Isolation Enhancement in Microstrip Patch Antennas for WiMAX Applications

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Abstract—Microstrip patch antennas with mutual coupling are proposed for WiMAX applications. To reduce mutual coupling between patch antennas using different methods like Split Ring Resonators (SRR), Slotted Meander Line Resonators (SMLR), Wave Guided Meta Materials (WG-MTM) and Planar-Electromagnetic Band Gap (P-EBG) structures are designed for WiMAX applications. In all four methods, antennas are engraved on 15x10 mm^2 FR4 substrate. The antenna is designed by applying FR4 substrate with thickness 3mm, permittivity 4.6. The proposed antennas are modeled using ADS software. The simulated result shows that the proposed antennas are optimized for 5.8 GHz resonant frequency. By comparing all four methods Split Ring Resonators only having more isolation of -37.5 dB and the return loss of -16.5 dB. The characteristics like return loss, radiation pattern, gain, directivity etc. are computed for all the designed antennas. These features show that the proposed patch antenna with SRR structure is well suited for WiMAX application compared to other three methods.

Keywords—Microstrip Antennas; Mutual Coupling; Split Ring Resonators (SRR); Wave Guided Meta Materials (WG-MTM); WiMAX.

Abbreviations—Planar- Electromagnetic Band Gap (P-EBG); Slotted Meander-Line Resonators (SMLR); Split Ring Resonators (SRR); Wave Guided Meta Materials (WG-MTM); Worldwide Interoperability for Microwave Access (WiMAX).

I. INTRODUCTION

WORLDWIDE Interoperability for Microwave Access (WiMAX) is one of the expertises in wireless. It is a telecommunications technology which qualifies wireless transmission of voice and data in several ways, extending from point-to-point links to occupied mobile access, where availability of bandwidth pooled with the mobility should afford the users with a better familiarity of high data rate services such as web surfing or video spilling. WiMAX is the furthermost substantial technology launched by the IEEE 802.16 working group. It is a 4G wireless technology mainly planned for wireless "Metropolitan Area Network". It features high speed, high data rate, wide coverage area and high reliability. It consists of a fixed wireless metropolitan area technology that supports coverage radius of kilometers and data transmission rate up to 74 Mbps.

Coverage predictions and performance evaluation of the IEEE 802.16 standard has not yet been extensively explored. The WiMAX Forum is an industry body formed to promote the IEEE 802.16 standard and perform interoperability testing.

The WiMAX forum has adopted certain profiles based on the 802.16 standards for interoperability testing and "WiMAX certification". WiMAX is a standard-based wireless technology that provides high throughput broadband connections over long distance. WiMAX can be used for a number of applications, comprising "last mile" broadband connections, high-speed connectivity for business patrons.

Isolation enhancement in array antenna applications poses a strong challenge in the antenna community. In antenna arrays, multiple antenna elements designed to operate at the same frequency share a common substrate.

A serious problem of coupling between antenna elements occurs, which may significantly interfere with neighboring antenna unit cells resulting in reduced antenna gain, operational bandwidth, and radiation efficiency [Ludwig, 2012]. Therefore, it is necessary to suggest a suitable method to overcome this coupling effect and to improve the performance of the antenna array.

In literature, several configurations like multiple dielectric substrate [Rajo-Iglesias et al., 2008], Electromagnetic Band-Gap (EBG) structures [Expósito-Domínguez et al., 2011] and Defected Ground plane Structures (DGS) [Habashi et al., 2012] have been investigated to reduce the mutual coupling effects between the antenna elements. In Farahani et al., (2010), EBG structures that suppress the surface current are proposed to be the suitable aid for overcoming the mutual coupling effects. DGS structures adopted as a solution increase the back-radiation, resulting in reduced front-to-back ratio, and multilayer dielectric substrates increase the weight of the antenna arrays. Other techniques involve the use of slotted complementary split-ring resonator [Bait-Suwailam et al., 2010] and waveguide metamaterials [Yang et al., 2012]. The idea of using meander lines for isolation enhancement has been extracted from [Cheung et al., 2012].

Slotted Meander-Line Resonators (SMLRs) are proposed to be the decoupling unit that occupies less space when compared to EBG structures and uses a single standard substrate. The decoupling unit has two sections of slotted meander lines cascaded and sandwiched between two patch antennas designed to work at 4.8 GHz. These SMLR structures act as a band stop resonator that specifically stops the surface current from one unit cell to another unit cell. The characterization of the SMLR decoupling unit and describes the surface current blocking mechanism [Gulam Nabi Alsath et al., 2013]. Surface waves and near fields can lead to coupling between coplanar and patch antennas [Jackson et al., 2003; Nikolic et al., 2005; Bhattacharyya, 2008]. The near-field coupling arises when an antenna is placed in the near-field zone of another antenna. The near-field coupling is strong in situations where the antennas are printed on dielectric substrates with very low permittivity [Nikolic et al., 2005].

II. Antenna Design Process

A Microstrip Line fed Microstrip patch antennas with mutual coupling for WIMAX application is designed. The proposed antennas are engraved on 15x10 mm^2 FR 4 substrate with relative permittivity of 4.6. Performance comparison of microstrip patches antennas using Split Ring Resonators (SRR) and Wave Guided Meta Materials (WG-MTM), techniques with reduced mutual coupling. Compared to existing methodologies more isolation and good radiation characteristics achieved.

All four methods using two microstrip patch antennas with same dimensions. The antennas operate at a resonant frequency of 5.8GHz. The proposed antenna is modelled using the ADS software. The two complementary SRRs connected with patches of length and width. The dimensions of patch are (15×10) mm2 as shown in figure 1. The incidences are etched on a dielectric substrate (FR4) with a wideness of 4.6 mm. The separation distance between the unit cells is 1 mm.

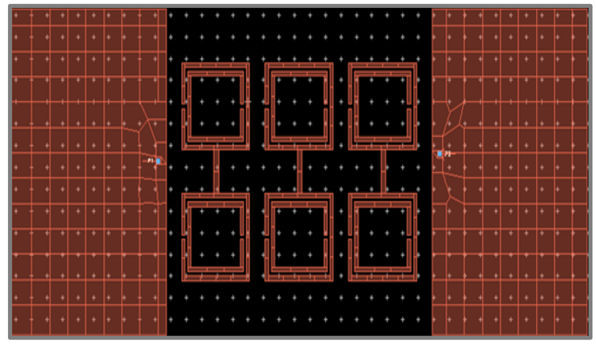


Figure 1: Geometry of Microstrip Patch Antennas with SRR

The WG-MTM is connected with patches of length and width. The dimensions of patch are (15×10) mm^2 as shown in figure 2. WG-MTM is made up of two parallel metal plates, and the lower plate is etched with patterns of periodical unit cells. By altering the geometry and dimension of unit cell, the particle exhibits enhanced electric or magnetic response with varying degrees, resulting in different effective medium stacked in the Planar waveguide.

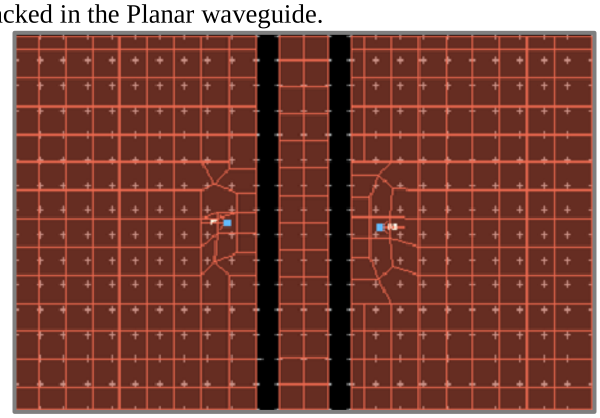
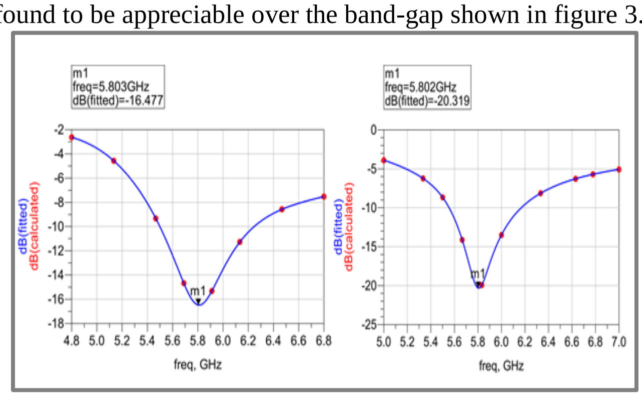


Figure 2: Proposed Microstrip Patch Antennas with WG-MTM

III. Results and Discussion

3.1. *S Parameter of Microstrip Patch Antennas with Different Resonator Techniques*

Strong rejection characteristics are observed for the SRRs, where the band-gap zone is clearly seen within the designed frequency range. From the scattering parameters, the attenuation constant can be extracted, and indeed, it was found to be appreciable over the band-gap shown in figure 3.



(a) (b)

Figure 3: S Parameter Plots for Return Loss Vs. Frequency for Microstrip Patch Antennas with Isolation: (a) SRR, (b) WG-MTM

S_{11} is a parameter which suggests how much power is radiated from load to the antenna. S parameter computation has been performed for microstrip patch antennas with SRR structure. For the given center frequency, the return loss will be minimized. S_{11} is a parameter which suggests how much power is radiated from load to the antenna.

Figure 3 (a) shows microstrip patch antenna with SRR operates at a center frequency of 5.8 GHz with a return loss of -16.47dB. Figure 3(b) shows microstrip patch antenna with WG-MTM operates at a center frequency of 5.8 GHz with a return loss of -20.3dB.So the antennas can be transmit power with a minimum loss and enhanced bandwidth which is more suitable for WiMAX applications. Figure 4, shows the current distribution of the microstrip patch antennas with SRR using ADS software. The 3D current distribution plot gives the relationship between the co-polarization (desired) and cross-polarization (undesired) components. Moreover it gives a clear picture as to the nature of polarization of the fields propagating through the patch antenna.

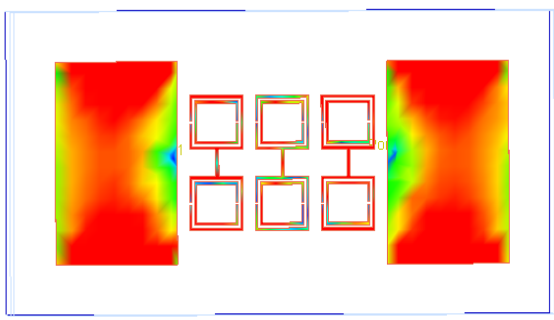


Figure 4: Simulated Electric Current Distribution of the Microstrip Patch Antennas with SRR at 5.8GHz

Figure 5, shows the current distribution of the microstrip patch antennas with WG-MTM using ADS software. It gives a clear picture as to the nature of polarization of the fields propagating through the patch antenna. The surface current distribution of the configuration is depicted in figure 5, from which suppression of surface current due to WG-MTM unit cell is evident.

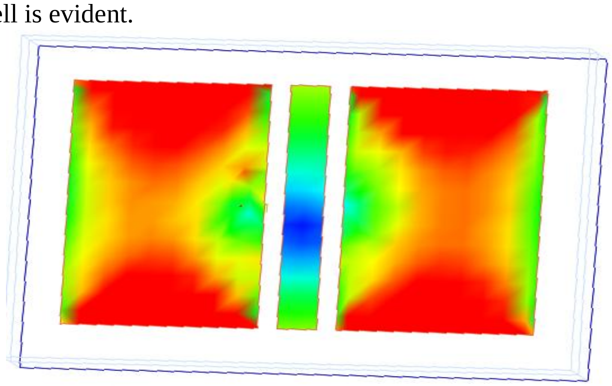


Figure 5: Simulated Electric Current Distribution of the Microstrip Patch Antennas with WG-MTM at 5.8GHz

3.2. Radiation Pattern of Microstrip Antennas with SRR and WG-MTM Structures

Radiation pattern shows "a graphical representation of radiation properties of an antenna". The 3D representation of the radiation pattern of microstrip patch antennas with SRR structure is measured at 5.8GHz is illustrated in figure 6. A symmetric figure eight pattern is obtained for proposed antennas.

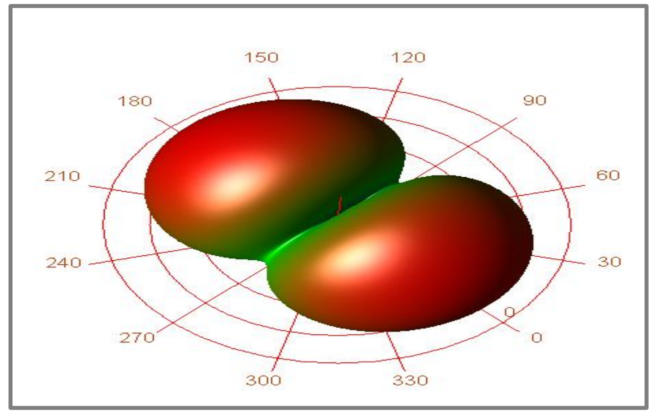


Figure 6: Radiation Pattern of Microstrip Patch Antennas with SRR Structure at 5.8GHz

The 3D representation of the radiation pattern of microstrip patch antennas with WG-MTM structure at 5.8GHz is illustrated in figure 7.

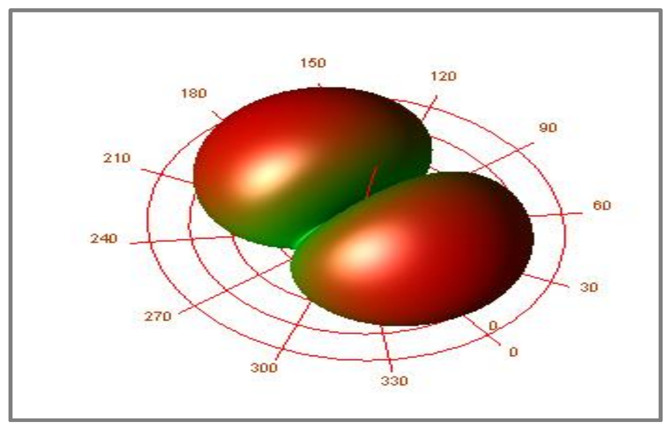


Figure 7: Radiation Pattern of Microstrip Patch Antennas with WG-MTM Structure at 5.8GHz

3.3. Isolation

To verify the band-gap effect on isolation enhancement in microstrip patch antenna arrays, a two-element array is constructed using microstrip patch antennas fed through a quarter wave transformer. The patch antenna dimensions are calculated for an operating frequency of 5.8 GHz. The antennas are printed over a standard FR4 substrate of height 3mm having a dielectric constant of 4.6 and loss tangent 0.021. The configuration ensures the suppression of the vertically polarized electric fields (space-wave) between the two patches. The transmission coefficient between the two patches is determined to gauge the mutual coupling effect. A reduction of about -37.5 dB and -13dB in the mutual coupling between the antennas are observed in SRR and WG-MTM structures. The extenuation of the space-wave by asset of the band-gap filtering is clearly observed in which the dispersal of the surface currents on the ground plane is plotted when one antenna is animated while the other antenna is dismissed with 50 ohm impedance.

Table 1: Simulated Results of Microstrip Patch Antennas with Different Resonator Structures

Parameter	Split-Ring Resonator (SRR)	Wave Guide-Metamaterial (WG-MTM)
Operating Frequency	5.8GHz	5.8GHz
Isolation (dBi)	-16.477	-20.3
Gain(dBi)	2.35	2.3
Directivity	8.2	8.5
Maximum Intensity	0.000678	0.00016
Effective Angle	1.9	1.77
Power Radiated	0.00128	0.0028

The different antenna parameters like gain, directivity, radiated power; maximum intensity, isolation and effective angle of microstrip patch antennas with SRR and WG-MTM structures are given in above table 1.

IV. Conclusion

The Microstrip patch antennas with isolation enhancement can be designed for WiMAX application. This proposed antenna is designed on FR4 suitable material and simulated by using ADS software. In proposed four methods, the isolation of SRR and WG-MTM becomes -37.5dBi, and -13dBi at 5.8 GHz. In above two methods Split Ring Resonator (SRR) only has more isolation compared to other three methods. This proposed SRR method can be achieved desired radiation pattern with gain of 2.35dBi at 5.8GHz which is most suitable for WiMAX applications.

The characteristics of both the antennas which include return loss, radiation pattern, gain etc. are analyzed. The obtained result shows that the designed antennas are well suited for WiMAX applications and so the proposed microstrip patch antennas with SRR structure is fabricated.

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