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Microstrip Patch Array Antenna Using a Parallel and Series Combination Feed Network

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***Abstract* - In this paper, we describe a 4 × 4 microstrip patch array antenna with a high gain and low side lobe level (SLL) using a parallel and series combination feed network with different power distribution ratios. Several quarter-wavelength impedance transformers are connected, and the power distribution ratio is controlled by adjusting the characteristic impedance of the feed network. The optimized 4 × 4 microstrip patch array antenna has a $|S_{11}| < -10$ dB impedance bandwidth of 220 MHz which is a fractional bandwidth of 2.1%. At 12.5 GHz, the antenna has a gain of 18.2 dBi and SLLs of –28.0 and –26.5 dB in the x-z and y-z planes, respectively. The size of the array antenna is 100 mm × 100 mm × 0.7874 mm ($3.5\lambda_o \times 3.5\ \lambda_o \times 0.028\ \lambda_o$ at 12.5 GHz).**

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***Index Terms* — Low side lobe level, microstrip patch array antenna, feed network.**

I. Introduction

Microstrip patch array antennas are widely used for a variety of applications because they offer good antenna performances and have a small size, low profile, and low cost. The feed networks of microstrip patch array antennas can be broadly categorized into parallel and series feed networks. A parallel feed network has the advantage of having a wide impedance bandwidth, but it is difficult to obtain high gain due to the loss from a long feed line length [1], [2]. In addition, there is a limit to reducing the side lobe levels (SLLs) due to unwanted radiation from the feed line [3], [4]. A series feed network has a small loss due to a short feed line length [5]–[7]. However, it is difficult to realize a desired power distribution ratio because the feed line width becomes very narrow when several radiation elements are connected to achieve the desired power distribution ratios. The parallel and series combination feed network can be designed by eliminating the disadvantages of each of the parallel and the series feed networks. Thus, the realization of the desired power distribution ratio by using the parallel and series combination feed network is much easier than the parallel or series feed network only.

In this paper, we describe the design of a 4 × 4 array antenna with a high gain and low SLL by controlling the power supplied to each microstrip patch. The optimized 4 × 4 microstrip patch array antenna has a $|S_{11}| < -10$ dB impedance bandwidth of 2.1% with a center frequency at 10.5 GHz. The gain of the array antenna is 18.2 dBi, and the SLLs are –28.0 and –26.5 dB in the x-z and y-z plane, respectively, at 10.5 GHz. The size of the array antenna is 100 mm × 100 mm × 0.7874 mm ($3.5\lambda_o \times 3.5\ \lambda_o \times 0.028\ \lambda_o$ at 12.5 GHz).

II. Array Antenna Structure and Characteristics

Figure 1 shows the proposed microstrip patch array antenna structure. In the design, a number of quarter-wavelength transformers are used to ensure that each output port has a desired level of power distribution ratio. The power is supplied by a coaxial line and is connected at the center of the whole feed line, which is implemented in a symmetrical manner with respect to the feed point. The substrate used for the design of the microstrip patch array is Rogers RT/Duroid 5880, with a dielectric constant of $\varepsilon_r = 2.2$, loss tangent of $tan\ \delta = 0.0019$, and thickness of $h = 0.7874$ mm.

The center frequency of each microstrip patch and feed network is designed to be at 10.5 GHz. The microstrip feed line is bent in some sections. Thus, the electrical length of the microstrip feed line connecting each node becomes one wavelength (λ). The width and length (W_p) of the microstrip patch are 9 mm, and the size of the designed array antenna is 100 mm × 100 mm × 0.7874 mm ($3.5\lambda_o \times 3.5\lambda_o \times 0.028\lambda_o$). Simulations were performed using ANSYS HFSS.

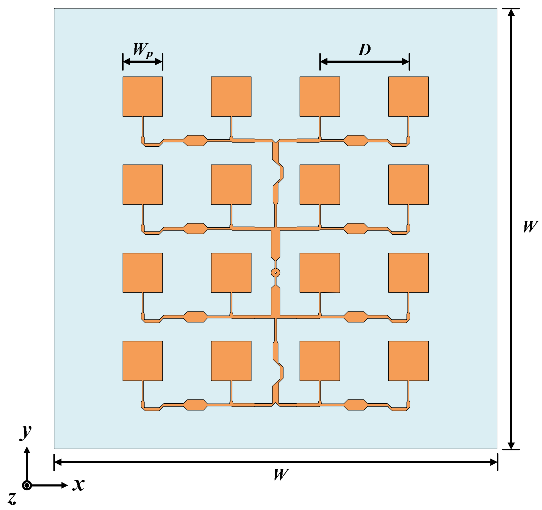
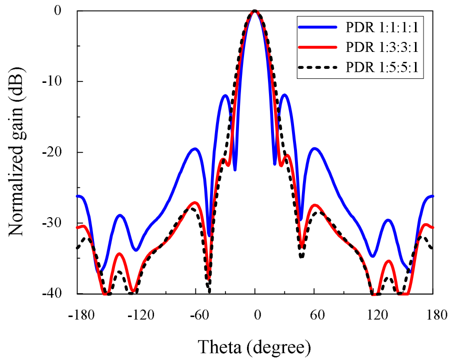


Figure 1. Geometry of the antenna.

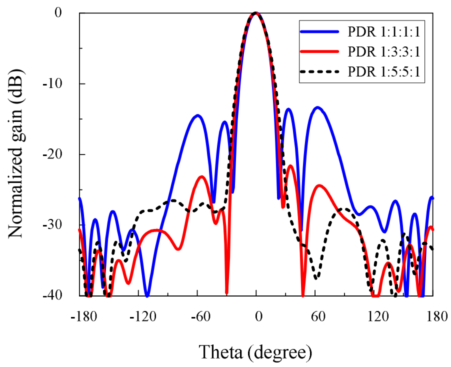
TABLE I. Gain and SLL of the array antenna at 10.5 GHz with respect to the power distribution ratio

PDR	Gain	SLL (x-z plane)	SLL (y-z plane)
1:1:1:1	18.8 dBi	–11.9 dB	–13.4 dB
1:3:3:1	18.8 dBi	–21.0 dB	–21.6 dB
1:5:5:1	18.2 dBi	–28.0 dB	–26.5 dB

Figure 2 compares the radiation patterns of the microstrip patch array antenna when the power distribution ratios are 1:1:1:1, 1:3:3:1, and 1:5:5:1. Table I shows the gain and SLL of the array antenna with each power distribution ratio. The SLL of the array antenna is highest when the power distribution ratio is 1:1:1:1, and the SLL decreases as the power distribution ratio increases.



(a)



(b)

Fig. 2. Radiation pattern of the 4 × 4 array antenna with variation of the power distribution ratio at 10.5 GHz: (a) x-z plane and (b) y-z plane.

Figure 3 shows the reflection coefficient of the optimized antenna as a function of the frequency. At a center frequency of 10.5 GHz, the reflection coefficient is –19.8 dB, and the impedance bandwidth for S_{11} less than –10 dB is 220 MHz, which is a fractional bandwidth of 2.1%. Figure 4 presents the radiation pattern of the optimized array antenna at 12.5 GHz. The gain is 18.2 dBi, and the SLLs are –28.0 and –26.5 dB in the x-z and y-z plane, respectively.

III. Conclusion

We designed a 4 × 4 microstrip patch array antenna with a high gain and low SLL using multiple quarter-wavelength impedance transformers in a parallel and series combination feed network. Using the proposed feed network, the desired power distribution ratio can be achieved by controlling the characteristic impedance of each feed line. The advantages of the proposed design include a smaller loss in the feed network as compared with that in a parallel feed network, and fabrication is easier than a series feed network. The designed microstrip patch array antenna has a bandwidth of 220 MHz, a gain of 18.2 dBi and SLLs of –28.0 and –26.5 dB in the x-z and the y-z planes, respectively, at 10.5 GHz.

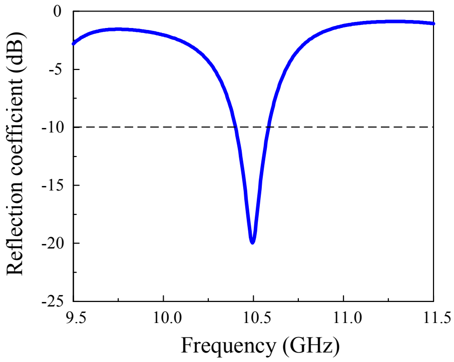


Fig. 3. Reflection coefficient of the optimized antenna.

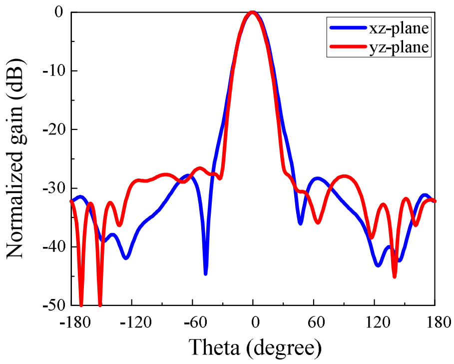


Fig. 4. Radiation pattern of the optimized antenna at 10.5 GHz.

Acknowledgment

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