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Improved Vivaldi Antenna with Radiation Pattern Control Features

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Abstract

Vivaldi antenna has been considered as a mitigation to the scattering effect of an antenna. However, the current performance of Vivaldi antenna suffers from multipath effect, interfering signals and radiation pattern control. This paper proposed an improved Vivaldi antenna which combined triple radiating slot to enable control of radiation pattern features. This is accomplished by controlling the position of the radiating element through the asymmetric arrangement of ideal switches to steer the beam in three desired-directions. The Using operating frequency lied between 900 MHz and 2.5GHz, the proposed design was fabricated and tested. Depending on the radiating element, the proposed antenna covered about ±90º with an almost equal gain at the three different focal in contrast to ±45º coverage of traditional rectangular microstrip antenna beam. The results satisfied pattern reconfigurability and the proposed design can be very useful for wireless communications where multipath fading problems are frequently encountered.

Keywords: *pattern reconfigurability, vivaldi antenna. taper slot, beam steering*

1. Introduction

In recent decade, reconfigurable antennas have attracted myriad positive reviews in contrast to other types of antennas due to their numerous application. This positive reviews can be attributed to the relative ease- of- implementation, adaptation and flexibility in terms of frequency, pattern and polarization [1-5]. In a multipath fading environment, it has been suggested to hold an antenna that can indicate the primary shaft to the desired coverage area while slimming down the unwanted beam in other charges, therefore mitigating the multipath propagation, consequently improve the channel capacity [6-7], several reconfigurable antennas have been investigated to suit different applications employing different feeding techniques such as microstrip line feeding [8-9], CPW to slot-line feeding [10], Antipodal feed [11]. Furthermore, different studies have been conducted on a switching microstrip element to steer the beam, in [12], a novel pattern control antenna was designed to guide the pattern null with a beam of 64º centered at broadside direction and provided a depth nulls greater than 18dB.

A pattern reconfigurable microstrip patch antenna achieved 9 distinguished angular direction with the use of 4-RF switches, yielded more than 70 percent efficiency while its linear polarization is preserved [6]. Shynu and Max [13] proposed a reconfigurable antenna with pattern switching of 65º and45ºin the fundamental mode of elevation and azimuth by means of Pin- diodes arrangement. Beam switching was realized in 4 directions while maintaining the resonant frequency and beamwidth. Greg and Jennifer [9] highlighted several important steps in the simultaneous integration of packaged RF- MEMS devices to the radiating structure of a microstrip antenna capable of reconfigurable pattern behavior.

Other technologies such as C2X (Car to Car) communication and Unmanned Aerial vehicles (UAVs) that are used for enhancing road safety and traffic efficiency do require such pattern reconfigurability to suit the demands of mitigating the problems of interferences between users and electronic jamming by channeling the main beam toward the direction of the incoming signals [14-15]. Though substantial progress has been achieved in this field, many applications do not require the level of complexity, which translate into higher power consumption. Therefore, there is still a need for a controlled radiation pattern antenna which is physically

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smaller and less complex, with high directivity and strong resistance to electronic- warfare-systems (EW) so as to ensure that the radiation emitted is concentrated in a single direction.

In view of these shortcomings, an improved Vivaldi antenna with a controlled radiation pattern is proposed in this paper. The idea is based on combining three Vivaldi antennas into one single radiating structure as to act as a singular unit multiple antennas fed by a microstripline by means of ideal switches, depending on the radiating elements, beams are steered from -90ºto 90ºfor the three different directions. This logic is examined in the remainder of this manuscript. The manuscript is organized as follows, in section II, the antenna structure and analysis are explained, in section III, the simulated and measured results are presented and finally, the conclusions and future recommendation are given in section IV.

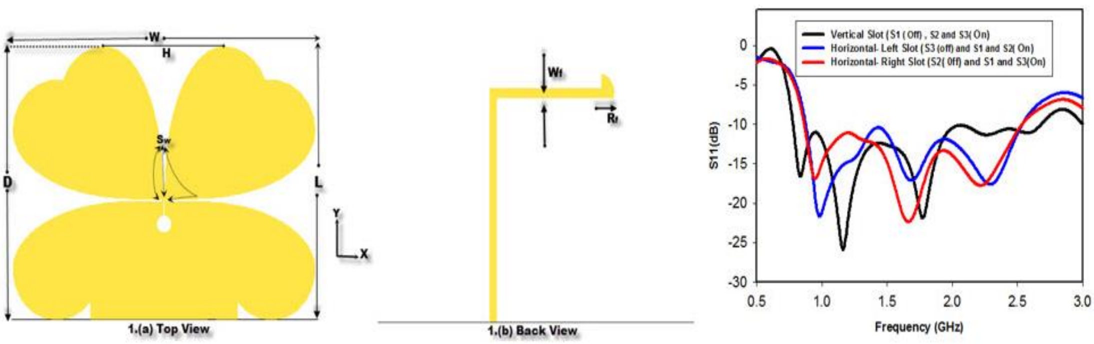

Figure 1. Antenna Structure and Simulated Return Loss

2. Antenna Structure and Analysis

The antenna proposed in this study as depicted in Figure 1 is a combination of three Vivaldi antenna which is designed on a FR4 substrate characterized by dielectric constant of 4.3 and a tangent loss of 0.025.The substrate is configured in a manner that the three taper slot has equal length of 103.9mm. Three ideal switches are incorporated in the form of metal bridge of 1mm×1mmto allow the signal to radiate towards the intended direction.

The operating frequency ranges between 900MHz to 2.5GHz covering GSM, GPS and Bluetooth operating bands. When designing a Vivaldi antenna, two major criteria are set into consideration. The first includes the modulation from the main transmission line (usually microstripline) to a slot-line for feeding the antenna, this modulation is characterized by a broad range of operating frequency. In addition, it should be characterized by a low reflection coefficient, which is capable of matching the potency of the antenna[16], secondly, consideration should be given to the dimensions and configurations of the antenna that is typically required to get the needed beam-width, sidelines and back lobes over the operating frequency range are also considered [17]. To achieve these conditions, the configuration presented in Table 1 are considered for parameter optimization in this study.

Table 1. Detailed Parameters of the Proposed Design

Variable	Dimension (mm)
Thickness of the substrate (T)	1.6
Permittivity(ε_r)	4.3
Tangent loss(δ)	0.025
Substrate size(W×L)	165×210
Antenna length(D)	160.28
Aperture size(H)	83.2
Circular slot radius(C_r)	4.5
Terminated Radius Circle(R_f)	5.1
Feedline w idth(W_f)	2.75
Horizontal taper slot radius	30
Vertical taper slot radius	40
Ideal sw itches(S1,S2,S3)	1×1

In this design, three ideal switches (S1, S2, S3) will determine which slot is radiating, for the Up mode, S1 is open while S2 and S3 are short- circuited to prevent the current to flow in other directions and when S2 and S1 are On, S3 will be Open and the current will flow in the left mode, while for the right mode to radiate, S1 and S3 should be On, and S2 will be Open.

3. Simulated and Measured Results

In order to evaluate the proposed Vivaldi antenna design, a prototype of the design with metal strips acting as switches is simulated, fabricated and tested, the photographic depiction of the fabricated Vivaldi antenna prototype is shown in Figure 2a. The reflection coefficients and radiation pattern are measured for three different modes (Up, Left and Right) of the designed Vivaldi antenna at three different operating frequencies (900MHz, 1800MHz and 2.5GHz). This was carried out using an E5071C network analyzer and in an anechoic chamber. The measurement results are further enumerated in Figure 2b, Figure 3, Figure 4 and Figure 5. The S11 characteristics of the simulated and measured result of the Up-Left- Right mode is depicted in Figure 2b. Results of the pattern characteristics among the three frequency ranges; 900MHz, 1800MHz and 2.5GHz, is presented in Figure 3, Figure 4 and Figure 5.These characteristics are further examined from the three modes: the Up-Left-Right mode to observe the characteristic pattern of each design in the E-plane and H- plane respectively.

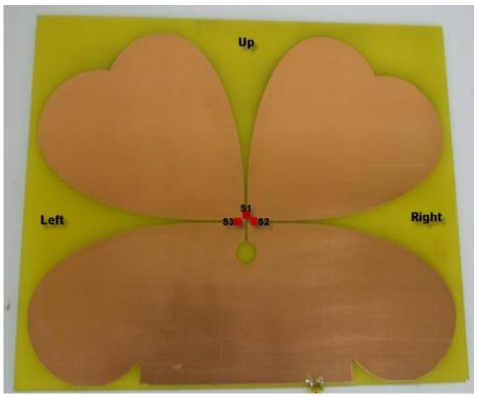

Figure 2a. Photograph of the fabricated Vivaldi reconfigurable antenna

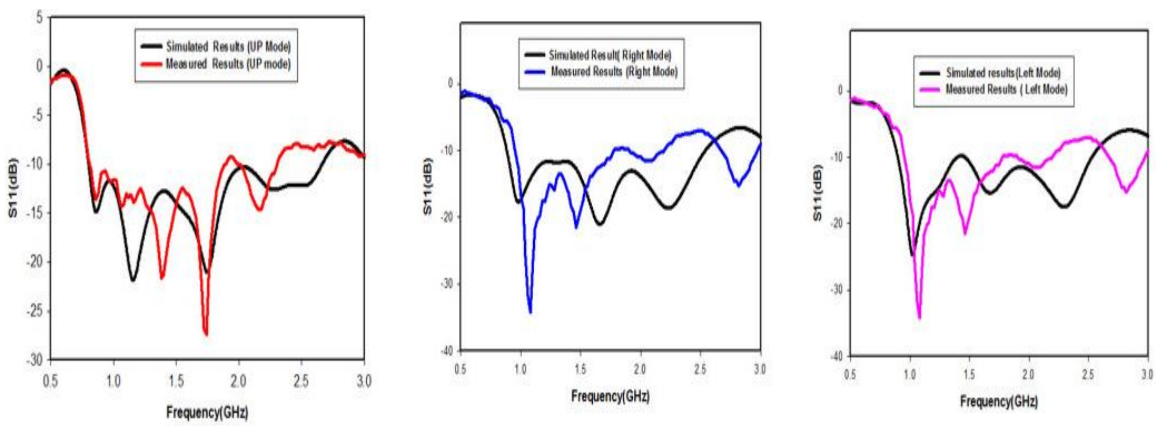

Figure 2b. Simulated vs Measured Results (UP Mode, Right Mode and Left Mode)

As it is illustrated in Figure 2b, the simulated return loss is less than -10 dB for the three examined directions covering a wideband starting from 900 MHz to 2.5GHz, which implies that 90% of the signal was transmitted with only 10% reflected, however, during the fabrication process, some reflection occurred due to slight misalignment which lead to a small frequency shift between simulation and measurement. Figure 2b highlights the comparison made between the measured and simulated results. From the graph, we can see that the measured frequency bandwidth in the Up mode (reflection coefficient below -10dB) covers 820MHz-2.5GHz with some fluctuation around 1.9GHz(-9dB) and 2-3GHz to 2.5GHz(-8dB) which is within the acceptable limit. On the other hand, the measured S11 responses in the Left and Right mode are very close to the simulated one though a negligible shifting in the resonance is observed, which is still covering the band(900MHz-2.5GHz) which is about 60MHz wider than the measured bandwidth(960MHz-2.5GHz). Nonetheless the wideband remained relatively significant.

In terms of radiation pattern control, the taper slot radiates at an almost equal gain in the desired beam while maintaining the antenna performance stable. The radiation pattern was simulated and measured for three different operating frequencies in the E and H plane and the results are compared as shown in Figure 3, Figure 4 and Figure 5. At the lower frequency (900MHz), the main lobe direction of 152º and 25º respectively was observed in the left and right mode with 3dB beamwidth above 90º and the radiation does not deviate towards other undesired directions.

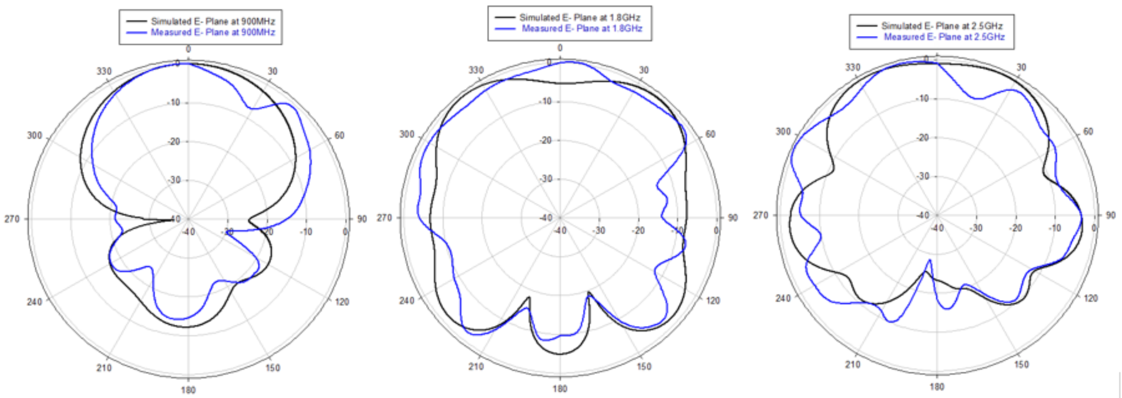

Figure 3a. Simulated vs Measured E- Plane Results in the UP mode at 900MHz, 1800MHz and 2.5GHz

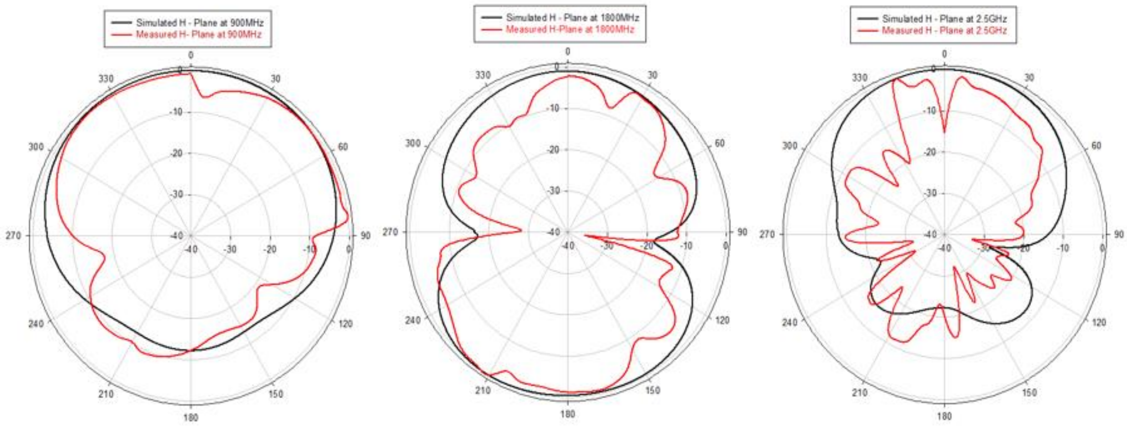

Figure 3b. Simulated vs Measured H- Plane Results in the UP mode at 900MHz, 1800MHz and 2.5GHz

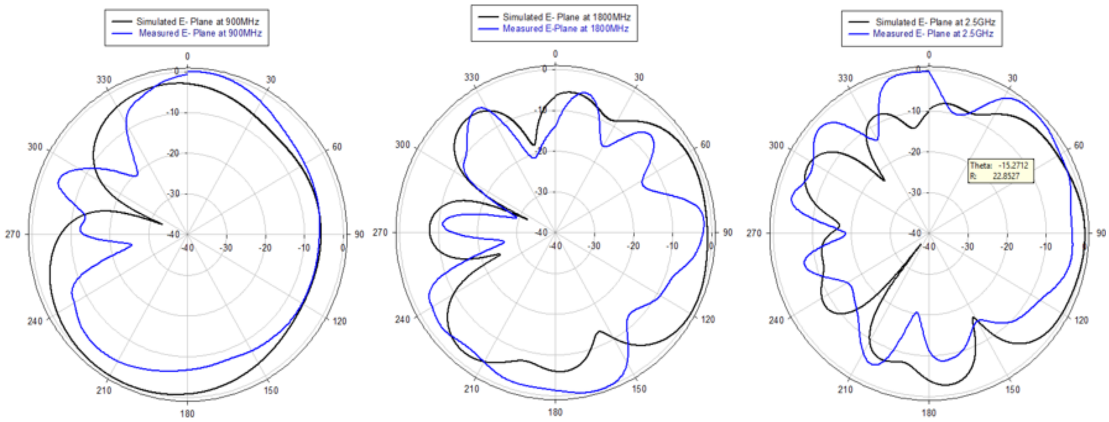

Figure 4a. Simulated vs Measured E- Plane Results in the Right mode at 900MHz, 1800MHz and 2.5GHz

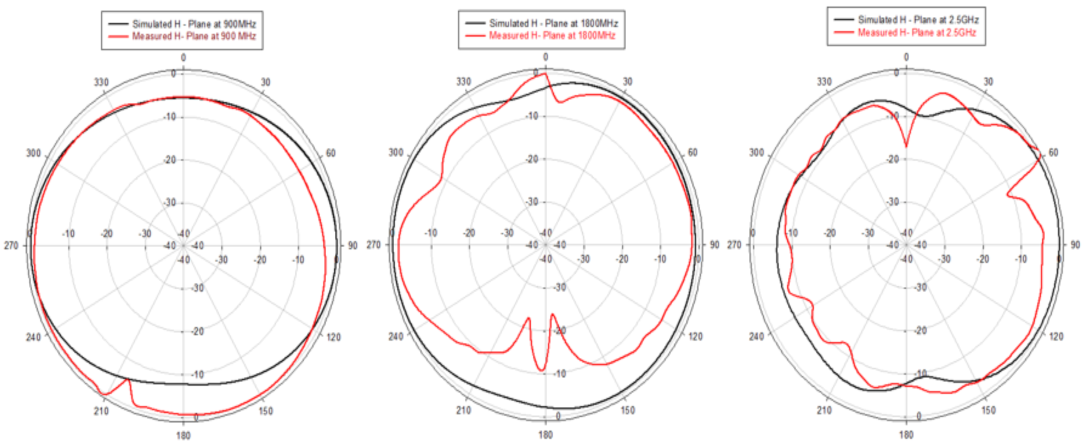

Figure 4b. Simulated vs Measured H- Plane Results in the Right mode at 900MHz, 1800MHz and 2.5GHz

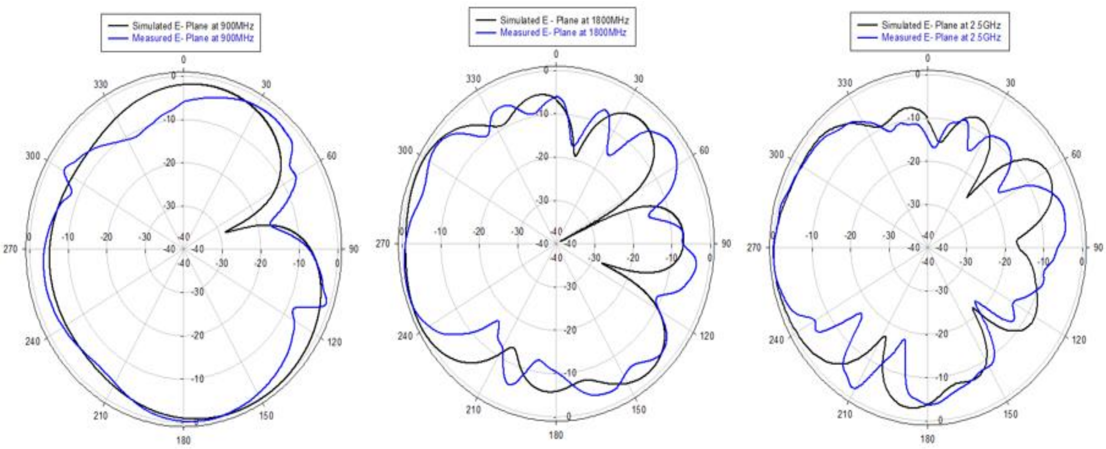

Figure 5a. Simulated vs Measured E-Plane Results in the Left mode at 900MHz, 1800MHz and 2.5GHz

As for the middle frequency (1.8GHz), main lobe is directed towards 51º, 26º and 154º at a side lobe level as low as -1.6dB which can be considered as an improvement. However, at the higher frequency (2.5GHz), the radiation pattern agrees with the lower frequency with a stable 3dB beamwidth above 90º a steady increase in the gain was observed for the three modes. As shown in table 2at a particular frequency (2.45GHz), the gain was also simulated and measured, it can be seen that the gain was almost equal, though there is a slight difference between the simulated and measured radiation pattern, which can be attributed to errors that occurred during the measurement in the anechoic chamber, the proposed design satisfied the pattern reconfigurability. This observation, therefore satisfies the core objective of this study. Radiation signals were directed towards desired directions while maintaining the gain equality, thus reducing the interference.

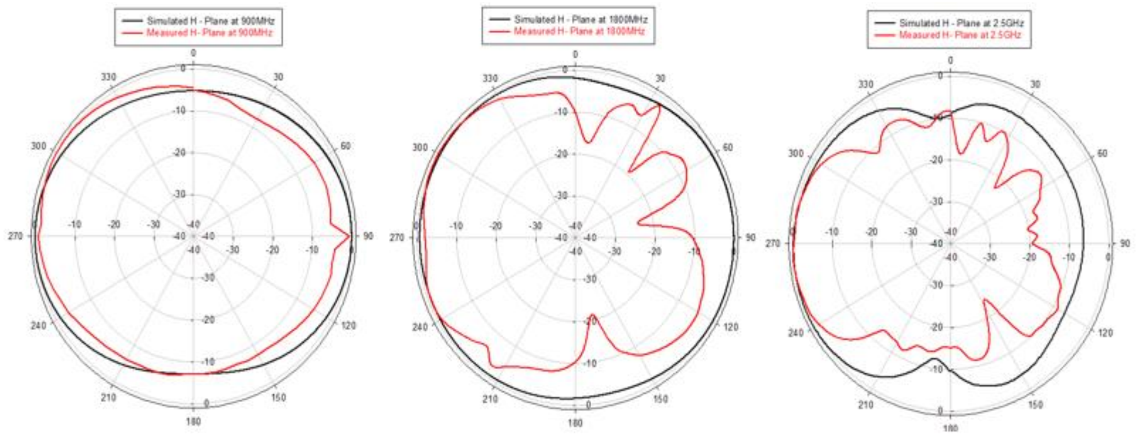

Figure 5b. Simulated vs Measured H- Plane Results in the Left mode at 900MHz, 1800MHz and 2.5GHz.

Table 2. Simulated vs Measured Gain at 2.45GHz

	Modes	Gain(dB)
Simulated	Up	4.16
	Right	4.65
	Left	4.71
Measured	Up	4.44
	Right	5.8
	Left	6

4. Conclusion

An Improved Vivaldi antenna with pattern control was designed and the study achieved 3 different beam angular position at three different frequencies, while a nearly equal gain was observed. The simulated results of the proposed antenna proved that changing the radiating element would ensure a better way to enable wireless communication systems to avoid noisy environment by maneuvering away from electronic jamming, consequently, optimizing the radiation energy by redirecting the signals towards only the user thus increase the channel capacity and broaden the coverage area of the wireless system. In the future work, the evaluation of the performance of the fabricated antenna with real switches compared to this with ideal switches will be carried out, an improvement on how to increase the gain for the Left and Right Mode will be also considered.

References

[1] Soufiane Tebache, Farid Ghanem, Adele Belouchrani. *Novel and Simple Approach for reconfiguring the pattern of an UWB CPW-Fed Monopole Antenna*. Seminar on Detection Systems Architectures(DAT). Algiers.2017:1-5

[2] Abdolmehdi Dadgarpour, Milad Sharif Sorkherizi, Tayeb A.dendni, Ahmed A Kishk. Passive Beam Switching and dual-beam radiation Slot Antenna loaded with ENZ medium and Excited through ridge Gap waveguide at millimetter-waves. *IEEE transactions on Antennas and Propagation,* 2017; 65(1): 92-102.

[3] H Yang, Y Cui, R Li. *A novel pattern reconfigurable antenna*. IEEE International Symposium on Antennas and Propagation (APSURSI). Fajardo. 2016: 1675–1676.

[4] G Augustin, BP Chacko, TA Denidni. Electronically reconfigurable uni-planar antenna for cognitive radio applications. *IET Microwaves, Antennas & Propagation*. 2014; 8(5): 367–376.

[5] Omar El Maleky, Farid Ben Abdelouahab, Mohammad Essaaidi, Nasri Abdelfatah. Miniature design of T- Shaped frequency reconfigurable antenna for S- Band Application using Switching Technique. *International Journal of Electrical and Computer Engineering (IJECE*). 2017; 7(5): 2426-2433.

[6] M Jusoh, T Aboufoul, T Sabapathy, A Alomainy, MR Kamarudin. Pattern-reconfigurable microstrip patch antenna with multidirectional beam for wimax application. *IEEE antennas and wireless propagation letters*. 2014; 13: 860–863.

[7] Zhu Anshi, Chen Zii, Wei Jianbin, zhen Yunhui. Study on Pattern Reconfiguration of Plasma Antenna Excited by Surface Wave. *Telkomnika Indonesian Journal of Electrical Engineering*. 2014; 12(9): 6658-6666.

[8] A Rebollo, R Gonzalo, I Ederra. Full w-band microstrip fed Vivaldi antenna. *Journal of Infrared, Millimeter, and Terahertz Waves.* 2016; 37(8): 786–794.

[9] GH Hu, JT Benrhard. Integration of packaged RF mems switches with radiation pattern reconfigurable square spiral microstrip antennas. *IEEE Transactions on Antennas and Propagation*. 2006; 54(2): 464-469.

[10] Y Li, Z Zhang, J Zheng, Z Feng, MF Iskander. Experimental analysis of a wideband pattern diversity antenna with compact reconfigurable cpw-to-slotline transition feed. *IEEE Transactions on Antennas and Propagation*. 2011; 59(11): 4222–4228.

[11] Dey, A Singhal. Design of antipodal Vivaldi antenna in a matching medium for microwave medical imaging. *International Journal of Engineering Research and Technology (IJERT)*. 2014; 3 (10): 978-979.

[12] N Haider, D Caratelli, A Yarovoy. Recent developments in reconfigurable and multiband antenna technology. *International Journal of Antennas and Propagation*. 2013; 13: 1-14.

[13] S Nair, MJ Amman. Reconfigurable antenna with elevation and azimuth beam switching. *IEEE Antennas and Wireless Propagation Letters*. 2010; 9: 367–370.

[14] Stubing, A Shoufan, SA Huss. *Enhancing security and privacy in c2x communication by radiation pattern control*. IEEE 71st, Vehicular Technology Conference (VTC). Taipei. 2010:1-5.

[15] M Sugak, S Ballandovich, P Terentieva, G Kostikov. *Development and experimental investigation of smart antennas for unmanned aerial vehicles*. NW Russia Young Researchers in Electrical and Electronic Engineering Conference (EICon-RusNW). St.Petersburg. 2016: 452–455.

[16] FA Dicandia, S Genovesi, A Monorchio. *Characteristic modes analysis for pattern reconfigurable antenna design. (APSURSI).* IEEE International Symposium on Antennas and Propagation.Fajardo.2016:417–418.

[17] Ahmed Boutejdar, Ahmad Mohammad, Saad Dosse Bennani, Soumia El Hani. Design of Compact Antenna Using Double U-DMS Resonators for WLAN, LTE and Wimax Applications. *TELKOMNIKA (Telecommunication Computing Electronics and Control).* 2017; 15(4): 1693-1700.