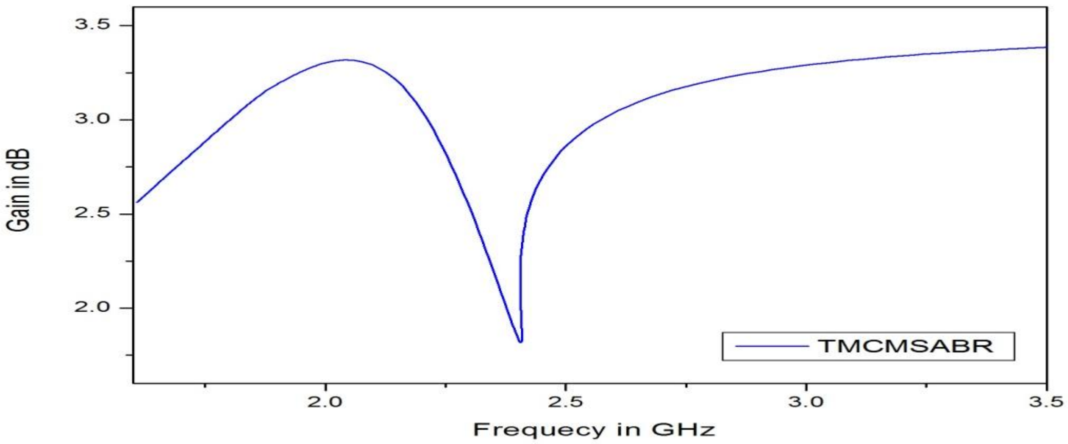

Figure 5. Variation of gain verses frequency of TMCMSABR

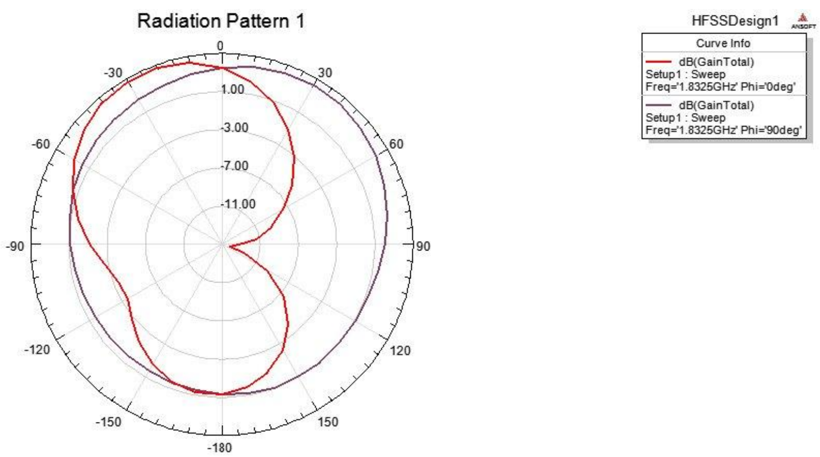

Figure 6. Typical Radiation Pattern TMCMSABR at 1.8325 GHz

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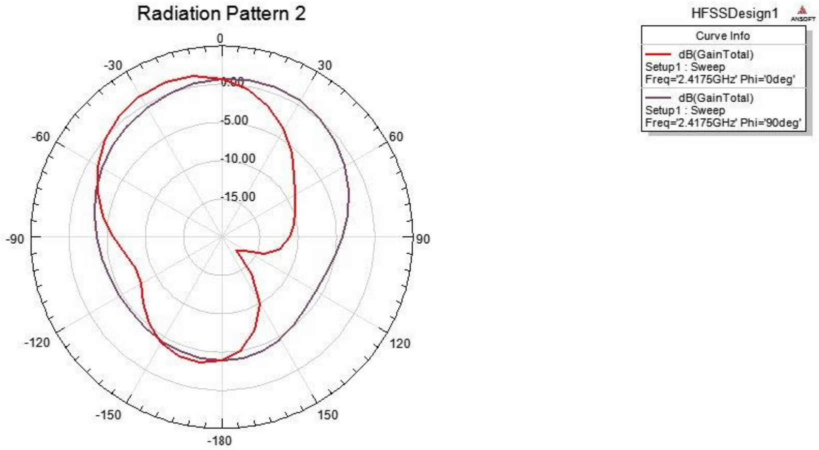

Figure 7. Typical Radiation Pattern TMCMSABR at 2.4175 GHz

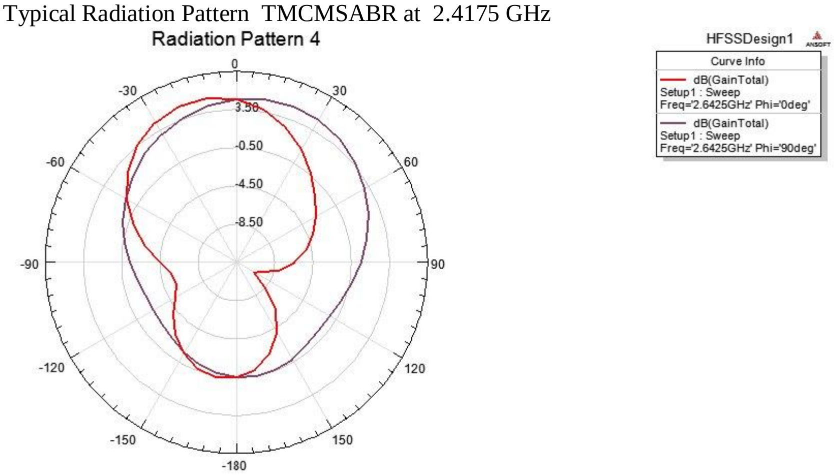

Figure 8. Typical Radiation Pattern TMCMSABR at 2.6425 GHz

Conclusion

The proposed TMCMSABR is specifically designed for operating at low wireless frequencies ranging from 1.4934 to 3.6966 GHz having band width of 2.2 GHz with optimum impedance bandwidth of 83.3 % This antenna is designed using a simple slot and stub loading techniques for the purpose notch band tuning. However , this antenna serves the purpose of rejecting the frequency band of 2.40-2.48 GHz because this band is fully crowded and designated 14 wireless networks channels by just spacing of 5 MHz apart and hence it is necessary to avoids adjacent and intra interferences between the operating bands. Therefore, the antenna is designed with a notch band of resonant frequency 2.4175 GHz. This band is having band width of 579.7 MHz in the range of 2.4887 to 2.1909 GHz and it covers complete Wi-Fi band. The gain of notch band is 1.45 dBi. The remaining two useful bands are; one resonates at 1.8325 GHz with bandwidth of 714.5 MHz (1.4764-2.1909 GHz) covers an applications of GSM 1800, GSM 1900, and GPS 1575 MHz with optimum impedance bandwidth of 38.9% having peak gain of 3.2 dBi and another resonates at 2.6425GHz with bandwidth of 1.19 GHz (2.4887-3.6796 GHz) covers an application of FCC ID range 2.63 to 2.68 GHz with optimum impedance bandwidth of 45% with peak gain of 3.28 dBi. The gain remains stable over entire range of operating bands except notch band. The typical radiation patterns shown are broadside and linearly polarized in both E and H plane.

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