Microstrip Patch Antenna Array at 5.8 GHz for Point to Point Communication

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Abstract - This paper described the design of microstrip patch array antenna with operating frequency at 5.8GHz for point to point communication. The array of four microstrip rectangular patch antennas with inset feed based on quarter-wave impedance matching technique were designed, simulated, fabricated and measured with the aid of microwave office software. The simulation and measurement result met the IEEE 802.11a standard and able to operate in upper UNII band for point to point communication. The 4x4 array has a return loss of -30.42 dB with 15% bandwidth. The gain obtained from simulation is 16 dB with 9^{o} half power beamwidth (HPBW).

Keywords: Array Antenna, Microstrip Antennas, Methods of Moment, inset feed

1. Introduction

Microstrip antennas are currently one of the fastest growing segments in the telecommunications industry and promise to become the preferred medium of telecommunications in the future. Microstrip antenna technology began its rapid development in the late 1970s. By the early 1980s basic microstrip antenna elements and arrays were fairly well establish in term of design and modeling [1]. In the last decades printed antennas have been largely studied due to their advantages over other radiating systems, such as light weight, reduced size, low cost, conformability and possibility of integration with active devices.

Wireless communication has experienced an enormous growth since it allows users to access network services without being tethered to a wired infrastructure. The two wireless systems that have experienced the most rapid evolution and wide popularity are the standard developed by IEEE for wireless local area networks (WLANs), identified as IEEE 802.1l and the Bluetooth technology. WLAN point to point application is based on IEEE 802.11a standard and operates in the upper Unlicensed National Information Infrastructure (UNII) band (5.725 to 5.875 GHz). Point to point communication brings a crucial responsibility to antennas since they are expected to provide the wireless transmission between those devices [2].

Besides being able to indicate good signal to noise ratio and immunity to noise, the antennas in microwave links will portray compact structures and ease of construction to be mounted on various devices. In high performance point to point application where size, weight, cost, performance, ease of installation are constraints, low profile antenna is very much required. To meet these requirements, microstrip antenna is preferred.

Although microstrip antenna has several advantages like low profile, light weight and simple to manufacture, it also has several disadvantages such as low gain, narrow bandwidth with low efficiency. These disadvantages can however be overcome with intelligent designs incorporated in whole antenna structures. One of the ways to overcome these problems is by constructing many patch antennas in array configuration.

2. Antenna Array Structure

Typical example of an array is shown in Figure 1. Usually the term array is reserved for an arrangement in which the individual radiators are separated as shown in Figure 1 (a-c). However the same term is also used to describe an assembly of radiators mounted on a continuous structure, shown in Figure 1(d). The total field of the array is determined by the vector addition of the fields radiated by the individual elements. This assumes that the current in each element is the same as that of the isolated elements. This is usually not the case and it depends on the separation between the elements. To provide very directive patterns, it is necessary that the fields from the elements of the array interfere constructively (add) in the desired direction and interfere destructively (cancel each other) in the remaining space [3]. Ideally this can be accomplished, but practically it is only approached. In an array of identical elements, there are five controls that can be used to shape the overall pattern of the antenna.

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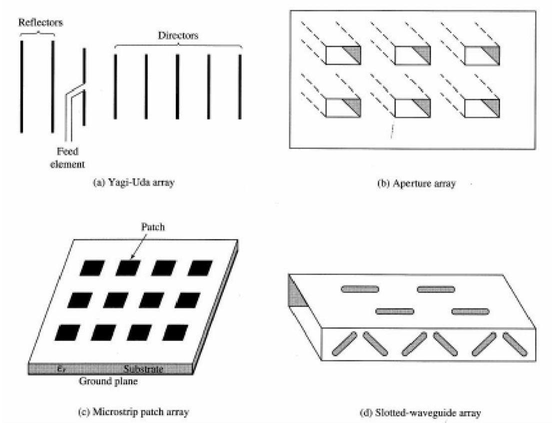


Figure 1: Typical wire, aperture and microstrip array configuration [3].

In general the radiation pattern of microstrip antenna array can be determined once the aperture is known. The amplitude and phase distribution at each element is usually determined from the intended application. Existing methods to feed microstrip arrays can be categorized into parallel and series feed. The parallel or corporate feed has a single input port and multiple feed lines in parallel with the output port. Each of these feed lines is terminated at an individual radiating element. The series feed usually consists of a continuous transmission line from which small proportion of energy are progressively coupled into the individual element disposed along the line. The series feed constitutes a traveling wave array if the feed line is terminated in a matched load.

For a uniform aperture distribution, the power is equally split at each junction of a corporate feed. However different power divider ratios can be chosen to generate a tapered distribution across the array. The disadvantages of this type of feed is that it requires long transmission lines between radiating elements and the input port hence the insertion loss of the feed network can be prohibitively large thereby reducing the overall efficiency of the array. In this paper the corporate feed with inset feed is being discussed.

3. Design consideration for 4x 4 Microstrip Patch Antenna Array

The design of the antenna array is started by selecting the suitable patch shape of the antenna. The rectangular patch is chosen because it simplifies the analysis and performance prediction. This antenna has been designed to operate at 5.8 GHz with input impedance of 50 Ω, using FR4 (ε_r = 4.5) and height (h) of 1.6mm. The design starts with the simple rectangular microstrip antenna with inset feed. Then, the microstrip antenna is simulated using the Microwave Office software. After the simulation, the microstrip antenna is fabricated using FR4, with dielectric constant (ε_r = 4.5) and height of 1.6 mm. Finally the microstrip antenna is measured using the network analyzer and the measured values are compared with the simulated values.

The single element design is shown in figure 2. The dimension of the patch is 15.5 mm x 11.5 mm with inset feed at 4.3 mm. The width of the transmission line is 3 mm.

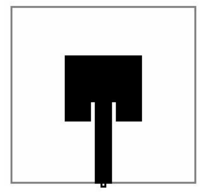


Figure 2: Single element rectangular patch antenna.

The equation below is used to calculate the length of patch.

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta l \qquad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \qquad (2)$$

$$\Delta l = \frac{0.412h\left(\varepsilon_{eff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)} \qquad (3)$$

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{1+\varepsilon_r}} \qquad (4)$$

where;

L= the length of the patch antenna

W = the width of the patch antenna

ε_{eff} = effective substrate

Δl = fringing field of the antenna

Figure 3 shows the configuration of the 4 x 4 microstrip patch array antenna design at 5.8 GHz. A coaxial feed is connected to the center of the array from the other side of substrate. Power divider and quarter-wave transformer impedance matching sections are used to couple the power to each element for radiation.

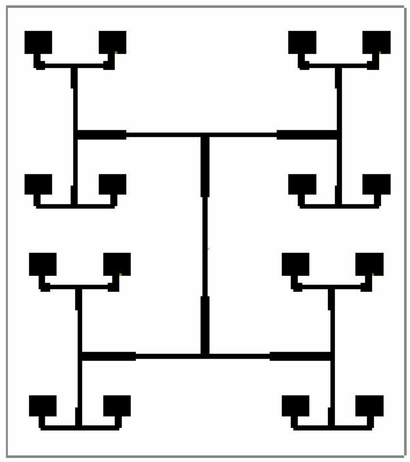


Figure 3: 4 x 4 microstrip patch antenna array.

T junction power divider and quarter wave transformer impedance matching sections were used to couple the power to each element for radiation. The output line impedances Z_1 and Z_2 can then be selected to provide various power divisions ratio. Thus for 50 ohm input line a 3 dB power divider can be made using two 100 ohm output lines.

4. Result and Discussion

Figure 4 shows the input return loss between simulation and measurement. The simulation result give a return loss of -43 dB at 5.88 GHz while the measurement result gives a return loss of -30 42 dB at 6 GHz. The bandwidth for simulation and measurement are between 11% and 15%.

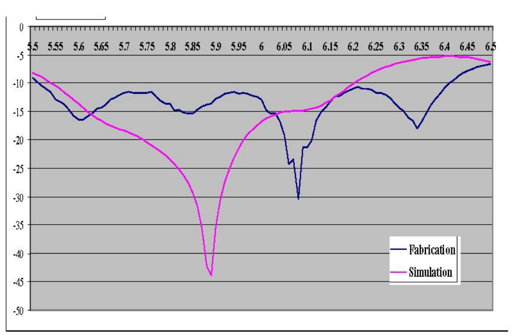
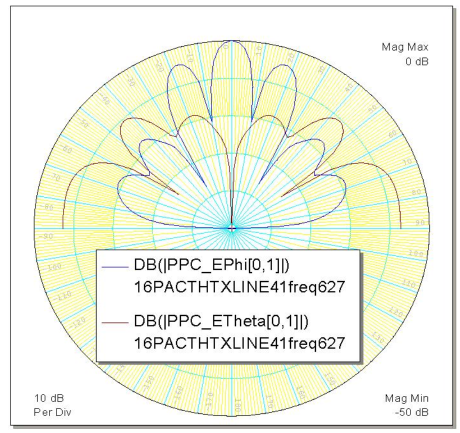


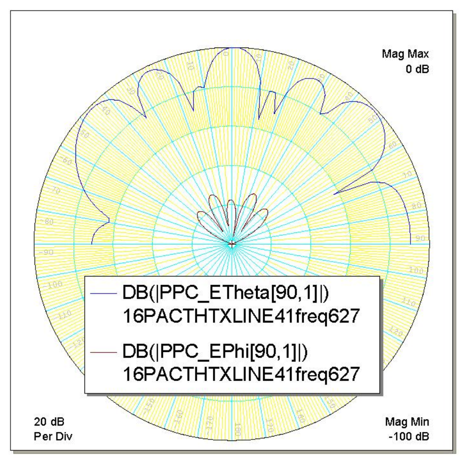
Figure 4: Input return loss of the 4x4 microstrip patch antenna array.

Figure 5 (a) and (b) show simulation result for E-Plane and H-Plane radiation pattern of 4 x 4 Array. Half power beam width (HPBW) obtained from the E-plane and H-plane radiation pattern is 8.92 degree and 9.33 degree respectively. The Gain obtained from the E-plane and H-plane radiation pattern is 16.071dB.

The radiation pattern for E plane is narrower compared to the H plane. The cross isolation between E and H plane from simulation is slightly different. The cross isolation for H plane is much better compared to the E Plane radiation pattern.



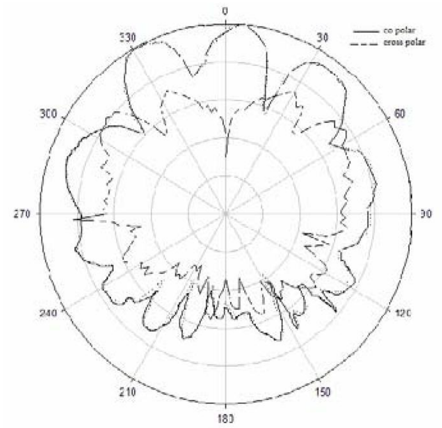
(a)



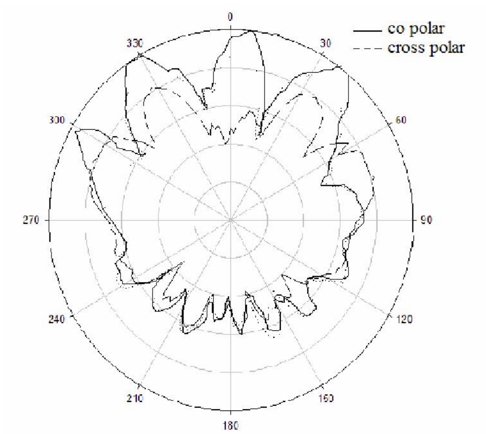
(b)

Figure 5: Four by four microstrip patch antenna array simulated radiation pattern,
(a) E Plane cut
(b) H Plane cut.

Figure 6 shows the E Plane and H Plane radiation pattern measurement. The co and cross polar isolation is nearly 15 dB. The beam width (HPBW) of the radiation pattern is 8^{o} and 7^{o} respectively. The simulated and measured results show a very similar E and H plane pattern even though the cross polar isolation has a difference radiation pattern



(a)



(b)

Figure 6: Measured radiation pattern of the 4x4 microstrip patch antenna array
(a) E plane
(b) H Plane

5. Conclusion

Four by four (4 x4) array of microstrip antenna with inset feed has been designed, simulated, fabricated measured and compared in this paper. The simulated and measured result shows that the return loss of the antenna is within the designed frequency band. A half power bemwidth (HPBW) value of about 9 to 10 and a gain of 16 dB (simulated) and 10 dB(measured) , compared to a horn antenna. The slightly shifted frequency is due to the FR4 board that has ε_r varies from 4.0 to 4.8.

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