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Design of Coplanar Vivaldi Antenna with Metamaterial and Dome Lens for Radar Applications

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Abstract - *Vivaldi antenna applications are widely used in Ground Penetrating Radar technology, Medical Imaging such as detecting brain tumors and breast cancer. In this study, a comparison of the return loss and gain of three modifications of the coplanar antenna design is carried out, namely SCVA (Standard Coplanar Antenna), CCVA (Corrugated Coplanar Antenna), CCVAM (Corrugated Coplanar Antenna with Metamaterial) which works in the frequency range. 0.5GHz – 5GHz. By comparing the three designs, it is obtained from the simulation results that the modification of CCVA (Corrugated Coplanar Vivaldi Antenna) and CCVAM (Corrugated Coplanar Vivaldi Antenna with Metamaterial) provides better performance than the SCVA design (Standard Coplanar Vivaldi Antenna) both in terms of Gain and Return Parameter loss. Although using the size and material of the FR-4 substrate with dimensions of 350mm x 400mm where in the Gain parameter the CCVAM (Corrugated Coplanar Vivaldi Antenna with Metamaterial) design has an advantage with a value of 7 dB to 6.4 dB in the frequency range 1 GHz - 2.7 GHz, but at the final frequency The CCVA (Corrugated Coplanar Vivaldi Antenna) design range has a value exceeding 2 designs with a value of 6.6 dB to 4.9 dB in the 2.7-5 GHz frequency range. Then for the return loss parameters, the three antennas have values below -10db but the lowest return loss values are generated from the CCVAM (Corrugated Coplanar Vivaldi Antenna with Metamaterial) design.*

Key Words: Vivaldi antenna, Bandwidth, gain, metamaterial

1.INTRODUCTION

There are so many variations of designs and modifications of antennas that have various applications in realizing telecommunications technology. The use of electromagnetic waves generated by the antenna is not only used for long-distance communication, moreover, along with the development of antenna technology, it is developed for radar applications in aviation and also the military, GPR (Ground Penetrating Radar), and medical imaging[1][2][3]. In previous studies, GPR used a working frequency range between 500 MHz to 1 GHz[4].

The antenna design is a patch antenna with a wide bandwidth invented by Gibson[5], the antenna is one of the designs that have high flexibility in optimization and modification efforts. The antenna has a tapered antenna slot called a tapered slot antenna (TSA).

This radar technology is used to monitor and detect objects that are difficult to see by the human eye. The radar itself is a technology that utilizes electromagnetic waves emitted by a transmitter or antenna[6]. Many studies discuss the application of radar using antennas and their various modifications to become a transmission medium and also a receiving medium[7][8][9].

The focus of this article is to produce an antenna design SCVA (Standard Coplanar Antenna), CCVA (Corrugated Coplanar Antenna), CCVAM (Corrugated Coplanar Antenna with Metamaterial) using FR-4 material on the substrate with a size of 350mm x 400mm for all design and copper on the patch and metamaterial to compare the return loss and gain performance of the three antenna designs. Which works in the S and C band frequency range and is intended for the use of radar technology.

2. DESIGN COPLANAR VIVALDI ANTENNA

In this study, we designed 3 models of Coplanar antennas, of which 3 variations used copper material on the patch and also FR-4 on the antenna substrate which can be seen in Fig- 1.

Table -1: Dimensions of 3 Antenna designs

Symbol	Dimension (mm)	Symbol	Dimension (mm)
A	350	I	550
B	400	D1	350
C	190	J	31
D	4	K	17
E	1	L	5
F	100	M	3
G	17.2	N	1
H	200	O	10

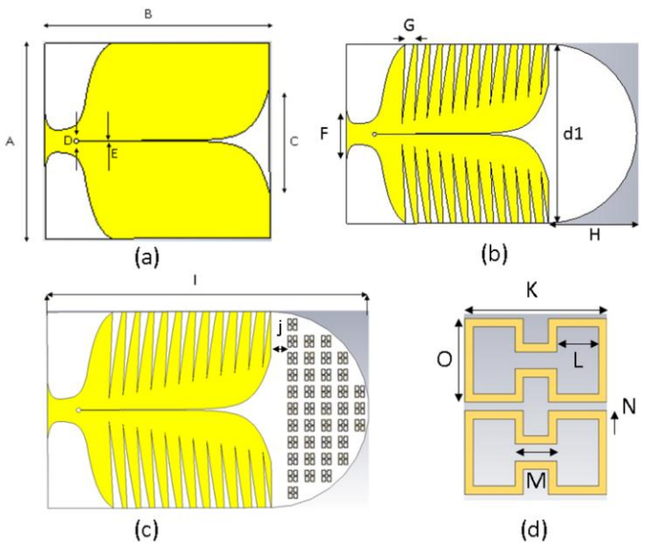


Fig-1: Coplanar Antenna Design. (a) SCVA, (b) CCVA, (c) CCVAM, (d) metamaterials

The dimensions of each antenna design can be seen in Table 1

The antenna was first introduced in 1979 by Gibson, several conventional antenna designs have three variations, namely, coplanar antennas, antennas, and balanced antennas. The antenna has a tapered antenna slot or called a tapered slot antenna (TSA) which can be seen in equation 1 [10]

$$Y = C_1 e^{Rx} + C_2 \quad (1)$$

Dimana,

$$C_1 = \frac{(y_2 - y_1)}{[e^{Rx_2} - e^{Rx_1}]} \quad (2)$$

$$C_2 = \frac{(Y_1 e^{Rx_2} - Y_2 e^{Rx_1})}{[e^{Rx_2} - e^{Rx_2}]} \quad (3)$$

R = Antenna taper

(x_1, y_1) is the initial coordinate of the antenna tapering

(x_2, y_2) is the final coordinate of the antenna tapering

Antenna Performance based on Simulation

Antenna Gain can be seen in Figure 2, where modifying the SCVA (Standard Coplanar Antenna) antenna with Corrugate (CCVA) slots, it can increase the Gain of the Antenna in all frequency ranges. By adding Metamaterial to the Corrugated Coplanar Antenna with Metamaterial (CCVAM) design, there is an increase starting from the low frequency of 1 GHz – 2.5 GHz. The addition of metamaterial affects the Gain value at low frequencies with a value of 7 dB at a frequency of 1 GHz, which in the Corrugated Coplanar Antenna (CCVA) design has a value of 6.4 dB, and for Standard Coplanar Antenna it only has a value of 5.5 dB.

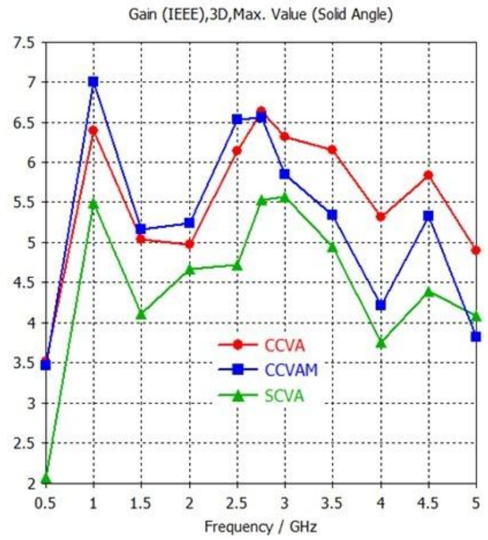


Fig- 2: Antenna Gain Performance

However, in the frequency range of 2 GHz – 5 GHz, the Corrugated Coplanar Antenna (CCVA) design has the highest gain dominance compared to the 2 Standard Coplanar Antenna (SCVA) designs and also the Corrugated Coplanar Antenna with Metamaterial (CCVAM). At 4.5 GHz the design with the highest gain value is the Corrugated Coplanar Antenna (CCVA) with a value of 5.9 dB followed by the Corrugated Coplanar Antenna with Metamaterial (CCVAM) design with a value of 5.4 dB, and the last design with the lowest gain value is the Standard Coplanar Antenna (SCVA) with a value of 4.4 dB. For the return loss parameter in Figure 3, it shows that the performance of the Antenna has an average return loss below -10 dB from a frequency of 500 MHz - 5 GHz. The simulation results from the SCVA, CCVA, and CCVAM Antenna designs have similar simulation results from all frequency ranges.

The addition of the Corrugated Coplanar Antenna (CCVA) modification resulted in a significant decrease in the 2.6 GHz frequency, then the Corrugated Coplanar Antenna with Metamaterial (CCVAM) modification resulted in a shift in the decrease in return loss from the CCVA modification at 2.6 GHz frequency to 3.48 GHz. Figure 4 shows the radiation patterns of the three antenna designs taken at a working frequency of 2.75 GHz

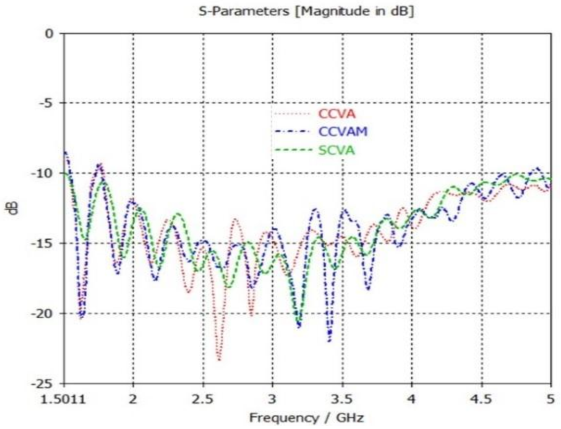
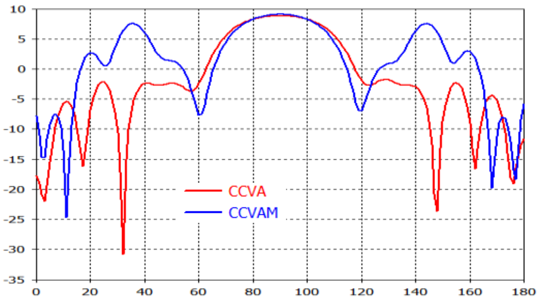
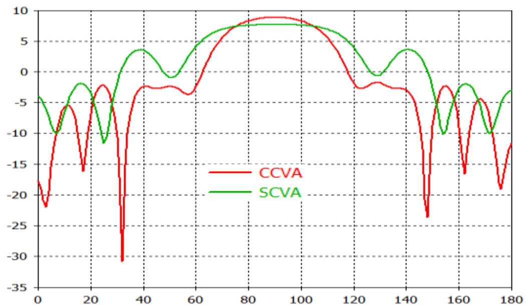


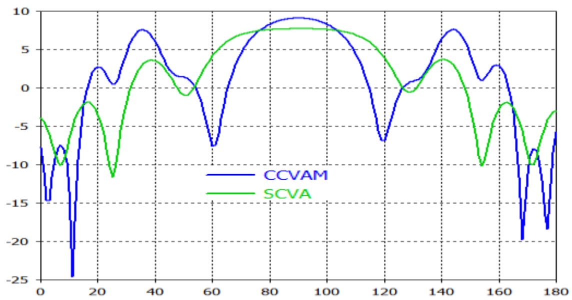
Fig. 3: Antenna Return Loss Performance



(a)



(b)



(c)

Fig-4: Radiation Pattern 3 antenna at 2.75 GHz (a) CCVA & CCVAM, (b). CCVA & SCVA., and (c). CCVAM & SCVA

Figure 4 shows a comparison of the far-field parameters, namely the magnitude of the main lobe, the direction of the main lobe, angular beamwidth, and side lobe level. It can be seen from the three comparison pictures that the CCVAM design has the Main Lobe Magnitude of 9.13 dB higher than both CCVA and SCVA designs where each has values of 8.89 dB and 7.73 dB, the CCVAM design has a Main Lobe Direction value by 90 degrees radiation pattern this design is more precise than the other two designs which each design (SCVA and CCVA) has a Main Lobe Direction of 91 degrees and 93 degrees. By adding metamaterials as well as dome substrates to the CCVAM and CCVA designs the radiation pattern becomes more where indicated by the Angular Beamwidth value in the CCVAM design, the value is 34.7 degrees more small compared to the CCVA and SCVA designs, namely 51.2 degrees and 57.7 degrees. On the Side Lobe Level CCVA design has advantages compared to the other two designs with the lowest value of -7.7 dB, the CCVAM design has the highest value of -1.5 dB and the SCVA design has a Side Lobe Level value of -4 dB.

3. CONCLUSIONS

In this study, we compare the performance of 3 antenna designs: 1) Standard Coplanar Antenna (SCVA); 2) Corrugated Coplanar Antenna (CCVA); 3) Corrugated Coplanar Antenna with Metamaterial (CCVAM) using 2 parameters, namely return loss and Antenna Gain. Of the three designs that have the best performance is the Corrugated Coplanar Antenna with Metamaterial with the lowest return loss value with a value of -22 dB at a frequency of 3.4 GHz and the highest gain with a value of 7dB at a frequency of 1 GHz. However, for each performance parameter, the antenna has a superior design, in the return loss parameter the Corrugated Coplanar Antenna with Metamaterial (CCVAM) design has the best performance, but for the Gain parameter, the design that has the best performance is the Corrugated Coplanar Antenna (CCVA) because it has a high gain value. More stable and dominates in the 2.5 GHz – 5 GHz frequency range. We also compared the three antennas using the radiation pattern parameter at a frequency of 2.75 GHz, there we found that the CCVAM design that applied the modification of the addition of the dome substrate and the addition of the metamaterial has several advantages in Main Lobe Magnitude this design is superior to a value of 9.13 dB compared to both designs with a value of 8.89 dB and 7.73 dB, respectively. Then on the Side Lobe Level, the CCVA design is superior with produces the lowest Side lobe value of -7.3 dB compared to both CCVAM and SCVA designs with a value of -1.5 dB and -4 dB.

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