

PATTERN AND FREQUENCY RECONFIGURABLE ANTENNA FOR BODY AREA NETWORK (BAN)

Article history

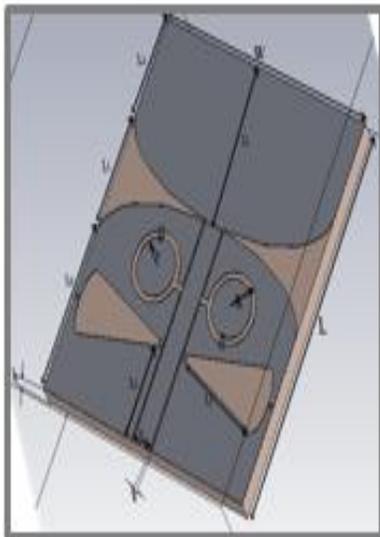
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Graphical abstract



Abstract

A new concept of antenna which quantifies the potential gain of pattern and frequency control in order to suit the requirements of wireless applications such as body area network is presented in this paper. The proposed antenna ranges from 3 GHz to 6 GHz for a wideband operation and operates at 3.5 GHz for a narrowband operation. It uses two types of feedings (CPW and Slotlines) for pattern control with integrated ring resonators for the switching of wideband operation to narrowband operation while maintaining the polarization. The upright return loss characteristics, the controlled radiation pattern and great bandwidth demonstrated at the resonant frequencies make this antenna suitable for applications in these fields.

Keywords: Reconfigurable antenna, feeding techniques, return loss, radiation pattern, antenna gain

Abstrak

Konsep baru antena yang secara kuantiti gandaan potensi corak dan kawalan frekuensi untuk memenuhi keperluan aplikasi tanpa wayar seperti rangkaian kawasan badan dibentangkan didalam kertas ini. Antena yang dicadangkan adalah antara 3 GHz untuk 6 GHz untuk operasi jalur lebar dan beroperasi pada 3.5 GHz untuk operasi jalur sempit. Ia menggunakan dua jenis suapan (CPW dan Slotlines) untuk mengawal corak dan cincin resonator disepadukan untuk pensuisan operasi jalur lebar ke operasi jalur sempit dengan mengekalkan polarisasi yang sama. Ciri-ciri kehilangan pulangan tegak, corak sinaran dikawal dan lebar jalur yang besar dipamerkan pada frekuensi salunan membuat antena ini sesuai untuk aplikasi dalam bidang ini.

Kata kunci: Konfigur antena, teknik suapan, kehilangan balasan, corak sinaran, gandaan

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1.0 INTRODUCTION

Wireless communication systems are designed to perform optimally. However, this is a theoretical assertion which is rarely the case in real scenarios. This is because an antenna rarely maximizes the obstacles it encounters along its path of communication. The propagation signals are degraded by the reflection and scattering in a multipath environment. Typical

examples include diffraction from buildings, landscape topography as well as opaque objects within the radius of operation, which cause fluctuations in radiation signal strength. Different techniques have been proposed to reduce the impact of reflection and diffraction of signal in order to maximize the signal strength of an antenna, consequently, address the multipath effect. One of such techniques includes diversity technique.

Example of diversity technique includes spatial diversity, pattern diversity as well as polarization diversity. This technique attempts to improve the signal to noise ratio and hence improve overall performance [1]–[3].

A reconfigurable antenna is an antenna with the ability to achieve diversity in wireless system and this diversity may be in terms of spatial, temporal, pattern and polarization depending on the goal of the design as well as the application. They are significantly recommended because they offer variety in the performance of the antenna to meet the diverse communication needs and reduce interference. This is achieved by alternating switches among several switching circuitry between several predetermined states with the objective of propagation diversity [4].

Reconfigurable antenna is a growing research work which is capable of revealing several underlying explanations on mitigation of multipath losses by antenna frequency tuning, radiation pattern tuning and polarization. Based on this capability, the integration of reconfigurable antenna is gaining wider research application, since only one radiating structure of a reconfigurable antenna can cover more than one wireless band on demand. This is realized by integrating switches into a reconfigurable antenna structure.

There are three major categories of reconfigurable antenna. One of which is frequency polarization (also known as patterns reconfigurable). A frequency polarization reconfigurable antenna plays a major role in an integrated system by integrating a single multifunctional antenna for different services [5], [6]. In a frequency reconfigurable antenna, only the frequency is reconfigurable while the radiation pattern of such antenna remains principally unchanged as the operating frequency switches. For Pattern reconfigurable antenna, the energy is concentrated in a particular direction by minimizing the gain in other directions without affecting the impedance bandwidth of the antenna. Frequency reconfigurable antennas provide frequency hopping and dynamic spectrum allocation while radiation pattern and polarization reconfiguration can be engaged to filter in band interference and upsurge the channel capacity [7].

A reconfigurable antenna by polarization is designed in order to switch the antenna states from linear polarization to right hand circular polarization (RHCP) or left hand circular polarization (LHCP). Research works have been carried on pattern and frequency reconfigurable antenna structure by means of PIN Diodes and dc bias network on the antenna topology [8], [9]. One approach which involves a compound reconfiguration was discussed in [7] as the use of pixel antennas known as reconfigurable apertures, which can be achieved by dividing the radiating surface of the antenna into small sections called pixels and rejoining same using RF-switches.

Due to broadband demands, a general realistic indication has shown that the wireless link quality

varies hastily in some wireless applications such as body area networks, hence this raised a permanent transmit power results in either misused energy (when the link is decent) or low consistency (when the link is corrupted).

Therefore, this paper seeks to quantify the potential gain of pattern and frequency control in order to maintain an upright external radiation antenna gain through most of the system (body) to avoid problems with an outstanding gain over a certain direction as the system (wearer) moves or turns. Hence aims at improving a reconfigurable antenna capability by integrating ring resonators on each sides of the ground as against controlling the pattern. Through this modification, a reconfigurable antenna can perform pattern and frequency reconfiguration simultaneously thus makes it more flexible and desirable in optimization of radiation pattern by minimizing the multipath effect in wireless communications systems.

2.0 ANTENNA STRUCTURE

2.1 Design with Ideal Switches

This paper deals with pattern as well as frequency reconfigurable antenna. This study builds on the extensive work done in previous studies particular on the design in [1]. The geometry of the proposed design is depicted in Figure 1, the antenna is printed on Taconic RF-30 (lossy) board; the substrate has a dielectric constant of 3 with a loss tangent of 0.025 and a thickness of 1.6 mm. The characteristic impedance was selected to be 50 ohms. The lower patch of the antenna grooves of two circular patches of equal dimensions on both sides of the ground with an inner radius and an outer radius of 4.5 mm and 5.5 mm respectively. The dimension of the feeding line (s) is taken to be 4.3mm and a slotline gap (g) of 0.3 mm.

The integration of ring resonators with slotted line on each ring which served as filters, enable the antenna to switch from a wideband operation to a narrowband operation, hence the extended design demonstrate a high overall performance together with the probability of changing the radiation pattern depending on the feeding techniques used, which could be either a Slotline or CPW feedings.

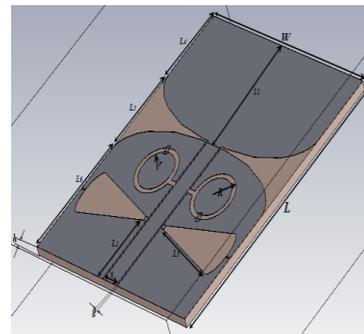


Figure 1 Perspective of the proposed antenna design

2.2 Frequency Adjustment

The simulated S_{11} in the OFF- state and ON- state of the antenna is depicted in Figure 2, through the integration of ring resonators that served as filters, the resonate frequency shifted from a wideband operation [3 GHz-6 GHz] to a narrowband operation resonating at 3.5 GHz.

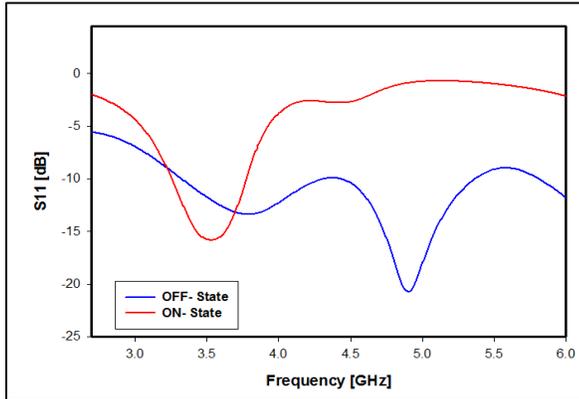


Figure 2 Simulated S_{11} in the OFF and ON state

In addition to frequency reconfigurability, the antenna was able to change the pattern depending on the feeding type that is used while maintaining the same resonant frequency. This was achieved by alternating the switches that were created on the antenna, which allowed only the functioning slot to radiate while others are blocked so that the maximum energy will be concentrated in the desired direction. The resultant simulated H plane 3D- radiation pattern of the process is shown in Figure 3.

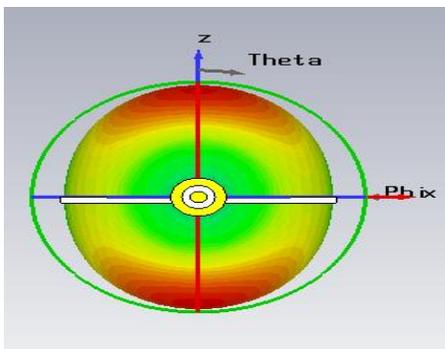


Figure 3a 3D-radiation pattern at State 0 (3.5GHz)

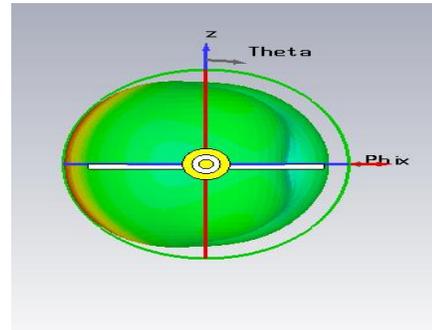


Figure 3b 3D-radiation pattern at State 1 (3.5GHz)

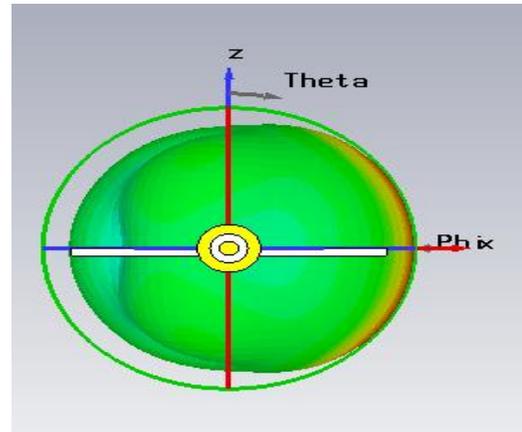


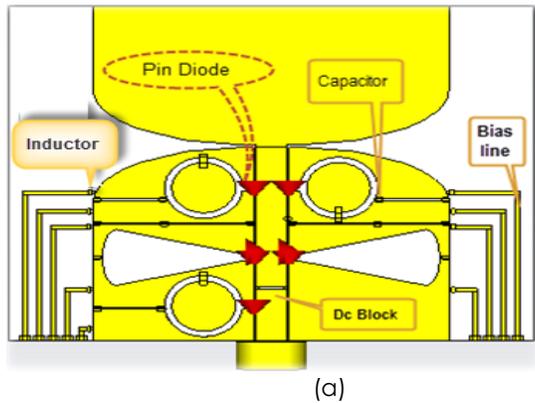
Figure 3c 3D-radiation pattern at State 2 (3.5GHz)

2.3 Extended Antenna Design with Pin Diodes

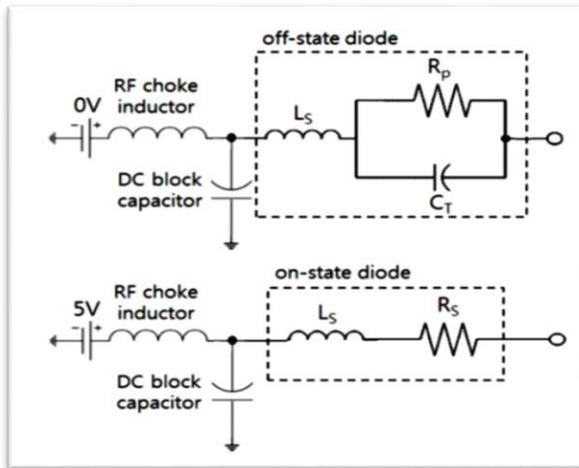
The extended pattern and frequency reconfigurable antenna is designed along with pin diodes and bias networks. Pin diode and bias network supports features such as high switching speed, lower power loss, biasing facility and low parasitic resistance. The suggested antenna in [4] demonstrated that bias line when positioned perpendicular to the radiation part tends to minimize the influence of radiation pattern such that there will be a need of inductors linked as RF chokes and capacitors to work as dc blocker. Thus it is expected that a semiconductor will enable the switching of ON/OFF states [10], which forms the underlying theory and motivation for this study, since multiple functions can be achieved with a single antenna.

In this study, a total of 7 pin diodes were used where the "ON" states indicate that the diode is forward biased that results in a series resistance with a parasitic inductance as showed in Figure 4(c) while the "OFF" states convey the impression of a reversed biased diode modeled as a series capacitance with parasitic inductance. With the help of the switch configuration depicted in Table 1, the proposed antenna achieved the main objective of this study. However, losses due to fabrication inaccuracy and error may occur though would have considerable negligible

consequence. The antenna shape is illustrated in Figure 4 and equivalent circuit models of pin diodes and dc blocks, as well as the switch configuration model employed for the achievement of pattern and frequency re-configurability.



(a)



(b)

Figure 4 Antenna design implemented with pin diodes (a) antenna layout in the OFF-state, (b) equivalent circuit model of pin diodes and dc blocks, (c) disposition of pin diodes as switches for the well working of the antenna

Table 1 Switch configuration layout

States	Switch arrangement						
	S1	S2	S3	S4	S5	S6	S7
0/WB UP	ON	ON	OFF	OFF	ON	ON	ON
1/WB LEFT	ON	OFF	ON	OFF	ON	ON	ON
2/WB RIGHT	OFF	ON	OFF	ON	ON	ON	ON
3/NB UP	ON	ON	OFF	OFF	ON	OFF	OFF
4/NB LEFT	ON	OFF	ON	OFF	OFF	OFF	OFF
5/NB RIGHT	OFF	ON	OFF	ON	OFF	OFF	OFF

3.0 RESULTS AND DISCUSSION

3.1 Ideal Case

The fabricated (ideal) antenna prototype is depicted in Figure 5 with dimensions.

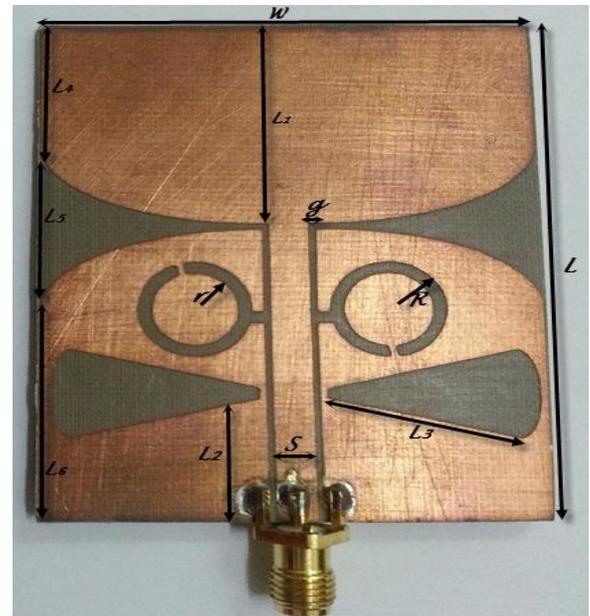


Figure 5 Shot of the fabricated ideally antenna prototype, W=50mm, L=60mm, L1=25mm, L2=5mm, L3=19.6mm, L4=15mm, L5=20mm, L6=25mm, R=5.5mm, r=4.5mm S=4.3mm and g=0.3mm

The simulated and measured S11 depending on the state of the switch for a wideband antenna is illustrated in Figure 6. The frequency is regulated using ideal switches, the S11 is less than -30dB at 4.7GHz and higher than -13dB at 2.3GHz. The impedance bandwidth of -10dB is nearly (2GHz) from 3GHz to 6GHz for state 0, a minor shift of 100MHz compared to the simulated results.

The divergence in the measured results compared to the simulated results can be attributed to the imprecise fabrication precision of the low profile antenna. However, based on the observed slight shift, the measured return loss agrees well with the simulated ones.

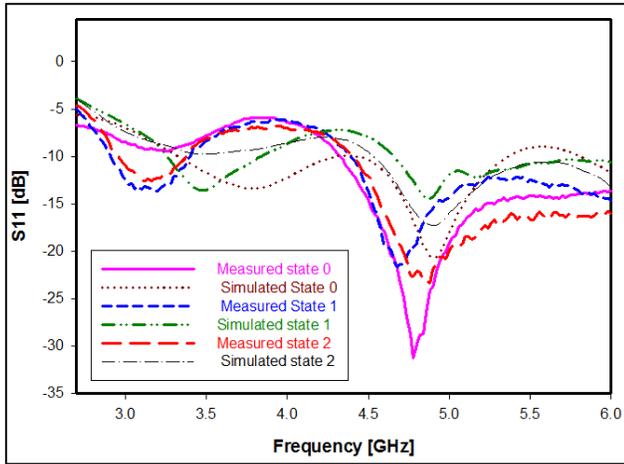


Figure 6 Wideband reflection coefficient of the ideally antenna for three different states

The implementation of the ring resonators on both sides of the ground, allowed the antenna to switch from the wideband operation to narrowband operation. This was achieved also by switching on S5 and S6; hence the ring resonators served as filters which results in obtaining a narrowband at 3.5 GHz as a center frequency and reject the wideband frequency. This was successfully achieved and a good performance was obtained for the three different directions as shown in Figure 7. However, a small inconsistency occurred due to the substrate loss tangent and manufacturing tolerance such as alignment.

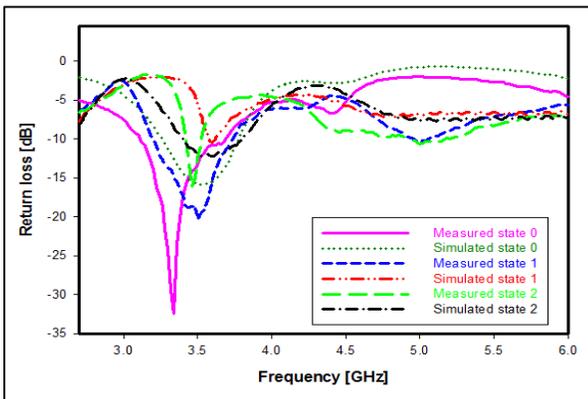


Figure 7 Narrowband reflection coefficient of the ideally extended antenna for three different states

In terms of pattern configurability, the assessment of six different possibilities is shown Figure 8, 9 and 10 where the simulated and measured H plane radiation pattern is plotted at 3.5GHz.

For every state, we have wideband antenna (a) and narrowband antenna (b). In state-0, the antenna is fed by CPW, the radiation pattern looks like a monopole antenna where the energy is maximum (peak) in the broadside direction and reducing the

gain in further directions without affecting the impedance bandwidth of the antenna. For (a), a higher gain than 5.4 dB is recorded for the simulated and a lower gain of 4.7dB for the measured. For (b), it is the other way round, a gain higher than 5.3dB is obtained for the measured value and lower gain of 4.6 dB is experienced for the simulated radiation pattern.

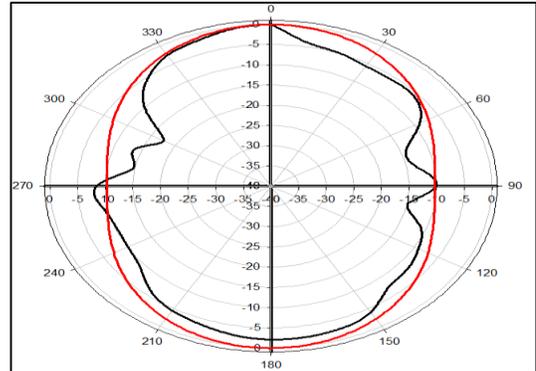


Figure 8a Radiation Pattern- State-0A

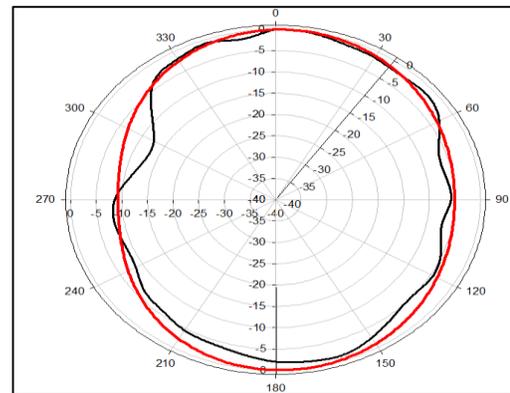


Figure 8b Radiation Pattern- State -0B

In state-1, by switching on S1 and S3, this allows the left slot to radiate and hence the maximum radiation intensity occurs at left angles to the boresight direction. For (a), the measured gain is higher compared to state-0 where a higher gain recorded to be 6dB for (b).

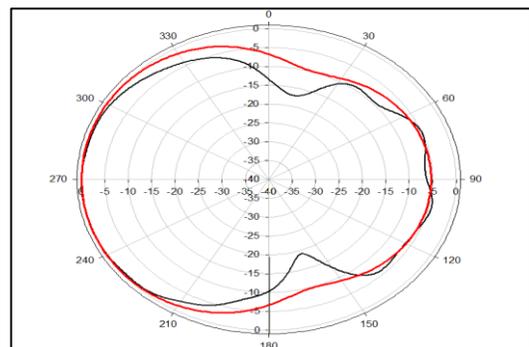


Figure 9a Radiation pattern- State-1A

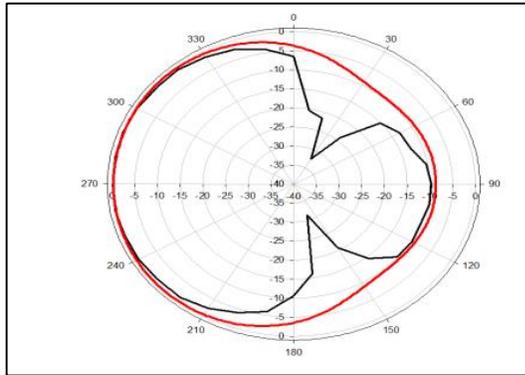


Figure 9b Radiation pattern- State-1B

While in state-2, S1 and S4 are ON which enable the right slot to radiate thus the energy is maximum in the right direction to the boresight direction, a gain higher than 5.5dB and 6.5dB is experienced respectively for (a) and (b).

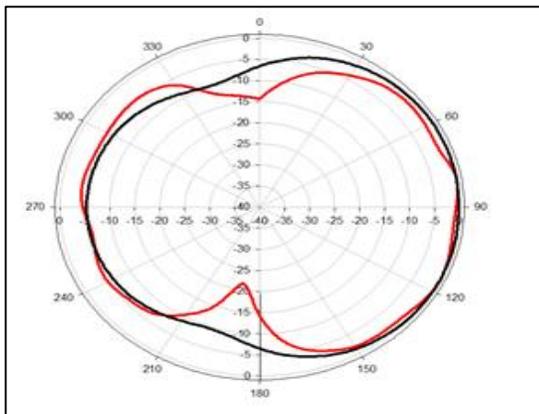


Figure 10a Radiation pattern- State-2A

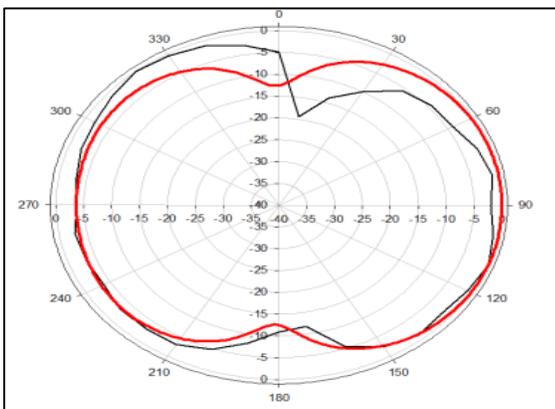


Figure 10b Radiation Pattern-State -2B

It can be concluded that different arrangement of radiating patches can make a different shape of

beam thus the radiation pattern is successfully reconfigured.

3.1 Real Case

In this case, the proposed antenna was implemented by means of pin diodes. Instead of having ideal switches that are fixed, pin diodes played the role of real switches, then by adding a second ring resonator on the left side of the ground, the antenna performance yielded a significant improvement.

A visual depiction of the fabricated prototype antenna is shown in Figure 11, where all the electrical components such as capacitors, inductors, and diodes are soldered properly. One antenna structure can be used to perform multiple functions depending on the biased diodes; a good overall performance is experienced. The measured reflection coefficients as well as the compared results of both real and ideal switched antenna are illustrated in Figure 12 (a) and (b).

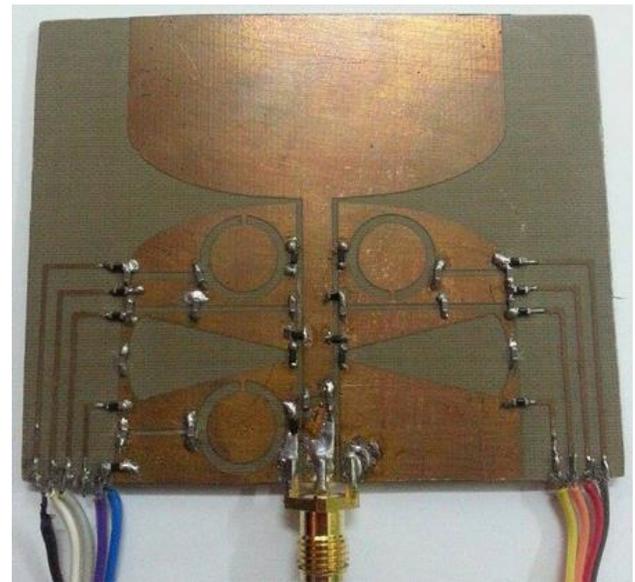


Figure 11 Photography of the fabricated antenna with pin diodes

A shift in frequency was experienced in the implementation of pin diodes. This can be attributed to the flow of electrical current while biasing the antenna as well as the improper calibration of the network analyzer. Such loss is expected in practice; nevertheless, the frequency was reconfigured as well.

In Figure 12 (a), there is a shift of 200MHz compared to the ideal, where the return loss is less than -25 dB at 2.8GHz. From the graph, it can be observed that the bandwidth is wider for the real cases than the ideal case, which highlights the advantage of added ring resonators to improve the bandwidth performance.

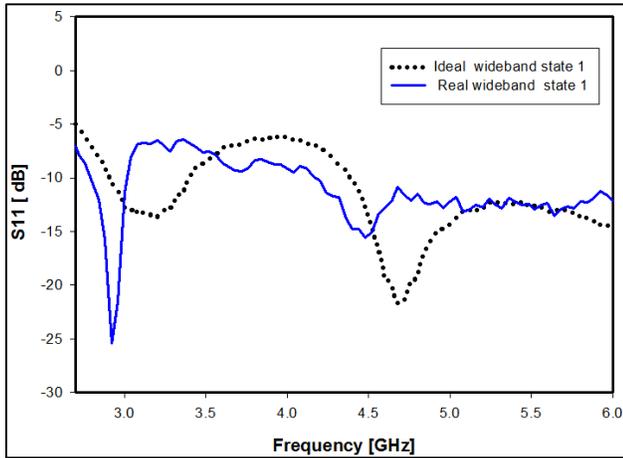


Figure 12(a) Compared reflection coefficient for ideal and real switching in state 1

In Figure 12 (b), the narrowband fed by the left slot yielded a good return loss which is less than -13 dB at 2.8 GHz with a shift of almost 300 MHz.

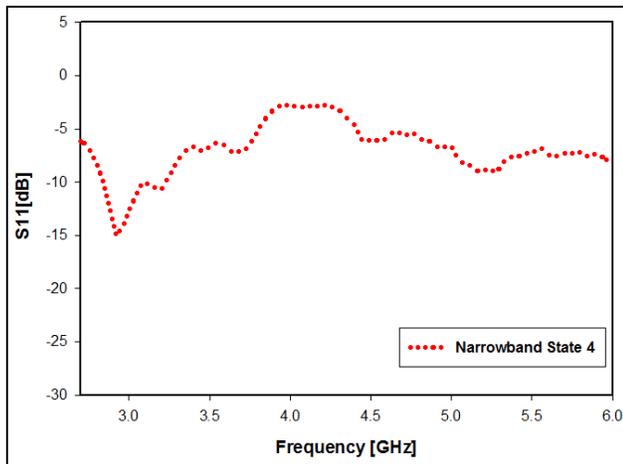


Figure 12(b) Reflection coefficient for narrowband real switching in state 4

Regardless the good results achieved, it is suggested that pin diodes [10] would be replaced by MEMS since its isolation is higher and provide a low loss which can result in very low capacitance and contact resistance. Meanwhile the feedline also can be considered for the optimization and hence improve the performance of the antenna.

Due to the equipment difficulties during the measurement, the radiation pattern for this case was not conducted. However the main objective of this paper is covered.

4.0 CONCLUSION

A new reconfigurable antenna with the frequency and pattern agility applicable for wireless communications such as body area network is presented in this monograph. The feasibility of switching from a wideband operation to a narrowband operation through the integration of ring resonators as well as the switching configuration was illustrated.

The antenna characteristics including reflection coefficient, gain, and radiation pattern were presented where the antenna was able to change the pattern depending on the feeding techniques while maintaining the same operating frequency without affecting the impedance bandwidth of the antenna.

Acknowledgement

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