Symmetrical L-slots Reconfigurable Triple band Antenna for Multiband Applications

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Abstract: This paper introduces a novel compact reconfigurable antenna that utilizes monopole technology and tunable frequencies through switch control. The antenna is fed by a coplanar waveguide (CPW) and features a unique patch design with two L-shaped slots and integrated switches. This inventive design enables remarkable reconfigurability, allowing the antenna to operate within the frequency ranges of [3.8-3.93 GHz], [5.05-5.3 GHz], and [7-7.5 GHz]. These frequency ranges are strategically chosen to align with specific application requirements. The antenna also boasts an almost omnidirectional radiation pattern. The experimental outcomes highlight the efficacy of the proposed antenna, which occupies a compact footprint of 34x35.4 mm², making it particularly well-suited for applications requiring multiband functionality.

Keywords: CPW-fed, multiband antenna, reconfigurable.

NOMENCLATURE

PIN diodes	Positive Intrinsic Negative diode.
MEMS	Microelectromechanical systems.
FR4	Dielectric Substrate.
CPW	Coplanar Waveguide.
SMA	A Sub-Miniature Connector.
CST	Micro-Wave Studio Simulator.

1. NTRODUCTION

Using configuration techniques is a popular method for improving antenna capabilities and allowing its adaptation across a wide range of applications. Antenna reconfiguration improves performance by allowing it to respond to changing demands more effectively by allowing for dynamic variations in operating frequencies. The use of several antennas adapted to different applications might bring difficulties in terms of size and performance, emphasizing the value of reconfigurability as a solution. The adaptability of antennas through reconfiguration is a useful feature, providing flexibility and diversity that accommodates a wide range of applications while simultaneously boosting capability.

Integration of switching components like as PIN diodes, varactor diodes, or MEMS switches is often used to enable dynamic modification of operating frequencies. To achieve the required versatility, these components are usually incorporated into the design. [01]-[20]

The focal point of this paper is a reconfigurable multiband antenna featuring a single feeding mechanism. The antenna is constructed on a planar surface and incorporates a radiating patch element along with two inverted L-slots on the ground plane.

These design characteristics are used selectively to exclude the presence of two lower frequency bands, [3.8-3.93 GHz] and [5.05-5.3 GHz]. The reconfigurability is achieved through the use of two switches implemented with metal pads. For reconfiguration, these switches provide an ON/OFF state. Importantly, the two switches function independently, allowing control of the corresponding lower frequency ranges.

2. ANTENNA DESIGN AND CONFIGURATION

In this section, we describe the geometric antenna configuration for reconfiguration multiband applications and the proposed model specifications. The design concept for this antenna is based on multi-strip shaped structure theory.

A. Antenna design and Configuration

The antenna's construction involves utilizing an FR4 dielectric substrate, characterized by a dielectric constant of 4.4, a thickness of 1.6 mm, and a loss tangent of 0.02. The layout of the proposed antenna is depicted in Figure 1. On one side of the substrate, the antenna element is printed.

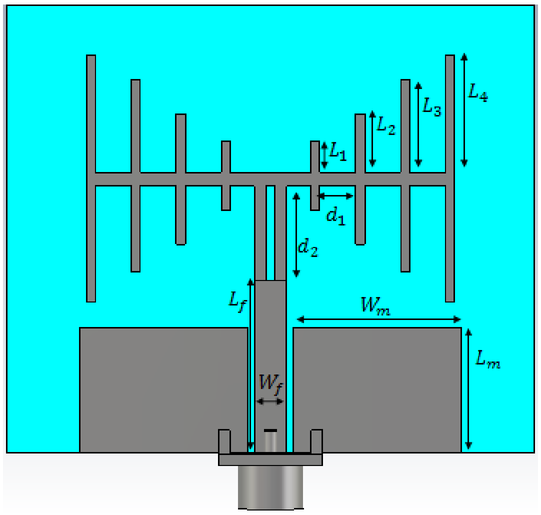

Fig.1: Geometry of the proposed antenna.

This employs a conventional coplanar waveguide (CPW) fed line configuration, employing a consistent single strip thickness denoted as W_f, and a defined spacing denoted as 'S' between the single strip and the coplanar ground plane. To excite the radiating patch, this CPW configuration is adopted. Symmetrically positioned on each side of the CPW feeding line are two finite ground planes, each characterized by a uniform size with a width denoted as W_m and a length denoted as L_m.

By introducing two L-shaped slots within the ground plane, alterations in the current distribution and path are achieved, leading to the exclusion of the frequency bands [3.8-3.93 GHz] and [5.05-5.3 GHz]. These frequency bands are then subject to control through the utilization of two switches. Positioned at the midpoint length of each L slot, these switches facilitate a reconfigurable operational mode. In its fundamental configuration (lacking slots and switches), the antenna's resonant frequencies are 3.9 GHz, 5.08 GHz, and 7.27 GHz. However, upon activating the reconfigurability mode, thanks to the presence of slots and switches, the antenna becomes adaptable, enabling the manipulation of two frequencies based on specific application requirements. Referencing Figure 2 for visualization, the tabulated dimensions of the antenna are presented below for reference.

Table 1: Optimized parameters of the proposed antenna.

Parameter	Value (mm)	Parameter	Value (mm)
W_m	15	d_2	8.4
L_m	11.1	L_1	2.75
W_f	2.94	L_2	5.2
L_f	6.7	L_3	8.25
d_1	3.2	L_4	10.4

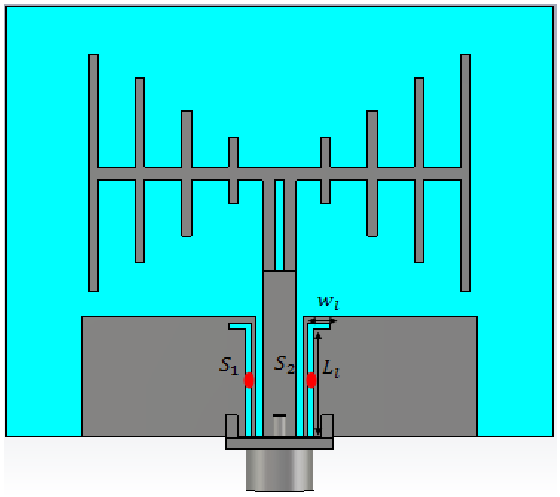

Fig.2: reconfigurable antenna with slots, the two L-slots along with switches mounted on the ground plan.

3. RESULTS AND DISCUSSION

The proposed antenna is simulated using the CST Microwave Studio simulator. Performance assessment of the antenna is conducted through an evaluation of key parameters, including the reflection coefficient reconfiguration, radiation pattern, and total gain.

A. Reflection Coefficient S11

In this section, an in-depth examination of the antenna's behavior in the reconfigurable mode is undertaken, along with an exploration of the impact of switches on the reflection coefficient (S11). Evidently, the resonant frequency displays variations based on different antenna switching scenarios. The design strategy revolves around an enhanced patch element incorporating an L-shaped slot within the ground plane, coupled with switches (implemented as ideal switches ensuring ON/OFF reconfigurability mode). Figure 3-a reveals the S11 response of the antenna corresponding to the initial design depicted in Figure 1. Upon introducing two symmetrical L-slots on the ground plane, the antenna's frequency bands consolidate from three to a singular band, an effect depicted in Figure 3-b. Subsequently, two RF switches, outlined in Figure 2, are used. These switches function in a binary state either ON or OFF and they exert control over the 3.9 GHz and 5.08 GHz frequency bands respectively.

When the switches are in the OFF state, as depicted in Figure 3-b, the antenna effectively rejects the 3.9 GHz and 5.08 GHz frequency bands. Conversely, toggling the switches to the ON state leads to the antenna's emission in the 3.9 GHz and 5.08 GHz frequency bands once more, as visualized in Figure 3-c

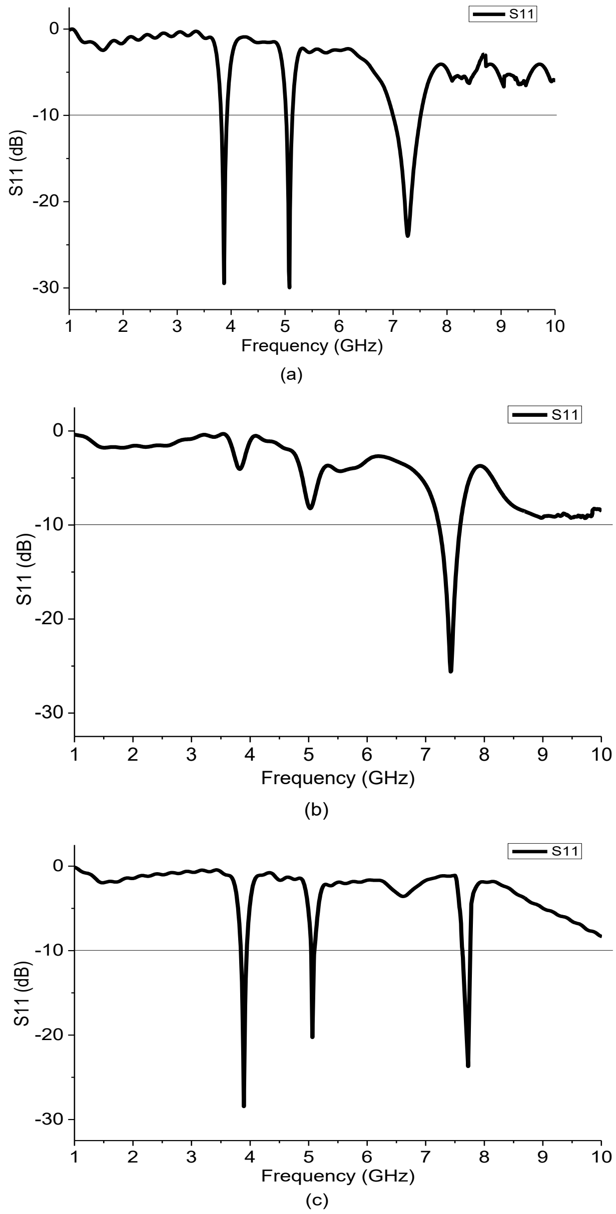

Fig. 3: S11 representation, (a) starting design, (b) single band, (c) three bands.

B. Surface Current Distribution

Figure 4 displays the surface current distributions for the three different resonant frequencies, to further explain the antenna operating mechanism figure 4 shows current distribution graduation at three frequency bands on the antenna radiating elements. Note that, the current density at each resonant frequency is indeed higher on the certain part of the antenna compared to the other part whose dimensions are supposed to control that particular frequency. The distribution of the surface current at the frequency band centered at 3.9 GHz, is shown in Fig. 4-a, and so are the frequencies of 5.2, and

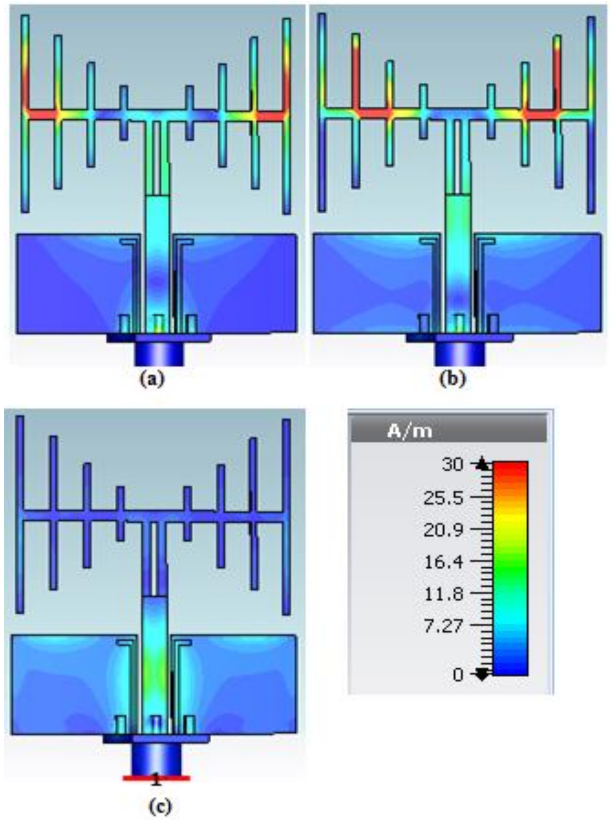

Fig.4. Current distributions in three different frequency bands, (a) at 3.2 GHz, (b) at 4.35 GHz and (c) at 10.5 GHz.

7.2 GHz in Fig. 4-b and Fig. 4-c respectively, it is clear from the radiating elements that there is a greater concentration of current distributions at the center frequency of the corresponding operating band., however, the surface current is guided in the same directions, suggesting that the elements actually work as half-wave dipoles. On the other side, the current distributions are lower at the non-excited elements as a parallel stubs open-circuit and their input impedance is infinite, however, it is clear that a significant distribution current is still present on the unexcited element, which is induced by the driver dipole element.

C. Radiation Pattern

Figure 5 indicates that the antenna radiation patterns at 3.9, 5.08 and 7.27 GHz. This result confirms that the antenna radiates bidirectional energy mainly. At targeted frequencies, the front-to-back ratios are approximately above 10 dB and the main beams are in the direction of the endfire, which indicates the spatial radiation property of the proposed antenna.

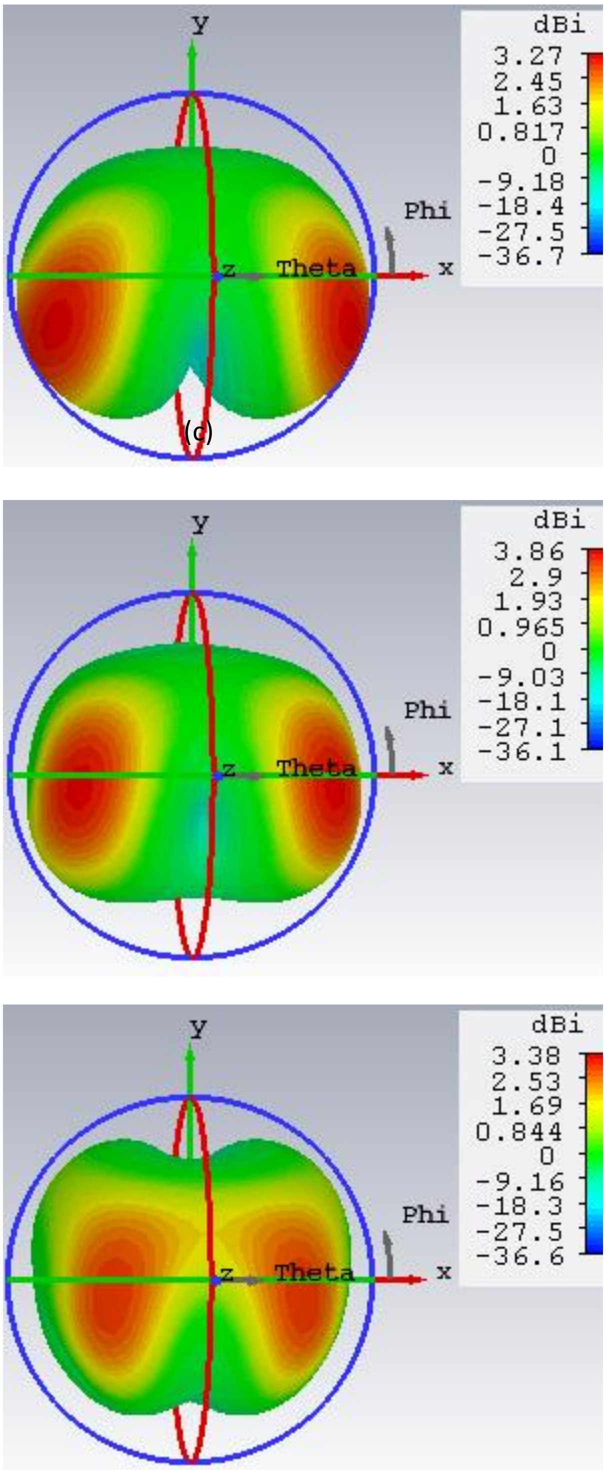

Fig.5: 3D Radiation patterns of the presented antenna at different frequency bands. (a) at 3.9GHz,(b) at 5.08 GHz and (c) at 7.27 GHz.

4. CONCLUSION

In this paper, a coplanar microstrip fed line antenna is proposed to achieve reconfigurable multiband characteristic and directional radiation patterns across the entire operating bandwidth and relatively good directional characteristics. The proposed antenna structure is also easy to manufacture and is ideal for WLAN and other communication bands.

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