All Sciences Proceedings
All Sciences Proceedings
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3rd International Conference on Innovative Academic Studies
September 26-28, 2023 : Konya, Turkey

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Mutual Coupling Reduction between two SIW Antennas by Using Isolation Wall

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Abstract – This paper focuses on two-element MIMO antenna system based on Substrate Integrated Waveguide (SIW) structure. The proposed antenna configuration operates at the central frequency of 5.86 GHz dedicated for Sub-6 GHz 5G communication applications. The design includes 30 metallic vias drilled on Preperm L960HF substrate. The operating frequency can be adjusted by changing the diameter sizes of the SIW antenna holes. The appropriate frequency band was obtained by performing parametric studies on hole sizes. Vertical metal Wall with 60 mm length and 10 mm width is mounted between the closely placed SIW antennas to suppress the mutual coupling. The presented MIMO antenna is excited with a 2.6 mm width feed line having 50 Ω characteristics matched impedance. With the added isolation wall, the S_{21} insertion loss was reduced from -18 dB to -28 dB without any significant change in the resonance frequency. In addition, the peak gain improved from 6.32 dBi to 7 dBi at 5.5 GHz.

Keywords – Substrate Integrated Waveguide (SIW) Antenna, Multiple Input Multiple Output (MIMO), Sub6 Ghz, Isolation Wall, Mutual Coupling,

I. INTRODUCTION

Multiple-input-multiple-output (MIMO) systems are considered the most common solution in the scientific world as a solution to the data traffic that is expected to increase with the arrival of 5G applications [1,2]. MIMO antenna configurations, which allow simultaneous signal data exchange, are seen as solutions between 30 GHz and 300 GHz, known as millimeter wave frequencies, as well as the sub6 GHz frequency bands [3].

The advantage of the Sub 6 GHz frequency band over the ISM band is that it allows more data to be carried and is less subject to interference. Various studies of MIMO antennas designed to operate in the Sub6 GHz frequency band have been published. [4-6].

Various antenna types have been used for MIMO systems in the literature [7,8]. The most commonly used of these are microstrip patch antenna-based MIMO antenna structures due to their compact structure and ease of production. In MIMO antenna systems, the number of antenna elements that enable multiple data exchange is increasing. Since this will cause the size of the system to increase, the antenna elements are positioned very close to each other. This decreasing distance causes mutual coupling between the antenna elements. Mutual coupling between antenna elements will affect the gain, directivity, envelope correlation coefficient (ECC) and radiation pattern, which are important performance criteria of MIMO antenna systems. Among the most preferred techniques to suppress mutual coupling in the literature are electromagnetic band gap (EBG) [9,10] and defected ground structure (DGS) [11] methods. Although these methods applied between antenna elements are successful in suppressing mutual coupling, but they cause a shift in the resonance frequency. In another study, defected isolation wall was used for mutual coupling between the patch antenna and the transmission line [12].

In this study, a Substrate Integrated Waveguides (SIW)-based MIMO antenna design is proposed.

The SIW antenna structure consists of three layers, just like the classical microstrip antenna design. Two conductive layers and a substrate material with dielectric properties between them. This structure has become very popular recently due to its various advantages. SIW structures are cost effective and easy to fabricate.

In this article, metallic isolation wall is addressed to design a two element high gain MIMO antenna using substrate integrated waveguide technique for sub6 5G communication system. At high frequencies, low loss dielectric material should be preferred. In the proposed design, Preperm L960HF substrate material with 0.63 mm thickness, relative permittivity 9.6 and loss tangent 0.0008 was used.

II. SIW ANTENNA DESIGN

Some parameters are critical in SIW antenna design. The most important of these are hole diameters, the distance between holes and width of waveguide. It is desirable that the antenna should operate at 5.8 GHz; hence, the cut-off frequency f_c of the SIW is selected to be 4 GHz, well below the desired frequency. The basic equations required in SIW design are given below [13].

$$\lambda_g = \frac{c}{f\sqrt{\epsilon_r}} \quad (1)$$

$$f_c = \frac{c}{2w_{eff}\sqrt{\epsilon_r}} \quad (2)$$

$$d \leq \frac{\lambda_g}{5} \quad (3)$$

$$p \leq 2d \quad (4)$$

In equation (1), the λ_g corresponds to guided wavelength and c is the light speed in vacuum. In equation (4), d and p explains the holes diameter and the distance between vias, respectively.

$$W_{siw} = W_{eff} + \frac{d^2}{0.95\,p} \quad (5)$$

In equation (5) the parameter W_{siw} is the SIW design equivalent width. The calculated parameters from the equations (1-5) are given in Table 1. In Fig. 1 is the top view of the proposed design presented.

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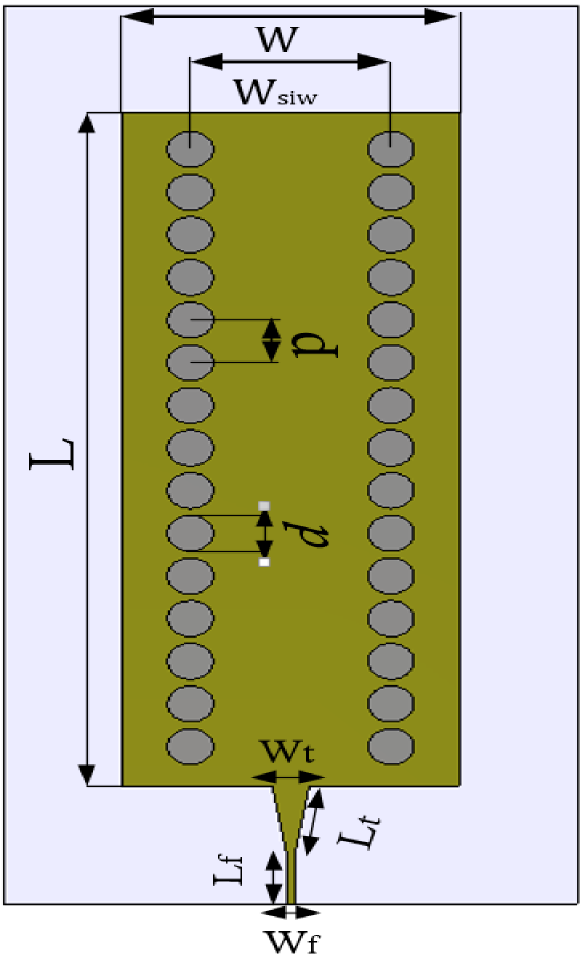

Fig. 1 Top view of the proposed SIW antenna

Table 1. Parameter list

Para-meters	Dimension (mm)	Description
L	60 mm	SIW antenna length
W	23.5 mm	SIW antenna width
Wsiw	14 mm	Width of waveguide
Wf	2.6 mm	Feed line width
Lf	6.08 mm	Feed line length
Wt	0.6 mm	Transmis. line width
Lt	4.51 mm	Transmis. line length
p	2.8 mm	Distance between vias
d	2 mm	Vias diameter
λg	16.7 mm	Guided wavelength
Weff	12.5 mm	Effective width

The current distribution of the proposed single SIW design at 5.8 GHz is presented in Fig. 2. As mentioned before, the hole diameter has an effect on the resonance frequency. To see this effect, a parametric study was carried out in Fig.3, taking into account equation (4).

As seen in the figure, according to the simulation [15] results, the best result was obtained with a hole diameter of 2 mm. Another important parameter is width of waveguide.

This parameter refers to the distance between holes arranged in parallel. In the current distribution in Fig. 2, it is clearly seen how the wave is guided between these holes. Width of waveguide effects also the operation frequency. To see this effect, a parametric study was carried out in Fig. 4 and it was determined that the most suitable distance for the design was 14 mm.

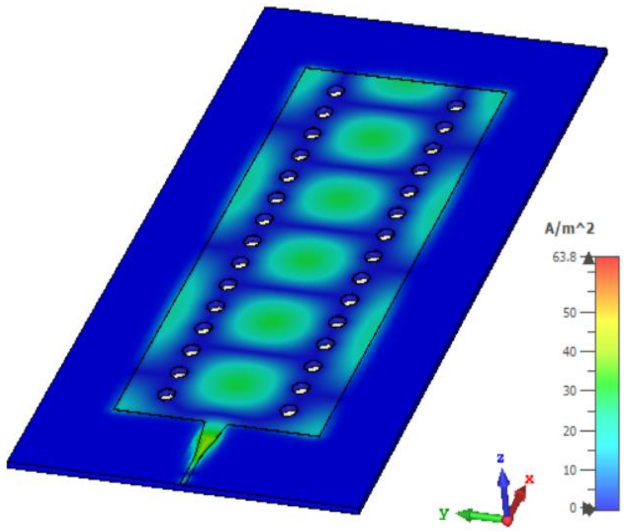

Fig. 2 Current distribution at 5.8 GHz

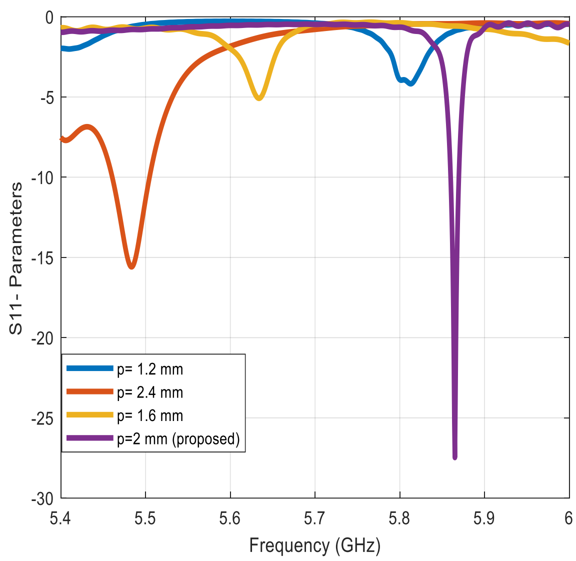

Fig. 3 Effect of hole diameter on resonance frequency

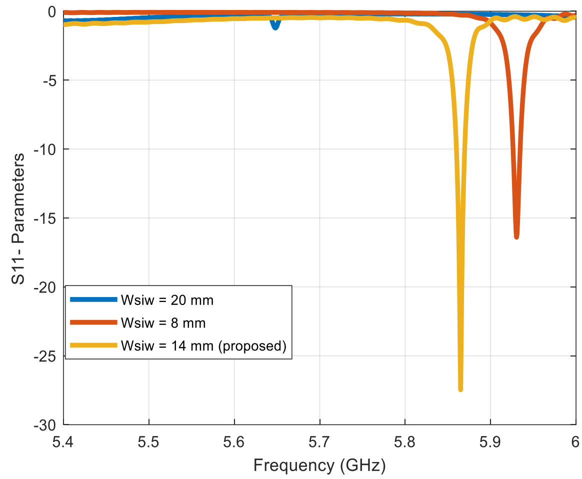

Fig. 4. Effect of width waveguide on resonance frequency

III. Effect of Isolation Wall

A 60 mm x 10 mm metallic isolation wall was used to reduce the mutual coupling between two antenna elements positioned close to each other. The distance between two antennas are 16.5 mm. Fig. 6 shows the effect of metallic isolation wall on mutual coupling. The placing of metallic wall did not cause a significant change in the operating frequency of the antennas, but mutual coupling reduced from -18 dB to -28 dB.

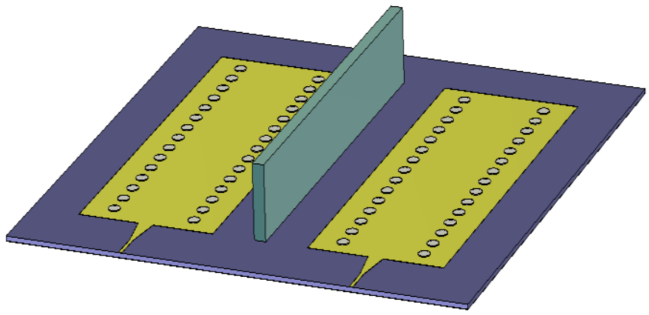

Fig. 5. 2x1 MIMO antenna with isolation wall

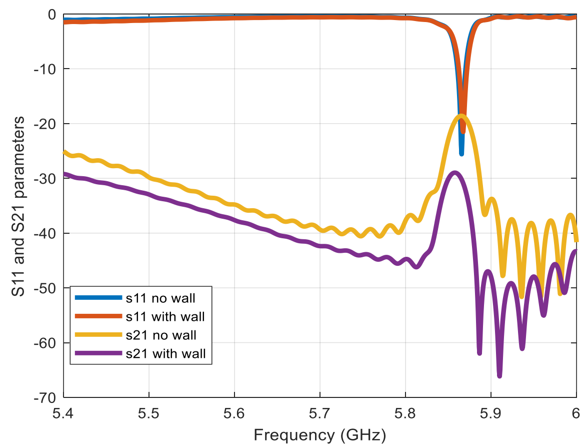

Fig. 6. Effect of isolation wall on mutual coupling

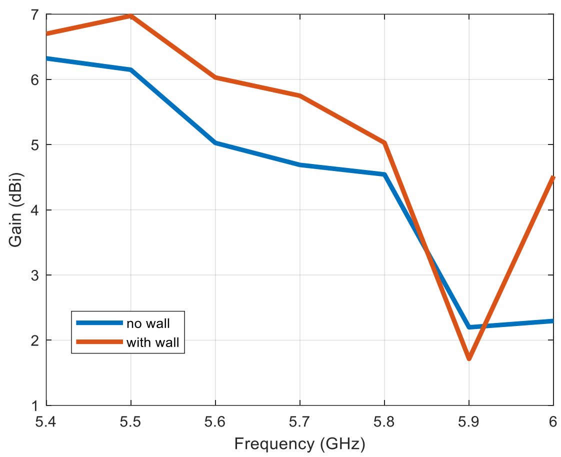

Fig. 7. Effect of isolation wall on antenna Gain

Fig. 7 shows the gain-frequency graph of the proposed design between 5.4 GHz and 6 GHz. With the effect of the isolation wall, 7dBi peak gain was achieved at 5.5 GHz. There was an increase in gain at every point up to 5.8 GHZ.

IV. Conclusion

In this study, it has been focused on mutual coupling reduction in a two-element SIW antenna structure. Metallic isolation wall was used to reduce mutual coupling without affecting the radiation performance of the antennas. With this technique, a reduction of approximately 10 dB was achieved. The recently popular sub6 GHZ frequency band was preferred as the application area. In future studies, slots will be etched in the isolation wall and its contribution to mutual coupling will be examined.

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