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Planar Microstrip Array Antenna with Rectangular Configuration Fed with Chebyshev Power Distribution for C-Band Satellite Application

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***Abstract*—A C-band satellite receiving antenna requires high gain and narrow beamwidth at around 4 GHz frequency. Microstrip antennas, which have a low profile characteristic, have remained promising for various wireless applications. This paper proposes a rectangular patch antenna design that arranged by planar arrays and Chebyshev feeding technique to achieve high gain and low sidelobe levels for C-band applications. The antenna design is simulated and parameterized by using CST Microwave Studio. The results show an increase of gain and decrease in the side lobe level obtained from the model using the Chebyshev technique compared to the uniform power divider technique. With the proposed feeding of the 4x4 array antenna, it achieves gain and sidelobe level of 16 dB and -28.5 dB, respectively. The 8x8 array antenna with the Chebyshev technique reaches gain performance, and sidelobe level of 20.2 dB and -24.3 dB, respectively. Meanwhile, the 16x16 microstrip array antenna can achieve gain and sidelobe level of 24 dB and -23.8 dB. These results indicate that the proposed array design can contribute to design an antenna suitable for C-band applications.**

Keywords*—*C band, antenna array, rectangular patch, Chebyshev

I. Introduction

An antenna is an essential component for satellite communication. For this application, the system requires an antenna that has high gain and narrow beamwidth. Generally, a C band satellite communication system uses a type of satellite dish antenna. The parabolic antenna has a high gain performance, but it has a large reflector dimension. By utilizing a microstrip array antenna that is a low-profile and low-cost characteristic but has a high gain performance, it can be another alternative of satellite receiver antenna.

Microstrip array antennas have also been considered and developed as satellite data receiving antennas [1] [2] [3]. The array antenna technique is used to get high gain, which is essential in a satellite system [4] [5] [6]. The use of a 16x16 microstrip array antenna can obtain up to 27 dBi gain [4]. One key to achieving a high requirement is to consider a particular feeding technique [7]. Point-to-point communication such as long-distance communication between satellites and earth stations requires an antenna type that has the characteristics of high gain, single narrow beamwidth, and low side lobe. Some antenna synthesis methods that can be used to meet these specifications are by using: Binomial method [8] [9], Dolph-Chebyshev method [10] [11] [12] [13], and Taylor line source method [14]. The purpose of Dolph-Chebyshev antenna synthesis technique due to its ease of development, modification, simple to practice and is proven to be able to get high gain, narrow beamwidth and small side lobes [15] [16] [17]. The Chebyshev technique has been successful in reducing the side lobe to -40 dB [15]. This paper study a rectangular configuration of microstrip array antenna design, which is fed with the Chebyshev technique to distribute power by the different square level of each patch array position could produce a high gain, narrow beamwidth, and a small sidelobe level.

II. Design of Planar Microstrip Array Antenna

A. Antenna Design Considerations

Microstrip antenna is designed to work at a frequency of 4 GHz as the C band satellite receiving antenna resonant frequency. The considered substrate material is FR-4 double layer with its dielectric constant value εr and substrate thickness of 4.3 and 1.6 mm, respectively. Simulation and parameterization conducted by using CST software are to achieve the expected parameters.

This study considers three rectangular array configurations, which are 4x4, 8x8, and 16x16 using rectangular patch elements. The used feeding technique is Chebyshev Distribution Design, which is expected to reach desired antenna performances, such as high gain, narrow beamwidth, and small side lobes level.

B. Single Element Microstrip Antenna Design

After determining the value of resonance frequency and substrate material used to make the microstrip antenna then using equations (1) and (2), we can find the initial estimated width and length of the rectangular patch.

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$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r + 1}} \quad (1)$$

$$L = \frac{c}{2fr\sqrt{\varepsilon r}} \quad (2)$$

Figure 1 shows the structure of a single element microstrip antenna. The patch width (W), the patch length (L), the substrate width (2W), the substrate length (2L), the substrate thickness (h), the conductor thickness (t), the microstrip line width (Wf), the length of microstrip line (Lf), the width of inset feed (Wi), and the inset feed length (Li) are 23.036 mm, 17.599 mm, 46.072 mm, 35.198 mm, 1.6 mm, 0.035 mm, 3.137 mm, 8.7994 mm, 1 mm, and 4.4 mm, respectively. These approximation values are simulated and characterized to reach the most optimum parameters.

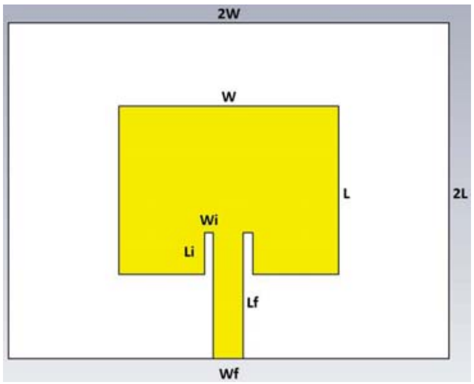

Fig 1. Single element microstrip antenna

C. *Chebyshev Planar Antenna*

The Chebyshev feeding technique is considered to produce a radiation pattern with narrow beamwidth and a small sidelobe level. The desired sidelobe level is to reduce unexpected radiation beam energy besides the main beam. Figure 2 shows the Chebyshev planar array technique used in the design of microstrip array antenna. It uses the unequal power divider method. The ratio of the amplitude consists of the first and second squares for the 4x4 array configuration. For the 8x8 array configuration, it includes the first to fourth. The 16x16 array configuration is divided into the ratio of the amplitude ratio to the beginning to eight square. The length between patches is a half-wavelength (λ/2).

TABLE I. AMPLITUDE-RATIO OF CHEBYSHEV PLANAR ARRAY

Array Antenna	**Chebyshev planar array current excitation weight**
4x4	0.576 : 1 : 1 : 0.576
8x8	0.58 : 0.66 : 0.875 : 1 : 1 : 0.875 : 0.66 : 0.58
16x16	0.1124 : 0.2055 : 0.3532 : 0.5265 : 0.7036 : 0.8577 : 0.9627 : 1 : 1 : 0.9627 : 0.8577 : 0.7036 : 0.5265 : 0.3532 : 0.2055 : 0.1124

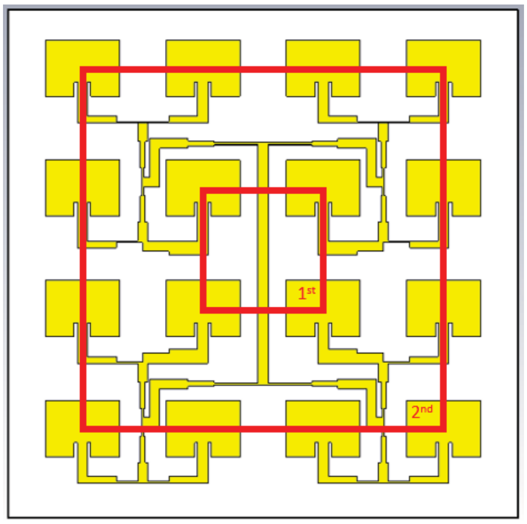

Fig. 2 Chebyshev planar array technique

III. Result and Discussion

The microstrip array antenna considers feeding of coaxial probe technique. Figure 3 shows the graph of the S11 parameter. By considering a limit of -10 dB, it indicates that the antenna working frequency is in a frequency range of 3.8776-4.0388 GHz with its bandwidth is 161.2 MHz.

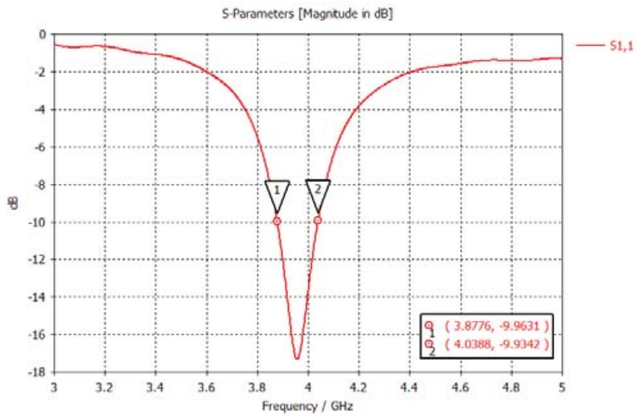

Fig. 3 Single element microstrip antenna Return Loss (S11) parameter

Figure 4 shows the radiation pattern at a frequency of 4 GHz. In the direction of phi = 0, the 4x4 array antenna with uniform excitation has gain and sidelobe level respectively of 11.9 dB and -13.1 dB. Figure 5 shows a radiation pattern at a 4 GHz frequency at the direction of phi = 0 for the 4x4 microstrip array antenna with the Chebyshev excitation has gain and sidelobe level of 16 dB and -28.5 dB, respectively. The simulation result between uniform excitation technique and Chebyshev planar array excitation show that for the 4x4 microstrip antenna arrays there is an increase of gain 4.1 dB and a side lobe level suppression of 15.4 dB.

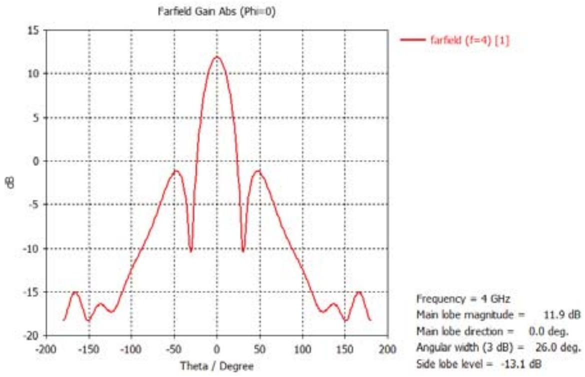

Fig 4. Radiation pattern 4x4 microstrip array antenna with uniform excitation

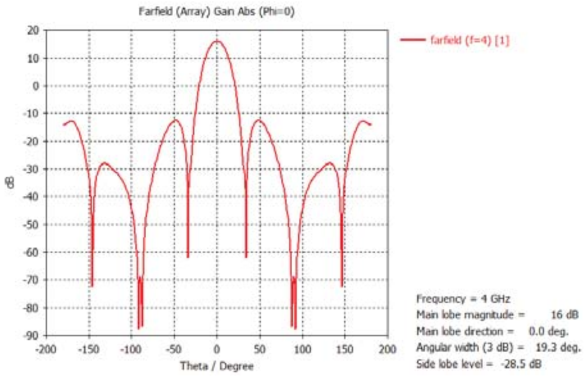

Fig 5. The Radiation pattern unequal power divider 4x4 microstrip array antenna

Figure 6 shows the radiation pattern at a frequency of 4 GHz in the direction of phi = 0 for the 8x8 microstrip array antenna with uniform excitation. It obtains a gain of 19.9 dB and a side lobe level of -13.7 dB. Figure 7 shows a radiation pattern at a 4 GHz frequency the direction of phi = 0 for the 8x8 microstrip array antenna with the Chebyshev planar array excitation has a gain of 20.1 dB and a side lobe level of -24.3 dB. For the 8x8 microstrip antenna array, there is an increase of antenna the gain of 0.2 dB and a side lobe level suppression of 10.6 dB.

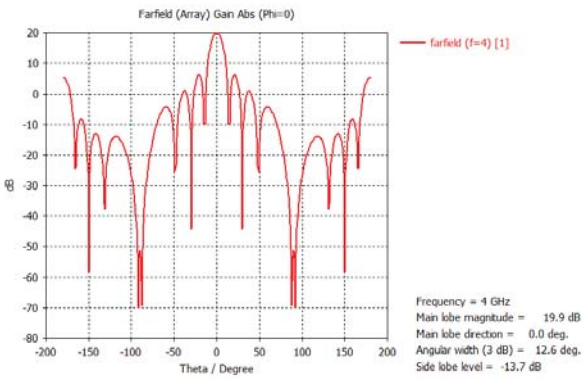

Fig 6. Radiation pattern 8x8 microstrip array antenna with uniform excitation

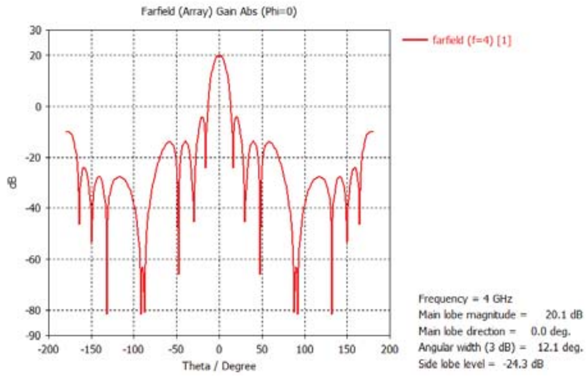

Fig 7. The Radiation pattern unequal power divider 8x8 microstrip array antenna

Figure 8 shows the radiation pattern at a frequency of 4 GHz in the direction of phi = 0 for the 16x16 microstrip array antenna with uniform excitation. This configuration obtains a gain of 21.7 dB and a side lobe level of -13.4 dB. Figure 9 shows that a radiation pattern at a frequency of 4 GHz in the direction of phi = 0 for the 16x16 microstrip array antenna with the Chebyshev planar array excitation has a gain of 24 dB and a side lobe level of -23.8 dB. The 16x16 microstrip antenna indicates an increase of antenna 2.3 dB gain and a side lobe suppression of 10.4 dB.

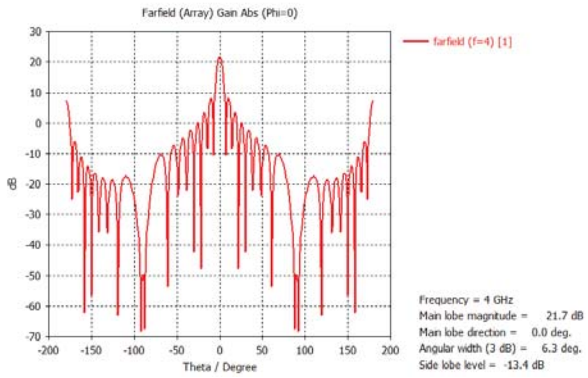

Fig 8. Radiation pattern 16x16 microstrip array antenna with uniform excitation

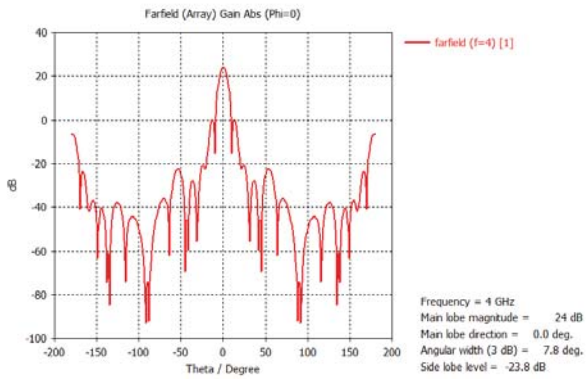

Fig 9. The Radiation pattern unequal power divider 16x16 microstrip array antenna

IV. Conclusion

High Gain Planar Rectangular Microstrip Array Antenna Based on Chebyshev power distribution has been designed and simulated by using CST software. With the proposed feeding of the 4x4 array antenna, it achieves gain and sidelobe level of 16 dB and -28.5 dB, respectively. The 8x8 array antenna with the Chebyshev technique reaches gain performance, and sidelobe level of 20.2 dB and -24.3 dB, respectively.

Meanwhile, the 16x16 microstrip array antenna can achieve gain and sidelobe level of 24 dB and -23.8 dB. The simulation result between uniform excitation technique and Chebyshev planar array excitation show that the feeding method can improve antenna performance in term of gain improvement and sidelobe level suppression. These results indicate that the proposed array design can contribute to design an antenna suitable for C-band applications.

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