Design and Performance Analysis of High Gain Narrow Band Patch Antenna Array at X-Band

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Abstract The paper proposes a high gain narrow band array of rectangular microstrip patch antennas. Each element of the array is rectangular in shape. A high dielectric and low lossy material Rogers-3006 with dielectric constant 6.51, loss tangent of 0.002 and thickness 1 mm have been used as a substrate. 50 Ω microstrip line feed is used to exit the microstrip antenna. We cannot achieve high gain and directivity with single element so 8×1 patch antenna array designed to achieve high gain and directivity for intrusion detection application at precise operating frequency of X-Band. The patch array has been targeted for the application of "Intrusion Detection", where high gain, narrow bandwidth and higher directivity are needed.

Keywords Microstrip antenna · Corporate feed network · Antenna array X-Band

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1 Introduction

Antennas are a kind of transducers for converting input electrical energy into output electromagnetic energy as radiation [1]. Antennas are energy receiver to collect the electromagnetic energy from the free space and converting into electrical energy. Microstrip antenna has been used as pivotal in many microwave applications [2]. The microstrip antenna has substrate in between two radiating patches and ground plane. High dielectric constants of the substrate are helpful in miniaturizing the dimension of antenna.

Required gain and directivity cannot be achieved with a single patch antenna so 8×1 patch antenna array is designed to achieve high gain and directivity for intrusion detection application at X-Band. The corporate-fed network with quarter wave transformer is used to match patch element impedance to 50 Ω input impedance [3].

At X-Band of high-frequency range (8–12 GHz), the microstrip antenna has acted as an effective response. A rectangular shaped array [3–5] of microstrip patch antenna, fed with suitable line [3], using RO3006 material provides high gain as compared with Teflon and FR4.

2 Dimension of Array Antenna

The first case in the design of the array is the right choice of the patch [6]. The suitable dimensions are critical for the performance of the array antenna.

For an efficient radiation from the antenna, the dimensions (length and width) of the rectangular microstrip antenna is given by the following equations [7].

The width, W, is:

$$W = \frac{c}{2f} \times \sqrt{\frac{2}{(\varepsilon_{r+1})}} \tag{1}$$

Here, f is the resonant frequency and ε_r is the dielectric constant of the substrate. In our design, the substrate is chosen as Rogers-3006 with and ε_r of 6.51.

The length, L, is:

$$L = \frac{c}{2f}\left(\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\left[1 + 12\frac{h}{W}\right]}\right)^{\frac{-1}{2}} - 2\Delta L \tag{2}$$

The overall dimension is tabulated in Table 1.

The element can feed by single line or by multiple lines in a feed network arrangement so we refer to multiple lines in a feed network; it is a combination of corporate-fed network with quarter wave transformer as shown in Fig. 1 (8 × 1 array antennas),

8 × 1 array is shown in Fig. 1.

Table 1 Design parameter of single microstrip patch antenna for 9.65 GHz

Width of patch	7.93 mm
Length of the patch (L)	5.72 mm
Input resistance of patch	50 Ω
Width of microstrip line (w_o)	0.1 mm
Length of microstrip line	2 mm
Dielectric constant of the substrate	6.51 (RO3006)

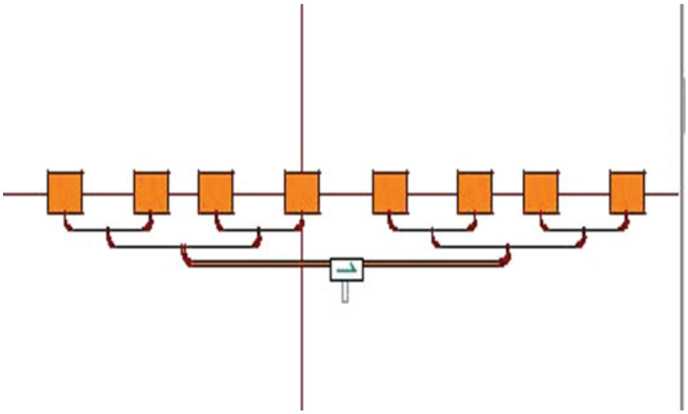


Fig. 1 Array of 8 × 1 microstrip square antenna

3 Results

A. **Return Loss**

This antenna has shown −17.76 dB return loss at 9.65 GHz resonant frequency which is shown in Fig. 2. At this frequency, antenna radiates maximum power and reflects minimum power.

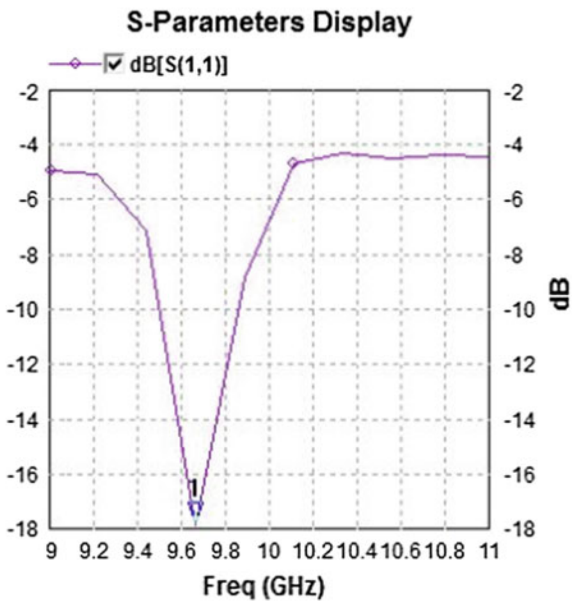
B. **VSWR**

VSWR is a measure of how much the mismatch in impedance happens. Figure 3 is the VSWR plot of our observation, and it reveals that VSWR obtained is 1.30:1. This is a good value because this ratio 1.30:1 is well within the 2:1 ratio of prescribed value of VSWR.

C. **Total Gain Versus Frequency**

Total gain of the antenna is 12.30 dBi for 9.65 GHz frequency as shown in Fig. 4.

Fig. 2 Return loss of 8 × 1 array antennas



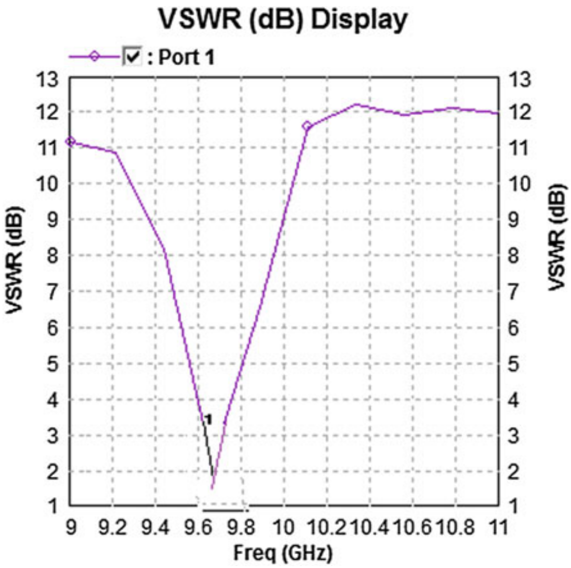


Fig. 3 Voltage standing wave ratio (VSWR) of array antennas

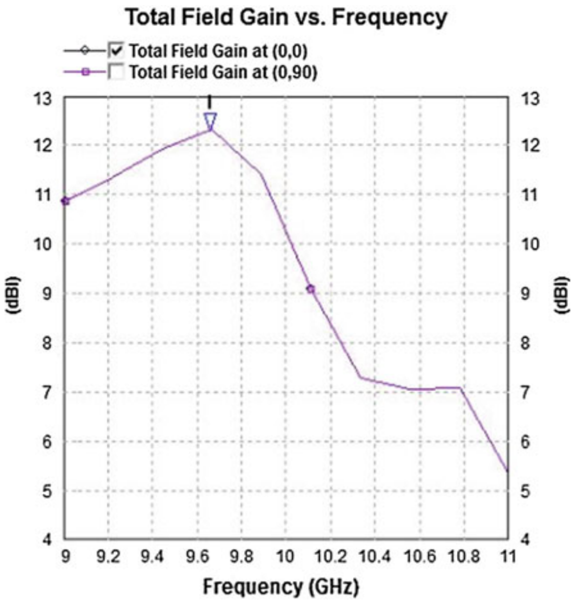


Fig. 4 Gain of 8 × 1 array antennas

4 Conclusion

Many applications in the areas basically of microwave sensors, the antenna should have very high directive characteristics, and the proposed array antenna is the one that fulfils this. An array antenna having multiple numbers of patches increases the gain (of 12.30 dBi), as obtained with our configuration. Hence, the given 8 $\times$ 1 patch antenna array gives enough confidence to use as intrusion detection sensor. The immediate further work is to build a prototype for lab testing and evaluation as intrusion detection sensor.

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