New Approach to Suppress Mutual Coupling Between Longitudinal-Slotted Arrays Based on SIW Antenna Loaded with Metal-Fences Working on VHF/UHF Frequency-Bands: Study, Investigation, and Principle

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***Abstract*- In this work it is demonstrated that substrate integrated waveguide longitudinal slotted array antenna (SIWLSAA) which is loaded with metal fences exhibits high-isolation across VHF/UHF bands. A reference SIWLSAA used for comparison purpose comprises of 3×6 slotted arrays constructed on the top and bottom sides of the FR-4 lossy substrate has maximum isolation of -63 dB between its radiation slots. Improvement in isolation is demonstrated using a simple new technique based on inserting a metal fence between each row of slot arrays. The resulting isolation is shown to be is better than -83 dB across 200 MHz to 1.0 GHz with gain greater than 1.5 dBi, and side-lobe level less than -40 dB. The proposed SIWLSAA is compact and has dimensions of 40×10×5 mm^3 ($0.026\lambda_0 \times 0.006\lambda_0 \times 0.002\lambda_0$) where λ_0 is 200 MHz. The proposed structure should find application in multiple-input multiple-output (MIMO) and radar systems.**

***Keywords*- Substrate Integrated Waveguide (SIW), slotted array antenna, reduction mutual coupling, metal fences, isolation, multiple output multiple input (MIMO) systems.**

I. Introduction

Slotted waveguide antenna arrays (SWAA) are becoming highly attractive components for communications and radar systems because they are highly power efficient, have low cross-polarisation and allow accurate control of the radiation patterns [1-2]. Extension on the work on SWAA has resulted in the development of waveguide longitudinal slot array antennas that can be accurately synthesised using Elliott's design procedure [3–6]. The design of such slot array antennas considers mutual coupling in the determination of slot parameters for a desired aperture distribution and input matching [7–11].

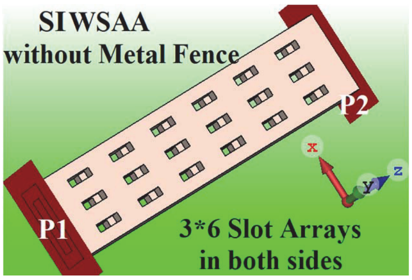
Investigation on SWAA has evolved and employ planar guide-wave structures referred to as substrate integrated waveguide (SIW) [12–16], post-wall waveguide [17–19] or laminated waveguide [20]. Guided-wave characteristics of the SIW are essentially like those of a metallic waveguide, and have attractive features including economic manufacture at low-cost with conventional microwave integrated circuit (MIC) technique, low profile, compact size and easy integration with other planar circuits. Unfortunately, SIW-based longitudinal slot array antennas are unsuitable for high performance applications because of unacceptable side-lobe levels (SLLs) [14]. Typically, substrate integrated waveguide longitudinal slot array antennas (SIWLAA) can only achieve -30 dB SLL using highly complex design [21].

In this paper, a new method is proposed to increase the isolation between radiation slots that involves inserting metal fences between longitudinal slot arrays of the substrate integrated waveguide. With this technique it is shown an improvement in mutual coupling suppression between the radiation slots improved by around 30 dB over the frequency range 0.2-1.0 GHz, and the minimum gain is more than 1.5 dBi and side-lobe level is better than -40 dB. The proposed technique is simple to implement and should enable SIWLSAA for application in MIMO and radar systems.

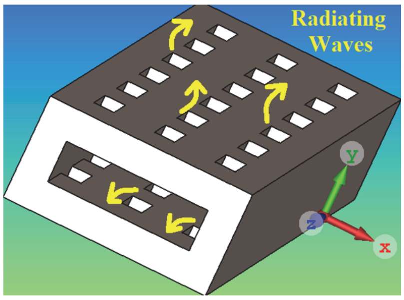
II. Substrate Integrated Waveguide Longitudinal Slotted Array Antenna

A reference longitudinal slotted array antenna, shown in Fig. 1, was fabricated on the substrate integrated waveguide. The antenna was constructed using 3×6 slotted arrays implemented on the top and bottom sides of the SIW. Unlike conventional designs the reference SIW has no via-holes which would otherwise increase manufacturing complexity. Reflection coefficient (S_{11}) and transmission coefficient (S_{12}) of SIWLSAA using EM full-wave simulations tool, i.e. CST Microwave Studio and HFSS, are plotted in Fig. 2. These plots show the antenna operates in parts of VHF and UHF frequency bands from around 200 MHz to 1.0 GHz (for $|S_{11}| \leq 10$dB). The maximum and minimum isolation of -63 dB and -60 dB are at 200 MHz and 1 GHz, respectively. The antenna resonates at 440 MHz with impedance matching of -64 dB.

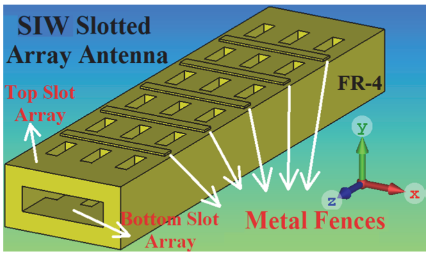
Metal fences have been inserted between the slots to suppress the mutual coupling between the radiation slots, as shown in Fig. 1. The results in Fig. 2 show the minimum mutual coupling suppression is improved by ~20 dB, and maximum suppression by ~40 dB. These results are summarized in Table. I.



(a) Reference SIWSAA without metal fences as isolator



(b) Reference SIWSAA without metal fences as isolator

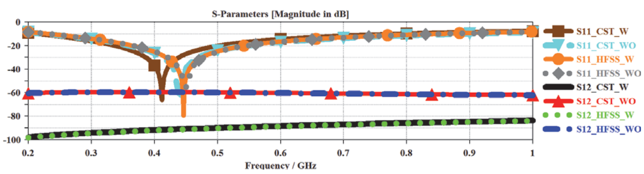


(c) Proposed SIWSAA with metal fences as isolator

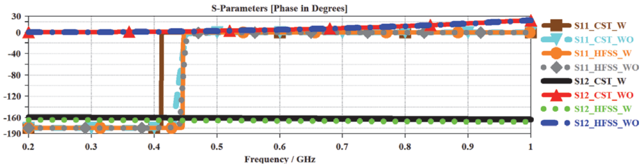
Fig. 1. Reference and proposed substrate integrated waveguide slotted array antennas (SIWSAAs).

The results presented in Table I show that with the metal fences the average reduction in mutual coupling between the radiation slots is ~30 dB over 0.2 – 1 GHz. There is negligible affecting on the frequency bandwidth compared to the reference SIWSAA.

Input impedances (Ω) and admittances (1/Ω) of the proposed substrate integrated waveguide longitudinal slot array antenna with application of the metal fences is shown in Fig. 3. The results were obtained using CST Microwave Studio and HFSS tools. There is excellent agreement between two EM full-wave simulators.



(a)

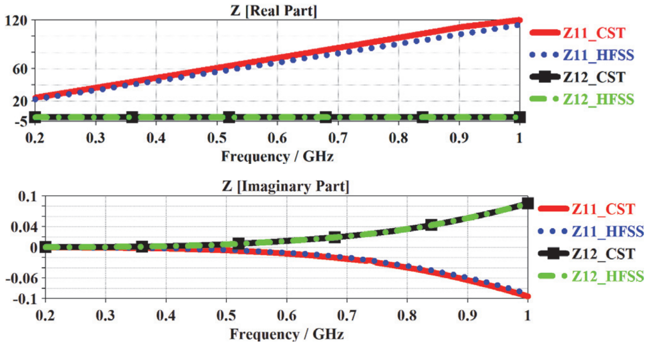


(b)

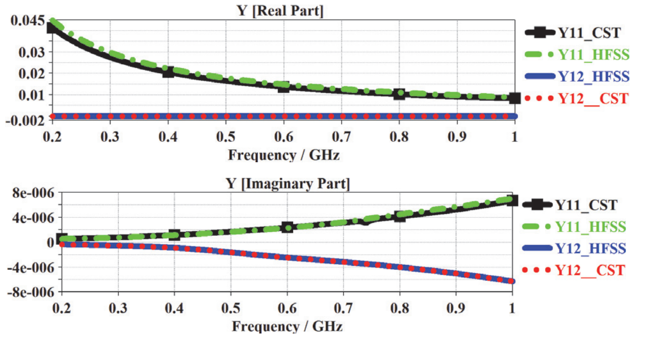
Fig. 2. S-parameter performances (S_{11} and S_{12}) of the reference and proposed SIWSAA.

TABLE I. S-PARAMETERS SPECIFICATIONS

For $\lvert S_{11}\rvert \leq$-10dB: 0.2–1.0 GHz, Δf=800 MHz, FBW=133.3%			
S_{12}	Min.	Max.	Ave.
Reference SIWSAA	-60 dB	-63 dB	-61.5 dB
Proposed SIWSAA	-83 dB	-98 dB	-91 dB
Suppression	~20 dB	~ 40 dB	~30 dB



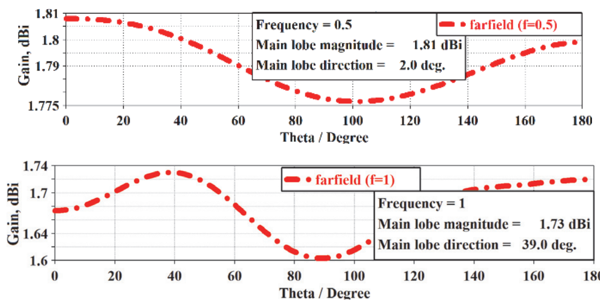
(a) Input impedances (Ω)



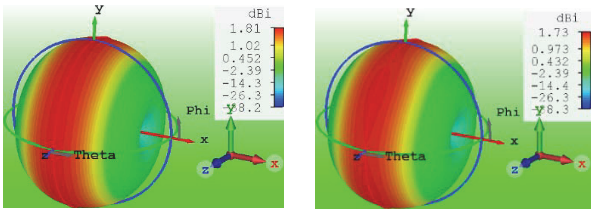
(b) Input admittances (1/Ω)

Fig. 3. Input impedances (Ω) and admittances (1/Ω) of the proposed substrate integrated waveguide slotted array antenna with metallic fences.

The 2-D and 3-D radiation characteristics of the proposed SIW slot array antenna is plotted in Figs. 4-6. Fig. 4, shows the 2-D gain plots at two operating frequencies of 500 MHz and 1.0 GHz. The gain is greater than 1.7 dBi. The maximum gain as a function of frequency is shown in Fig. 5.



(a) 2-dimentional



@ 0.5 GHz @ 1 GHz

(b) 3-dimentional

Fig. 4. Radiation patterns at operating frequencies of 0.5 and 1.0 GHz.

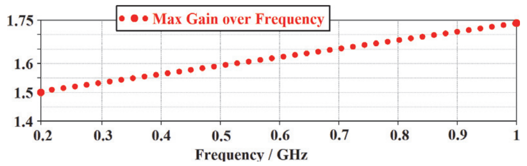


Fig. 5. Maximum gain plot versus frequency.

The radiation patterns of the reference and proposed SIWLSAA with no and with metal-fences in the E- and H-planes at 0.5 GHz and 1 GHz are plotted in Fig. 6. These results show that after implementing the metal-fences the radiation patterns are virtually unaffected. The side-lobe level obtained is -40 dB which is significantly better than that reported in literature.

The above results confirm the proposed substrate integrated waveguide longitudinal slotted array antenna provides high isolation between adjacent radiation slots. The technique is very easy to implement and is a low-cost solution.

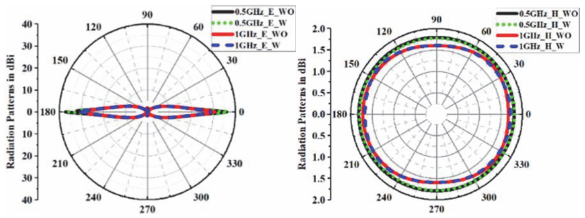


Fig. 6. Radiation patterns of the reference and proposed substrate integrated waveguide longitudinal slotted array antenna without (WO) and with (W) metal fences in E- and H- planes at 0.5 and 1 GHz.

III. Conclusion

Metal fences located between longitudinal slot arrays of the substrate integrated waveguide is shown to significantly enhance isolation between the radiating slots. The results confirm the proposed technique has negligible effect on the antennas operational bandwidth and radiation characteristics. Compared to a reference SIWLSAA the proposed technique provides isolation improvement on average of around 30 dB. The technique is simple to implement and should applicable for MIMO and radar systems.

Acknowledgments

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