Assessment of Vivaldi Antenna Parameters for Biomedical applications

Emine AVŞAR AYDIN[1]
1- Adana Science and Technology University, Aeronautics Engineering, Adana, TURKEY
Email: eaydin@adanabtu.edu.tr or rasvaenime@gmail.com

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ABSTRACT:
In this paper, Microstrip-fed Vivaldi antenna is presented for Ultra-Wide Band (UWB) biomedical applications and antenna characteristic parameters such as radiation pattern, return loss (S11), and voltage standing wave ratio (VSWR) are evaluated. However, by using different values of antenna parameters such as stub angle, substrate thickness, and relative dielectric constant, antenna performance in the UWB frequency range is developed to create antenna structure with the best efficiency, gain, and directivity. The design and modeling of the antenna are performed in CST Microwave Studio. Additionally, this can be used in terms of an attractive configuration for biomedical applications.

KEYWORDS: Vivaldi Antenna, ultra-wide band (UWB), radiation pattern, return loss (S11), voltage standing wave ratio (VSWR), biomedical applications.

1. INTRODUCTION

Cancer is a serious disease that has begun to emerge in living organisms. This sickness is caused by the uncontrolled division of DNA damage-resultant cells. One of the most important steps in the treatment of the disease is early detection of the cancerous cell. Mammography, ultrasonography and MR imaging methods are frequently used to image cancerous tissue [1]. Microwave imaging methods [3-6] have been investigated to overcome disadvantages of the exist methods to find the tumor at higher accuracy and sensitivity [2]. Some advantages of microwave imaging are that it is cheaper and less harmful than other methods and is more responsive and results are easier to interpret. The purpose of microwave imaging is to obtain the dielectric and conductivity properties of the examined object by taking advantage of the electrical field measured at the antennas and the electrical field information generated at the object. For this reason, antenna design [6-9] and integration into the microwave imaging system are crucial for achieving the desired results.

Additionally, it is desired that the antennas should have a suitable radiation pattern at a fairly high efficiency and appropriate gain values for high accuracy detection of the location and size of the tumor tissue. Firstly, Vivaldi antennas presented by Gibson [10] are commonly used in microwave imaging applications due to their wide band operation [11-12]. In this study, a corrugated Vivaldi antenna was designed for microwave imaging systems.

In this study, a Vivaldi antenna which can operate in 0-10 GHz UWB frequency range has been designed. By using CST Microwave Studio program, antenna radiation pattern, return loss (S11) and voltage standing wave ratio (VSWR) were investigated and parameters were changed to determine the best performing antenna structure.

2. ANTENNA DESIGN

There are various advantages of Microstrip-fed Vivaldi Antenna and this makes it popular for microwave imaging applications. It has a planar configuration and it is compact and lightweight. The antenna can achieve ultra wideband operation with admissible efficiency, gain, and directivity. Symmetric beam in the E-plane and the H-plane is realizable. UWB Vivaldi antenna is preferred for its attractive configuration for biomedical applications [13-15]. The designed antenna is shown in Fig. 1 and the antenna parameters and values are given in Table 1.

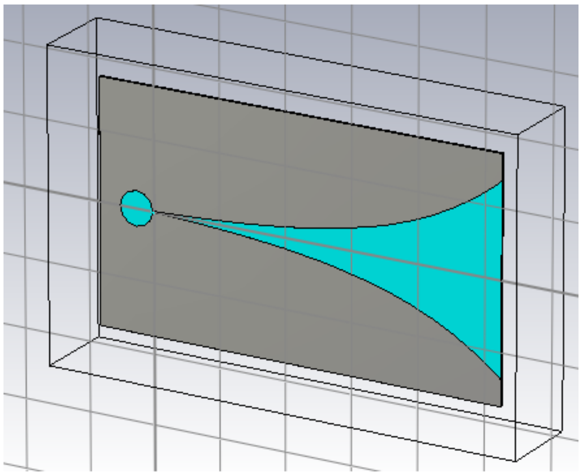


Fig. 1. The view of the designed antenna.

Table 1. Antenna Parameters and values.

Antenna Parameters	Values
Taper factor	30.0
Tan delta	0
Substrate height	0.63456
Stub start angle	90
Stub radius	5.65644
Slotline width	0.32984
Slotline length	0.44469
Microstrip taper width	1.50356
Microstrip taper width	16.38834
Microstrip coupler width	0.44469
Microstrip coupler width	7.50058
Microstrip coupler inset	0.22234
Flare length	104.92732
Flare height	54.96193
Conductor height	69.95155
Cavity diameter	10

3. SIMULATION RESULTS

The S11 return loss graph for the different relative dielectric constants (ε_r) of the bottom layer used in the modeled annealing is shown in Fig. 2 and the VSWR graph is shown in Fig. 3. In the graphs in the figures, the effect of substrate's relative dielectric constant according to S11 return loss and VSWR parameter was investigated. As ε_r increases, the bandwidth increases and the VSWR parameter decreases, thus improved antenna performance has been observed.

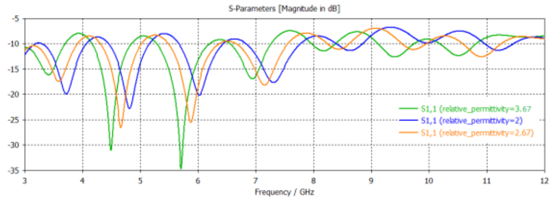


Fig. 2. S11 return loss graph for different dielectric constant values

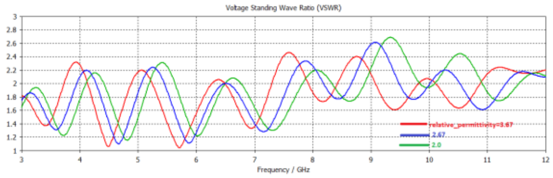


Fig. 3. VSWR graph for different dielectric constant values

In order to ensure that the antenna can operate efficiently at the desired frequencies (0-10 GHz frequency range), the behavior of the antenna with respect to the stub angle is investigated by choosing the dielectric constant $\varepsilon_r = 3.67$ where the best performance is obtained. The effects of stub angle on the S11 return loss and VSWR are shown in Fig. 4 and Fig. 5, respectively.

Figure 4 shows the S11 return loss graph obtained when the stub angle is changed to 30°, 80° and 120°. It is seen here that the best S11 bandwidth is obtained at 80° stub angle for 0 - 10 GHz frequency. Figure 5 shows the VSWR change graph depending on the stub angle. It is also evident here that the lowest VSWR value is obtained at a stub angle of 80 °. The results of S11 and VSWR obtained in Fig. 4 and Fig. 5 support each other.

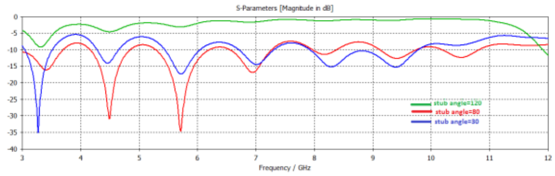


Fig. 4. S11 return loss graph for different stub angles

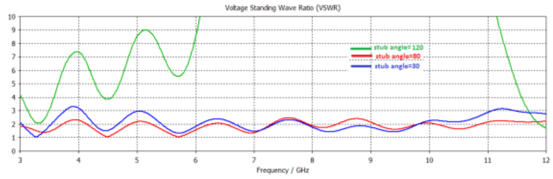


Fig. 5. VSWR graph for different stub angles

In order to investigate the effect of substrate thickness (h) on antenna performance, S11 and VSWR plots are obtained according to different substrate thicknesses, results are given in Fig. 6 and Fig. 7, respectively. In the graphs, $\varepsilon_r = 3.67$ and stub angle =

80 are chosen. It can be seen that as the substrate thickness decreases, the -10 dB bandwidth and the VSWR value are improved, the best results can be achieved when the substrate thickness is 0.63456 mm.

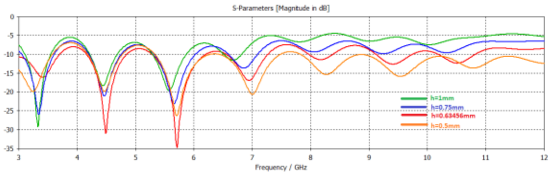


Fig. 6. S11 return loss graph for different substrate thicknesses

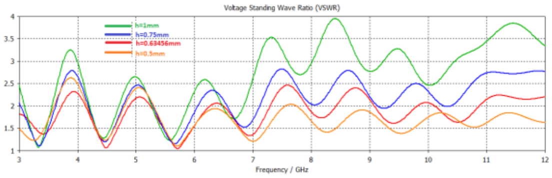
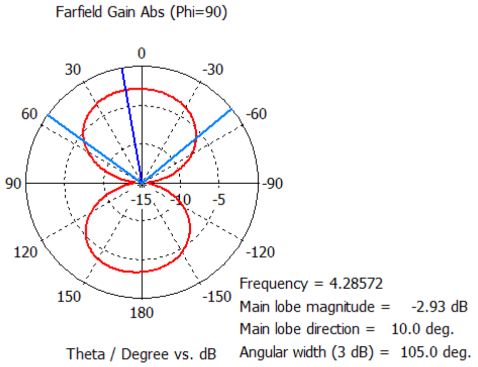


Fig. 7. VSWR graph for different substrate thicknesses

When antenna performance is examined in terms of bandwidth, return loss and VSWR parameters, it has been observed that the radiation performance of the antenna improves as stub angle and dielectric constant increase and the substrate thickness decreases. In addition, it is seen that the angle of propagation of the antenna showing the best behavior in this range is 80°, the substrate thickness h = 0.63456 mm and the relative dielectric constant $\varepsilon_r = 3.67$.

In Fig. 8, radiation patterns of the antenna for different frequencies are shown.



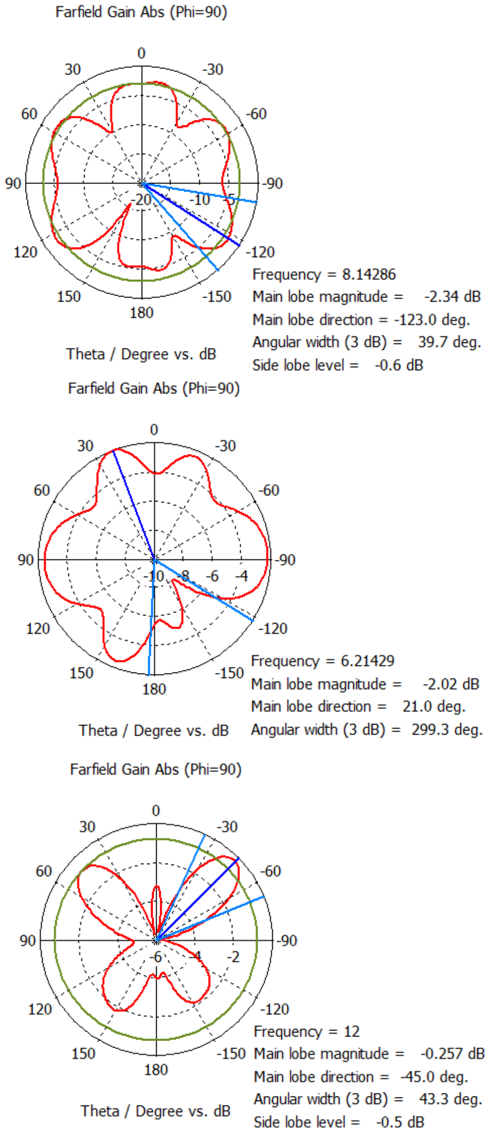


Fig. 8. Radiation patterns of the antenna for different frequencies

4. CONCLUSION

In this study, a compatible Microstrip Vivaldi Antenna is designed in the frequency range of 0-10 GHz for UWB applications. Additionally, the importance of the dielectric material, stub angle, and substrate thickness in determining the operating frequency of the UWB antenna is emphasized. For this purpose, the effects of the dielectric material, stub angle, and substrate thickness are investigated. It is seen that performance of the antenna improves, as stub angle and dielectric constant increase and the substrate thickness decreases. As a result, UWB Vivaldi antenna is designed and it is a good option that can be preferred in biomedical applications due to its attractive configuration.

5. ACKNOWLEDGMENT

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