Inverted V-Shape Slot Self-Diplexing Antenna for X-band Applications

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Abstract

The concept for a self-diplexing inverted v-shape slot antenna focused on a substrate integrated waveguide (SIW) is presented in this proposed study. The suggested antenna has two parallel inverted v-shape slots and impedance 50Ω microstrip insert feed lines. A sequence of transverse parallel slots of variable lengths are present in the top layer of the SIW cavity, and they result in two resonance frequencies at 9 GHz and 10.3 GHz. The antenna can independently tune its frequency in both of its working bands. For X Band applications including weather radar and wireless systems, the recommended antenna features a unidirectional radiation pattern, gains of 5.87 dBi and 3.98 dBi at two resonance frequencies of 9 GHz and 10.3 GHz.

1. Introduction

Technology and communication are becoming increasingly integral parts of everyone's daily lives in the modern day. With the development of numerous aspects, including high stability, higher performances, low profile, and minimal cost, plays the most important role in wireless communication [1-2].In RF and satellite transceiver systems, the signals from the uplink and downlink frequency bands are divided using higher-level diplexers or triplexers. In satellite and RF communications networks, a higher order diplexer or triplexer reduces co-channel interference and enabled greater isolation levels across antenna input ports [3-4]. Due to this, the transceiver system's overall size and weight rose. Among RF researchers, the novel idea of self-diplexing SIW [5-7] and self-triplexing SIW[8–9] antenna types are gaining popularity. wherein higher-order diplexers and triplexers are not required, allowing for the creation of RF and satellite transceiver systems that are small, lightweight, and affordable.

Diplexers & triplexers often function as a filter or even as a frequency selective device [10].defective ground structures [11]. These are essentially based on several techniques, such as multilayered substrates or patches with an electromagnetic bandgap [12] and meander lines [13]. The system's size, manufacturing cost, and design complexity all increase when using the aforementioned approaches. This is the primary challenge with wireless communication systems.

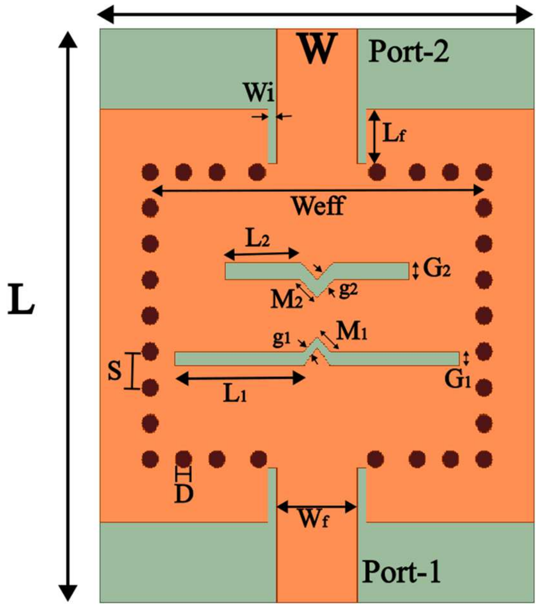


Figure 1: The "Inverted V" slot SIW antenna's design layout.[L= 32, W = 26, Weff = 20, L2 = 4.5, L1 = 7.7, Lf =3, Wi =0.5, Wf = 4.8, M1 = 0.8, M2 = 1, D = 1, S = 2, g1 = 0.6, g2= 1, G1 = 0.8, G2 = 1 (all in mm)].

In this study proposes a unique and superior technology, a planar SIW-based inverted v-shape self-diplexing antenna with a better impedance bandwidths. This new technology allows for the simplification of the system's size and the accomplishment of frequency tunability at both of the resonant frequencies (9GHz and 10.30GHz). The analysis of the suggested antenna is provided forth in the paragraphs that follow. In section 2, the proposed inverted v-shape self-diplexing antenna analysis and design are described.

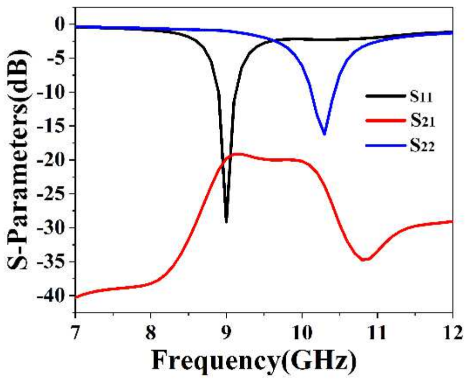


Figure 2: S-parameters of the proposed antenna (Simulated).

2. Proposed self-diplexing antenna Design

The given structure's arrangement is shown in Figure 1. A SIW groove of dimension L×W serves as the antenna's resonator. Metallic vias that join the top and bottom conducting planes form the cavity's sidewalls. The antenna's four rows of conducting vias, which is based on the SIW cavity concept, serve as an ideal boundary wall for the antenna construction. With a substrate layer in the centre, these conducting vias are also employed to provide suitable conductivity between the bottom layer and upper layer. The metallic via's spacing and diameter are wisely selected as d/s ≥ 0.5. in order to preserve minimal radiation losses and energy leakage. Two 50Ω microstrip insert feed lines emanating from opposing ends of the cavity feed the antenna.

$$w_{eff} = w - \frac{d^2}{0.95s} \quad (1).$$

$$w_{eff} = w - \frac{1.08d^2}{s} + \frac{0.1d^2}{w} \quad (2).$$

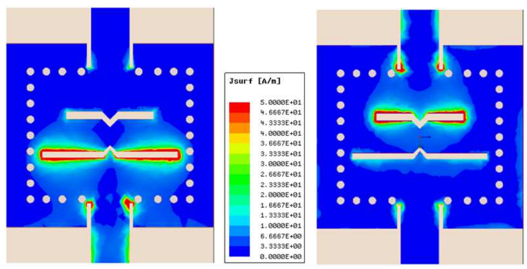
$$w = \frac{2w_{eff}}{\pi} \cot^{-1} \left[\frac{\pi s}{4w_{eff}} ln \frac{s}{2d}\right] \quad (3).$$

2.1 Design Configuration

On the antenna's upper plane, as seen in Fig. 1, there are two transverse slots with the designations slot-I and slot-II. Slots I and II have widths of G1 and G2 and lengths of L1 and L2 on one side and the same on the other. The inverted v-shape slot's centroid has lengths of M1, M2, and widths of g1 and g2, respectively. The slots are fed via ports port-1 and port-2, allowing the antenna to operate between 9 and 10.3 GHz. As a result of the ports' symmetry, more field energy is passed amid port-1 and port-2, leading to isolation values of (S12 > 19.75 dB) and (S21>24.6 dB) as illustrated in Fig.2.The impedance bandwidths (S11 and S22) for two bands in the case of the simulated antenna are 8.90 to 9.13 GHz and 10.12 to 10.43 GHz, and have With 2.55% and 3%.

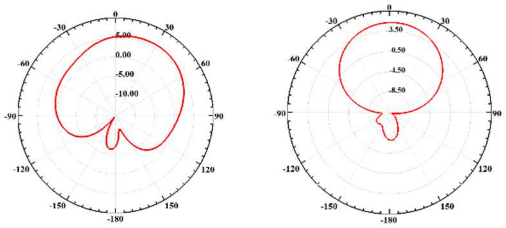
2.2 Surface Current & Electric-field Distribution

When slot-I is etched on the upper layer of the SIW cavity, as seen in Fig. 3 (a), the bottom portion of the antenna closest to slot I is totally under control of the surface current. Simultaneously, the top of the hollow has relatively little surface current. As a result, it is obvious that slot-I is the most important factor for lower resonant frequency, whereas slot-II is disregarded. The same technique is used to characterise the radiation phenomena of slot-II in the top half area of the cavity, and it has a greater resonance frequency than 10.3 GHz. When the port is turned on, as shown in Fig. 3 (b), slot-II emits radiation whereas slot-I experiences no radiation.

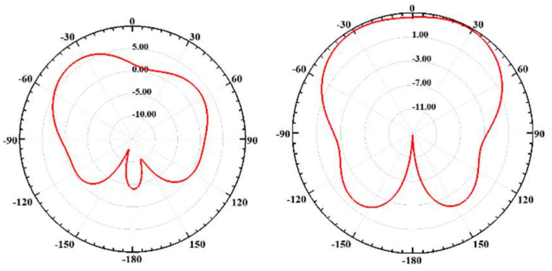


(a) (b)

Figure 3:The surface current density distribution on the proposed antenna's top layer at 9.3 GHz (When port-1 is excited) and 10.3 GHz (When port-2 is excited).



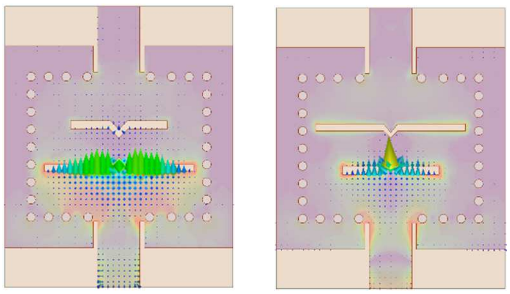
(a) (b)



(c) (d)

Figure 4: 2-D simulated radiation pattern of "inverted v-shape" slot antenna at port-1 is excited (a) φ=0◦, (b) φ=90◦ at 9 GHz and port-2 is excited (c) φ=0◦, (d) φ=90◦ at 10.3 GHz.

The self-diplexing antenna's e-field distribution is seen in Fig. 5. When feed-1 is turned on, the current density in slots-I' takes control in the bottom part of the SIW cavity, and the proposed antenna resonates at 9GHz (Fig. 5(a)). The e- field distribution, however, is hardly observable in the upper part of the SIW cavity. The same scenario is seen when feed-2 is energized. In this scenario, slot-II has an impact on the top part of the SIW cavity. In the bottom part of the SIW cavity, the antenna resonates at 10.3GHz without emitting any radiation (Fig. 5(b)).



(a) (b)

Figure 5: The electric field distribution pattern at (a) slot-I (b) slot-II.

3. Results and discussions

The suggested SIW-based inverted V-Shape self-diplexing antenna is simulated by Ansys HFSS E-M17.2 developed on a thick Rogers RT/duroid 58-80 substrate of 1.57 mm (εr = 2.2, tanδ = 0.0009) in order to determine the proposal. In Fig. 1, the proposed antenna's final optimised dimensions are shown.

The self-diplexing antenna's e-field distribution is depicted in Fig. 5. When feed-1 is energized, the current density in slot-I' is in charge of the SIW cavity's bottom half. and the proposed antenna resonates at 9 GHz (Fig. 5 (a)). The e-field distribution, however, is hardly observable in the part of the SIW cavity. The same scenario is seen when feed-2 is energized. In this scenario, slot-II have an impact on the upper part of the SIW cavity. The antenna resonates at 10.3GHz in the SIW cavity's bottom without emitting any radiation (Fig. 5(b))

Table 1: Comparison of the performance of self-diplexing antenna parameters

Para./Ref.	**Freq. (GHz)**	**Gain(dB)**	**B.W. (%)**	**FTBR(dB)**	**Isoation(dB)**
[5]	8.97 11.3	4.3, 4.2	12.5, 6.25	>19	25
[6]	8.2610.4	3.56, 5.24	1.93, 2.68	23, 20	27.9
[10]	2.45 5	1.3, 4.4	N.A	Approx 0	26.5
[11]	0.921.85	N.A.	N.A.	N.A.	17
[12]	5.4,. 5.5	4, 4	N.A	Approx 10	30
[13]	9.65, 10.45	5.75, 5.95	1.32, 1.4	N.A.	24
[14]	4.29, 7.52	5.38, 5.82	0.98, 1.72	>22	32.8
Propose work	**9, 10.3**	**5.87, 3.98**	**2.55, 3**	**>17**	**>19.75, >24.6**

Figure 4 displays the simulated 2D radiation patterns. The radiation is unidirectional and, at both frequencies, has a maximal radiation in the broadside direction because of the cavity-backed construction. The simulated gains at lower and upper frequencies are 5.87 dBi and 3.98 dBi, respectively. Table 1 compares many parameters between the current study and earlier published studies. Along with other an-tenna characteristics, the suggested antenna has excellent self-diplexing characteristics and is sui-table for usage in real-world applications.

4. Conclusion

This research proposes a SIW cavity-backed inverted v-shape self-diplexing antenna with double transverse slots. Because of its planar design and simple insert feeding method, the proposed antenna consists ease of design, compactness, simplicity of integration with other radio frequency modules, and high isolation between the two working frequencies. This makes complicated diplexers superfluous, resulting in a more compact radio frequency front-end modules. The suggested antenna may be a possibility for X-band transceiver systems since it achieves satisfactory gain of 5.87 dBi at 9 GHz and 3.98 dBi at 10.3 GHz, along with a unidirectional radiation pattern.

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