Implementation of a Frequency Reconfigurable Slotted Antenna through the TLBO Algorithm

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Abstract: The concept of reconfigurability has been associated with existing microstrip patch antennas that are designed for single-use by implementing necessary geometric modifications through the exchange and display of the antenna. This is particularly relevant when addressing factors such as resonant frequency, polarization, and impedance bandwidth. A compact and simple antenna featuring a microstrip line feed and a mechanism for frequency reconfiguration has been developed and assessed. Specifically, a Slotted Microstrip Patch Antenna capable of UWB frequency reconfiguration has been designed for cognitive radio applications. The design incorporates a microstrip patch, feed, and ground, all constructed according to specified parameter values. To achieve frequency reconfigurability, two diodes are strategically placed within a rectangular slot on the patch. The proposed antenna is intended for use in Ku-band (12.7–13.80 GHz) and X-band (8.05–9.75 GHz) satellite communication applications. It has been shown that modifying the switch configurations can alter the antenna's operational frequency while maintaining the emission pattern. Ultimately, the development of this UWB Frequency Reconfigurable Slotted Antenna was guided by the Teaching Learning Based Optimization (TLBO) algorithm.

Keywords: Slotted Antenna, Microstrip, patch, Frequency Reconfigurable, PIN Diodes, Cognitive Radio, TLBO, Patch antenna.

I. INTRODUCTION

Reconfigurable frequency receiver cables consist of radio cable components that can independently change their physical configuration, altering the repeat characteristics of the receiving device while maintaining constant radiated power. Reconfiguring a receiving cable model potentially affects other parameters, such as design range and repeat behavior, and vice versa. This relationship is one of the main obstacles to the development of reconfigurable receivers. This type of reconfiguration includes multi-band or possibly stopband capabilities, coordinated impedance switching, or the relocation of a tone repeat.

These tunable receiving devices are divided into two types: they are constantly being replaced. To operate in specific and isolated frequency groups, reconfigurable frequency tunable radio cables interchangeably accommodate uniquely changing instruments. The real difference between the two types lies in the degree of variation in the electrical length, which allows tuning to different repeat groups, and in the techniques used to achieve these changes. The most common approach to achieving frequency reconfigurability is to implement a transmitter tuning reconfiguration system in microstrip receiver cables to change the effective electrical length, which is expected to change the operating frequency.

The operating frequency is primarily determined by the electrical length of the antenna. For example, if the most common straight dipole radio cable has a half-wavelength and unidirectional radiation that is fixed and perpendicular to the dipole pivot point, it will oscillate in its initial main mode. With a similar radiation design, the radio cable must be shortened to exactly half the wavelength at the repeat, in the unlikely event that one wishes to operate the receiving device with a longer repeat. Frequency-reconfigurable radio cables have the advantage of limiting the amount of overall receiving equipment by allowing the reuse of the entire volume of the receiving cable thanks to their unique operating modes.
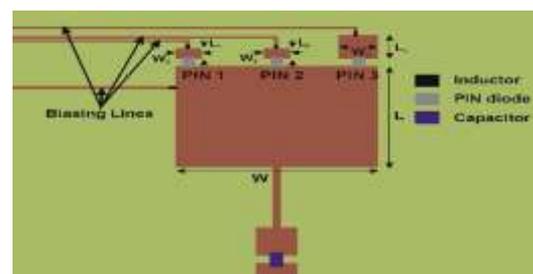

Figure 1: Frequency Reconfigurable Antenna

II. TEACHING LEARNING BASED OPTIMIZATION

Teaching Learning Based Optimization (TLBO) represents a population-centric optimization methodology that emulates the instructional dynamics found within a traditional classroom setting. The components of this algorithm include both students (learners) and an instructor. It operates in two distinct phases: the teacher phase, where students acquire knowledge from the instructor, and the student phase, during which students engage in peer learning. The academic performance of students is treated as algorithmic outputs that are influenced by the instructor's effectiveness.

In parallel, contemporary wireless communication systems have increasingly concentrated on the primary benefits of these antennas encompass the reduction of the necessity for multiple antennas within a single system, the capability to adjust an antenna for various applications, the narrowband resolution characteristic of microstrip antennas, the ability to filter out unwanted signals and interference from non-operational frequency bands, and their applicability in cognitive radio technologies. Given the inherent design complexities associated with these antennas compared to traditional models, optimization. This study aimed to implement the teaching-learning-based optimization (TLBO) approach to enhance the design and performance of frequency-reconfigurable antennas through the integration of a chaotic system.III. Antenna Design with modes of operation

III. ANTENNA DESIGN WITH MODES OF OPERATION

A comprehensive planning and analysis of a simple yet conservative antenna featuring a frequency reconfiguration mechanism and microstrip line feed has been conducted. For applications in cognitive radio, a microstrip patch antenna with a tunable ultra-wideband (UWB) frequency has been developed. This particular design incorporates both feed and ground elements, along with a microstrip patch that is tailored according to specific parameter values. To facilitate frequency reconfigurability, two diodes are integrated into a rectangular slot on the patch. Enhanced gain is achievable by reducing the dimensions of the patch through the truncation of its corners, employing microstrip patches of varying sizes.

To facilitate frequency reconfiguration, two PIN diodes are positioned within a rectangular slot. The modulation of frequency in radio cables is accomplished by adjusting the lengths of the apertures; consequently, PIN diodes are employed in segments of varying lengths. These diodes are modeled as collective RLC arrays.
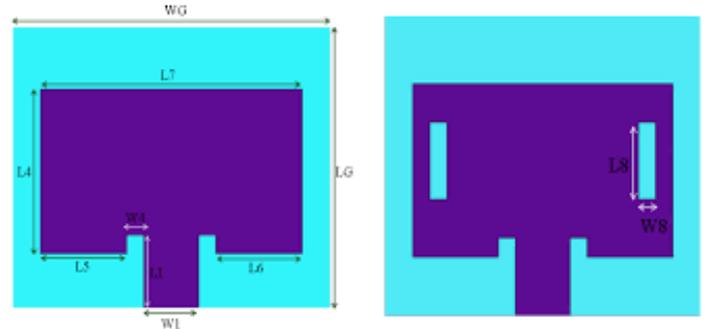

Figure 2: Proposed Slotted Patch Design

The designs proposed utilize HFND4005 PIN diodes. In the configuration of the PIN diodes, an inductance of R = 4 kΩ is observed in the forward bias (ON) state, while a capacitance of C = 0.017 pF is noted in the switching bias (OFF) state.

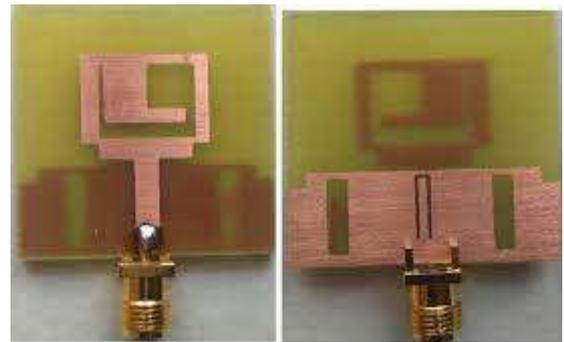**Figure 3: Fabricated Microstrip Patch Antenna**

The diodes measuring 1.5 x 0.75 mm are strategically placed at the corners of a rectangular slot that has been rotated 45 degrees about the z-axis.

Table 1: Parameters of Proposed Antenna Design

Parameter	Value (mm)
Substrate Length (Ls)	29
Substrate Width (Ws)	28
Substrate Height	1.6
Patch Length (L)	10.5
Patch Width (W)	14
Microstrip Feed Width	3.5

The HPND4005 pin diodes, known for their availability and suitability for manufacturing processes, have been selected

for this application. The switching capabilities of pin diodes facilitate the reconfiguration of frequency ranges, enabling the antenna to alternate among various frequency bands.

IV. SIMULATED & EXPERIMENTAL RESULTS

The antenna is constructed on a 1.6 mm thick FR4 substrate, exhibiting a loss tangent of tan δ = 0.027. The receiver is produced through a standard photolithography technique. The antenna supports both single-band and dual-band operational modes. Figure 4 illustrates the return loss curve derived from both simulated and experimental data, while Figure 5 presents the voltage standing wave ratio (VSWR) curve for the same datasets.
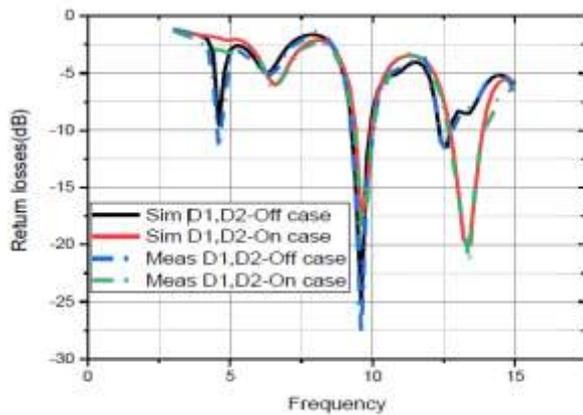

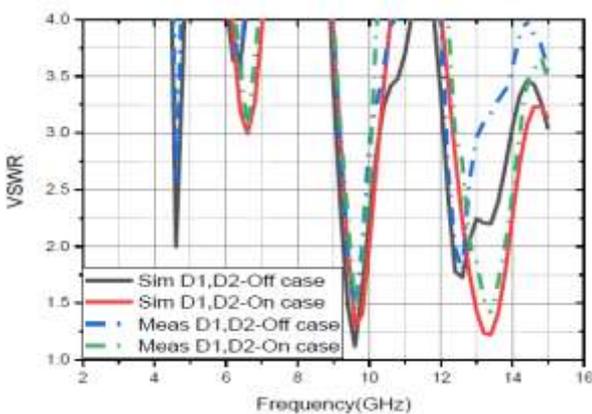**Figure 4: Simulated & Measured S11 of Proposed Antenna**

Figure 5: Simulation and Measurements of VSWR of Proposed Antenna

The optimal recurrence rate is identified as being below 2 and exceeding 10 dB, respectively. In the dual-band configuration, the return loss is anticipated to exceed 10 dB within the frequency range of 12.7 GHz to 13.8 GHz, reaching a

maximum of 16.2 dB. The frequency of 13.2 GHz is designated as the thunder frequency (fr) within this dual-band context. A comparative analysis of the two groups in this dual-band setup indicates that this resonant recurrence band demonstrates elevated values. The single band configuration will function exceptionally well between 9.19GHz and 9.76GHz. The 2D radiation patterns and 3D polar plots for the D1&D2 on and off cases are shown in Figs. 6 and 7. Four switching states— 00,01,10,11—are included in this suggested design when all cases are taken into account, with the 00,11 cases accounting for both diodes D1, D2-On and Off situations. In these states, single and double bands are present.
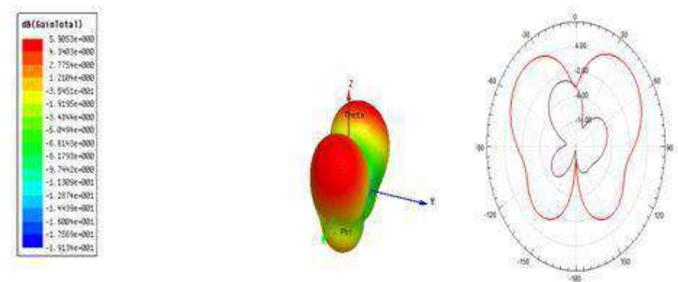

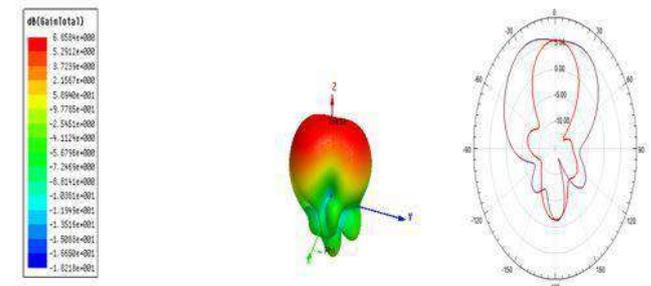**Figure 6: 3D polar plot & 2D radiation pattern of proposed design**

Figure 7: 3D polar plot & 2D radiation pattern of proposed design

VI. CONCLUSION

The functionality of reconfigurable antennas must be maintained in a fluctuating environment while ensuring optimal electromagnetic properties. The introduction of a switching mechanism embodies the principle of reconfigurability. To adjust the antenna's electrical length, which in turn governs the operational frequency, switching technology is employed, utilizing PIN diodes to modify the antenna's physical configuration. The antenna is designed for Ku-band applications

(12.7–13.80 GHz) and X-band satellite communications (8.05–9.75 GHz). The proposed antennas are particularly well-suited for commercial devices such as laptops and mobile phones that require dynamic band switching.

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