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Beamwidth Enhancement of Array Microstrip Antenna for Radio Altimeter Application

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Abstract—In this paper, an array microstrip antenna with 2x2 configuration has been simulated and measured for radio altimeter. The goal of this study is to achieve a proper beamwidth for this application with acceptable VSWR. Thus, the spacing between patches has been varied to obtain the beamwidth. The simulation shows the antenna has 50.2 x 60 degrees beamwidth with VSWR of 1.21, where after measurement the antenna has gained VSWR of 1.238, 250.04 MHz bandwidth and beamwidth of ±48 x ±65 degrees.

Keywords: Beamwidth; Microstrip Array Antenna; Radio Altimeter; VSWR.

I. INTRODUCTION

The use of radio altimeter has been widely considered beneficial for altitude measurement. It has a substantial function for the flying vehicles to measure its height against the ground level. The distance is calculated by adjusting the time interval of the transmitted and received signal of the antenna.

Radio altimeter requires small and thin antenna which is suitable with the structure of the aircraft. The antenna also needs the beamwidth of 50° × 60° and 10 dB gain [1]. The purpose of the beamwidth is to avoid backscattering and rain attenuation from rain.

Research on microstrip antenna for radio altimeter has been conducted using array method [2,3,4,5], I-slot [6], slotted rook shape [7], T-slot [8], pentagon method [9], E-shape [10], dipole with sierpinski carpet fractal technique [11], star chain fractal cpw method [12], rectangular patch with double l-probe fed [13], conformal patch [14] and verre de champagne fractal cpw method [15]. There are two research [2,3] where both of antennas have gain above 10 dB, but not with the beamwidth. In this paper, a 2x2 array microstrip antenna is proposed where the space between patch is coordinated so that the beamwidth of 50.2° × 60° from simulation can be attained with the desired VSWR and bandwidth on the frequency of 4.3 GHz.

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II. ANTENNA DESIGN

The proposed antenna for this paper is amicrostrip antenna with rectangular patch on full groundplane. Where copper with the thickness of 0.035 mm is chosen as the material for groundplane, patch and feed line. The substrate of the antenna is FR-4 which has a 4.3 dielectric constant and height of 1.6 mm. Table 1 shows the variable of the initial antenna and the structure can be seen in Figure 1.

The array method is applied in order to maintain the gain value.Hence, there are 4 patches in a 2x2 planar configuration on the antenna. Each patch is linked to a 100Ω feed line and finally connected to the main 50Ω feed line.

Table 1. Variables of Antenna Structure

Variable	Parameter	Size (mm)
W_1	width of patch	19.93
L_1	length of patch	16.6
W_2	width of groundplane	31.02
L_2	length of groundplane	25.92
W_3	width of 50Ω feedline	4
W_4	width of 100Ω feedline	0.626
L_3	length of feedline	4.79
Ho	height of insetfed	4.97
Gap	gap of insetfed	2
H	thickness of FR-4	1.6
T	thickness of copper	0.035
S_1	up-down space	36.56
S_2	left-right space	29.76

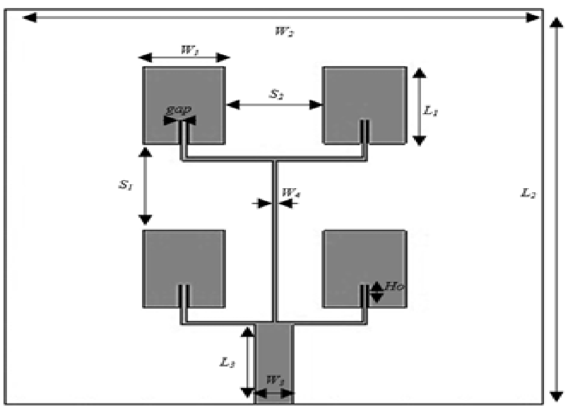

Figure 1. Front View (back view)

In Table 1, it is written that there are S_1 and S_2, used as the variable for spacing between the patch. Initially, the spacing on this paper can be found by eliminating the wavelength of antenna with twice the size of the width and length of patch. These spacing, S_1 and $S_2$is used to determine the beamwidth of 50° × 60°.

The variation on the spacing value of the antenna is employed first. Decreasing the spacing between patches can affect the value of the beamwidth, however we still have to adjust VSWR of the resonant frequency. Thus, all of the parameter antenna is simulated for obtaining the optimized structure.

III. RESULT AND DISCUSSION

The 2x2 array antenna has been simulated and analyzed by using CST Studio Suite 2017. In theoptimization process, up-down spacing (S_1), left-right (S_2), width of feed line (W_3), and width of patch (W_1)were varied. At first, the spacing of the patch is decreased, both S_1 and S_2. The graph in Figure 2 and Figure 3 displays respectively the study of S_1 and S_2, where both spacing are eliminated, then the beamwidth can be maintained.

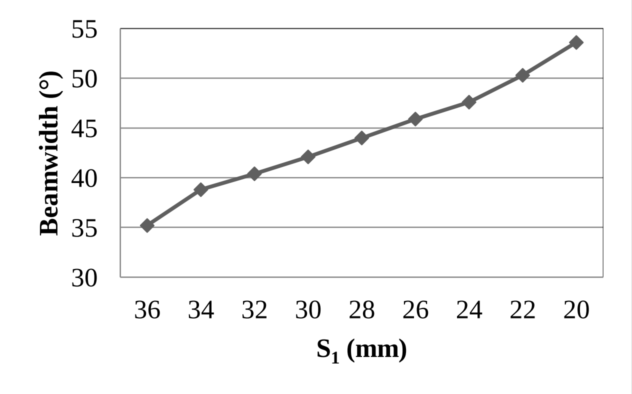

Figure 2. The effect of decreasing S_1 on azimuth

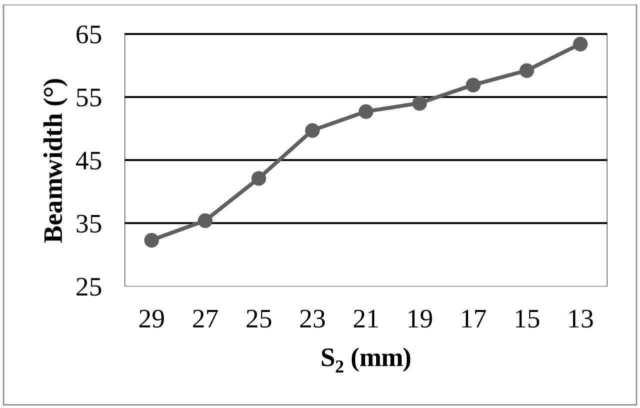

Figure 3. The effect of decreasing S_2on elevation

When S_1 is decreased up until 22 mm (0.315367λ) and S_2 = 15 mm (0.215023λ), a 50.3° × 59.2° beamwidth has been reached, which seems close to the desired beamwidth. However, other parameters should be looked into, one of them is VSWR. The affect of decreasing of the spacing on VSWR can be viewed in Figure 4.

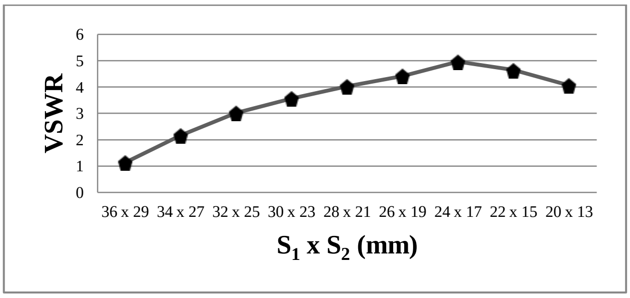

Figure 4. The effect of decreasing S_1xS_2on VSWR

Graph in Figure 4 depicts that the value of VSWR is declining along with the decreasing of spacing between patches. Although the beamwidth is close to 50° × 60°, it can be denied that VSWR is higher than 2. So, a new optimization of another parameter is needed. In this study, the better VSWR can be accomplished by limiting the width of patch (W_1) which can be seen in Figure 5.

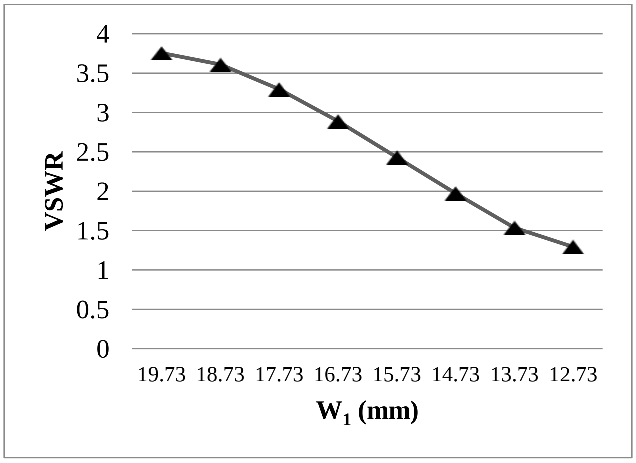

Figure 5. The effect of limitingW_1on VSWR

As depicted in Figure 5, the value of VSWR can get lower than 2 by deducting the width of patch. Despite achiving VSWR of 1.29 when W_1 = 12.73 mm, another parameter should be studied as its contribution might sharpen the value of VSWR. The width of 50Ω feed line (W_3) then was chosen to be considered. Figure 6 shows the outcome of modifying W_3 on VSWR.

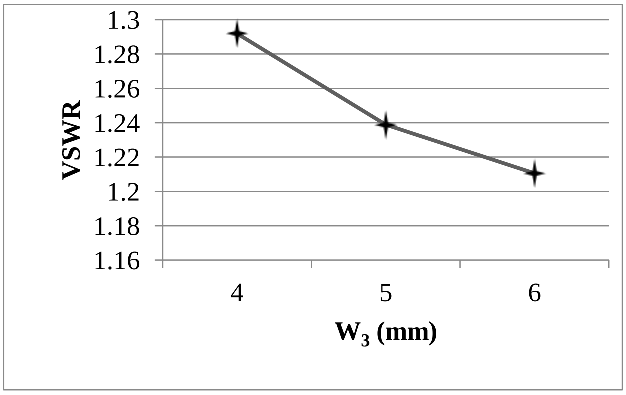

Figure 6. The effect of wideningW_3on VSWR

After widening the width of 50Ω feed line, the optimal VSWR is 1.21 where W_3 = 6 mm. Changing the width of patch and 50Ω feed line apparently can influence the beamwidth. The closest beamwidth, which was 50.3° × 59.2° where S_1= 22 mm (0.315367λ) and S_2 = 15 mm (0.215023λ), shifted into 44.2° × 58.6°. The obtained beamwidth isn't close to 50° × 60°. Supposedly, the beamwidth of the antenna is getting smaller as its aperture changes. Therefore, to make the beamwidth reach the requirement, the both of the spacing should be adjusted again. The graph in Figure 7 and Figure 8 show the beamwidth increment when the spacing of S_1 and S_2 are eliminated.

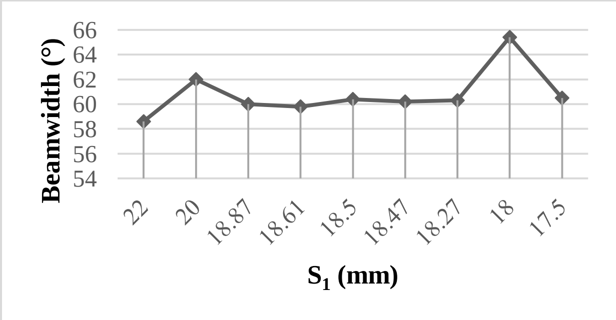

Figure 7. The effect of decreasing S_1 on azimuth

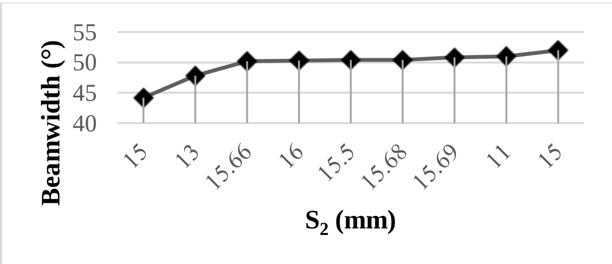

Figure 8. The effect of decreasing S_2on elevation

When the spacing of S_1 is decreased, the beamwidth on azimuth plane of antenna is fluctuating, unlike the spacing of d_2 is steadily increased. However, the beamwidth of 50.2° on the azimuth plane and the elevation of60° in Figure 9 can be obtained with using spacing S_1 = 18.87 mm (0.270498λ) and S_2 = 15.66 mm (0.224483λ). The antenna has VSWR of 1.21 with bandwith of 206 MHz (return loss ≥ 10 dB) and gain of 6.717 dB which can be seen in Figure 10 until Figure 12.

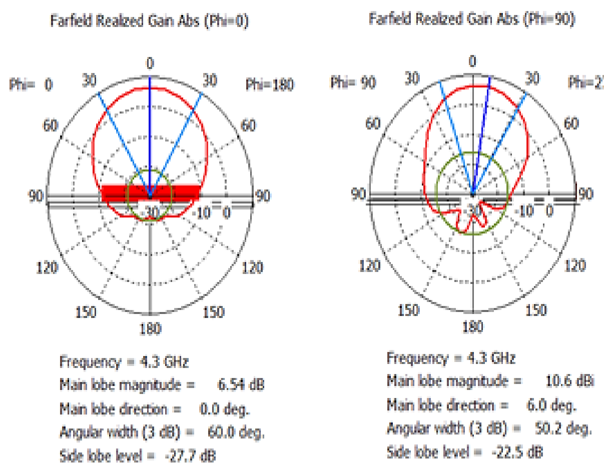

Figure 9 : The beamwidth of the proposed antenna

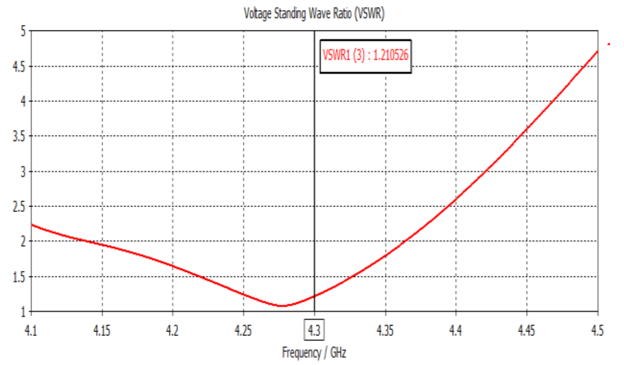

Figure 10 : VSWR of the antenna

The new structure of the proposed antenna displays in Table 2 to sum up the optimal design of the antenna. Table 3 depicts detailed information for comparing the other study about microstrip antenna for radio altimeter that has been done before to validate there is an enhancement of beamwidth in this study.

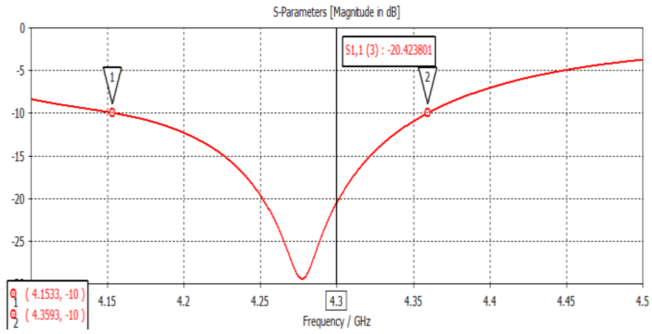

Figure 11 : Bandwidth of the antenna

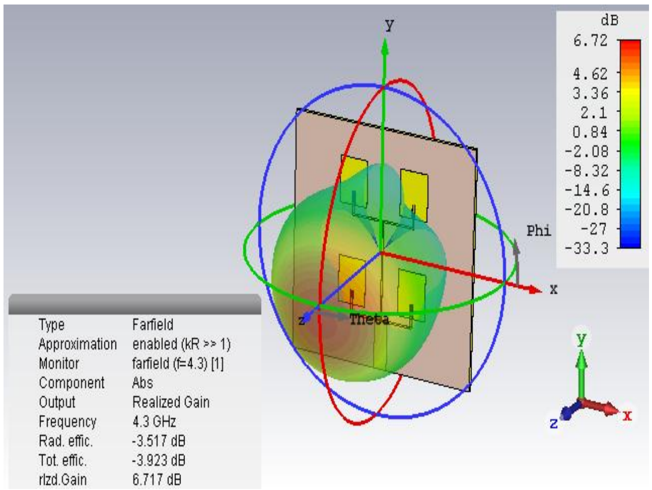

Figure 12 : Gain of the antenna

Table 2. The New Structure of Antenna

Variable	Parameter	Size (mm)
W_1	width of patch	12.73
W_3	width of 50Ω feedline	6
S_1	up-down space	18.87
S_2	left-right space	15.66

Table 3. Comparison between recent research

Description	Beamwidth
Compact antennabased on bi-layersubstratetechnology	33° × 37°
E- shape modification with parasite element	±37.9° × ±58.5°
Linear array rectangular patch microstrip antenna with proximity coupled feeding	20.9° × 66.2°
This work	50.2° × 60°

The simulated antenna is then fabricated with FR-4 epoxy substrate. The front and back view of the antenna are respectively shown in Figure 14. The beamwidth, gain VSWR are measured to know the performance of the antena. The beamwidth of antenna after measurement is ±65° for elevation plane and ±48° for azimuth plane, as displayed in Figure 15 and Figure 16 where both simulated and measured beamwidth are compared. In terms of VSWR, the antenna is tested by using T5280A Vector Network Analyzer. As shown in Figure 17, the simulated and measured VSWR are compared to see the difference.


(a) (b)

Figure 14 : The fabricated antenna with (a) the front and (b) back view

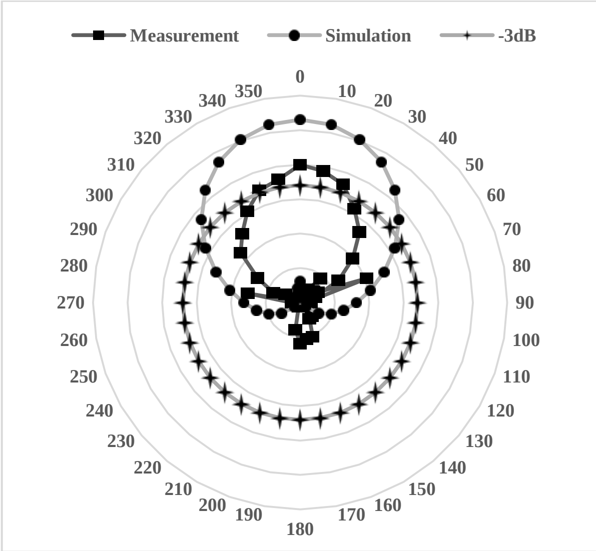

Figure 15 : The comparison of simulated and measured beamwidth of azimuth plane

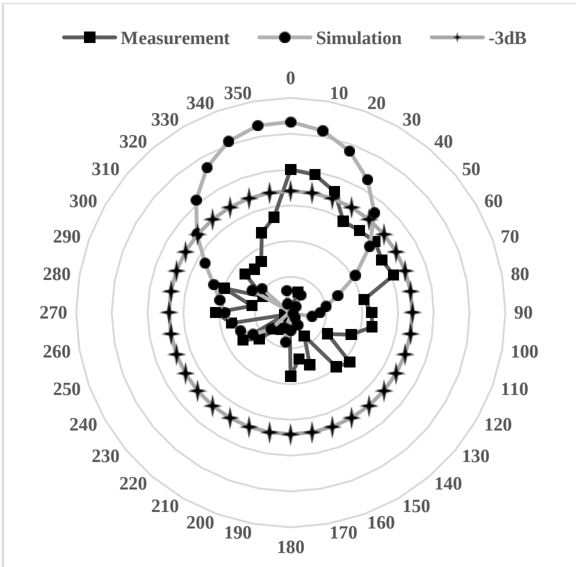

Figure 16 : The comparison of simulated and measured beamwidth of elevation plane

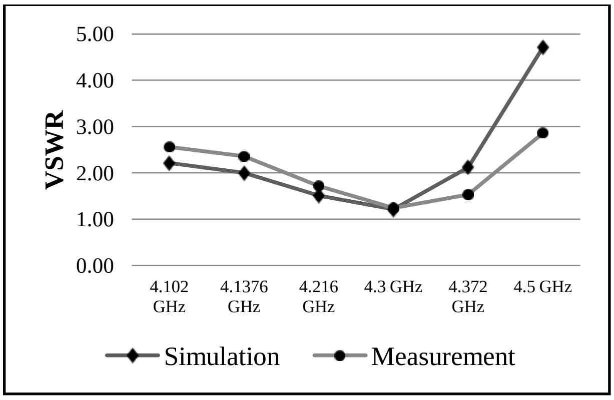

Figure 17 : The comparison of simulated and measured VSWR of the antenna

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From the above graph, it shows that the measured antenna has VSWR of 1.238 on the frequency of 4.3 GHz with 250.04 MHz bandwidth. The radiation pattern in Figure 15 and Figure 16 also potrayed that the antenna has unidirectional pattern with the gain of 6.695 dB. Table 4 will be displaying the comparison between gain antenna both from simulation and measurement of this paper and recent research to recognize the effect of each shape with gain.

Table 4. The Comparison of Gain Antenna between Recent Research

Paper	Type	Sim. Gain	Meas. Gain
[2]	Array antenna based on the meta-material zeroth-order resonator	6.6 dB	N/A
[3]	Circular1x4 array	12 dB	N/A
[4]	Compact antenna based on bi-layer substrate	8 dB	8 dB
[5]	Linear 1x4 array with proximity coupled feeding	13.17 dB	13.46 dB
[6]	I-slot	8.16 dB	N/A
[7]	Slotted rook shape	3.64 dB	N/A
[9]	Pentagon method	7.44 dB	N/A
[10]	E-shape	9.5 dB	9.276 dB
[11]	Dipole with sierpinski carpet fractal technique	11.3 dB	N/A
[13]	Rectangular patch with double L-probe fed	5.95 dB	N/A
This work	2x2 array	6.717 dB	6.695 dB

IV. CONCLUSION

The antenna with the right beamwidth and desired VSWR for radio altimeter has been achieved in this study. Such beamwidth can be obtained by analyzing the combination between the up-down and left-right spacing of the patch. The 50.2° x 60° beamwidth is finally reached by giving space of 0.270498λ for the up-down spacing and 0.224483λ for the left-right spacing. However, other parameters like the width of patch and 50Ω feed line can also effect the performance of the antenna. The measured antenna has VSWR of 1.238 on 4.3 GHz frequency with 250.04 MHz bandwith.

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