Dual Polarized Antenna Array on a Very Thick Substrate

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Abstract- ***Microstrip antennas are widely used in the wireless industry due to their high gain and low profile. Dual polarized antennas can obtain higher data rates, and a more stable link between customer and provider in telecommunications. Conventional dual polarized antennas consist of two independent elements positioned orthogonal to one another, increasing cost, size, and weight. In this paper, we will discuss the design of a dual polarized antenna array which uses dual polarized single element radiators on a very thick substrate material of various ε_r using probe feeding technique. An ETI patent pending feed line design is introduced to increase cross polarization rejection while scanning, further increasing the reliability of wireless communication.***

Index Terms- Isolation, Square Patch, Thick Substrate, cross polarization cancellation

I. Introduction

There are many parameters to consider when designing and constructing a microstrip antenna array on a very thick substrate. The feed method, size of the element, ε_r and thickness of the substrate material, and the location of the feed point are all crucial in designing a successful microstrip antenna. In this paper, the design parameters will be discussed in the design of a square dual linearly polarized array to operate from 2.4 to 2.5 GHz.

II. Design & Results

Low loss substrate material was chosen to achieve higher efficiency. Rogers 6006 .300" with ε_r =6.15 was initially used for the design. After some prototyping, the antenna array was heavy and efficiency versus substrate thickness was lower compared to that of a lower ε_r substrate. The material was switched to Taconic TLY-5 .250" with ε_r=2.2 for this design, but both patch sizes were redesigned.

A probe feed microstrip network was used because of its simplicity, but this technique provides a narrow bandwidth due to the inductance of the probe. Equation 1 is a good estimation for probe feed inductance [1] where h is the substrate thickness, c and c_0 are the speed of light in free space and in the dielectric material, and d is the diameter of the probe.

$$X_L = \frac{60\omega h}{c_0} ln\left(\frac{2c}{\omega d}\right)$$

Equation 1

A thicker probe is usually desired to reduce the inductance to provide a better match for the network by reducing the radiation loss, but is more difficult to work with. The 50Ω feed location was found using Equation 2 [2] where L is the length of the patch, X_0 is the feed location from the edge, and Ω is the resistance.

$$\Omega = cos^4\left(\frac{\pi X_0}{L}\right)$$

Equation 2

The dimension of the square patch was difficult to determine because traditional microstrip equations are not accurate with thick substrate material. Equation 3 gives a rough estimation of the resonating frequency of a patch [3].

$$f_{res} = \frac{.49c_0}{\sqrt{\varepsilon_r}\, L}$$

Equation 3

However, this equation does not take into account the thickness of the substrate material and the inductance of the probe feed. A more accurate equation that takes into account the thickness of the material is given by Equation 4 [4].

$$f_{res} = \frac{0.5c_0}{\sqrt{\varepsilon_r}(L + 2\Delta L)}$$

$$\Delta L = h\,\frac{0.412\,(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1 + 10\frac{h}{W}}}$$

Equation 4

Using a CAD program, two patch sizes were simulated with different ε_r material and tuned by trial and error to the correct resonant frequency. The final patch size was of 3.83cm for ε_r =2.2and 2.11 cm for ε_r =6.15. The simulated results and experimental result are shown in Figure 1.

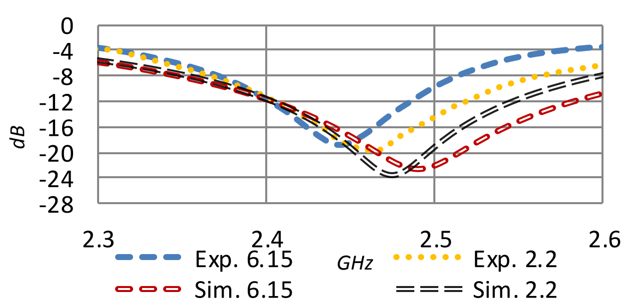

Figure 1 Return Loss of Substrate Materials and Patch Sizes

The actual resonant frequency was lower than the simulated results due to the inductance of the probe. The resonant frequency can be shifted up by adding capacitance to the circuit.

An experiment was conducted with a square patch element 3.94cm by 3.94 cm. A ¼" sleeve made with ε_r =6.15 material was experimented with to tune the antenna's resonant frequency with a larger patch. This sleeve was put around the probe to create a capacitance to counteract the inductance of the probe. Data was taken with and without the dielectric sleeve. Figure 2 shows the measurement of the reflection coefficient of the element with and without the bushing.

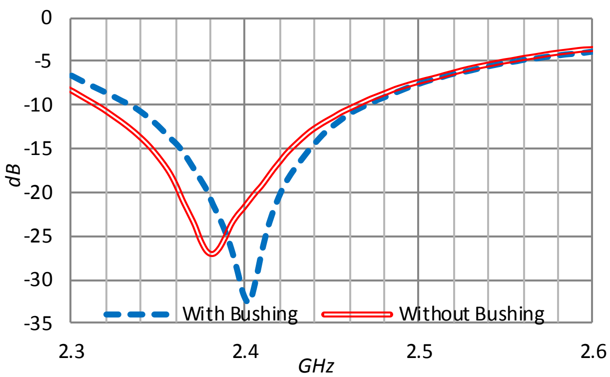

Figure 2 Reflection Coefficient with and without Bushing

The impedance match was better at resonant frequency, but the -10dB bandwidth of the element decreased slightly from 1.496 % to 1.492%, but still covered the 100MHz band.

ETI's feed line technique (patent pending) was introduced to achieve high cross polarization rejection while scanning in elevation. The feed point location was fed 180° out of phase with the adjacent radiating element. The concept is shown in Figure 3.

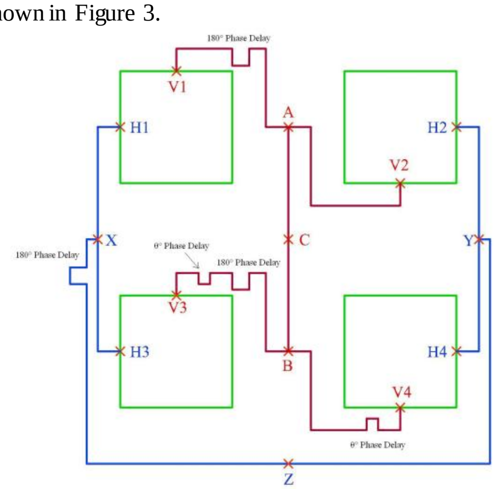

Figure 3 ETI Feed Technique for Arrays

The feed lines need an additional 180° phase shift in addition to the phase shift for the desired scan angle. The basic concept of this feed is while one polarization is being employed, the other polarization is cancelled. The graph in Figure 4 shows the co- and cross-polarization of the antenna without the feed technique.

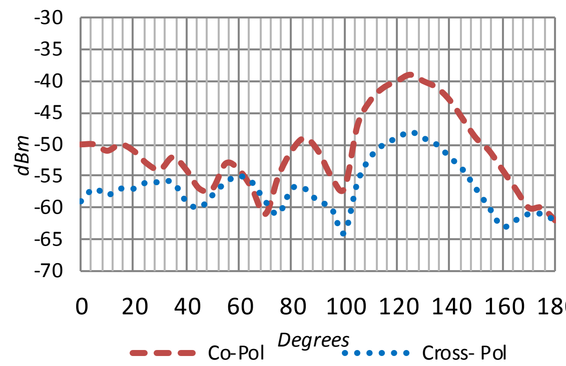

Figure 4 Cross-Polarization and Co-Polarization Radiation Pattern of Array without Cancellation

The cross polarization is 9dB less at the main beam. With the feedline technique the received cross polarization was reduced by more than half. The graph in Figure 5 shows the co and cross polarization of the antenna with the feed technique.

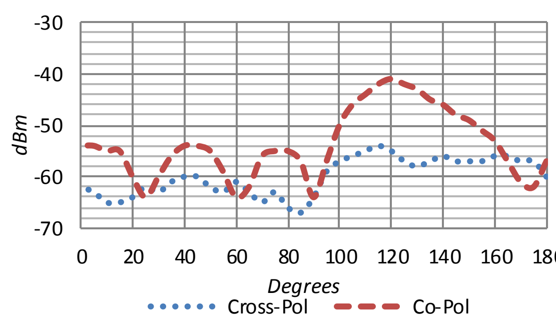

Figure 5 Cross-Polarization and Co-Polarization Radiation Pattern of Array with Cancellation

When cancellation technique was used, isolation was increased by approximately 4dB at the main beam. This technique can be used for scanning, and non-scanning arrays to reduce cross polarization interference and produce a more stable link.

III. Conclusion

A dual polarized element antenna array was designed and constructed using probe line feed on a very thick substrate material. To achieve a better match, the reactance from the probe needs to be counter acted with a capacitance. This can be done with a sleeve of high dielectric material. Equations for the dimension of the patch found in textbooks are not as accurate as CAD software simulation in finding the resonant frequency of a microstrip antenna on very thick substrate. With the use of ETI's patent pending feedline technique, cross polarization isolation was increased by 4dB

References

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