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Perfomance Evaluation of Reconfigurable Circular Patch Antenna

Dr.V.Nandalal
Department of ECE
Sri Krishna College of Engineering and Technology
Coimbatore, India
nandalal@skcet.ac.in

N.Sathishkumar
Department of ECE
KPR Institute of Engineering and Technology
Coimbatore, India
sathishkumar2490@gmail.com

Abstract**—**A new probe-fed patch antenna polarization reconfiguration is presented in this proposed work. The antenna is composed of a circular radiating patch and a switchable feed network. By controlling the operating states of four pairs of pin diode in the feed network, the feed point of the circular patch can be switched. Therefore, a reconfiguration between four linear polarization directions at a 45 degree interval (22.5 degree, 67.5 degree, 112.5 degree and 157.5 degree) can be realized. All the different polarization states own similar matching and radiation characteristics. Simulated and measured results indicate that antenna can achieve reconfigurable quadri-polarization diversity features with an invariable operating frequency and excellent radiation performance, which are very attractive for wireless communications. In addition, the proposed design can offer more reconfigurable linear polarization directions by adding more switchable paths in the feed network.

Keywords—Patch Antenna;Pin Diode;Network

I. Introduction

Antennas play very important role in the field of wireless communications. Some of them are Parabolic Reflectors, micro strip Antennas, Slot Antennas, and Folded Dipole Antennas. Each type of antenna is good in its own properties and usage. We can say antennas are the backbone for wireless communication without which the world could have not reached at this age of technology. Micro strip patch antennas play a very significant role in today's world of wireless communication systems. A Micro strip patch antenna is very simple in the construction using a conventional Micro strip fabrication technique. Rectangular and circular patch antennas are the most commonly used micro strip patch antennas.

Dual characteristics, circular polarization, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning and triple band frequencies can be easily obtained from these patch antennas. Micro strip antennas are widely used in the microwave frequency region because of their simplicity and compatibility with printed circuit technology, making them easy to manufacture. Generally a micro strip antenna or a patch antenna consists of a patch of metal on top of the grounded substrate. The substrate is made of a dielectric material. Various methods are used to feed a micro strip antenna such as inset feed, coaxial feed, aperture coupled or slot coupled feed and proximity coupled feed. Micro strip patch antenna has the important advantage of being low profile and if the substrate is thin enough, they may also be comfortable. HFSS software is used to carry out the results. HFSS software is a fully featured software package for electromagnetic analysis and design in the high frequency range.

II. ANTENNA PARAMETER

Antenna Gain

Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power P0 at a distance R which is given by $S = P0/4\pi r^2$. An isotropic antenna radiates equally in all directions, and it's radiated power density S is found by dividing the radiated power by the area of the sphere $4\pi r^2$. An isotropic radiator is considered to be 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation.

$$S = \frac{P_0 G}{4\pi R^2} = \frac{|E|^2}{\eta}$$

Gain is achieved by directing the radiation away from other parts of the radiation sphere. In general, gain is defined as the gain-biased pattern of the antenna.

The surface integral of the radiation intensity over the radiation sphere divided by the input power P0 is a measure of the relative power radiated by the antenna, or the antenna efficiency.

$$\frac{P_r}{P_0} = \int_0^{2\pi}\int_0^{\pi} \frac{G(\theta,\emptyset)}{4\pi} \sin\theta d\theta d\emptyset = \eta_e$$

Where P_r is the radiated power. Material losses in the antenna or reflected power due to poor impedance match reduce the radiated power

EFFECTIVE AREA

Antennas capture power from passing waves and deliver some of it to the terminals. Given the power density of the incident wave and the effective area of the antenna, the power delivered to the terminals is the product.

$$P_d = SA_{eff}$$

For an aperture antenna such as a horn, parabolic reflector, or flat-plate array, effective area is physical area multiplied by aperture efficiency. In general, losses due to material, distribution, and mismatch reduce the ratio of the effective area to the physical area. Typical estimated aperture efficiency for a parabolic reflector is 55%. Even antennas with infinitesimal physical areas, such as dipoles, have effective areas because they remove power from passing waves.

DIRECTIVITY

Directivity is a measure of the concentration of radiation in the direction of the maximum.

$$\boldsymbol{Directivity} = \frac{\boldsymbol{Maximum\ radiation\ intensity}}{\boldsymbol{Average\ radiation\ intensity}}$$

$$\boldsymbol{Directivity} = \frac{\boldsymbol{U_{max}}}{\boldsymbol{U_0}}$$

BEAMWIDTH

Beamwidth of an antenna is easily determined from its 2D radiation pattern and is also a very important parameter. Beamwidth is the angular separation of the half-power points of the radiated pattern.

$$S(\theta,\emptyset) = \frac{P_0 G(\theta,\emptyset)}{4\pi R^2}$$

$$U(\theta,\emptyset) = \frac{P_0 G(\theta,\emptyset)}{4\pi}$$

III.DESIGN METHODOLOGIES

GROUND PLANE

In telecommunication, a ground plane is a flat or nearly flat horizontal conducting surface that serves as part of an antenna, to reflect the radio waves from the other antenna elements. The plane does not necessarily have to be connected to ground. Ground plane shape and size play major roles in determining its radiation characteristics including gain. To function as a ground plane, the conducting surface must be at least a quarter of the wavelength (λ/4) of the radio waves in size. In lower frequency antennas, such as the radiators used for broadcast antennas, the Earth itself (or a body of water such as a salt marsh or ocean) is used as a ground plane. For higher frequency antennas, in the VHF or UHF range, the ground plane can be smaller, and metal disks, screens and wires are used as ground planes. At upper VHF and UHF, the metal skin of a car or aircraft can serve as a ground plane for whip antennas projecting from it. In micro strip antennas and printed monopole antennas an area of copper foil on the opposite side of a printed circuit board serves as a ground plane. The ground plane doesn't have to be a continuous surface.

SUBSTRATE

FR-4 (or **FR4**) is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing).

ANTENNA FEEDING

A feed line is used to excite to radiate by direct or indirect contact. There are many different methods of feeding and four most popular methods are micro strip line feed, coaxial probe, aperture coupling and proximity coupling.

Micro strip Line Feeding

Micro strip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as

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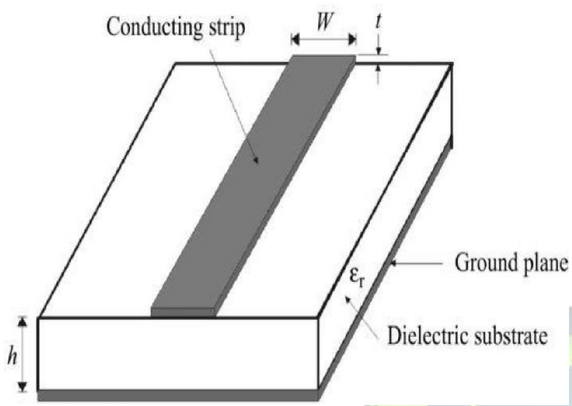
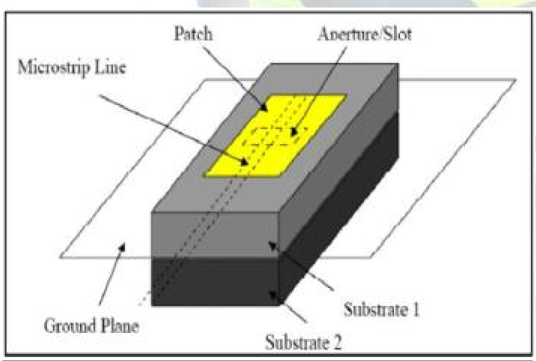
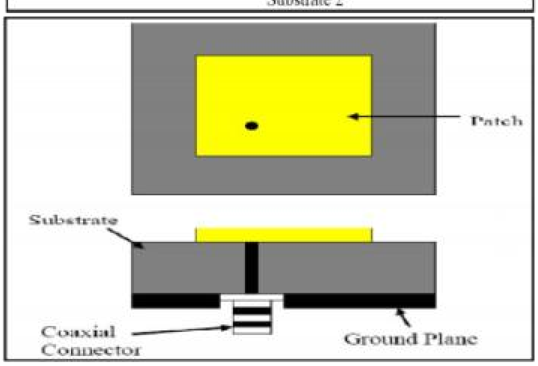
substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth



Coaxial Feeding

Coaxial feeding is feeding method in which that the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane. Micro strip antennas can also be fed from underneath via a probe as shown in figure 4.2. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna





The position of the feed can be altered as before (in the same way as the inset feed, above) to control the input impedance.

Comparison of the characteristics for different feed techniques

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor due to Soldering	Good	Good
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	2-5%

CIRCULAR PATCH

A patch antenna (also known as a rectangular micro strip antenna) is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane.

A NOVEL QUADRI POLARIZATION ANTENNA DESIGN

The patch in the antenna is made of a conducting material Copper (Cu) or Gold (Au) and this can be in any shape like rectangular, circular, triangular, elliptical or some other common shape. The circular patch antenna is designed so as it can operate at the resonant frequency. The important parameters for the design of a Hexagonal micro strip patch antenna are

Frequency of Operation (fr):

The resonant frequency of the antenna is depending on the application. The presented antennas are designed for UWB applications. The frequency range of UWB band is approximately 3.1 to 10.6 GHz. The resonant frequency selected for this design is 2.02 GHz.

Radiation Efficiency(%):

Radiation efficiency is key performance for reconfigurable antennas. The introduced switches or

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other tuning mechanisms in the reconfigurable designs produce additional power loss. However, the values of the radiation efficiencies are not provided in most of the published designs. A radiation efficiency of smaller than 45% is realized in. On the other hand, a larger than 79% efficiency is achieved in this design, which is comparable with conventional patch antennas.

Gain(dB):

The definition of antenna gain is close to that of antenna directivity. The difference between these two parameters is the gain takes into account the efficiency of the antenna and its directivity together. Therefore the gain of this antenna is 6.9 dB

Dielectric Constant of the Substrate (εr):

The dielectric constant of a substrate (εr) plays an important role in the patch antenna design. A substrate with a high dielectric constant reduces the dimensions of the antenna but it affects the antenna performance too. So, there is a trade-off between size and performance of a patch antenna. The dielectric material chosen for this antenna is FR-4 lossy, which is having a dielectric constant of 4.3.

IV.SOFTWARE TOOL

HFSS STUDIO 15.0

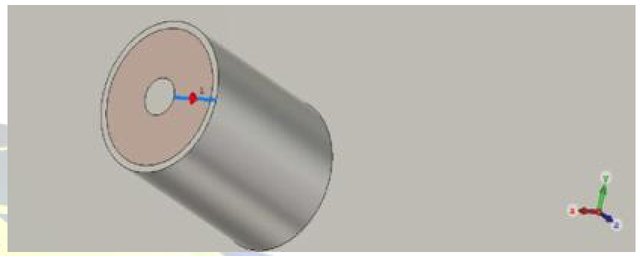
HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft 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. Ansoft HFSS can be used to calculate parameters such as S Parameters, Resonant Frequency, and Fields. Typical uses include:

- Package Modeling – BGA, QFP, Flip-Chip PCB Board Modeling
- Power/Ground planes, Mesh Grid Grounds, Backplanes Silicon/GaAs
- Spiral Inductors, Transformers EMC/EMI
- Shield Enclosures, Coupling, Near- or Far-Field Radiation Antennas/Mobile Communications
- Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section(RCS), Frequency Selective Surfaces(FSS) Connectors
- Coax, SFP/XFP, Backplane, Transitions Waveguide
- Filters, Resonators, Transitions, Couplers Filters

V.SIMULATED RESULTS

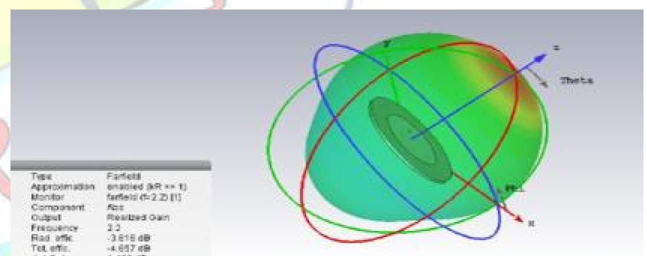
ANTENNA DESIGN

The antenna is stimulated using a substrate FR-4 and the result is stimulated using HFSS(High Frequency Structural Stimulator) and using HFSS antenna parameter like Bandwidth(GHz),Gain(dB) and Efficiency(%)

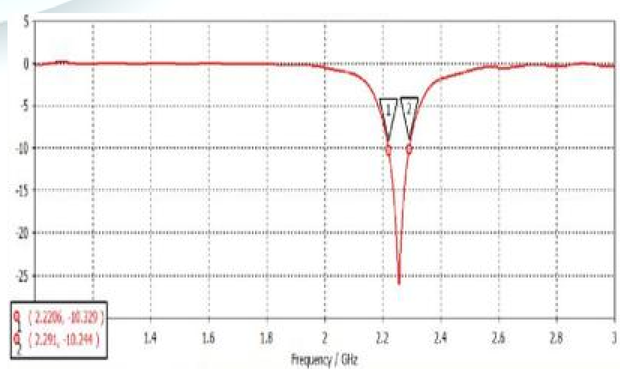


RADIATION PATTERN

In the field of antenna design the term radiation pattern or antenna pattern or far-field pattern refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source.



The antenna design has been optimized to have good impedance of 50 Ohms matching in the frequency range of 2-3 GHz and the resonant frequency occurs at 2.2 GHz.



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CONCLUSION AND FUTURE WORK

In this paper, a novel polarization reconfigurable circular patch antenna is proposed. By changing the operating state of four pairs of PIN diodes, the antenna can realize reconfigurable quadri-polarization diversity features. Furthermore, the operating frequency is maintained at different polarization states with excellent radiation performance. To be mentioned, the proposed design can offer more reconfigurable linear polarization directions by adding more switchable paths in the feed network. With all these attractive properties, the proposed antenna is very attractive for wireless communications.

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