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Development of Low Sidelobe Level Array Antenna for Synthetic Aperture Radar Sensor

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Abstract. The radiation pattern of the array antenna is an important characteristic in the synthetic aperture radar (SAR) sensor to maintain the quality of the images. In this work, an array antenna consists of five elements square microstrip antenna (SMA) having a low sidelobe level for SAR sensor is presented. The proposed antenna is designed to propagate in circular polarization with a corner-truncated technique. The low sidelobe level is obtained by implementing the Chebyshev polynomial to distribute the power to each element of the patch. For five elements square array antenna, the simulated axial ratio bandwidth (<3 dB) of about 11.2 MHz (0.88 %), which is consistent with the measured fabricated model of 10.5 MHz (0.83 %). The maximum sidelobe levels of the proposed antenna for measurement and simulation are about 20.0 dB and 21.5 dB, respectively. The both measured and simulated results are in line with the theoretical design made by using Chebyshev polynomial of 20 dB. The low side lobe level and reasonable axial ratio bandwidth indicate the antenna is satisfying the specifications of SAR sensor.

1. Introduction

A Synthetic Aperture Radar (SAR) sensor has played an important role in current remote-sensing technology. Various applications such as land mapping, land use, oceanography, and disaster monitoring are the implementing of this technology. Even further, the SAR sensor can be operated to measure the changing in the earth surface to millimeter accuracy [1]. As compare with the detection radar, the SAR sensor has a complex system due to the image generating as a result. In image construction, the SAR system receives the back scattering signal from the object or target area. The radiation pattern of the array antenna is an important characteristic in the synthetic aperture radar (SAR) sensor to maintain the quality to the images.

The low sidelobe level of the antenna is one of the critical parameters in radiation pattern to satisfy the SAR sensor requirements [2]. The high sidelobe level is potential to produce the error recorded data and resolution degradation of the SAR images. In mountainous areas or city with high buildings, the backscattering signal from sidelobe can be captured by the sensor causing errors data in recording the signal from the main lobe as illustrated in Figure 1. As can be seen in Figure 1, the backscattering signal from the sidelobe can be recorded by SAR sensor and disrupt the target signal from the mainlobe.



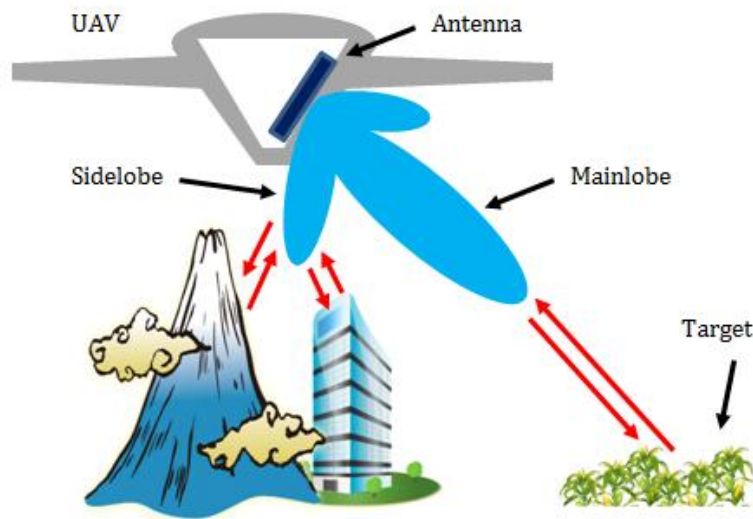


Figure 1. Illustration of the sidelobe effect on the data recording.

In previous work [3]–[6] several arrays antenna has been developed for the SAR sensor. The performance of the antenna, however, was not satisfactory in terms of the sidelobe level. In general, the high sidelobe is found in radiation pattern of the antenna with the sidelobe level of 12 dB. The sidelobe effect can be overcome by managing the difference between sidelobe and main lobe higher. Therefore, the compression of the sidelobe is obligatory for be done to avoid an error in recording data of the SAR sensor.

The purpose of this work is to present the development of low sidelobe level array antenna for SAR sensor. The low sidelobe level is obtained by arranging the power distribution of each element of the radiator. A Chebychev polynomial is adopted to distribute the power in the feed network of the proposed antenna. The coefficients of excitation are implemented in managing the weight of the power divider in the fed network in reduction the sidelobe level. The five elements Square Microstrip Antennas (SMA) are arranged in 1x5 array configuration and designed for of 20 dB sidelobe level. A corner truncated and proximity fed method are employed in generating the circular polarization. The circular polarization is beneficial since the future SAR requires a sensor that insensitive to Faraday rotation effect and produces more information from the target. The proposed antenna is operated in L-Band (1.27 GHz) and planned to be installed onboard an Unmanned Aerial Vehicle (UAV). In next section, the description of the SAR sensor will be presented. The design of proposed antenna and research result will be discussed in section three and four, respectively. Finally, the conclusion from this work will be presented in the last section.

2. SAR Sensor

In general, the SAR sensor consists of several parts, which is a transmitter (Tx), a receiver (Rx) and antennas as shown in Figure 1 [7]. The transmitter sub-system consists of a I-Q generator, an up-converter, a power amplifier (PA), switch, band-pass filters (BPF), High-power amplifier (HPA) and an isolator. On the other hand, the major component of the receiver subsystem consist of two band pass filters (BPF), Low-Noise Amplifier (LNA), I/Q demodulators and two Low-pass filter. The local oscillator is operated in both transmitter and receiver sub system.

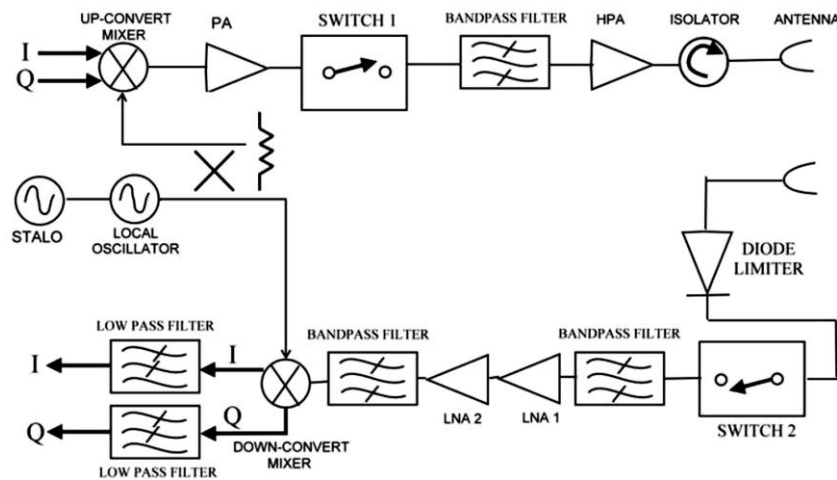


Figure 2. Block diagram of SAR sensor.

Based on the Figure 2, the antenna is operated as transmitter and receiver the electromagnetic wave. In the SAR system, the characteristics of the antenna are similar for both transmitter and receiver. In terms of power, the transmitter antenna is working with high power, while the receiver antenna with low power since receives the reflected signal from the target.

3. Antenna Design

3.1. Power Distribution

The power distribution of each element of the array antenna is calculated based on uniform space ($d = \lambda_0/2$) and sidelobe level of 20 dB. The excitation coefficient is used to arrange the power ratio in the feed network. The Array Factor (AF) for five elements array ($P = 5, M = 2$) can be derived as [8].

$$AF(u) = a_1 + a_2 \cos 2u + a_3 \cos 4u \tag{1}$$

In here, $u = 2 \pi (d/\lambda) \cos \theta$, for uniform spaced ($d = \lambda / 2$) then u can be simplified as $u = \pi \cos \theta$. The excitation coefficient of the array factor for five elements antenna can be obtained by substituting the Chebyshev polynomial and AF can be expressed as

$$AF(u) = 1 + 1.5022 \cos 2u + 0.4317 \cos 4u \tag{2}$$

3.2. Geometry Design

Five elements square microstrip antenna with corner truncated and proximity feed are employed in the proposed antenna. The power ratio in a corporate feed network is configured based on the array factor calculation. Figure 3 is shown the illustration of the power distribution to each element.

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Figure 3. Power distribution for each patch.

The T junction power divider is implemented at the feed network as presented in Figure 4. In Figure 4, the input power P_1 is delivered to the intersection on a microstrip of width W_1 and impedance Z_1 . The line then branches into two arms with power, width and impedance given by P_2 , W_2 , Z_2 and P_3 , W_3 , Z_3 , respectively. The power on each arm can be obtained using the equations

$$P_2 = \frac{Z_1}{Z_2} P_1 \text{ and } P_3 = \frac{Z_1}{Z_3} P_1$$

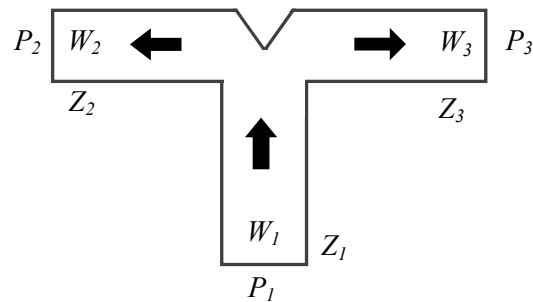


Figure 4. T Junction power divider.

The power distribution based on the excitation coefficient of the array factor can be realized in a corporate feed network as shown in Figure 5. In this Figure, the A, B and C T Junction are operated for dividing the source power as illustrated in Figure 4. The power dividing ratio each T junction is listed in Table 1.

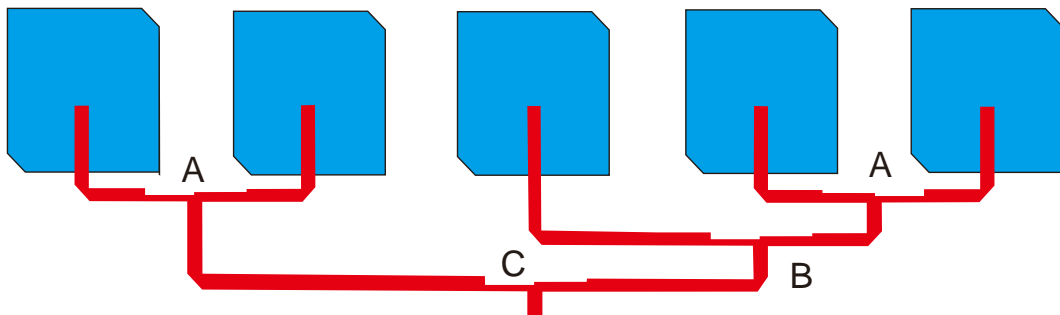


Figure 5. Geometry design of the Chebyshev array antenna.

Table 1. The power dividing ratio of the T Junction.

T Junction	P_2	P_3	Ratio (P_2/P_3)
C	$1.5022+0.4317$	$1+1.5022+0.4317$	0.66
B	1	$1.5022+0.4317$	0.52
A(right)	1.5022	0.4317	3.48
A(left)(mirror A right)	0.4317	1.5022	0.29

In this work, a Nippon Pillar substrate (NPC-H220A) is employed having a thickness 1.6 mm, a dielectric constant $\epsilon_r = 2.17$ and a loss tangent $\delta = 0.0005$. The photograph of fabricated feed network and the patches are shown in Figure 6 and 7, respectively.

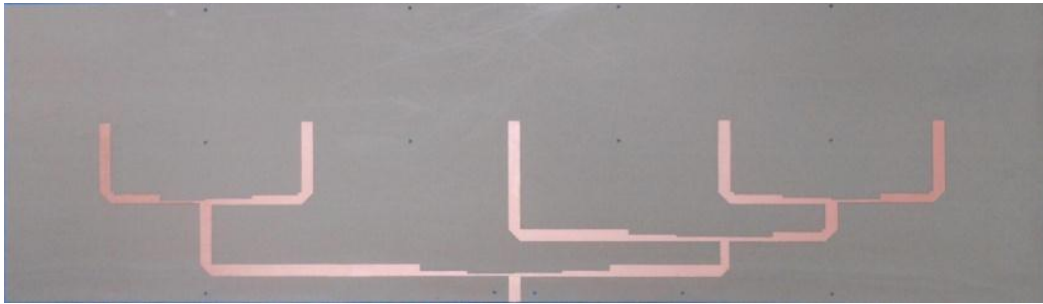


Figure 6. Power distribution on fabricated feed network.

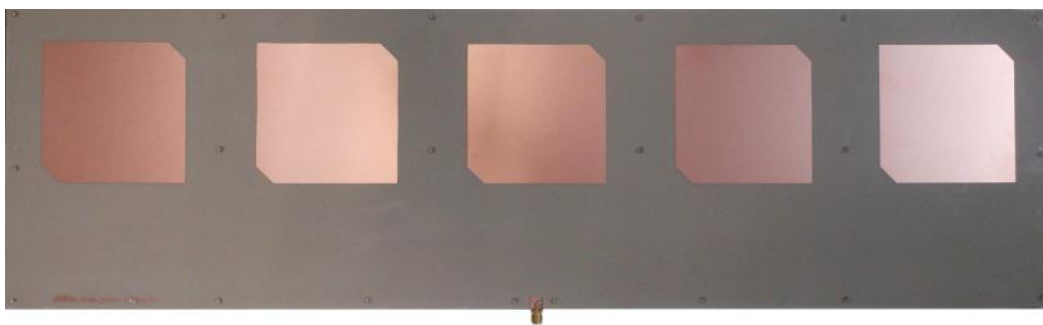


Figure 7. Photograph of fabricated 1x5 corner-truncated SMA.

4. Result and Discussion

Figures 8 to 11 shows the characteristics of the proposed antenna. In Figure 8, simulated and measured the reflection coefficient (S_{11}) as a function of frequency is plotted. The return losses at 1.27 GHz are lower than 29.21 dB and 16.29 dB in the simulation and the measurement, respectively. Such degradation is probably caused by the transitions mismatch. The measured S_{11} characteristics show slightly broadened characteristics from 1.242 GHz to 1.312 GHz of 5.51%. Meanwhile, the simulated S_{11} shows slightly narrower than measured result ranging from 1.244 GHz to 1.300 GHz.

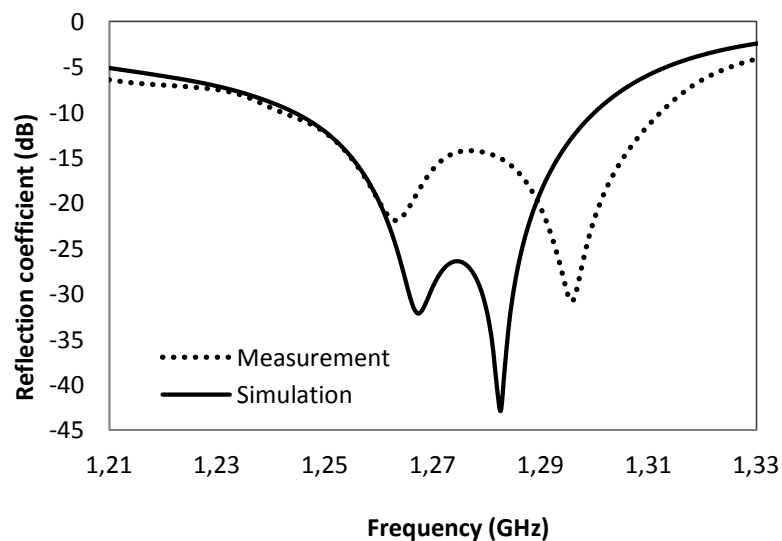


Figure 8. Reflection coefficient plotted as a function of frequency.

The polarization characteristic of the antenna is shown through the axial ratio (AR) as presented in Figure 9. The AR characteristics are slightly shifted to the higher frequency end, but the bandwidth remains almost the same in both simulation and measurement. A simulated axial ratio bandwidth of 0.9% is obtained from 1.264 GHz to 1.275 GHz where the measured results show a bandwidth of 0.83% from 1.268 GHz to 1.278 GHz.

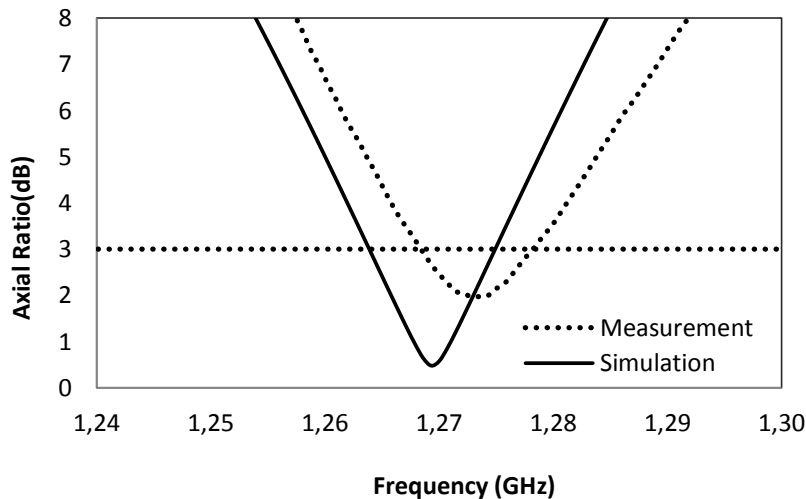


Figure 9. Axial ratio (AR) plotted as a function of frequency.

The performances of the antenna in terms of gain and sidelobe level are presented in Figure 10 and Figure 11. A maximum gain of 11.9 dBic in simulation and 10.4 dBic in measurement is obtained. Figure 11 shows the sidelobe level in radiation pattern of the antenna at the theta plane. The good agreements between calculation, simulation and measurement result are presented. The 3 dB beamwidth for calculation, measurement and simulation are 24, 23 and 22.25 degrees, respectively. The first side lobe appears at -36° and 32.4° with sidelobe level 20.8 dB and 19.5 dB for the simulation, for the measured are -58.7° and 36° with side lobe level 20.5 dB and 15.5 dB, respectively.

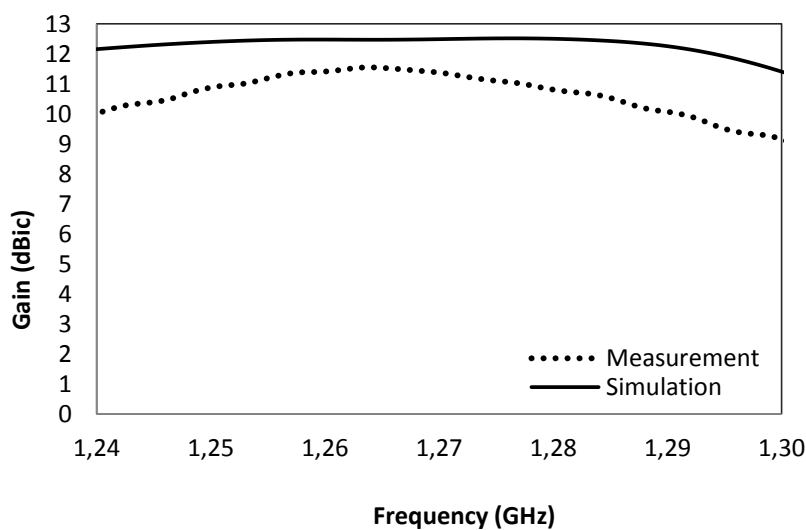


Figure 10. Relationship between antenna gain and frequency at θ angle of 0° .

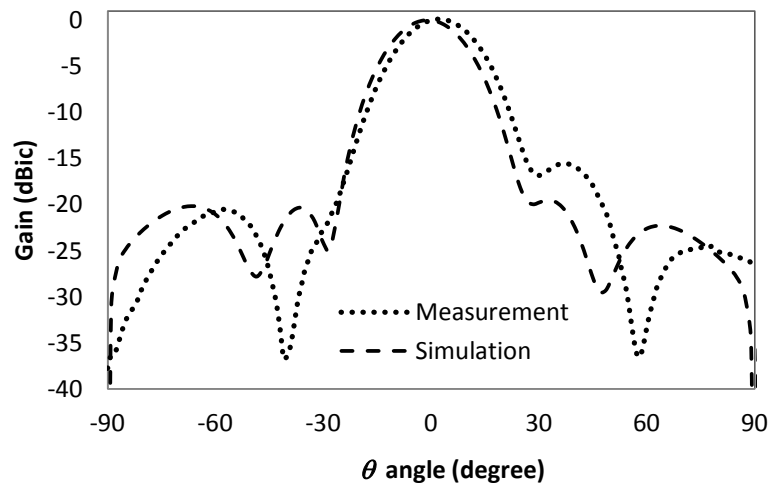


Figure 11. Normalized radiation pattern of the array antenna in the theta plane ($x - z$ plane) at $f = 1.272$ GHz.

5. Conclusion

In conclusion, the low sidelobe level array antenna for synthetic aperture radar sensor is designed and comprehensively characterized by simulation and experiment in 1.27 GHz centre frequency (L-band). Simulation results exhibit that proposed antenna can operate at low sidelobe level, which is in good agreement with the experiments. Moreover, the fabricated antenna has shown good performance in terms of return losses and axial ratio. This low sidelobe level and good properties of the array antenna is satisfying the requirements for a SAR sensor.

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