Bandwidth and Gain Enhancement with Cross-Polarization Suppression in Microstrip Antenna with Superstate

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Abstract

This paper presents a modification of a rectangular microstrip patch antenna (MPA) which improves the S_{11} bandwidth from 6.6% to 17.5% at center frequency of 28 GHz. The gain of this antenna at center frequency has been improved by using dielectric superstate from 6.81 dB to 10.73 dB. Further, gain improvement and cross-polarization suppression are also achieved by using multi-strip frequency selective surface (FSS) as a superstrate.

1 Introduction

Millimeter wave antennas are gaining a wide range of attention due to their flexibility to use in different applications such as radio astronomy, automotive radars, and wireless communications, etc. With the ever-increasing demand for wireless communications in several dimensions of applications, a higher bandwidth presence is very essential to meet the demand of the day. The 5G technology demands higher frequency bands to support multi-Gbps speed rates. To realize these applications, microstrip patch antennas (MPAs) are playing a vital role because of their various advantages such as ease to design, low cost, robust in nature, and simple to manufacture.

Low profile, high gain, lightweight, and simple structure antennas are the key requirements of modern wireless communication systems. This is to take care of reliability, mobility, and high efficiency [1]. MPA meets all these standards. MPA is suited to planar as well as nonplanar surfaces. Their design considerations are simple. However, their relatively narrow bandwidth limits their usage in particular systems. To overcome this, a modified rectangular MPA is presented here, mainly focusing on enhancing bandwidth (BW) and gain. The BW available in the range of mm-wave is capable of achieving a larger throughput transmission [2]. In [3] a compact MPA is presented having a BW of 1.1GHz at the center frequency of 28GHz. In [4], a conventional MPA antenna and slotted MPA are presented which offer the BW of 2.39GHz and 2.48GHz respectively. In current work, we present the modification of a conventional square microstrip patch antenna to achieve a BW of 5.12 GHz at an operating frequency of 28 GHz.

Next, the gain of MPA antenna is investigated. Research has been conducted to enhance the gain in various ways in [5]. One of the simplest solutions to enhance gain is to use the dielectric superstate. In [6] a dielectric superstate is used to enhance the gain by 4 dB. Similar to [6], we used the superstate made of a dielectric layer of Rogers TMM 10i material with relative permittivity $\epsilon_r = 9.8$ and $tan\delta$ =0.002 to enhance the gain. The gain enhancement from 6.81 dB to 10.73 dB has been achieved. For the same frequency of operation, the surface area of the MPA in [3] and [4] are 7.04 mm^2 and 9.9 mm^2 respectively. The proposed modified rectangular MPA has a surface area of 8.3 mm^2 with better bandwidth.

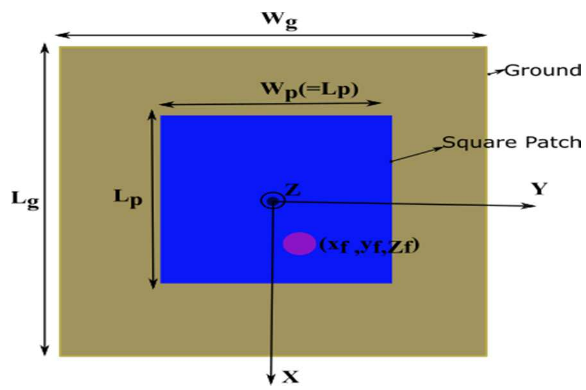

Figure 1. Conventional square microstrip patch antenna.

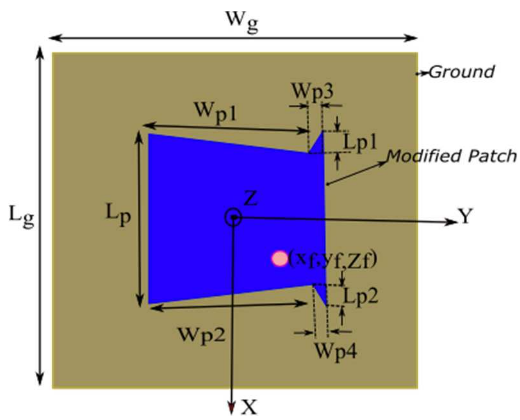

Figure 2. Modified rectangular microstrip patch antenna (MRPA)

TABLE I. SQUARE PATCH ANTENNA DESIGN PARAMETERS

Parameter	Value (mm)	Parameter	Value (mm)
Lp	2.68	Lg (=Wg)	5.36
Wp	2.68	yf	0
xf	0.55	h	0.5

TABLE II. Modified Patch Antenna Design Parameters

Parameter	Value (mm)	Parameter	Value (mm)
Lp	2.9	Wp4	0.12
Lp1	0.4937	Lg=(Wg)	5.8
Lp2	0.4901	h	0.5
Wp1	2.8	x_f	0.6
Wp2	2.78	y_f	0.6
Wp3	0.1	Z_f	0.5

In addition to the gain and BW, polarization purity is also a major concern in this work. Here, controlling the polarization of MPA is presented by which we can successfully eliminate unwanted polarization components with improved co-polarization.

2 Proposed Antenna Design Configuration

A square microstrip patch antenna (MPA) has been designed using Rogers R04232(tm) substrate with relative permittivity of 3.2, $tan\delta = 0.0018$ with a dimension of $L_g \times W_g \times h$ and a ground plane with dimension $L_g \times W_g$. The square patch was excited using a coaxial probe feed at (x_f, y_f, z_f) as shown in Fig. 1 and the optimized numerical values from the simulation in ANSYS Electromagnetics Suite 2016 full-wave solver are presented in Table I. S_{11}band width of 1.85 GHz is achieved for this square MPA as shown in Fig. 3. The gain plot for the central frequency is shown in Fig. 4 and the gain of 6.7 dB is achieved at $\theta, \phi = 0^o$.

In typical MPAs, length (L) is responsible for the resonating frequency, and width (W) is for bandwidth [8]. To enhance the BW, the square patch shown in Fig. 1, is modified as shown in Fig. 2. In this design, we varied the width of the patch (in forms of W_p's) at the two edges of the patch L_p. The numerical values of modified MPA are presented in Table II. Variation of W_{p1} is responsible for the lower band of frequency and variation of W_{p2} is responsible for the upper band of frequency. S_{11}bandwidth (-10 dB) of 5.12 GHz is achieved with this modified design which is shown in Fig. 3. Hence bandwidth enhancement has been achieved from 1.85 GHz to 5.12 GHz. The gain of this modified MPAs is shown in Fig.4.

Table III. FSS Design Parameters

Parameter	Value (mm)	Parameter	Value (mm)
X_F	13	g_F	1.4
Y_F	11.6	t_F	0.4

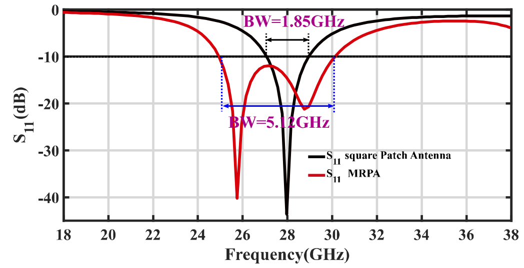

Figure 3. Comparison of $\mathbf{S_{11}}$ of microstrip patch antennas.

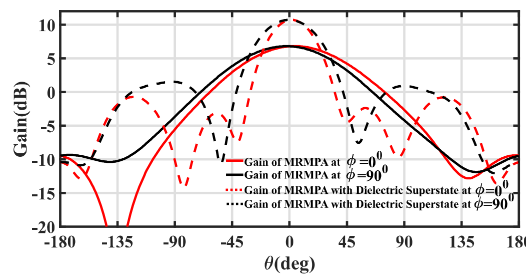

Figure 4. Gain of the proposed antenna. system.

3 Gain Enhancement using Dielectric Superstate

Next, gain enhancement of modified MPA is considered. Rogers TMM 10i™ with relative permittivity $\epsilon_r = 9.8$ and $tan\delta$ =0.002 is used as a dielectric superstrate. 1.7 mm thick dielectric superstate is placed at a height of 5.4 mm ($\sim \lambda/2$ corresponding to the frequency of 28 GHz) from the substrate of the modified MPA as shown in Fig. 5. With dielectric superstrate, the gain of the antennas at the direction ($\theta = 0^0$) is 10.73 dB. With this superstate gain has improved by 4 dB as shown in Fig. 4, but the S_{11} band width has reduced slightly due to the use of a dielectric superstrate. Superstrte works by reflecting the waves back

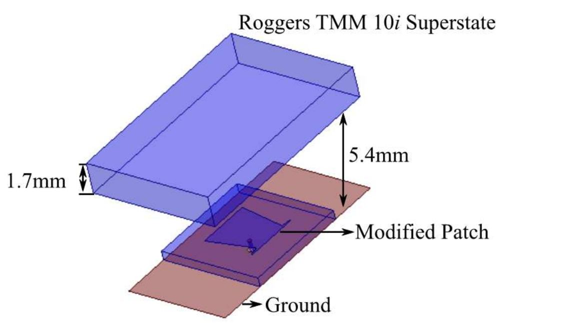

Figure 5. Proposed modified rectangular microstrip antenna (MRPA) with dielectric superstrate.

towards the feeding antenna. This reflected power interacts with the feed of the feeding antenna and that's why S_{11} band width changes.

4 Polarization Control using FSS

The two gain components of the antenna of Fig. 2 and antenna with dielectric superstate of Fig. 5 are presented in Fig. 7. Two orthogonal components are equally present on two sides of the operating band. The use of dielectric superstrate of Fig. 5 improved the gain but due to inherent nature of the superstrate both the co- and cross-polarizations of the antenna get enhanced. This leads to problems as many applications demand signals of high polarization polarity. Our next aim in this study is to suppress undesired cross-component of the radiated field. To suppress the undesired or one of the polarization

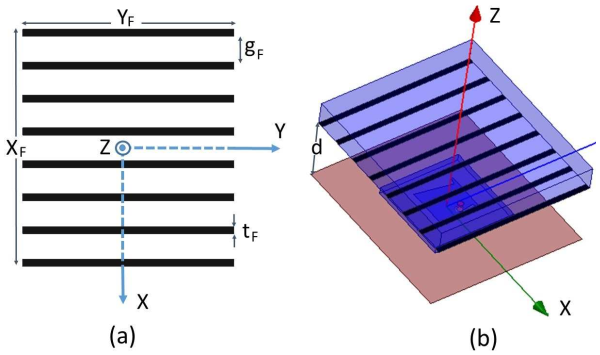

Figure 6. (a) Proposed FSS (b) Proposed FSS with dielectric are working as a superstrate on the MRPA

components a frequency selective surface (FSS) is presented as shown in Fig. 6 (a). The FSS design parameters are presented in Table III. The FSS is placed at a height of 4.5mm from the ground plane of MRPA with a rectangular dielectric (permittivity $\epsilon_r = 9.8$ and $tan\delta$ =0.002) slab of thickness 1.7 mm as shown in Fig. 6(b). The suppression of the cross-polarization component is shown in Fig. 7. The MRPA is exciting both X-

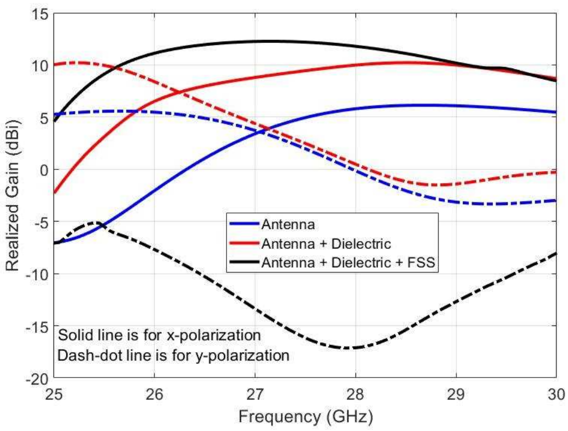

Figure 7. Two orthogonal components of gain of MRPA (of Fig. 2), MRPA with dielectric superstate (of Fig. 5) and MRPA with dielectric and FSS

polarization and Y-polarization but the FSS in Fig. 6(a) suppresses one component and improved the other component. The difference in gain between the two components is more than 12 dB throughout the band. In this way, this novel design FSS superstate not only suppresses the undesired polarization but also enhances the desired polarization of the radiated fields.

5 Conclusion

This paper has successfully modified a rectangular microstrip patch antenna to improve the S_{11}bandwidth at 28 GHz. This modification enhanced BW by 280% over the rectangular microstrip patch antenna. Next, the dielectric superstrate has been used to enhance the gain of the modified antenna. The addition of a superstrate improves the gain by 4dB (i.e., from 6.81dB to 10.73 dB) compared to the MPA. An FSS is proposed for reducing cross-polarization component and successfully enables to reduce cross-polarization by 12 dB from the co-polarization component over the band of 25 GHz to 30 GHz.

6 References

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