Development of CSRR Embedded Metamaterial Monopole Antenna for Mifi router based Data card

I. Gowri Shankar

Abstract

Recently, antenna and its feed system in wireless communications require to be multifunctional for enhancing flexibility and feasibility, such as easy of integrate, low-profile, inexpensive and ease of fabrication, and wideband or multiband operating.The objective of the project is to design and develop a simple monopole antenna based on composite metamaterial resonators for multiband operation. The antenna has frequency notched function since the composite CPW (Co-Planar Waveguide) metamaterial resonators CSRR (closed-ring resonator and SRR) which is embedded on the planar monopole that resonates for multiple frequency bands. The antenna resonates for the frequency of (UMTS) 1.92 to 2.17 GHz (Wi-MAX) 3.4 to 3.5GHz, (WLAN) 5.725 to 5.875GHz which has good impedance matching and radiation performance.

Index Terms- *CPW, CSRR, Monopole, UMTS, WiMax*

1. Introduction

The multiband or broadband antennas have aroused high interest in recent years for application to multimode communication systems. Because of low cost and process simplicity, printed monopole antennas are very popular candidates for these applications. The currently popular designs suitable for wireless local area network (WLAN) operation 5.2/5.8 GHz (5.15–5.35 GHz/ 5.725–5.825 GHz) and Universal Mobile Telecommunications System (UMTS) bands have been reported. The key design configurations in order to meet this multi-band operation include a monopole antenna fed with a meandered coplanar waveguide (CPW), a CPW-fed monopole antenna with two resonant paths, a CPW-fed tapered bent folded monopole antenna, a microstrip-fed double-T monopole antenna, a meander-line monopole antenna with a backed microstrip line, a C-shaped monopole antenna with a shorted parasitic element, and a branched monopole antenna with a truncated ground plane. However, to further support the worldwide interoperability for microwave access (WiMAX) applications, none of the above available designs can achieve a dual-band response with sufficiently large bandwidth to additionally cover the 3.5/5.5 GHz (3400–3500/5725–5850 MHz) WiMAX and HiperLAN bands.

In [8], the authors presented a CPW-fed split ring monopole antenna with a square conductor-backed plane for dual-band WLAN applications. This design generally needs to consider many dimension parameters and the resulting bandwidth is still not sufficient to cover the 3.5 GHz WiMAX bands. In this letter, a new antenna is proposed for the purpose of WiMAX and HiperLAN mode operations.

One of the most common elements of metamaterials, which was introduced by Pendry et al. in 1999, is the split ring resonator (SRR). SRR is an nonmagnetic conducting unit, in which and its periodic array yields negative effective magnetic permeability with an enhanced magnitude when the frequency of the incident electromagnetic field is close to the SRR resonance frequency. The resonance frequency of the SRR depends on its geometrical parameters. The structure can show resonant behavior at frequencies that are much larger than its size. Experimental demonstration of this structure at microwave frequencies has been achieved by many groups. The application of metamaterials to increase antenna performance is of great interest. It was shown that introducing metamaterials could enhance the radiated power of the antenna. Moreover, negative magnetic permeability materials are a candidate for obtaining properties such as an electrically small antenna size, high directivity, and tunable operational frequency. Furthermore, by utilizing a combination of right handed (RH) and left handed (LH) materials in a composite (CRLH) transmission line, a backward to forward scanning capability is obtained. Antennas composed of single negative materials that resonantly couple to external radiation was invented by Isaacs. Even if the radiation wavelength is much larger than the antenna size, the antenna is sensitive to radiation due to the resonant coupling. By feeding such a resonator one can obtain an electrically small antenna when operating at microwave frequencies.

2. ANTENNA DESIGN

Fig. 1 illustrates the geometry of the proposed dual wideband antenna for WiMAX dual-mode operation. The antenna was implemented on an inexpensive FR4 substrate with thickness of 1.6 mm and relative permittivity of 4.6. It can be seen from Fig. 1 that the rectangular monopole and 50ohm CPW feedline are printed on the top side of substrate of the antenna.

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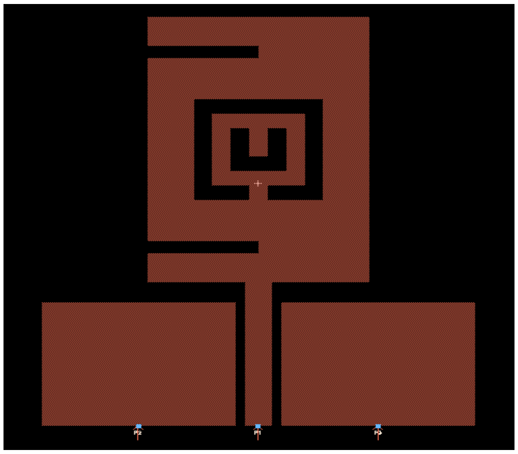

***Figure – 1** CSRR Embedded Monopole Metamaterial Antenna*

In the proposed antenna configuration, the rectangular monopole can provide the fundamental band and next higher resonant band at 5.7 GHz is obtained by embedding the CSRR structure in the antenna respectively, This CSRR plane resonates based on electrically coupled to the rectangular monopole. By properly tuning the dimensions and spacing to semi-ground plane CSRR embedded plate, the antenna can create the second resonant frequency in individual resonant radiation band based on an over-coupling condition. This mechanism can remarkably increase the resonant radiation bandwidth.

3. DESIGN FORMULAS

The dimension of the slot antenna is referred to the guide wavelength (λg) which given by,

$$\lambda_g = \frac{c/f}{\sqrt{\varepsilon_{eff}}}$$

Where εeff is an effective constant $\varepsilon_{eff} \approx (\varepsilon_r + 1)/2$
In this case, $\varepsilon_{eff} \approx (4.4+1)/2 \approx 2.7$
$\lambda_g = 33.16$ mm (for f= 5.5 GHz)

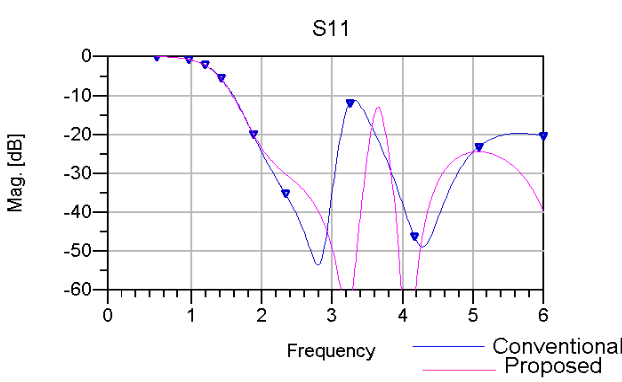

***Figure 2* - Simulation result of conventional and proposed CSRR Results**

Fig. 2 shows the simulated return losses for the proposed antenna which can be optimized with choosing the dimensions

4. EFFECT OF GROUND STRUCTURES

All these antennas as shown in Figure 3 and 4 have the same dimensions as that of Figure1, except that they have different geometrical ground planes.

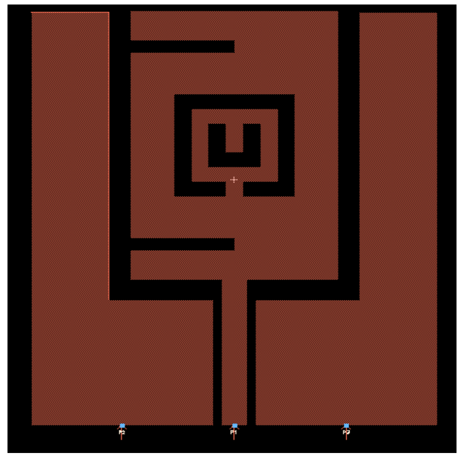

Figure 3. Full Ground

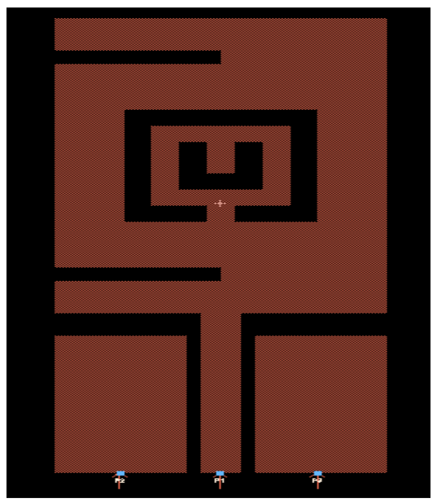

Figure 4. Patch Equivalent Ground

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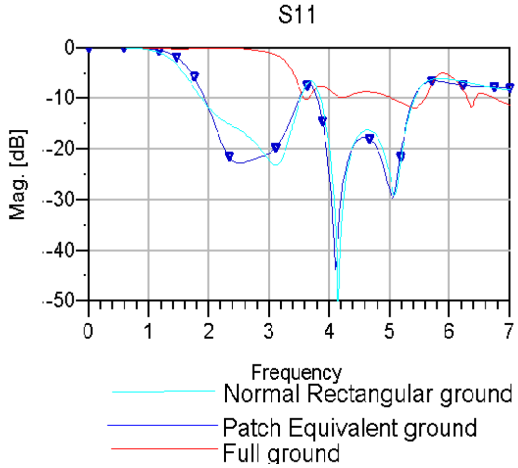

Figure5. *Comparison of Rectangular, Equivalent and full ground structures Return loss in dB*

From Figure 5 it is clear that Rectangular and equivalent ground structures are giving better performances.

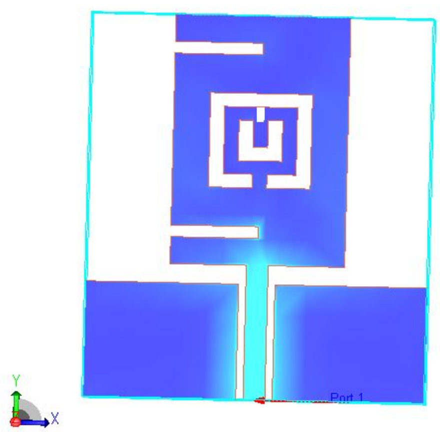

Figure 6. *Current Distribution of Rectangular ground structure antenna*

5. RADIATION PATTERN

The 3-D and 2-D radiation patterns shows as in Figure 7 and 8 that the proposed antenna has high directivity, gain and efficiency in Figure 9.

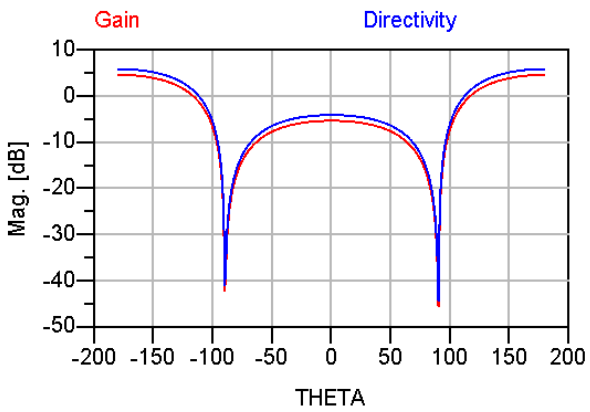

Figure 7. Gain and Directivity of the proposed Antenna

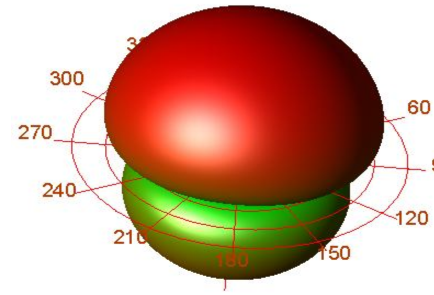

Figure 8. 3-D radiation pattern of E field

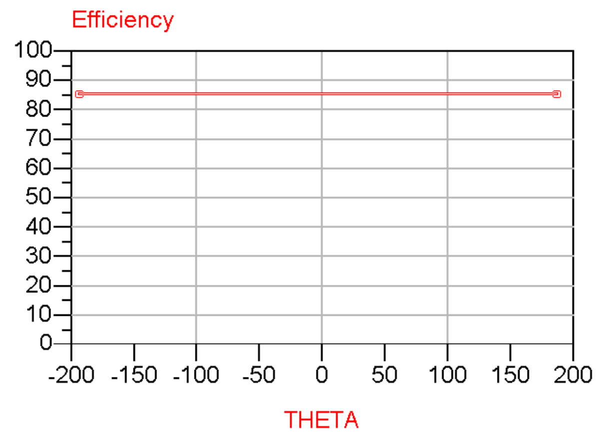

Figure 9. Efficiency

6. EXPERIMENTAL RESULTS AND DISCUSSION

The simulated return losses for the proposed antenna with the conventional and the proposed CSRR embedded on the plane are shown in Fig. 2. The resemble result between the conventional and proposed is shown in Table - 1. The antenna gain across the 3.4 – 3.5 GHz and 5.725 – 5.875 GHz dual band of the proposed antenna comparison with convention monopole are also studied. It is clearly seen that the SRR metamaterial layer antenna, the antenna gain is merely high. In the proposed methodology, the antenna with CSRR metamaterial embedded on the monopole increases the gain to 7.9 dBi. The radiation efficiency of the conventional antenna is about 68%. But, the proposed antenna increases the radiation efficiency to 86%. More specifically, the antenna gain of proposed CSRR embedded metamaterial antenna is equivalently high when compared to a CSRR antenna.

PARAMETER	CSRR MONOPOLE	CSRR EMBEDDED MONOPOLE
Gain (dBi)	5.6	7.4
Directivity (dB)	7.0	7.9
Efficiency (%)	68	86

Table – 1 Comparison of Conventional and proposed metamaterial antenna

7. CONCLUSION

A simple printed monopole antenna with a CSRR metamaterial embedded on the monopole plane for UMTS, WiMAX and HiperLAN mode operation has been presented. The use of CSRR metamaterial structure produces the multi band has increased impedance bandwidth very remarkably to sufficiently covers the (1.92 – 2.17, 3.4 – 3.5 & *5.725 to 5.875)* GHz bands. The final results show satisfactory performance and good agreement with the simulated results. In future using optimization in structure the antenna size is further being reduced.

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REFERENCES

1. [1] Wen-Chung Liu, Chao-Ming Wu, and Yen-Jui Tseng ‘Parasitically Loaded CPW-Fed Monopole Antenna for Broadband Operation’ IEEE TRANS ON ANTENNAS AND PROPAGATION, VOL. 59, NO. 6, JUNE 2011
2.
3. [2] Kim, Y. and D. H. Kw on, “CPW-fed planar ultra wideband antenna having a frequency band notch function,” *Electronics Letters*, Vol.40, No.7, 403–405, 2004.
4.
5. [3] I. Oppermann, M. Hamalainen, and J. Iinatti, *UWB Theory and Applications*. New York: Wiley, 2004, ch.1, pp. 3–4.
6.
7. [4] G. R. Aiello and G. D. Rogerson, “Ultra-wideband wireless system,” IEEE *Microwave Mag.*, vol. 4, no. 2, pp. 36–47, Jun. 2003.
8.
9. [5] Z. N. Chen, “Novel bi-arm rolled monopole for UWB applications,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 2, pp. 672–677, Feb. 2005.
10. [6] J. Liang, C. Chiau, X. Chen, and C. G. Parini, “Study of a printed circular disc monopole antenna forUWBsystems,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 11, pp. 3500–3504, Nov. 2005.
11. [7] J. Liang, L. Guo, C. C. Chiau, X. Chen, and C. G. Parini, “*Study* of CPW-fed circular disc monopole antenna,” *IEE Proc. Microw., Antennas Propag.*, vol. 152, no. 6, pp. 520–526, Dec. 2005.
12. [8] Q. Wu, R. H. Jin, J. P. Geng, and M. Ding, “CPW-fed quasi circular monopole with very wide bandwidth,” *Electron. Lett.*, vol. 43, no. 2, pp. 69–70, Feb. 2007.
13.
14. [9] A. Al-Zoubi, F. Yang, and A. Kishk, “A broadband center-fed circular patch-ring antenna with a monopole like radiation pattern,” *IEEE Trans. Antennas Propag.*, vol. 57, pp. 789–792, 2009.
15. [10] V. P. Sarin, V. Deepu, C. K. Aanandan, P. Mohanan, and K.Vasudevan, “Wideband printed microstrip antenna for wireless communications,” *IEEE Antennas Wireless Propag. Lett.*, vol. 8, pp. 779–781, 2009.
16. [11] M. John and M. J. Ammann, “Wideband printed monopole design using a genetic algorithm,” *IEEE Antennas Wireless Propag. Lett.*, vol. 6, pp. 447–449, 2007.
17. [12] S. K. Oh, H. S. Yoon, and S. O. Park, “A PIFA-type varactor-tunable slim antenna with a PIL patch feed for multiband applications,” *IEEE Antennas Wireless Propag. Lett.*, vol. 6, pp. 103–105, 2007.
18. [13] C. H. Chang and K. L. Wong, “Printed PIFA for penta-band WWAN operation in the mobile phone,” *IEEE Trans. Antennas Propag.*, vol. 57, pp. 1373–1381, 2009.

ISSN 2229-5518

19. [14] Nasimuddin and Z. N. Chen, "Wideband multilayered microstrip antennas fed by coplanar waveguide-loop with and without via combinations," *IET* Microw. *Antennas Propag.*, vol. 3, pp. 85–91, 2009.

20. [15] W. C. Liu, "Design of a multiband CPW-fed monopole antenna using a particle swarm optimization approach," *IEEE Trans. Antennas Propag.*, vol. 53, pp. 3273–3279, 2005.

21. [16] K. Chung, T. Yun, and J. Choi, "Wideband CPW-fed monopole antenna with parasitic elements and slots," *Electron. Lett.*, vol. 40, pp. 1038–1039, 2004.

22. [17] J. S. Chen, "Dual-frequency annular-ring slot antennas fed by a CPW feed and microstrip feed," *IEEE Trans. Antennas Propag. Lett.*, vol. 53, pp. 569–571, 2005.

23. [18] A. Amador-Perez and R. A. Rodriguez-Solis, "Analysis of a CPW fed annular slot ring antenna using DOE," in *Proc. IEEE Antennas Propag. Soc. Int. Symp.*, 2006, pp. 4301–4304.