

Microstrip Patch Antenna Array with Metamaterial Ground Plane for Wi-MAX Applications

Chirag Arora, Shyam S. Pattnaik and R.N. Baral

Abstract In this paper a microstrip patch antenna array, loaded with a pair of Split Ring Resonators (SRR), has been presented. This antenna is designed for IEEE 802.16a 5.8 GHz Wi-MAX applications. A pair of SRR has been etched on the ground plane of the antenna. This loading of SRR provides better matching conditions in the desired frequency band along with improvement in gain and enhancement in bandwidth. The unloaded antenna array resonates at 5.8 GHz with gain and bandwidth of 4.15 dBi and 425 MHz, respectively, whereas when the same antenna array is loaded with split ring resonators, the gain increases to 5.9 dBi and bandwidth reaches to 600 MHz. The electrical length of the patch is $0.23\lambda \times 0.3\lambda$. Suppression of higher harmonics and reduction in mutual coupling between the elements of patch antenna array, due to metamaterial loading, has also been analyzed.

Keywords Microstrip patch antenna · Mutual coupling reduction · Split ring resonator · Negative permeability · Wi-MAX · Metamaterial

1 Introduction

Microstrip patch antennas are usually low-gain antennas and still used very commonly due to low cost and easy fabrication [1]. Due to excitation of surface waves over the substrate layer, they also have reduced radiation efficiency [2, 3]. However, microstrip patch antennas can be easily grouped in the form of arrays to obtain

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enhanced bandwidth and high gain. An integrated array designed in this way is small in size and lightweight [4, 5]. Linear array of microstrip patch antennas are used for various applications, such as multiple input multiple output systems, radar applications, etc. One of the most important requirements for these applications is high integration densities to efficiently utilize the maximum available space present on the substrate [6]. Also, necessary isolation between adjacent patch antenna and additional incorporated components on the same substrate is required. To reduce the total size of an array, the elements of an antenna array can be placed close to each other. However, by reducing the gap between the antenna elements, mutual coupling due to excited surface waves becomes higher, resulting in performance degradation of the antenna array. Hence, an approach is required which is capable to reduce the inter-element spacing, while preserving the necessary isolation. Several techniques to improve the problem of mutual coupling have been proposed in the previous literature. However, all of these methods have some pros and cons. Zhu et al. proposed a ground plane pattern that efficiently decreases mutual coupling. However, this method also distorts the radiation pattern to a large extent [6]. Farabani et al. introduced the electromagnetic band gap structure for isolation between circular patch antennas, but structures were complex and optimization of design was difficult to achieve [7]. A method of inserting a slot was suggested by Yang et al., which considerably reduced the inter-element mutual coupling. Though this technique was simple to implement, it considerably changed the rear-end radiation pattern of the antenna [2]. Also, all such periodic structures increased the antenna dimensions and weight to a large extent. In [8], Ibraheam et al. tilted the patch elements along the elevation to reduce the mutual coupling between elements. Though this method provided good results, the structure is difficult to implement as precise tilting is required.

In the present work, isolation between the elements of microstrip antenna array was achieved by use of a pair of SRRs etched on the ground plane of array. SRRs act as canonical metamaterial structures, giving rise to an effective negative permeability, with a stopband in its resonant frequency band [9]. This proposed approach not only improves the isolation between two antenna elements but also helps in suppression of higher harmonics.

2 Antenna Design

Figure 1a shows the geometrical structure of a two-element conventional microstrip patch array and Fig. 1b depicts the antenna array with split ring resonators etched on the ground plane. The proposed microstrip patch antenna array is designed on FR-4 substrate of thickness (h) = 1.48 mm, dielectric constant (ϵ_r) = 4.4 and loss tangent = 0.01. 50 Ω SMA coaxial connector is used to feed the array. The use of an FR-4, which is an inexpensive substrate, makes the design low profile, easy to fabricate, and economical. Figure 2 shows the cross-sectional view of the proposed antenna array.

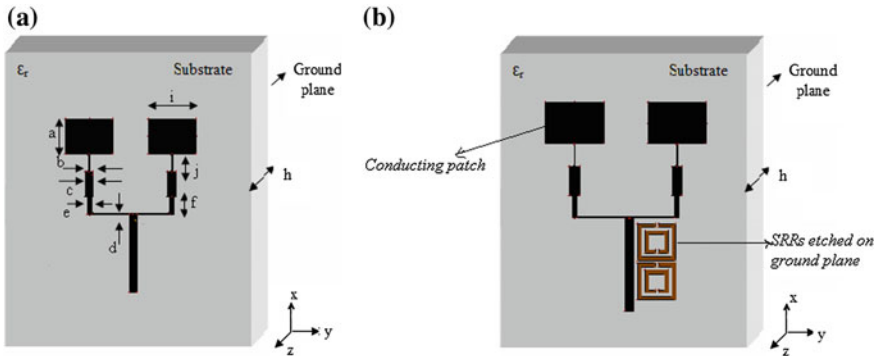


Fig. 1 Geometrical sketch of **a** 2-element antenna array. **b** Proposed antenna array with SRRs loaded on ground plane

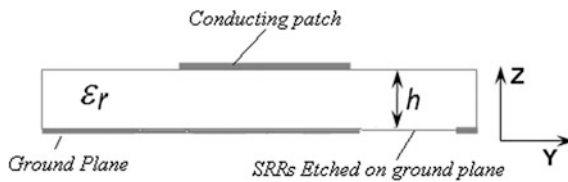


Fig. 2 Cross-sectional view of the proposed antenna array

Table 1 Dimensions of conventional patch antenna array

Parameters	Dimensions (mm)
a	11.95
b	0.5237
c	2.8758
d	0.5237
e	1.38
f	7.55
i	15.88
j	7.55
h	1.48

The width (W) and length (L) of patch, as calculated using transmission line model equations [10, 11], are 15.88 and 11.95 mm respectively. Thus the aspect ratio (L/W) of the patch is 0.75. Table 1 shows the various dimensions of the conventional antenna array. The corporate feed network is used to edge feed the elements of the array. The spacing between the two patched of the antenna array is $0.96 (\lambda_g/2)$, where λ_g is the guided wavelength. This type of feeding network provides power split using quarter wave impedance transformer [12].

To match the patch with 50Ω line, a quarter wave transformer of 109.2Ω is used. The width (w) of this quarter wave transformer and 50Ω transmission line, as calculated from [11], is 0.5237 and 2.8758 mm, respectively. The length of quarter wave transformer is calculated as 7.55 mm. SRRs are etched on the ground plane in such a way that they do not increase the overall size of the proposed antenna array, that is, the dimensions of loaded as well as unloaded antennas are the same. The geometrical dimensions of the SRR are as follows: length of outer split-ring $L_s = 10.50$ mm, width of rings (w) = 0.2 mm, gap between split of rings (g) = 0.2 mm, and distance between outer and inner split-rings (s) is set to as 1 mm. The distance between antenna array and SRRs is 1 mm in both vertical and horizontal directions. The spacing between two SRRs is fixed at 0.2 mm.

3 Results and Discussion

In this section, the simulated results of the proposed antenna array in loaded and unloaded conditions are presented. Figure 3 depicts the return loss characteristics of the proposed array under both, loaded, and unloaded conditions. It is observed that the unloaded antenna array resonates at 5.8 GHz with bandwidth of 425 MHz, whereas when a pair of SRRs is etched on the ground plane of the conventional array bandwidth increases up to 600 MHz at the same resonant frequency, thus corresponding to the bandwidth improvement of 3 %. The dimensions of the array under both the conditions are the same. Thus, the bandwidth has improved at no extra hardware cost. Figure 2 also shows that better matching conditions are obtained when the array is loaded with the SRRs. It is observed that under loaded conditions the dip reaches to -55 dB, which was -33 dB for unloaded conditions. Figures 4 and 5 represent the radiation pattern characteristics of loaded and unloaded antenna array in azimuth and elevation plane respectively. It is observed

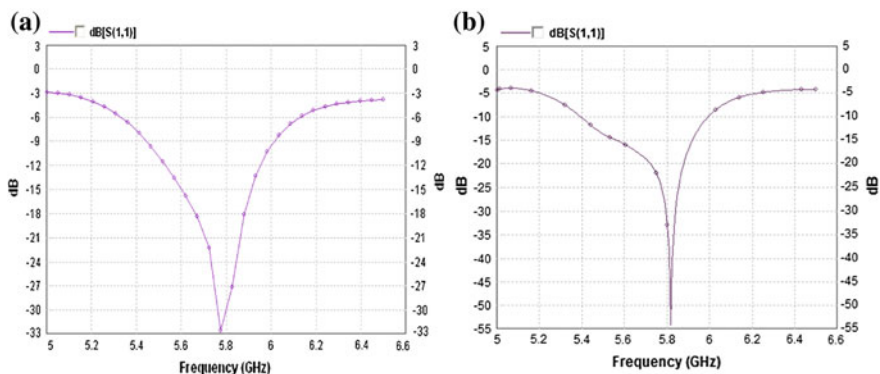


Fig. 3 S_{11} characteristics of **a** Unloaded antenna array. **b** Proposed antenna array with SRRs loaded on the ground plane

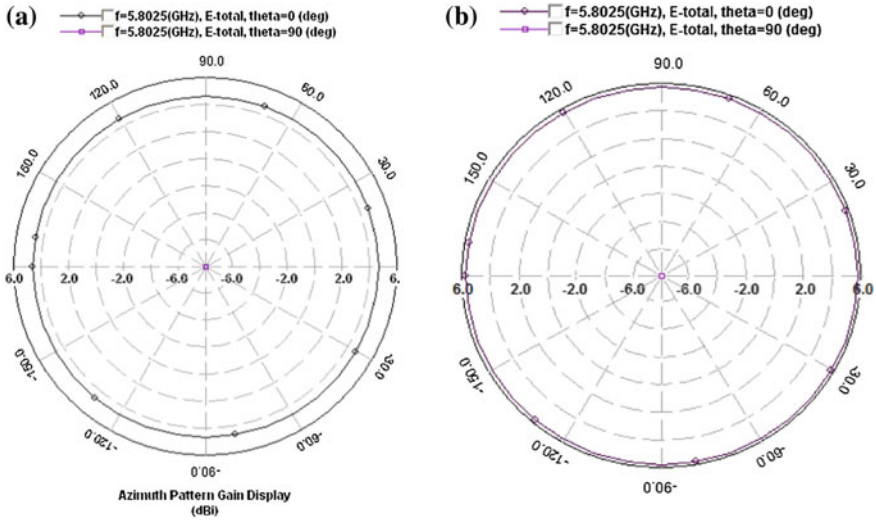


Fig. 4 Azimuth plane radiation pattern characteristics of **a** Unloaded antenna array. **b** Proposed loaded antenna array

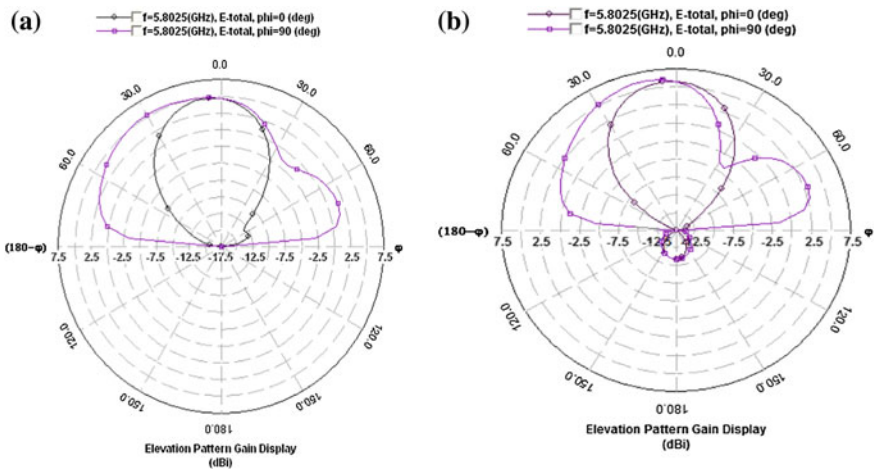


Fig. 5 Elevation plane radiation pattern characteristics of **a** Unloaded antenna array. **b** Proposed loaded antenna array

that the conventional antenna array resonates with gain of 4.15 dBi. However, when SRRs are etched on the ground plane of the array the gain increases to 5.9 dBi.

The inductance (L) of the microstrip patch antenna array with the capacitance (C) of SRRs produces the LC resonant circuit of the SRR loaded antenna. This inductance and capacitance compensate each other and hence excellent matching is

obtained at the resonant frequency. Also, under loaded conditions, magnetic coupling between antenna array and SRR develop the electric field between the gap capacitance at the splits and capacitance between outer and inner rings of SRR. Due to this magnetic coupling, mutual inductance between the elements of the array gets reduced and the time-varying magnetic flux generated by the antenna induces current on SRR. It produces a large electric field across the capacitance associated with SRR. This capacitance of SRR is quite large to match with the inductance of the array, which leads to reduction in mutual coupling between the elements of the array.

4 Conclusions

In this paper a microstrip patch antenna array, with SRRs etched on the ground plane, has been presented. The proposed antenna can be used for IEEE 802.16a 5.8 GHz Wi-MAX applications. Under loaded conditions, better matching conditions along with improvement in bandwidth and gain is observed. Loading of SRRs not only suppresses the higher harmonics but also reduces the surface waves and mutual coupling between the elements of patch antenna array. The advantage of this proposed antenna is that its performance gets improved at no extra size and cost. Fabrication of this antenna array is under process and measured results shall be presented in subsequent publications.

References

1. James, R., Hall, P.S.: Handbook of Microstrip and Printed Antennas. Wiley, New York (1997)
2. Yang, J.O., Yang, F., Wang, Z.M.: Reducing mutual coupling of closely spaced microstrip MIMO antennas for WLAN application. *IEEE Antennas Wirel. Propag. Lett.* **10**, 310–312 (2011)
3. Liu, Z.: Suppression of the mutual coupling between microstrip antenna arrays using negative permeability metamaterial on LTCC substrate. In: *IEEE Antenna Propagation Symposium Society*, pp. 1258–1259 (2013)
4. Elhefnawy, M., Ismail, W.: A microstrip antenna array for indoor wireless dynamic environments. *IEEE Trans. Antenna Propag.* **57**(12), 3998–4002 (2009)
5. Pham, N.T., Gye-An, L., De Flaviis, F.: Microstrip antenna array with beam forming network for WLAN applications. In: *Proceedings of IEEE International Symposium Antennas Propagation Society*, vol. 3A, pp. 267–270 (2005)
6. Zhu, F.G., Xu, J.D., Xu, Q.: Reduction of mutual coupling between closely-packed antenna elements using defected ground structure. *Electron. Lett.* **45**(12), 601–602 (2009)
7. Farabani, H.S., Veysi, M., Kamyab, M., Tadjalli, A.: Mutual coupling reduction in patch antenna arrays using a UC-EBG superstrate. *IEEE Antennas Wirel. Propag. Lett.* **9**, 57–59 (2010)
8. Ibraheam, M., Krauss, A., Irteza, S., Matthias, A.H.: Reduction of mutual coupling in compact antenna arrays using element tilting. In: *Proceedings of Microwave Conference (GeMIC)*, pp. 1–4, Germany (2014)

9. Joshi, J.G., Pattnaik, S.S., Devi, S., Raghavan, S.: Magneto-inductive waveguide loaded microstrip patch antenna. *Int. J. Microw. Opt. Technol.* **7**(1), 11–20 (2012)
10. Garg, R., Bhartia, P., Bhal, I., Ittipiboon, A.: *Microstrip Antenna Design Handbook*. Artech House, Boston (2001)
11. Balanis, C.A.: *Modern Antenna Handbook*. Wiley, New York (2011)
12. Pozar, D.M.: *Microwave Engineering*. Wiley, New York (2008)