Radiation Pattern Reconfigurable FM Antenna

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Abstract. In this work, a radiation pattern reconfigurable antenna design using compact printed spiral monopoles that operates at 102 MHz is reported. The proposed antenna changes its radiation behaviour that responds towards a desired direction with the use of RF switches. The antenna is printed on a 76.6mm × 50mm PCB layer providing more than 20MHz bandwidth at -10 dB threshold and is easily fabricated with low manufacturing cost. The antenna was also simulated on 500mm × 500mm ground plane that represents the roof top of a vehicle.

1. Introduction

Communication is defined as the transmission of data such as music, pictures, video and other information using electrical signal and optical signal. Music, pictures, video and other data is transmit from the source to the destination using optical or light waves for shorter distance meanwhile wired and radio communication used for longer distance. This transmission is of the data happens with the unique invention such as antenna that is more practical in various communication system [1]-[9].

Invention of the antenna is strongly acceptable in transmission of electromagnetic wave at wide distance and its very vulnerable to the external electromagnetic filed which has a ability to interfered with the transmit signal. Somehow the researchers have enhanced the capability of the antenna in transmitter and receiver side by fixing the amplifier to increase the strength of the signal that have to transmit. Recent work shows that antenna could be implemented using various techniques and material [10-13]. This is due to the fact that the wireless communication is reaching the enormous growth because of high user, multifunctional and also more frequency band used to transmit the data, thus to support the use of the antenna is getting larger. This phenomenon is leads to large equipment,
communication system and also increasing the cost and problem electromagnetic compatibility. To overcome this issue the researchers has improved the antenna by remodelling the design and shapes where it can give a result in term of reconfigurable. For example, the reconfigurable antenna such as frequency, radiation and polarization has owned advantages where it can change the properties of the antenna based the design purpose [1-5]. A few elements have to consider when designing the reconfigurable antenna for example material used to fabricate such as FR4, Rogers TM6 because every material has own dielectric properties where plays an important role in transmitting and receiving the signal. Besides that, matching network and switch also contribute an important role in reconfigurable antenna to increase the efficiency. The main properties of the antenna are gain and radiation pattern. By using the different types of design these properties can change depends on the requirement. The advantages of radiation pattern reconfigurable antenna are to reduce the interference caused by the other signal in free space. For example, the antenna will change its radiation pattern according to the desired signal and direction. The radiation pattern will change the direction with the implementation of the switch on the designed antenna [1].

2. Antenna design configuration
A detailed of the proposed antenna structure will be presented in two categories as a single element and four element antennas as follows:

2.1 Single Element Antenna (SEA) Design
The main purpose for design the reconfigurable antenna is to overcome the problem faced by the FM user in area which is affected by the interference. The substrate used for design and fabricate the antenna is FR4. The spiral shape is designed at top of the substrate which is tends more effective towards the signal. The antenna is initially design and simulated as single element antenna. The concept of the single element antenna is adopted based on work [14]. The size of the antenna design is 100mm × 50mm. After several of modification and simulation the design for single element antenna is finalized. The example of modification that done on the design is changing the width of the spiral and size of ground. The output from the single element antenna which is the radiation pattern is omnidirectional where the SEA has the ability to cover all the direction as per expected and the size of the spiral shape and ground is finalized which is 0.7mm and 40mm. The actual size of single element antenna, size of the spiral and size of ground plane is shown in Figure 1, Figure 2 and Figure 3 respectively.

![Figure 1. Actual Size](image-url)
3. **Four Element Antenna (FEA) Design**

Four element antenna is designed using a combination of four single element antennas. Each single element antenna is made up by using each single element antenna which is stated in the previous section. Each single element antenna is placed at 90° to each other and it is presented in a square shape after combined. The purpose of using a four element antenna is to cover all four directions which are east, north, west, and south which are 0°, 90°, 180°, 270° respectively. Figure 4 and Figure 5 below show the general layout of FEA and Structure of FEA for each side respectively.
4. Switching mechanisms
Steering mechanism is successor of the four-element antenna. The radiation pattern is changing due to the configuration of the switch used. The use of switching to synthesize beamforming mechanism have adopted in [15-17]. The switch used is PIN Diode BAR50-02V [18]. The dimension of the switch is 1.5mm × 0.5mm. There are two conditions for the switch when designing process which is “ON” condition and OFF” condition. When the switch is ON the RF current will flow from feeder to the microstrip and when the switch is OFF the RF current will not flow from the feeder to microstrip antenna. They are four configurations of the switch to get four different direction of the radiation pattern. The switched are labelled as switch1, switch2, switch3 and switch 4. The configuration of the switch is stated Figure 6 as below and followed by the direction of the radiation pattern in Table 1.
Figure 6. Placement of Switch.

Table 1. Configuration of switch respected pattern direction.

| Direction of Radiation Pattern/Switch Configuration | S1 | S2 | S3 | S4 |
|-----------------------------------------------------|----|----|----|----|
| East (0°)                                           | Off | Off | Off | On |
| South (270°)                                        | Off | Off | On  | Off|
| West (180°)                                         | Off | On  | Off | Off|
| North (90°)                                         | On  | Off | Off | Off|

The DC biasing is done to enhance the measurement and parameters of the FEA. The Dc biasing consists of capacitor and inductor. The 470 pF capacitor used in this DC biasing is to block the DC flow from the feeder to spiral monopole antenna allow the AC flow from the feeder to the antenna, because the DC flow from the feeder could harm the spiral monopole antenna. The capacitor is only responsible to block the DC and it is doesn’t affect the RF current from the feeder. The capacitor is connected parallel with inductor to improve the DC flow. The 1uH inductor is used to block AC flow from the spiral monopole antenna. Figure 7 shows the schematic of switching mechanisms.

Figure 7. Schematic Of Switching Machanisms.
5. Result and discussion

Reflection coefficient is SEA based on the simulation is presented in Figure 8. The resonant frequency which should be at 98 MHz is almost achieved by optimize the design of SEA also seen from the figure below.

![Figure 8. Reflection coefficient is SEA.](image)

The pattern obtained from SEA is omnidirectional pattern which means the pattern radiated from the antenna at 360°. The pattern radiated from the SEA is having ability to cover for almost all the direction. Figure 9 below shows the radiation pattern of SEA in 2D form.

![Figure 9. Simulated Radiation Pattern of SEA](image)

The simulated reflection coefficient of FEA was presented in Figure 10 below. From the figure the measured and simulated result slightly differ because of imbalanced surface current in antenna. However, the radiation patterns at 102 MHz in the azimuth plane of four directions are shown in Figure. 11.
6. Conclusion
The Radiation Pattern Reconfigurable Antenna is successfully design and fabricated to achieve the objectives of the project. The antenna is new where, to date no research has been conducted to develop pattern reconfigurable antenna operating at VHF band. The proposed antenna operates at VHF band, by achieving S11 less than -10dB and gain of -20 dB at each steered angle. Four RF switches are used to control the beam directions of the antenna. The proposed antenna is capable for steering its beam to 0, 90, 180 and 270 degrees according to the switching condition. The antenna is first simulated using
CST, and then fabricated and the S11 result is measured. The proposed antenna could be used in combating interference scenario specifically that operates in VHF band such as FM radio. Moreover, the antenna is also should practically test using mobile application such as car radio to measure the capability of the antenna more accurate. Besides that, the design of the antenna should revise to reduce the size and make it more compatible for any application. The antenna is also could be implemented with an algorithm to switch automatically towards the desired frequency. The received RSSI or the reference of the coordinates from online maps could be used to make the decision mechanism in the algorithm.

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