Analysis of Electronically Reconfigurable Beam Steering Antenna Array using Phase Shifter Technique

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Abstract. The effect of PIN diodes position on reconfigurable ring antenna performance is investigated and studied in this work. The proposed antenna consists of two ring radiator patches, facilitating 1.25% bandwidth centered at 5.85 GHz. Simulation and measurement result is presented successfully to demonstrate the integration effect of PIN diodes with antenna to steer the antenna beam toward the desired direction. Besides being low profile, an average gains up to 8 dBi is achieved at all reconfiguration scenarios.

1. Introduction
Nowadays, reconfigurable antennas with steerable beam are preferable in wireless applications to enhance their performance by reducing the problems associated caused by multipath propagation components [1]. For instant, the localization estimation systems accuracy as one of the most critical technologies is highly demanding on the development of reconfigurable antennas [2-4]. The developments in wireless communication systems features good transmit/receive signals. Therefore, a reconfigurable antenna tends to meet desired requirement to cover various configuration. A reconfigurable antenna is being capable to modify its frequency, polarizations and radiation properties by using switching technique [1, 5].

Antenna arrays have been applied for the purpose of reconfigurable characteristics whereas multiple radiating elements are considered. Hence, the ability to control azimuth and elevation scan angles at high speed is highly conceivable [1]. Furthermore, an array antenna has asymmetrical structure thus an equal number of pin diodes can be interfaced on each side. Hence, the using of nonlinear components can be minimized along with the costing. A reconfigurable antenna using switching mechanism can lead the flow of current in desired path. The flow of current in different
paths changes the radiation properties of an antenna [5-7]. The switching mechanism can be manipulated by connecting or disconnecting the switches.

In [8], the beam steering direction has been achieved by the antenna current distribution. The design consists of $3 \times 3$ square-shaped metallic pixels with nine switching configurations. As a result, the reconfigurable antenna obtained a higher achievable rate comparable with Omni-directional antenna in different selective transmitted power. Furthermore, reconfigurable antenna performs better SNR and shows lower bit error rate compare to Omni-directional antenna.

Here, this project presents a compact two array antenna with an ability to reconfigure the beam at $0^\circ$ and $90^\circ$ at 5.85GHz. The analysis also shows the result of with and without phase shifter for the reflection coefficient and radiation pattern.

2. Antenna design configuration

Fig. 1 shows the proposed antenna with a single microstrip ring radiator patch which has been selected due its low profile characteristics and unidirectional radiation pattern. The circular patch antenna is fabricated on Rogers Duroid 5880 substrate with a thickness of 0.787mm and dielectric constant of 2.2. The proposed antenna is connected by A (SMA) probe through the microstrip line feed. All the simulated design has been carried out using CST software. Two array elements have been designed and fabricated with and without phase shifter as demonstrated in Fig. 2 and Fig. 3, respectively.

Below is the design formulas used to calculate the dimensions of the conventional circular patch:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F} \left[\ln \left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}}$$  \hspace{1cm} (1)

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$  \hspace{1cm} (2)

![Figure 1. Single Element](image_url)
Figure 2. Two-Array antenna without phase shifter (a) simulated (b) fabricated prototype
The proposed two-array elements are developed and feeding by using a simple power divider of $\lambda/4$ transformer with $\sqrt{2}Z_o$ to match $2Z_o$ to $Z_o$ transmission line.

3. Result and discussion
The reflection coefficient for the single element is shown in Fig. 4. A good return loss indicates that an antenna has high power signal reflected in transmission line. It can be noticed that single element is simulation result is able to achieve reflection coefficient at $-11.5$ dB for operating frequency of 5.85 GHz and bandwidth of 72.6 MHz.

The reflection coefficient for the single element is shown in Fig. 4. A good return loss indicates that an antenna has high power signal reflected in transmission line. It can be noticed that single element is simulation result is able to achieve reflection coefficient at $-11.5$ dB for operating frequency of 5.85 GHz and bandwidth of 72.6 MHz
The realized gain obtained for single element antenna is 4.7 dBi which considered as average gain. Fig. 5 shows the radiation pattern in polar form. Radiation from antenna is in straight upward direction with 0 degree, this indicates a good front-to-back ratio. However, Fig. 6 shows the main lobe radiates in lobe direction of 280 degree which is not strongly focused. From the simulations carried out, the input power is transmitted through the two upper transmission lines via pin A and pin A1 or through two transmission lines beneath via pin B, pin B1, pin C and pin C1 in configuration 1 and configuration 2 respectively.

![Reflection Coefficient](image)

**Figure 4.** Reflection coefficient of the single element antenna.

![Radiation Pattern](image)

**Figure 5.** Radiation Pattern in polar form for theta in degree.

Fig.7 shows the simulated reflection coefficient of the two array ring patch antenna. It can be seen that it is operating at 5.85 GHz with the return loss -11.95 dB with bandwidth of 74.2 MHz. Fig. 8 illustrates both simulation and measurement results which share almost same trend of variation in S11. When come to focused frequency 5.8GHz, It can be seen that measurement result shows better
performance by having about -20dB lower S11 compared with simulated one due to slight variation during the fabrication process or less interference in measurement environment.

Figure 6. Radiation Pattern in polar form for phi in degree.

Figure 7. Reflection coefficient of two-array circular patch antenna
High gain is attained with 9.742dBi. The proposed antenna implies high ability to radiate its power signal towards certain direction. Radiation from the antenna is highly focused. Radiation pattern results from simulation are demonstrated in Fig. 9 and Fig 10. It can be seen that the main lobe of the radiation pattern is highly focused toward directions 0 degree and 90 degree.
4. Conclusion
In this paper, the performance of the proposed antenna with beam steering variation has been presented. The developed antenna has two element antenna arrays which are designed with six PIN diodes. Several configurations are carried out by connecting and disconnecting the PINs alternatively to control beams steering at 5.8 GHz. Simulation results at configuration 1 demonstrates high gain whereas the lobes of radiation is highly focused, however, side lobes and back lobes of radiation in configuration 2 have shattered away from straight line in direction. Gain result of configuration 3 and configuration 4 share similar characteristic. Radiation pattern of both configuration 3 and configuration 4 radiate away from straight direction but in opposite directions.

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