Design and Modelling of Frequency Reconfigurable Antenna by Using Bow-Tie Geometry

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Abstract. The proposed work presents a design for a frequency-reconfigurable, bowtie-shaped, microstrip patch antenna with a wide coverage area. HFSS software is used to do simulations on the suggested antenna, which is constructed of a Flame Retardant -4 base material. The antenna can be configured to operate at a different frequency by simply turning the diodes on and off. Signals can be released at 4.78 GHz, 9.925 GHz, 10.33 GHz, 10.65 GHz, and 2.4 GHz, depending on the states of the diodes. A coplanar waveguide (CPW) feed including a conducting ground, two PIN diodes, and a shorting pin is used by the system. In conclusion, this frequency-reconfigurable bowtie antenna represents a significant advancement for the sector. The resonance frequency of the antenna can be precisely and dynamically controlled thanks to the creative application of pin-diodes in conjunction with tuning diodes. With a wide tuning range of 3.04 to 5.89 GHz, it can be used in situations where it's necessary to be flexible when operating in different frequency bands.

Keywords: Bow-Tie antenna · Frequency-Reconfigurable · pin diode · Tuning diode

1 Introduction

Antenna is crucial to telecommunication, RF technology, and wireless communication systems. So, the other important point of attention is that they take note of it as their style of communication [1]. Such as radio wave, microwaves, visible lights, and so on, transmitting electric signals into a one-directional electromagnetic wave that moves in only one direction and reflects. These include communication using aerials, television, radio, mobiles, wireless internet routers, radars, satellite communications and many more [2]. Re-Configurability of antenna polarization, radiation pattern, and operating frequency is extremely desirable because of the rapid growth of wireless communications and the growing need to combine several wireless technologies onto one platform [3]. Reconfigurable antennas adjust their radiation pattern, polarization, impedance bandwidth, and

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operating frequency in accordance with the host system's operational specifications. These antennas may be customized for a range of applications and operating conditions thanks to their adaptable design [4]. Frequency-reconfigurable antenna technology is a significant advancement in wireless communication. Because of its dynamic nature, frequency-reconfigurable antennas are commonly utilized in modern communication systems [5]. Their capacity to accommodate multi-band and multi-standard applications is a significant advantage [6]. Furthermore, frequency re-configurability makes communication networks more efficient overall by guaranteeing that devices can communicate across several frequency bands efficiently and without the need for numerous antennas [7]. A patch antenna, often referred to as a rectangular micro strip antenna, is a low-profile radio antenna that is suitable for mounting on a level surface. It is made up of a bigger metal sheet known as a ground plane covered with a flat, rectangular sheet of metal, or "patch" [8]. There are many uses for micro strip antennas, including commercial communication systems, satellites, and even biological applications [9]. In summary, a micro strip transmission line is made up of a ground plain and a strip conductor that are divided by a dielectric medium [10]. The dielectric substance acts as a structural substrate for the formation of thin film metal conductors. Typically, conductors are made of copper or gold. This work presents a frequency reconfigurable micro strip patch antenna in the shape of a bowtie [11]. This is a frequency reconfigurable antenna of minuscule dimensions [12]. Division II explains about the techniques for designing antennas. In Division III, Simulation Results, it is described how the ground plane and shorting pin affect the radiation pattern and return loss [13].

2 Methodology

- Gather Requirements and Specifications:
- Collect all the necessary information, including specifications, performance expectations, and any constraints that the product or process needs to meet.
- Design physical properties like size, shape, materials used, etc., that will define the product or process.
- Consider desired functionality and performance.
- Develop Performance Parameters
- Create specific metrics that will be used to evaluate the success of the product or process.
- These may include efficiency, accuracy, durability, safety standards, etc.
- Simulation in HFSS and Prediction Using Measurements
- HFSS Simulation: Use specialized software (HFSS, likely referring to High-Frequency Structure Simulator) to model the product/process under various conditions.
- Prediction Using Measurements: Gather actual measurements of relevant characteristics like: Measurements, Substrate (base material), Antenna operation, Radiation pattern, Band-width, Gain, Current distribution, VSWR (voltage standing wave ratio).
- Performance Review and Analysis.
- Analyse the results from both simulation and measurements.
- Compare the results to the performance parameters defined earlier.

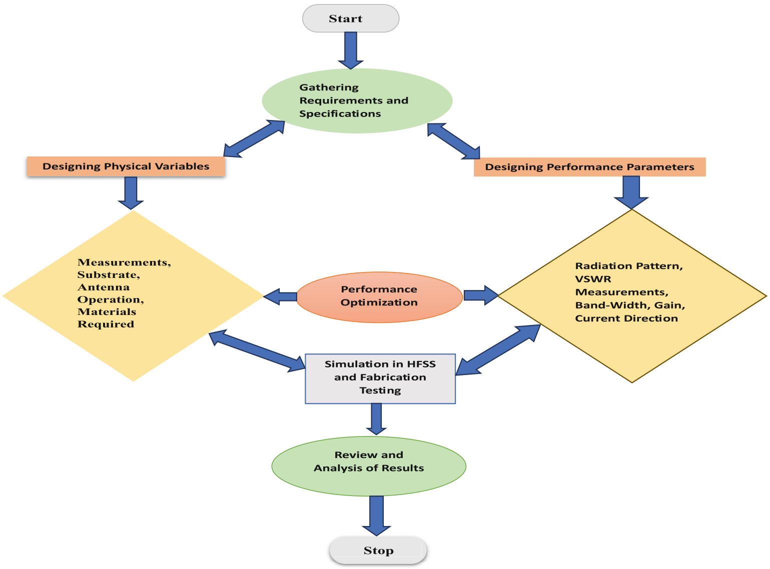


Fig. 1. Flow chart for Antenna Design Methodology

Existing Model

The bowtie antenna is constructed using a 10 × 10 × 1.59 mm^3 FR4 substrate with a dielectric constant of 4.4 and a loss tangent of 0.025. A coplanar waveguide (CPW) on the upper surface of the substrate provides unbalanced supply to the two triangular bowtie elements. A full ground plane on the bottom surface shorts the antenna and provides a ground reference for the CPW feedline. The ground plane lies 0.5 mm below the CPW feed edge. A shorting pin connects the CPW ground to bottom ground plane, creating a shunt inductive effect that can be utilized to modify the radiation pattern and resonant frequency. PIN diodes are utilized to control the current flow between the two bowtie components. The antenna performance is simulated in the CST [14].

Proposed Model

The suggested antenna is based on the dimensions of the current model, which has a FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.59 mm. For developing the antenna and simulating it in the HFSS program, the dimensions given in the current model are derived from the suggested model, as seen in Fig. 1. Initially, a 6 mm × 6 mm square patch was used to create a bowtie-shaped patch. To eliminating feeding symmetry, the two bowtie flags are fed at distinct positions. The antenna receives electricity from the conductive ground and the CPW feed. A conductor backed (or ground backed) CPW has a lower characteristic impedance than a regular CPW. Because the average CPW's impedance was quite big from port impedance, the impedance matching was extremely poor when the CPW was employed in the design. Conductor-backed CPW's impedance was reduced to match port. Here we neglected the shorting pin requirement to make the design simple and to get desired radiation patterns, S11 parameters, current distributions, and VSWR measurements at the low frequency ranges from 2.4 GHz. The proposal intends to contribute to adaptive wireless communication systems by overcoming these problems and enhancing the performance of bow-tie antennas across multiple operating frequencies. The proposed model is as shown in below figure.

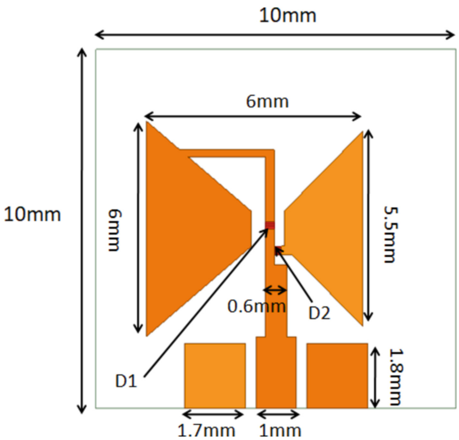


Fig. 2. Proposed Bow-Tie Antenna

3 Simulation Results

There is no shorting pin present since the antenna is simulated with a CPW feed and full ground at the bottom. Figure 2 below illustrates the S11 parameter in simulation. Both diodes d1 and d2 must be in the ON state for the antenna to function as a dual band antenna. With 2.0 GHz and 1.5 GHz, as well as a −10 dB bandwidth, respectively, the resonant frequencies are 4.78 GHz and 2.4 GHz. Diode d1 is turned on and diode d2 is turned off, allowing the antenna to radiate at frequencies of 2.4 GHz and 10.33 GHz with a bandwidth of 2.0 GHz and 1.16 GHz, respectively. Since the feed line and the capacitor interact reciprocally, there are two resonance frequencies in this situation. The antenna is in the ON state when the diode d2, is in the ON state and the d1 is in OFF state when it emits at 2.4 GHz and 9.925 GHz frequency, with a bandwidth of 2.0 GHz and 1.3 GHz. The antenna has a bandwidth of 1.45 GHz and 1.22 GHz, respectively, and emits radiation at 4.71 GHz and 10.65 GHz while both diodes are in the OFF state. Because the antenna radiates due to mutual contact in the second flag even when no flag is active, this scenario is undesirable when both diodes are off. This antenna does not show the radiation pattern since the beams are narrow and the electric field intensity is low. The study and computation of the antenna's bandwidth in relation to the resonant frequency for every diode condition are provided. Figure 3 displays the VSWR plot for each of the two diodes' four distinct situations in addition to the S11 parameters.

4 S11 Parameters

S11, or return loss, is one of the most important metrics for antenna characterization [15]. It gauges the amount of power reflected from the antenna and, as a result, the impedance match between the feed line and antenna [16]. Good impedance matching is shown by a low S11 value, which means that more power is supplied to the antenna and less is reflected. A standard aim is S11 <- 10 dB, which indicates that less than 10% power is reflected [17]. The return loss is often given in decibels (dB). Understanding the bandwidth and impedance matching of the frequency reconfigurable bowtie antenna design is possible with the help of the S11 parameter. Result figures of S11 parameters as shown below.

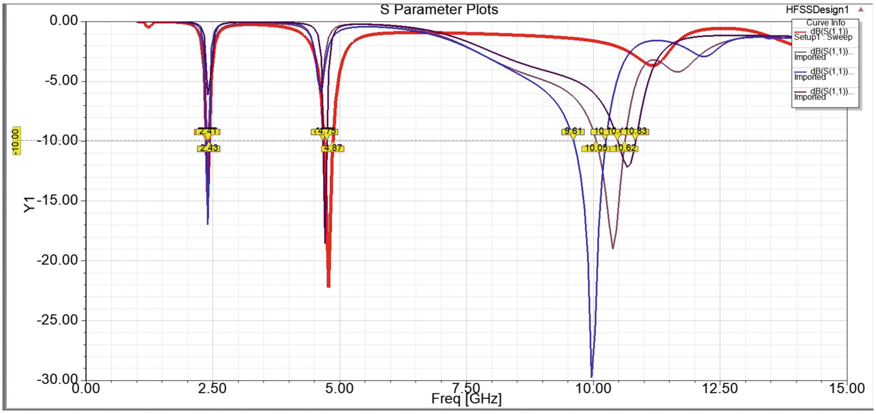


Fig. 3. S11 Parameters for diode conditions

5 VSWR Parameters

See Fig. 4.

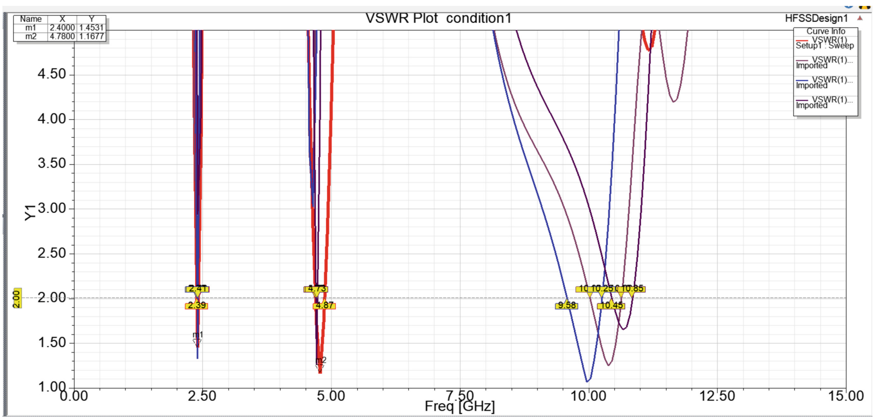


Fig. 4. VSWR Parameter

6 Current Distributions

The current distributions for four different conditions of both the diodes are represented in the below Figures (Fig. 5(a)–(d)).

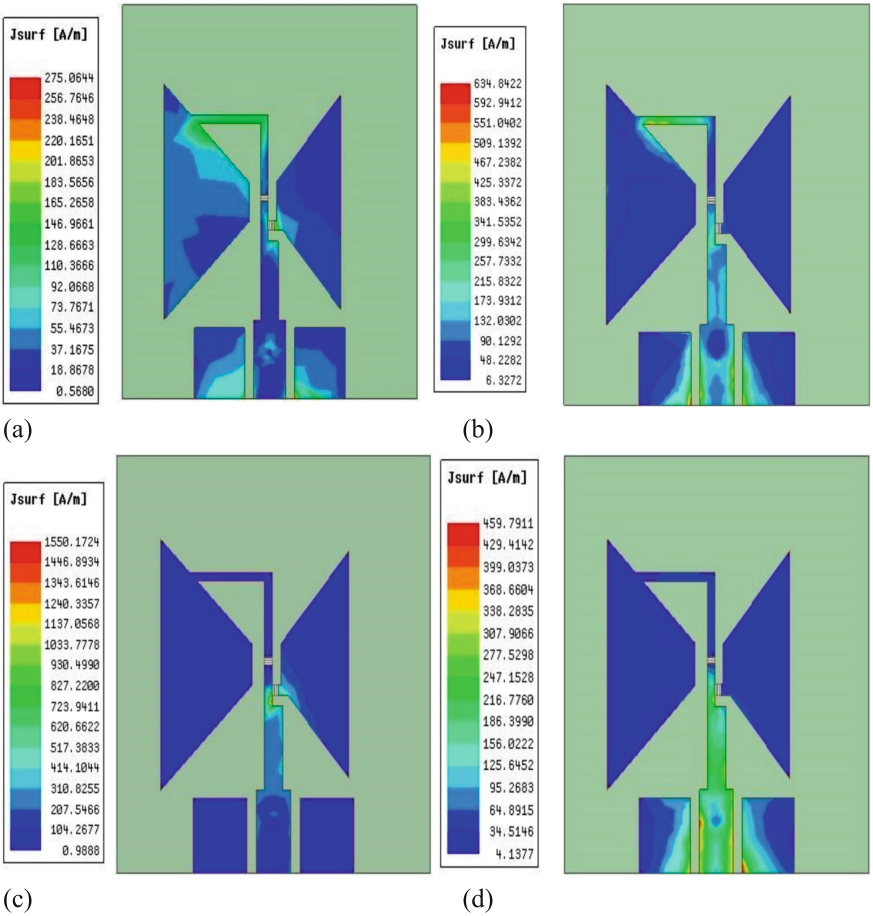
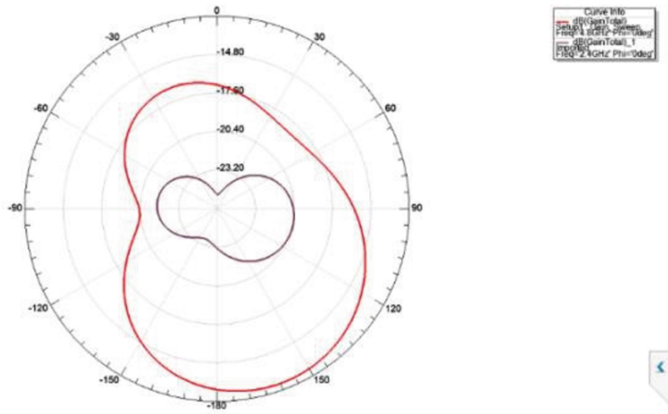


Fig. 5. **(a)** Condition1 = d1 ‘ON ‘and d2 ‘ON’ **(b)** Condition2 = d1 ‘ON’ and d2 ‘OFF **(c)** Condition3 = d1 ‘OFF’ and d2 ‘ON’ **(d)** Condition4 = d1 ‘OFF’ and d2 ‘OFF’

The current distribution analysis for the four diode conditions provides further evidence of the antenna’s frequency reconfigurability [18]. With both diodes ON, strong current density flows along the edges and tips of both triangular patches. When diode 1 is ON and diode 2 is OFF, the current is concentrated mainly on the left patch with minimal current on the right. The opposite occurs with diode 1 OFF and diode 2 ON - current flows primarily through the right patch with very little on the left. Finally, with both diodes in the OFF state, the current flow is restricted and there is low current density on both patches. In summary, the current distribution can be controlled to different parts of the bowtie antenna structure based on the PIN diode switching states. The ability to reshape the current flow supports the frequency reconfigurability achieved with this design across the 2.4 GHz to 10.65 GHz range [19].

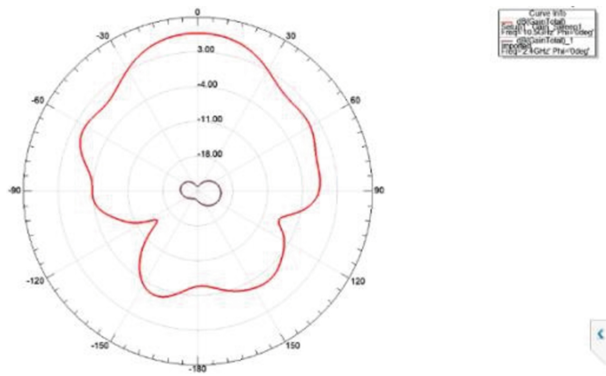
7 Radiation Field Patterns

The Far Zone Radiation Patterns are generated by the antenna in the different diode condition are shown in below Fig. 6(a)–(d) with the different frequency ranges.



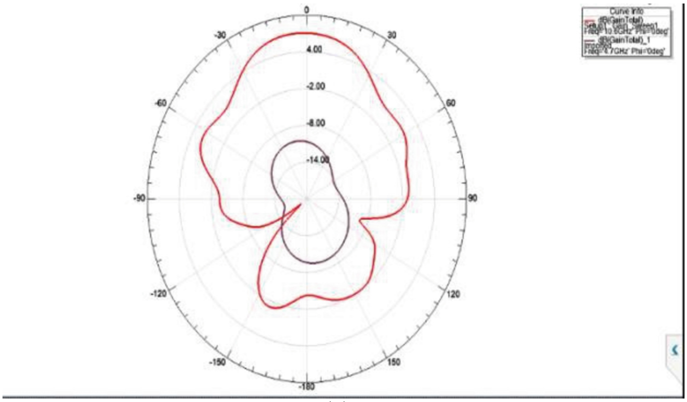
(a)

Fig. 6. **(a)** Far Zone Radiation Pattern at 2.4 GHz and 4.8 GHz. **(b)** Far Zone Radiation Pattern at 2.4 GHz and 10.5 GHz. **(c)** Far Zone Radiation Pattern at 2.4 GHz and 10 GHz. **(d)** Far Zone Radiation Pattern at 4.7 GHz and 10.6 GHz



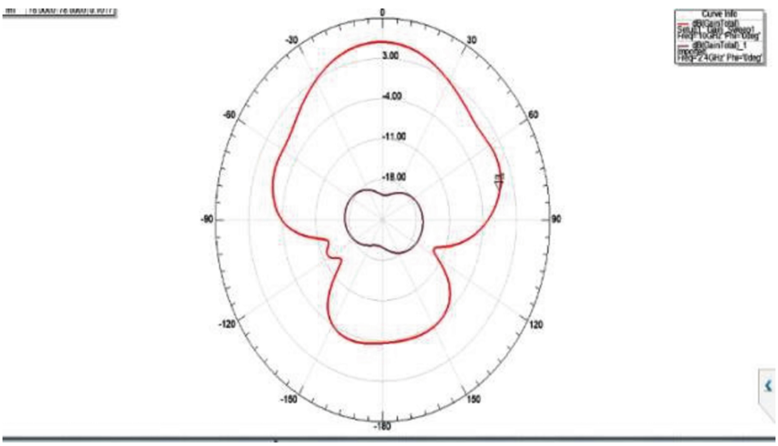
(b)

Fig. 6. (*continued*)



(c)

Fig. 6. (*continued*)



(d)

Fig. 6. (*continued*)

8 Conclusion

In-order to wrap up this research and present the suggested frequency-reconfigurable bowtie antenna, the following important elements should be emphasized. Multiband functioning was made possible by the shown frequency re configurability from 2.4 GHz to 10.65 GHz utilizing PIN diodes and a shorting pin. Consistent directional radiation patterns were attained over the operational frequency range. Ground plane offsets and shorting pin placements were optimized as design characteristics to achieve effective impedance matching. Verified downsizing, measuring 14.8% less in size than earlier bowtie antenna concepts. Broad impedance bandwidths spanning resonant frequency between 1.16 GHz to 2 GHz was obtained. Verified excellent VSWR between 1–2 throughout all operational bands and a reflection coefficient <- 10 dB. Over 90% radiation efficiency was attained, and a good peak realized gain from 3.2 dB to 5.4 dB was reached. Demonstrated that bowtie antennas are suitable for the frequency-agile adaptive communication systems of today. Reconfigurable antennas and electronically guided arrays in the future can be built upon the demonstrated bowtie antenna. Reconfigurability notion was validated by current distribution data, which demonstrated antenna reshaping due to diode states. The design criteria and goals mentioned in the literature aligned well with the performance measures. To put it briefly, the salient characteristics and conclusions support the effective design, optimization, modeling, and evaluation of a small, frequency-reconfigurable bowtie antenna, which is intended to be utilized in contemporary, flexible wireless communication applications.

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