DESIGN OF DUAL POLARIZED RECONFIGURABLE PATCH ANTENNA FOR L-BAND APPLICATIONS

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ABSTRACT

A compact dual polarized reconfigurable patch antenna is proposed. Four pairs of varactor diodes are symmetrically placed along the slot. The Circular polarization radiation with compact size is achieved by symmetric- square slot cut along the orthogonal direction of the patch radiator. The antenna will design and simulate by using HFSS simulation software. In this design we consider FR4 substrate. A single coaxial probe feed technique used to excite the resonant modes of the patch antenna By varying the capacitance values of the switches with single DC voltage, the resonant frequencies of the two modes can be simultaneously changed. Moreover, by introducing a specific difference between the length and width of the rectangular-ring slot, good CP performances and high bandwidth can be obtained over a broad frequency range. The antenna operating frequency range from 1 GHz-3 GHz and directional radiation patterns are obtained.

Index Terms — FR4 Substrate, HFSS, Coaxial Probe feed, CP.

I. INTRODUCTION

Microstrip patch antennas are widely employed in wireless communications because of several advantages like ease of fabrication, low profile and low cost. However they have the disadvantage of narrow bandwidth which is not suitable for modern mobile communication systems. Some of the limitations are low efficiency, low power, narrow frequency bandwidth, poor polarization purity, and poor scan performance. Microstrip antennas are applicable in the GHz range i.e., f > 0.5GHz.

The major disadvantage in Microstrip patch antennas is bandwidth. The bandwidth is typically limited to a few percent. Various techniques have been proposed to enhance bandwidth in Microstrip patch antennas in order to rectify this problem. Some of them are by using stacked patches, shorted patch, shorting pin and by using slotted patches

Circularly polarized Microstrip antennas have been widely used in many applications such as mobile, satellite communications, radars and global positioning systems (GPS), RFID applications, Wireless LAN. Circular polarization provides greater mobility and freedom in the orientation angle between a transmitter and a receiver in comparison with a linearly polarized microstrip antenna.

Microstrip patch antennas have unstable radiation patterns over the operating band. To overcome this problem Frequency-reconfigurable patch antennas having tunable narrow frequency bands came in to existence because of their stable radiation patterns

Reconfigurable Antennas

Reconfigurable antennas exhibit many advantages over their traditional counterparts. The antenna can be used to support multiple functions at multiple frequency bands. This will significantly reduce the hardware size and cost. Antenna reconfiguration is normally achieved in one of three ways, switching parts of the antenna structure in or out using electronic switches, adjusting the loading or matching of the antenna externally and changing the antenna geometry by mechanical movement.

Switching or tuning within an antenna or in an external circuit can be achieved by means of PIN diodes, GaAs FETs, MEMs devices or varactors. MEMS devices have the advantage of very low loss, but the disadvantages are high operating voltage, high cost and lower reliability than semiconductor devices. GaAs FETs used in switching mode, with zero drain to source bias current, have low power consumption but poorer linearity and higher loss. PIN diodes can achieve low loss at low cost, but the disadvantage is that in the on state there is a forward bias DC current, which degrades the overall power efficiency. Varactor diodes have the advantage of providing continuous reactive tuning rather than switching, but suffer from poor linearity. These devices have been used and deployed in many antennas in a number of ways as reported in many publications.

The reconfigurable concept when is referred to antennas, it means the capability to change the characteristic antenna electrical parameters through electric or mechanic mechanisms. Ideally, a reconfigurable antenna is designed to change the resonant frequency, input impedance, bandwidth, polarization, and radiation pattern as a function of the requirement systems.

Reconfiguring an antenna is achieved through deliberately changing its frequency, polarization, or radiation characteristics. This change is achieved by many techniques that redistribute the antenna currents and thus alter the electromagnetic fields of the antenna's effective aperture. Reconfigurable antennas can address complex system requirements by modifying their geometry and electrical behavior, thereby adapting to changes in environmental conditions or system requirements (i.e., enhanced bandwidth, changes in operating frequency, polarization, and radiation pattern). Reconfigurabulity has become an important and desired feature of modern, agile, radio-frequency (RF) systems for wireless and satellite communications, sensing, and imaging. There is a shift toward incorporating smart, cognitive, and agile RF devices that can both sense the surrounding RF environment and communicate at the same time in any contested/congested environment. Some of the new desired capabilities include frequency-agile, software defined, and cognitive radios to cope with extendable and reconfigurable multiservice, multi standard, and multiband operation, as well as with efficient spectrum and power utilization. These concepts can significantly reduce the number of components and thus hardware complexity, and cost compared to today's radio technology, which relies on incompatible communications systems with inflexible hardware. An electrically reconfigurable antenna relies on electronic switching components (RF-MEMs, PIN diodes, or varactors) to redistribute the surface currents, and alter the antenna radiating structure topology and/or radiating edges. The integration of switches into the antenna structure makes it easier for designers to reach the desired reconfigurable functionality. The ease of integration of such switching elements into the antenna structure has attracted antenna researchers to this type of reconfigurable antennas despite the numerous issues surrounding such reconfiguration techniques. These issues include the nonlinearity effects of switches, and the interference, losses, and negative effect of the biasing lines used to control the state of the switching components on the antenna radiation pattern. Next, three different examples of electrically reconfigurable antennas are described.

II. Dual polarized reconfigurable patch antenna

Existing Method

The structure of the proposed antenna with detailed dimensions is shown in Fig. 1. The antenna is built on a 3.175-mm-thick RT/Duroid 5880 substrate (dielectric constant). A rectangular patch is printed on the top of the substrate, and a rectangular-ring slot is etched in the patch; the patch is therefore divided into a center patch and an outer ring patch. A square ground with50 mm×50 mm is printed on the bottom of the substrate. A SMA connector is placed along the diagonal line of the patch to excite two orthogonal modes of the patch. Twelve varactor diodes (SMV2019-079LF, Skyworks Solutions Inc.) are symmetrically placed along the slot to bridge the gap between the center patch and the outer ring patch. The anodes of the varactors are soldered to the outer ring patch, meanwhile, the cathodes of the varactors are soldered to the center patch. The capacitance of the varactor diodes changes from 2.22 pF to 0.30 pF when the reverse bias voltage increases from 0 V to 20 V. It should be mentioned that the number of the varactor diodes is selected as twelve. Because few varactors will lead to high cross polarization levels. On the other hand, more varactor diodes will result in more complicated Antenna structure. In the existing design Antenna operates in the frequency range of 1.92 - 2.51 GHz and the efficiency rises from 41% to 61%.Main drawbacks in existing design are polarization occurs only one side, less efficiency and less bandwidth. To rectify this drawbacks an Antenna is proposed with increased efficiency and bandwidth which operates in frequency range of 1 – 3 GHz.

Proposed Antenna Design

A Compact dual polarized reconfigurable patch antenna is proposed for L-band applications. This antenna consists of rectangular patch etched with a rectangular ring slot. Four pairs of varactor diodes are placed along the slot, this is because more varactor diodes lead to complicated antenna structure and less varactor diodes lead to high cross polarization levels. so to restrict these problems twelve varactor diodes have been used.

The antenna is constructed on a ground of 100 × 100 mm square ground with a substrate placed above it. The substrate used in this design is FR4 epoxy substrate with a thickness of 3.175 mm. A rectangular patch is designed on the top of the substrate, and a rectangular ring slot is etched in to the patch. Therefore the patch is divided in to two patches namely

- Center patch and
- Outer ring patch

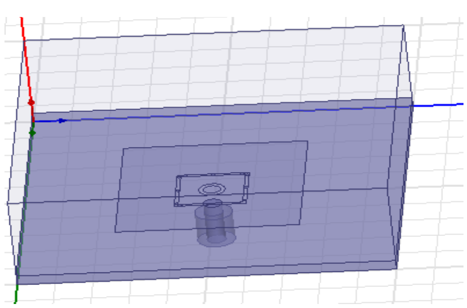


Fig 1: Model Design

Twelve varactor diodes which are used in this design are placed symmetrically along the slot between the center patch and outer ring patch. these varactor diodes acts as a bridge between center patch and outer ring patch. The cathodes of varactor diodes are connected to outer ring patch and anodes are connected to center patch. The capacitance of varactor diodes changes from 0.3 to 2.85 pF. The varactor diodes act as switches in this design.

Coaxial probe is used as a feed in this design. This feed is located on the diagonal line of the patch to excite two orthogonal modes TM_{01} and TM_{10} respectively. Main reason for using coaxial probe as a feed is to excite the resonant modes of the patch antenna by varying the capacitance values of the varactor diodes with single DC voltage.

The resonant frequencies of the two modes (TM_{01} and TM_{10}) are determined by the equivalent length and width of the entire patch. The equivalent length or width is determined by three factors:

- The physical length of the entire patch
- The capacitance values of the varactor diodes
- Location of the slot

In order to achieve the CP operation over a wide frequency band by tuning the capacitance values of varactor diodes, Phase difference of 90^0 is maintained by introducing a difference between the length and width of the rectangular ring slot. Moreover, by introducing a specific difference between the length and width of the rectangular ring slot, good CP performances and high bandwidth can be achieved over a broad frequency range.

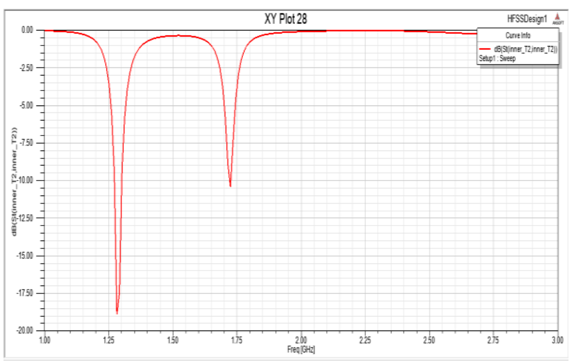
A wide Bandwidth and gain is achieved by using FR4 epoxy as a substrate with a operating frequency ranging from 1 to 3 GHz. Suitable directional radiation patterns and Return loss of the antenna are obtained over a operating frequency range.

This Antenna is designed and simulated using High Frequency Structural Simulator (HFSS). HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. HFSS can be used to calculate parameters such as S Parameters, Resonant Frequency, and Fields.

III. RESULTS

RETURN LOSS:

It is defined as the ratio of the Fourier transforms of the incident pulse and reflected signal. It is usually expressed as a ratio in decibels (dB). Return loss is related To Both Standing Wave Ratio (SWR) And Reflection Coefficient (Γ). Increasing Return Loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. For a matched line the return loss is low. A low return loss is desirable and results in a



lower insertion loss. Return loss is used in modern practice in preference to SWR because it has better resolution for small values of reflected wave.

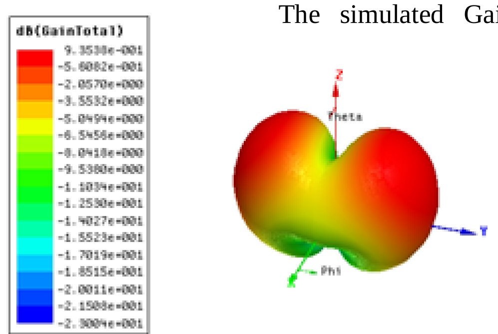
Fig 2: Return Loss

The measured return loss is shown in fig.6.1 which is carried out by the HFSS software. It can be observed that circular polarized operations frequency varies from 1 to 2 GHz. The above result shows 1.285 GHz and 1.73 GHz. It comes under L-band applications.

GAIN:

Gain of a rectangular microstrip patch antenna with air dielectric is roughly estimated between 7–9 dB. The ratio of the intensity in a given direction to the total input power gives the Gain.

$$\text{Gain} = 4\pi \times \frac{radiation\ \ intensity}{Total\ \ input\ \ power}$$



The simulated Gain is shown in fig 6.2 which is carried out by the HFSS software. It can be

Fig 3: Gain

Observed that the operating frequency varies from 1 to 3 GHz. Maximum Gain of 9.35 dB is obtained at the frequency of 1.285 GHz

RADIATION PATTERN:

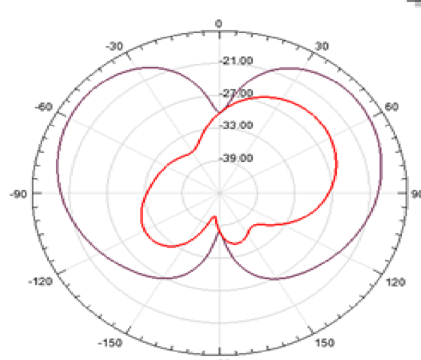
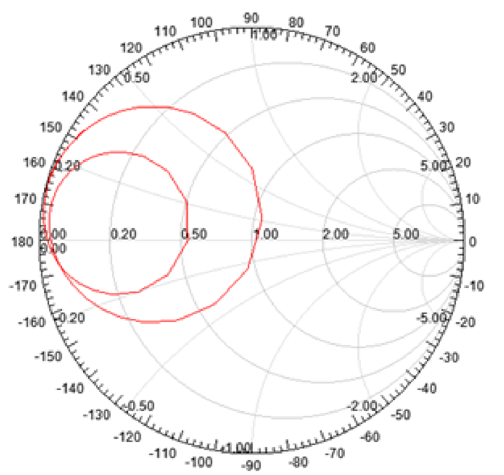


Fig 4: Radiation Pattern

An Antenna radiation pattern or Antenna pattern is defined as a mathematical function or graphical representation of the radiation properties of the Antenna as a function of Space Coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization." The radiation property of most concern is the two- or three dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius.

The simulated Radiation Pattern is shown in fig 6.3 which is carried out by the HFSS



software. It can be observed that the operating frequency varies from 1 to 3 GHz. Suitable Radiation Pattern is obtained at the frequency of 1.285 GHz.

SMITH CHART:

The Smith chart is one of the most useful graphical tools for high frequency circuit applications. The chart provides a clever way to visualize complex functions and it continues to endure popularity decades after its original conception.

Fig 5: Smith Chart

From a mathematical point of view, the Smith chart is simply a representation of all possible complex impedances with respect to coordinates defined by the reflection coefficient. The domain of definition of the reflection coefficient is a circle of radius 1 in the complex plane. This is also the domain of the Smith chart.

The smith chart impedance plot is shown in the above fig.6.4. It nearly touches the line (1,0) point which indicates one of the frequency value of 1.285GHz. It is related to the load (antenna).Then at that frequency the total signal is radiating without any reflection.

IV. CONCLUSION

A compact Dual Polarized Reconfigurable patch antenna is proposed. By varying the capacitance values of the varactor diodes that are symmetrically placed along the etched rectangular-ring slot, the resonant frequencies of the two orthogonal modes can be simultaneously tuned. A specific difference between the length and width of the rectangular-ringslot is introduced to produce a difference between the two modes, so that good CP performances can be obtained over a wide frequency range. The antenna achieves a operating frequency ranging from 1 GHz to 3 GHz .Stable directional radiation patterns are achieved at all operating frequencies. The antenna owns a low profile structure. Therefore, the proposed antenna is very attractive for future wireless communications.

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