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A Comprehensive Survey on Pattern Reconfigurable Antenna for Sub 6G Applications

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Abstract: *A Survey of Yagi-Uda antenna is proposed in this paper. This project focuses on the design and implementation of a pattern reconfigurable Yagi-Uda antenna operating in the 5 to 6 GHz frequency band. The antenna design switches between the reflector and director accordingly of a Yagi-Uda antenna by using radio frequency PIN diodes. This enables the antenna to switch between the maximum and minimum radiation towards desired signals or keeping away from the unwanted /interfering signals. The proposed pattern reconfigurable antenna is designed to dynamically adjust its radiation pattern to optimize performance in varying environments. Simulation and experimental results demonstrate the antenna's capability to operate efficiently within the 5 to 6 GHz range, offering significant improvements in coverage, signal quality, and interference management. The findings highlight the potential of pattern reconfigurable antennas as a key technology for next-generation wireless communication systems.Recent developments in antenna technology have highlighted the importance of incorporating reconfigurable features, especially in scenarios with changing signal environments. By utilizing radio frequency (RF) PIN diodes, the Yagi-Uda antenna design presented here not only allows for variable control of its radiation pattern but also maintains a compact and cost-effective configuration. This adaptability is essential for implementations within contemporary wireless networks, such as Wi-Fi, 5G, and various other developing communication systems, where effective spectrum usage and dynamic coverage are necessary*

Keywords: Antenna , Yagi-Uda, Pattern Reconfigurable

I. INTRODUCTION

Antennas play a crucial role in communication systems by enabling the transmission and reception of electromagnetic waves, which are essential for various forms of wireless communication. Their functionality extends across multiple applications, including mobile networks, broadcasting, and satellite communications.[1]

A pattern reconfigurable antenna has the ability to change its radiation pattern dynamically. It responds to different working conditions or what users need. This flexibility of the antenna boost its performance make communication better. These include wireless communication, radar, and satellite systems. The interest of antennas that can be reconfigured has grown because they offer extra features and adaptability. It uses the principle of multiple-input multiple-output (MIMO) methods has led to research on different antennas that can be reconfigured.

A Yagi-Uda antenna is a directional antenna with a simple design consisting of a driven element, a reflector, and one or more directors. It focuses signals in one direction, providing high gain and improved reception. Commonly used in TV antennas and radio communication, it offers efficient signal transmission and reception.Yagi-Uda antenna changes its radiation pattern using PIN diodes by selectively activating or deactivating its passive elements (directors and reflector). Advances in the design of antennas have increasingly been driven by the requirement for efficient adaptive communication systems[3]. Pattern reconfigurable antennas belong to this category of tremendous innovation within this domain. A pattern reconfigurable antenna, as in the case presented, improves signal quality and reliability while improving the efficiency of a whole wireless network as it has the ability to respond dynamically to changing conditions. This flexibility is particularly precious in next-generation technologies such as 5G and beyond, in which seamless connectivity and high-speed transfer of data are a priority. This changing nature of the radiation pattern of a Yagi-Uda antenna is quite significant in terms of interference reduction and maximizing network efficiency.

Figure 1.1: Antennas (Source: myninja.ai)

II. PROPOSED METHOD

In this work, the proposed model has a microstrip patch Yagi-Uda reconfigurable antenna aimed at beam switching which can be built on the substrate such as RT – Duroid 5880, FR4 Epoxy ,Rogers RO4003C and Polyimide etc.. Copper and other elements such as silver , brass, gold , graphene, aluminium can be used as the radiator. The design of the antenna can be simulated and the performance evaluated using softwares such as CST (Computer Simulation Technology), ANSYS HFSS (High-Frequency Structure Simulator) ,FEKO , COMSOL Multiphysics, SONNET Suites.

III. SOFTWARE COMPONENTS

The first step is to develop the antenna by using CST as a simulation software. The design will be implemented in way that the radiation pattern of the antenna can be changed by using pin diodes. The direction can be changed by turning on and turning off of diodes.

The software's that can be used here are CST (Computer Simulation Technology) , ANSYS HFSS (High-Frequency Structure Simulator) ,FEKO , COMSOL Multiphysics ,SONNET Suites .

1. **CST:** CST (Computer Simulation Technology) Studio Suite is an advanced software package for the simulation of electromagnetic fields over a wide range of frequencies. With advanced 3D modeling, visualization and integration with off the shelf software, CST is popularly applied in industries including telecommunications, aerospace, and automotive for accurate and efficient EM simulation.

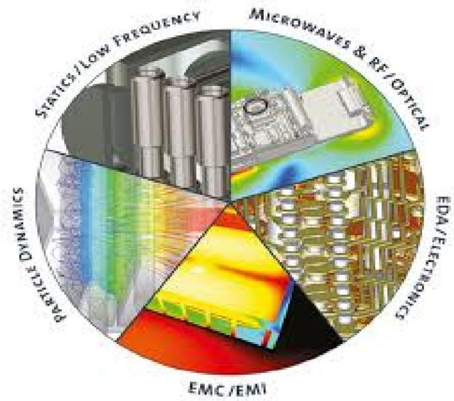

Fig. 3.1 CST interface (source: simuserv.com)

2. **(ANSYS HFSS (High-Frequency Structure Simulator)** : It is a leading electromagnetic simulation software used for designing and analysing high-frequency components such as antennas, microwave circuits, and RF devices. It utilizes the Finite Element Method (FEM) to provide highly accurate 3D EM field solutions, making it ideal for complex structures and high-frequency applications. HFSS offers advanced features like parametric modelling, optimization, and adaptive meshing, enabling precise simulations of electromagnetic behaviour. Its robust integration with other ANSYS tools enhances multi-physics capabilities, making it a

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preferred choice for engineers and researchers in industries like telecommunications, aerospace, and electronics.

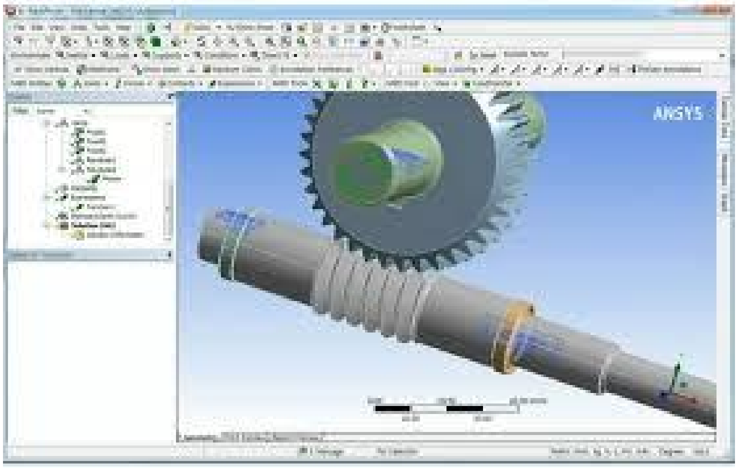

Fig 3.2 Ansys Interface (source : ansys.com)

3. **COMSOL Multiphysics:** It is a versatile simulation software platform that uses the Finite Element Method (FEM) to model a wide range of physical phenomena, including electromagnetic fields. It allows for multiphysics analysis, enabling the coupling of electromagnetic simulations with other domains like thermal, structural, and fluid dynamics. This flexibility makes COMSOL ideal for designing antennas, RF devices, and complex systems where multiple physical effects interact, widely used in research and industrial applications. It can also integrate CAD and other external software inside it. It is popular choice for researchers, engineers ,and scientists too. It is used to predict system behaviours, and innovate across a wide range of industries, including telecommunications, automotive, aerospace, biomedical, and energy sectors. It allows users to simulate and analyze various physical phenomena, such as electromagnetics, fluid dynamics, structural mechanics, heat transfer, and chemical reactions, in a single environment

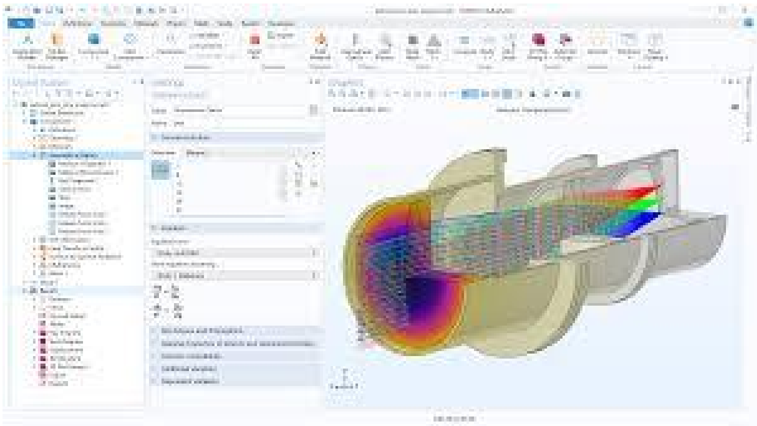

Fig 3.3 COMSOL Multiphysics interface (source:comsol.com)

IV. HARDWARECOMPONENTS

After the completion of simulation, the design will be printed using fabrication techniques. The materials used are as follows:

1] Substrates:

Substrates that can be used for Antenna are RT – Duroid 5880, FR4 Epoxy,Rogers RO4003C

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1.1) RT-Duroid 5880:

RT/duroid 5880 is a high-frequency laminate material known for its low dielectric constant (around 2.20) and low loss tangent, making it ideal for microwave and RF circuit designs. Composed of polytetrafluoroethylene (PTFE) reinforced with glass microfibers, it offers excellent electrical properties and minimal signal attenuation, even at high frequencies. This substrate is widely used in applications such as antennas, microwave circuits, and radar systems due to its stable performance up to 40 GHz and beyond. Its thermal stability and durability make it a preferred material in critical fields like aerospace, defence, and telecommunications, where precision and reliability are essential.

Parameter	**Value**
Dielectric Constant (εr):	2.2
Loss Tangent (tan δ):	0.0009
Thermal Conductivity	0.20 W/m·K
Frequency range	

Table 4.1.1 RT Duroid 5880 parameters

Key Features: RT-Duroid 5880 is known for its low dielectric constant and low loss tangent, making it ideal for high-performance microwave and RF antenna designs. Its stable electrical properties ensure minimal signal loss and excellent efficiency in high-frequency circuits

FR4 Epoxy

Parameter	**Value**
Dielectric Constant (εr):	4.4
Loss Tangent (tan δ):	0.02
Thermal Conductivity	0.30 W/m·K
Frequency range	

Table 4.1.2 FR4 Epoxy parameters

FR4 Epoxy is a commonly utilized substrate material in the fabrication of printed circuit boards (PCBs). Composed of woven fiberglass reinforced with an epoxy resin, it offers a robust combination of mechanical strength, durability, and reliable electrical insulation. While its dielectric properties are less ideal for high-frequency applications compared to specialized materials, its affordability and versatility make it a practical choice for a wide range of low to moderate frequency uses. As a result, FR4 Epoxy remains a preferred option in fields such as consumer electronics, automotive systems, and industrial equipment, where cost-effectiveness and dependable performance are critical.

Key Features: FR4 Epoxy is widely used in cost-sensitive antenna designs due to its affordability and mechanical robustness. Although it has a higher loss tangent and dielectric constant compared to other materials, it is suitable for lower frequency applications and is commonly used in prototyping and commercial electronic circuits.

2] Metals:

The metals that can be used as radiating elements are Aluminium , silver gold , graphene brass.

2.1) Copper

Parameter	**Value**
Electrical Conductivity	5.8×1075.8 \times 10^75.8×107 S/m
Relative Conductivity	100%
Thermal Conductivity	400 W/m·K

Table 4.2.1 Parameters of copper material

Key Features: Copper is the most widely used radiating material due to its excellent electrical conductivity and low resistive losses. It provides high efficiency in transmitting and receiving electromagnetic waves, making it suitable for

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both low and high-frequency antenna designs.Corrosion Resistance **is** Good, but prone to oxidation which can be mitigated with surface treatment

2.2) Aluminium

Parameter	**Value**
Electrical Conductivity	3.5×1073.5\times10^73.5×107S/m
Relative Conductivity	61%
Thermal Conductivity	235 W/m·K

Table 4.2.2 Parameters of Aluminium material

Key Features: Aluminium is lightweight and has good electrical and thermal properties, making it ideal for applications where weight reduction is critical, such as aerospace and satellite communication systems. Its slightly lower conductivity than copper is offset by its cost-effectiveness and structural benefits.Corrosion Resistance is Good, especially when anodized, forming a protective oxide layer

2.3) Silver

Parameter	**Value**
Electrical Conductivity	6.3×1076.3 \times 10^76.3×107 S/m
Relative Conductivity	106%
Thermal Conductivity	430 W/m·K

Table 4.2.3 Parameters of Silver material

Key Features: Silver is the best conductor of electricity and provides the highest efficiency for radiating elements. It is used in high-performance antenna designs where minimal signal loss is crucial. However, its high cost and tendency to tarnish often limit its use to thin coatings over other conductive materials rather than bulk applications.Corrosion Resistance is Excellent, though susceptible to tarnishing in sulphur-containing environments
Gold and graphene can be used for the antenna but they make it costly and low availability.

3] Pin Diodes :

PIN diodes serve to dynamically steer the antenna's radiation patterns. Such devices act as switches to control the path of current or the electrical dimensions of the antenna elements, therefore making it possible to change the reconfiguration pattern on demand. By switching the operating point of the PIN diodes from on to off and vice versa different beam directions and shapes of the radiated patterns can be realized thereby increasing the versatility of the antenna for use in different communication modes.The use of PIN diodes in antenna design greatly improves its flexibility, allowing the antenna to adapt to changing signal conditions by directing its radiation toward specific targets or reducing interference from unwanted directions. This level of control is essential for modern communication systems like 5G, cognitive radio, and IoT devices, which require efficient and reliable signal handling. The quick response of PIN diodes allows the antenna to adjust in real-time to its surroundings, making it perfect for applications like mobile communication, radar systems, and technologies that need adaptive signal direction. This adaptability not only boosts signal quality and network performance but also helps make wireless systems more energy-efficient and better at using the available frequency spectrum.

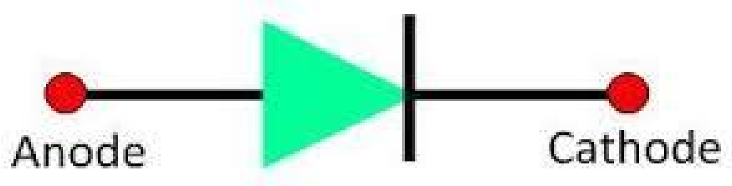

Fig 4.3.1 Symbol of Pin Diode (source:circuitglobe.com)

V. METHODOLOGY

The first step is to do the survey and find the parameters. After that do the simulation on the software and simulate to get good and approximate results. Do the fabrication of the simulated antenna. Once the fabrication of antenna is completed, test the antenna to work accurately.

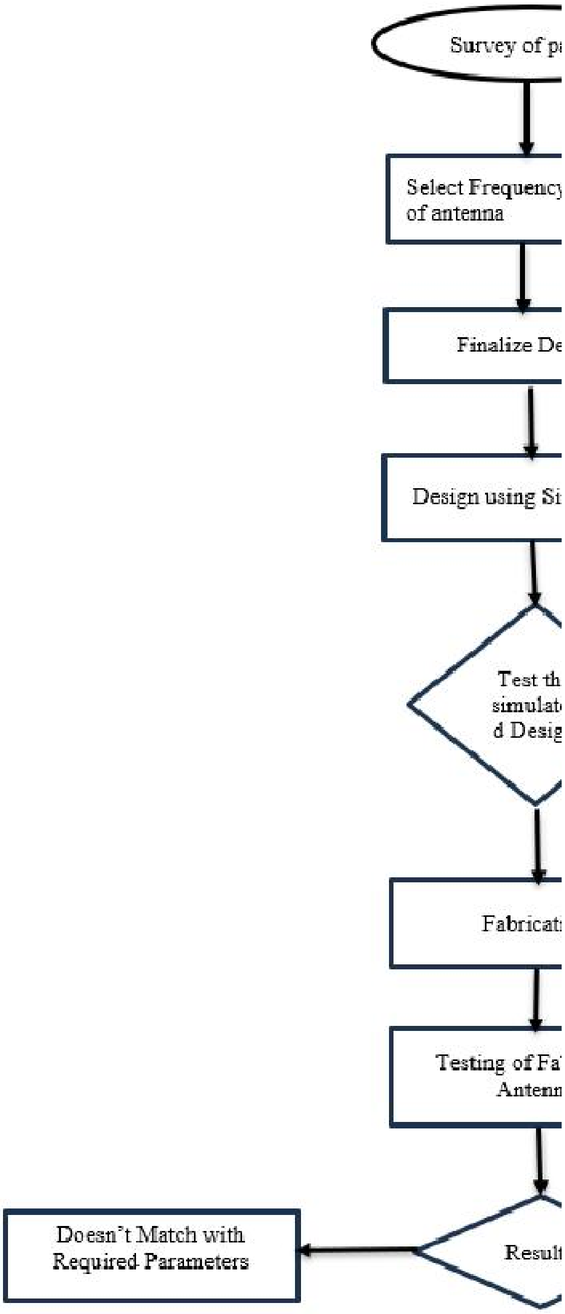

Fig 5.1 Flowchart of methodology

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VI. LITERATURE SURVEY

The first paper gives development of a switchable printed Yagi-Uda antenna with pattern reconfiguration capabilities, enhancing its adaptability to different signal environments. This design aims to improve signal targeting and reduce interference in wireless communication systems[1].

Then we surveyed about creation of frequency-agile, polarization-diverse microstrip antennas and frequency-scanned arrays, patented in 1983. Their work introduced innovative approaches for dynamic frequency and polarization control, providing a foundation for adaptive antenna technologies[2]. Chung, K., et al. proposed a reconfigurable microstrip patch antenna with switchable polarization, enabling the antenna to dynamically change its polarization state. This innovation is aimed at improving signal quality and versatility in different communication scenarios[3]. The design of a pattern-reconfigurable antenna array with large beamwidth coverage by combining novel antenna elements. Their approach offers flexible beam steering, making it suitable for applications requiring broad and adaptable signal coverage [4]. We studied the development of a wideband L-probe patch antenna with pattern reconfigurability, allowing it to adapt its radiation pattern over a wide frequency range. This capability is critical for enhancing performance in modern wireless communication systems [5].

Title	Authors	Method	Type of antenna	Principle
Pattern and Frequency Reconfigurable Annular Slot Antenna Using PIN Diodes	Symeon Nikolaou, Ramanan Bairavasubramanian,Cesar Lugo, Dane C. Thompson	By matching impedance reconfigure frequency and radiation pattern. (5.2 -6.4 Ghz)	Planar annular slot antenna	Frequency reconfiguration
Frequecy and Pattern Reconfigurable Antenna for Emerging Wireless Communication Systems	Amjad Iqbal, Amor Smida, Nazih Khaddaj Mallat, Ridha Ghayoula.	Changing radiation pattern By frequency shifting. (2.5 – 4.2 Ghz)	Wire patch antenna	Frequency Shifting
Switchable Printed Yagi-Uda Antenna with Pattern Reconfiguration	jung-Woo Baik, Seongmin Pyo, Tae-Hak Lee, and Young-Sik Kim.	Pattern Reconfiguration by switching pin-diodes. (3 Ghz)	Planar Yagi-Uda antenna	Same Frequency with Pattern Reconfiguration.
Electronically pattern reconfigurable antenna for IOT applications	Luca Santamaria, Robert staraj, Fabien Ferrero and Leonaldo Lizzi	Reconfiguring pattern by pin diodes (1.25-2.54 Ghz)	Fan Type Microstrip patch antenna.	Pattern Reconfigurable with Frequency

Table 6.1 literature Survey

VII.APPLICATIONS

- Radio
- Point-to-Point Wireless Communications
- Wi-Fi Networking
- Wireless Video Transmission
- Radar Systems, Fixed Wireless Access (FWA
- Industrial, Scientific, and Medical (ISM) Applications
- Microwave Communication Systems

VIII. CONCLUSION

By this survey we can easily find the best softwares and materials for the design and development of the pattern reconfigurable yagi-uda antenna for the sub 6g applications.

IX. ACKNOWLEDGMENT

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