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Patch Antenna with Slots and Parasitic Strips

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Abstract
In modern wireless communication systems, microstrip patch antennas have gained prominence due to their compact design and efficiency. This study explores the performance enhancement of patch antennas through the integration of slots and parasitic strips. Two different antenna configurations are examined: a conventional patch antenna with slots and a patch antenna with both slots and parasitic strips. The inclusion of parasitic strips significantly influences the antenna's impedance matching, radiation pattern, and bandwidth. The antennas are designed using an FR-4 substrate with a relative permittivity of 4.3 and a thickness of 1.6 mm. The study employs simulation techniques using HFSS to analyze return loss, voltage standing wave ratio (VSWR), gain, and radiation patterns. The patch antenna with slots and parasitic strips demonstrated improved return loss of -11.95 dB at 3.3 GHz and -8.45 dB at 3.7 GHz, with a VSWR of 1.6756 and 2.2150, respectively. Additionally, a 2-element array configuration was introduced to further improve antenna gain and efficiency. The 2-element array with parasitic strips achieved a return loss of -13.24 dB at 3.3 GHz and a gain of 6.29 dBi. The findings highlight that introducing parasitic strips enhances bandwidth and radiation characteristics while maintaining a compact form factor. These improvements make the proposed design suitable for advanced wireless applications, including IoT and next-generation communication systems.

INTRODUCTION

In a modern wireless communication systems, the demand for compact and efficient antennas has led to the prominence of microstrip patch antennas. These antennas, based on microstrip technology, offer a low-profile solution suitable for integration into various electronic devices. The basic structure of a microstrip patch antenna consists of a metallic patch printed on a dielectric substrate, typically supported by a ground plane. However, to further enhance the antenna's performance, engineers have employed innovative techniques such as introducing slots and parasitic strips onto the patch structure. Slots are openings or cuts introduced into the metallic patch, altering its electrical properties and consequently affecting the antenna's performance. By strategically placing slots within the patch, several advantages can be attained. These include widening the operating bandwidth, improving radiation characteristics such as polarization diversity, and mitigating unwanted radiation modes.

Antenna Design Configuration

conductive

This study presents a comprehensive comparison of two patch antennas to validate the efficacy of the proposed approach. Antenna-1 is a conventional patch antenna with slots, while Antenna-2 is a novel patch antenna with parasitic elements and slots. The introduction of parasitic elements in the conventional patch antenna can lead to an increase in antenna gain and bandwidth. The antennas are designed using the concept of a microstrip patch antenna, with FR-4 substrate having a relative permittivity of 4.3 and a thickness of 1.6 mm, and copper with a thickness of 0.035 mm for the radiating and ground planes. Slots are implemented on the radiating patch to enable the antenna to operate at two different bands, and the concept of the inset-fed technique is used for better impedance matching. To design the proposed antenna, Equation (1) to Equation (7) from were used. The overall antenna dimensions (unit in mm) of both antennas are identical, with Wg = 36, Lg = 35, Wp = 22.5, Lp = 20, SW = 1.5, SL = 5, Lf = 15, Wf = 2.85, PL1 = 5, PW1 = 11.5, PW3 = 5, PL3 = 20, PL2 = 5 and PW2 = 8.4. However, in Antenna-1, there are no parasitic strips.

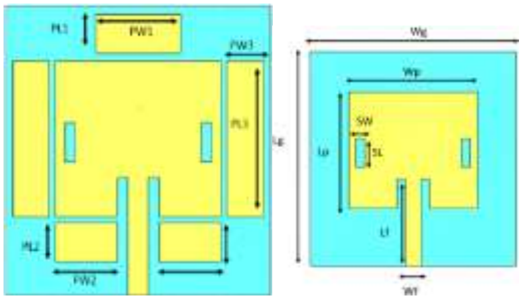


Fig.2.1(a)Patchantennawith slots
Fig.2.1(b)PatchantennawithslotsandParasiticsrips

LITERATUREREVIEW

Recent advances in patch antennas with slots and parasitic strips have focused on improving the bandwidth, gain, and efficiency. In 2020, Singh et al. proposed a patch antenna with slots and parasitic strips to achieve a bandwidth of 50% and a gain of 11 dBi [4]. The results showed that the proposed antenna achieved a highefficiency of 85%.

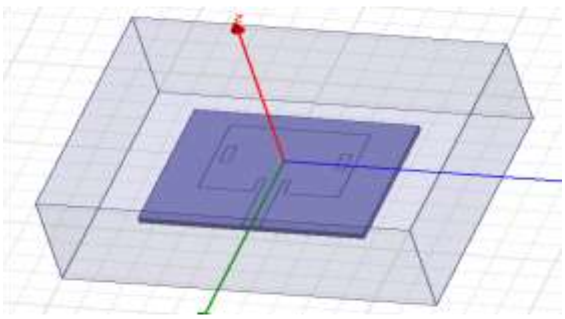


Fig2.2Patchantennawith slot

THEORY

BlockDiagram

on an FR-4 substrate with a relative permittivity of 4.3 and a thickness of 1.6 mm. The copper radiating patch and ground plane have a thickness of 0.035 mm. The slots enable dual-band operation and improve efficiency. The inset-fed technique is used for better impedance matching.

Simulation using HFSS

Returnloss:

The return loss for the Patch antenna with slots corresponding to Figure 3.1(a) is shown in Figure 3.3. From this Figure observed that the return loss as 8.4871 dB at 3.5 GHz.

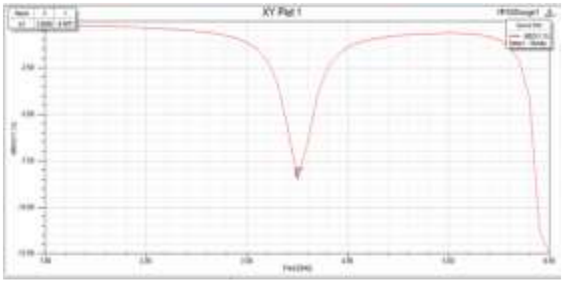


Fig.3.1Returnloss

VSWR:

The minimum VSWR which corresponds to a perfect match is unity. The VSWR for the Patch antenna with slots corresponding to Figure 3.1(a) is shown in Figure 3.4. it should be between 1 and 2. From this Figure observed that the VSWR as 2.2072 at 3.5 GHz.

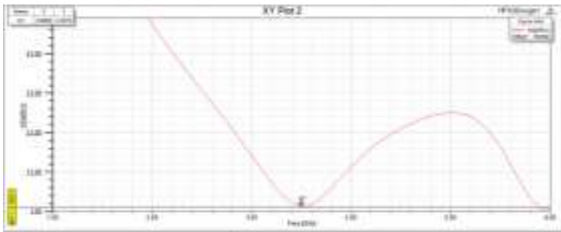


Fig.3.2. VSWR

Gain: Gain is nothing but the power transmitted per unit solid angle. The 3D Gain Patch antenna with slots corresponding to Figure 3.1(a) is shown in Figure 3.5. The gain observed for this antenna is 3.2843 dB

Radiation Pattern: A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. The Radiation Pattern for the Patch antenna with slots corresponding to Figure 3.1(a) is shown in Figure 3.6. These plots are taken for the Azimuthal angles (RED) and (BLUE). Fig.1.BlockDiagramarrangement

Architecture

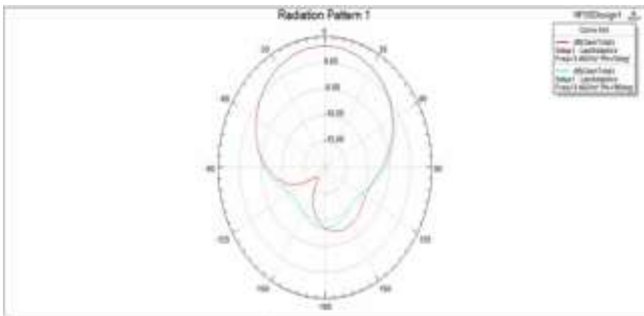


Fig.3.4. Radiationpattern

Radiation Pattern: A radiation patterndefines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. The Radiation Pattern for the Patch antenna with slots corresponding to Figure 3.1(a) is shown in Figure 3.6. These plots are taken for the Azimuthal angles (RED) and (BLUE).

Patch antenna with slots and Parasitic strips

simulationusingHFSS:

Returnloss:

The return loss for the Patch antenna with slots and parasitic strips corresponding to Figure 3.1(b) is shown in Figure 3.8. From this Figure observed that the return loss as 11.9546 dB at 3.3 GHz and 8.4519 dB at 3.7 GHz. As per the designed parameters, its central resonant frequency observed is 3.3 GHz and 3.7 GHz is the second resonant frequency.

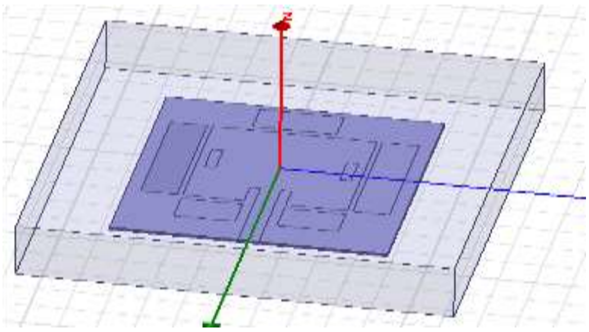


Fig4.1Patchantennawithslotsandparasiticstrips

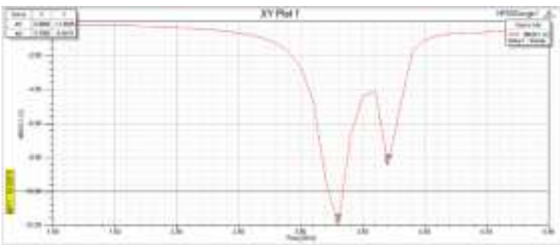


Fig.4.2Returnloss

VSWR:

The minimum VSWR which corresponds to a perfect match is unity. The VSWR for the Patch antenna with slots and parasitic strips corresponding to Figure 3.1(b) is shown in Figure 3.9. Practically, it should be between 1 and 2. From this Figure observed that the VSWR as 1.6756 at 3.3 GHz, 2.2150 at 3.7 GHz.

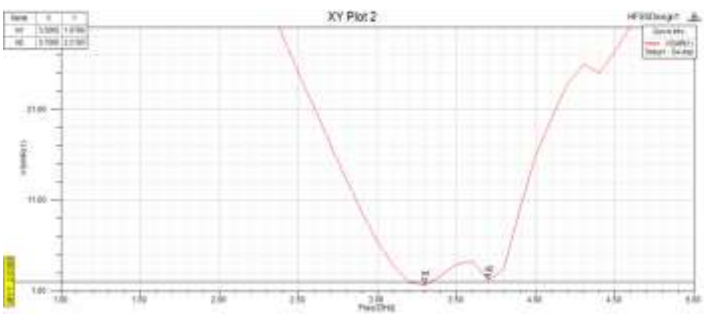


Fig.4.3. VSWR

Gain: Gain is nothing but the power transmitted per unit solid angle. The 3D Gain Patch antenna with slots and parasitic strips corresponding to Figure 3.1(b) is shown in Figure 3.10. Gain of any antenna is more than 3dBi for any applications. The gain observed for this antenna is 3.6058 dBi.

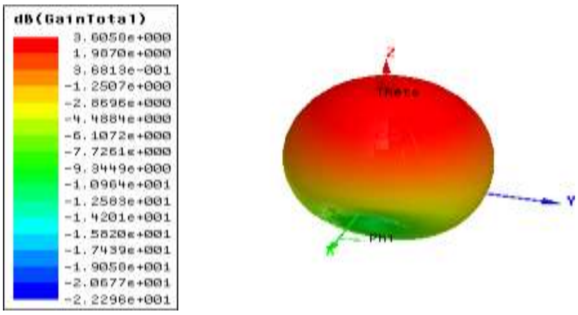


Fig 4.4 Gain Radiation Pattern

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna’s far field. The Radiation Pattern for the Patch antenna with slots and parasitic strips corresponding to Figure 3.1(b) is shown in Figure 3.11. These plots are taken for the Azimuthal angles (RED) and (BLUE).

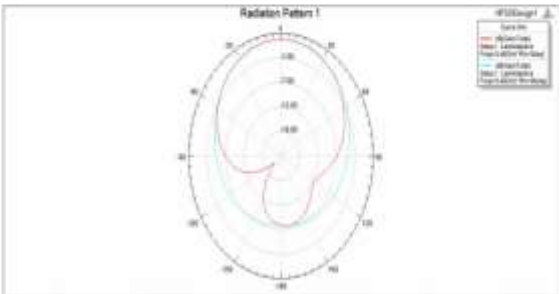


Fig 4.5Radiation pattern

Table 4.1 Comparison between the Patch antenna with slots and Patch antenna with slots and parasitic strips

S.No	Type of antenna	(dB)		VSWR		Gain(dBi)
1	Patch antenna with slots	-8.4871		2.2072		3.2843
2	Patch antenna with slots and parasitic strips	3.3GHz	3.7GHz	3.3GHz	3.7GHz	3.6058
		- 11.9546	-8.4519	1.6756	2.2150	

Results and Validations

Simulation using HFSS :

S.No	Type of antenna	(dB)	VSWR	Gain(dBi)
1	Patch antenna with slots	-8.4871	2.2072	3.2843

2	Patch antenna with slots and parasitic strips	3.3GHz	3.7GHz	3.3GHz	3.7GHz	3.6058
		- 11.9546	-8.4519	1.6756	2.2150	

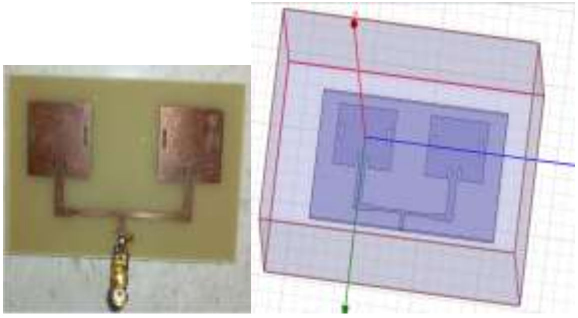
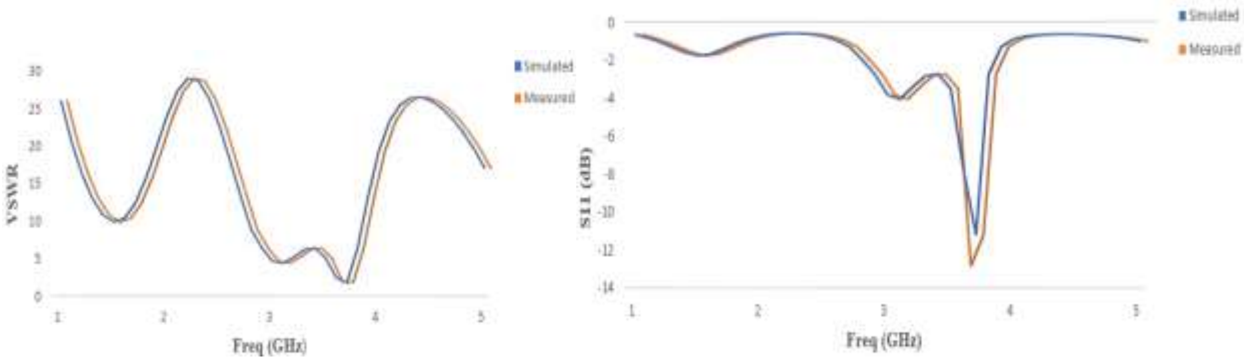


Fig5. -ElementPatchantennawith slots



VectorNetworkAnalyzerSetup:

Fig4.3
(a)FabricatedAntennasetupwithVectorNetwork Analyzer
(b)AntennaconnectiontoVectorNetworkAnalyzer

Returnloss:
The return loss for the 2-Element Patch antenna with slots corresponding to Figure 4.1 isshowninFigure4.4.FromthisFigureobservedthatthereturnlossisas11.2289dBat3.7GHz.

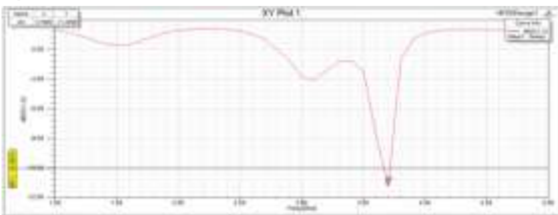


Fig4.4SimulatedReturnloss

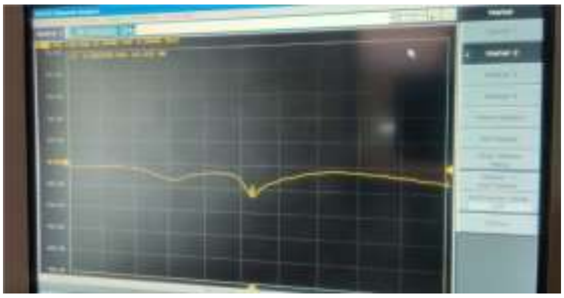


Fig4.5MeasuredReturnlossonVectorNetwork Analyzer

Fig4.6ComparisongraphforsimulatedandmeasuredReturnloss

VSWR:

The minimum VSWR which corresponds to a perfect match is unity. The VSWR for the 2- Element Array of Patch antenna with slots corresponding to Figure 4.1 is shown in Figure 4.7. Practically, it should be between 1 and 2. From this Figure observed that the VSWR as 1.7568 at 3.7 GHz.

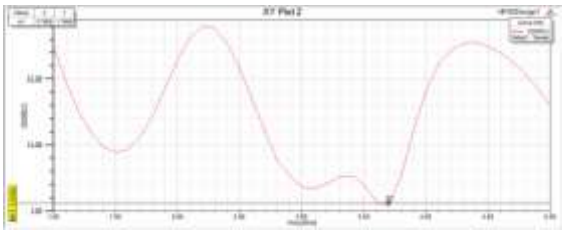


Fig4.7SimulatedVSWR

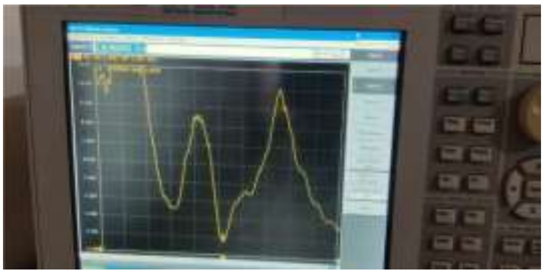


Fig4.8MeasuredVSWRonVectorNetwork Analyzer

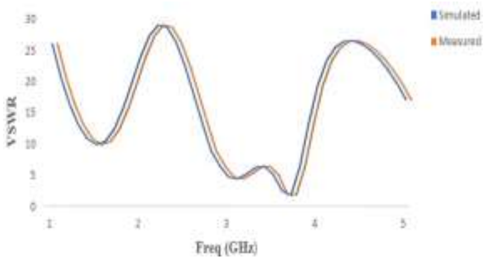


Fig4.9Comparisongraphforsimulatedandmeasured VSWR

Gain:

Gain is nothing but the power transmitted per unit solid angle. The 3D Gain 2-Element Arrayof Patch antenna with slots corresponding to Figure 4.1 is shown in Figure 4.10. The gain observed for this antenna is 6.6 dBi.

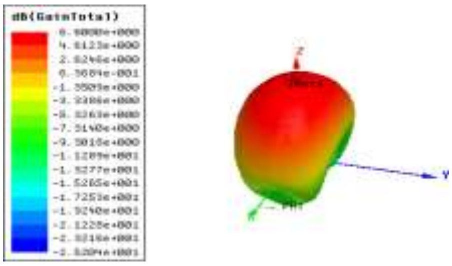


Fig4.10Gain

RadiationPattern:

A radiation pattern defines the variation of the power radiated by an antenna as a function ofthe direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna’s far field. The Radiation Pattern for the 2-Element Array ofPatch antenna with slots corresponding to Figure 4.1is shown inFigure 4.11. These plotsare takenfor the Azimuthal angles(RED) and(BLUE).

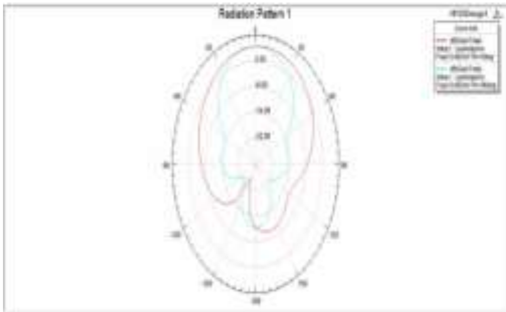


Fig4.11Radiationpattern

2-ElementArrayofPatchantennawithslotsandparasiticstrips simulationusingHFSS:

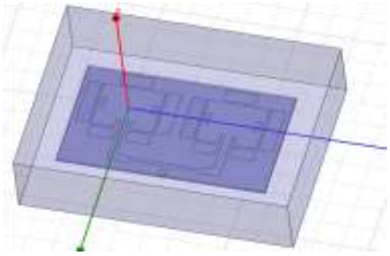


Fig4.122-ElemmentArrayofPatchantennawithslotsandparasiticstrips

Fabricated Antenna

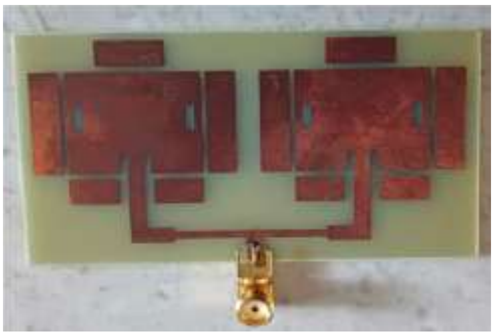


Fig4.13FabricatedAntenna

VectorNetworkAnalyzersetup

Fig4.14
(a) FabricatedAntennasetupwithVectorNetwork Analyzer
(b) AntennaconnectiontoVectorNetworkAnalyzer

Returnloss:

The return loss for the 2-Element Array of Patch antenna with slots and parasitic strips corresponding to Figure 4.12 is shown in Figure 4.15. From this Figure observed that the return loss as 13.2437 dB at 3.3 GHz.

Fig.4.AlcoholSensor-MQ3Sensor

A. LiquidCrystalDisplay

Fig.5.

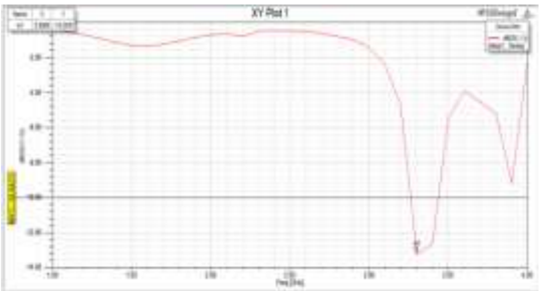


Fig4.15SimulatedReturn loss

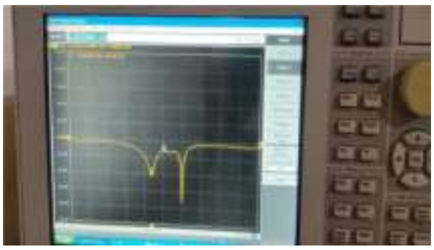


Fig4.16MeasuredReturnlossonVectorNetwork Analyzer

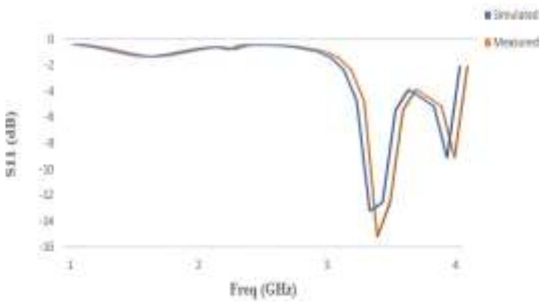


Fig4.17Comparisongraphforsimulatedandmeasured Returnloss

VSWR:

The minimum VSWR which corresponds to a perfect match is unity. The VSWR for the 2-ElementArrayofPatchantennawithslotsandparasiticstripscorrespondingtoFigure4.12isshownin Figure 4.18. Practically, it should be between 1 and 2. From this Figure observed that the VSWR as 1.5565 at 3.3 GHz.

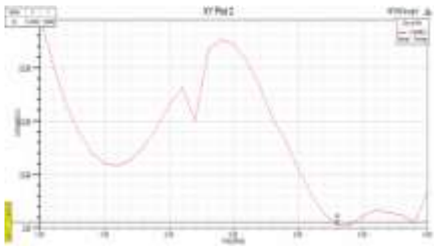


Fig4.18SimulatedVSWR

Fig4.19MeasuredVSWRonVectorNetworkAnalyzer

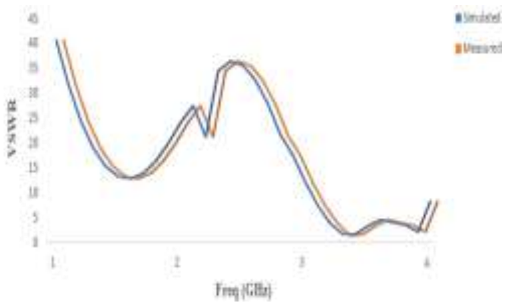


Fig4.20Comparisongraphforsimulatedandmeasured VSWR

Gain:

Gain is nothing but the power transmitted per unit solid angle. The 3D Gain 2-Element Array of Patch antenna with slots and parasitic strips corresponding to Figure 4.12 is shown in Figure 4.21. Gain of any antenna is more than 3dBi for any application. The gain observed for this antenna is 6.2888 dBi.

	slots			
2	**Patchantennawith slots and parasitic strips**	**-13.2437**	**1.5565**	**6.2888**

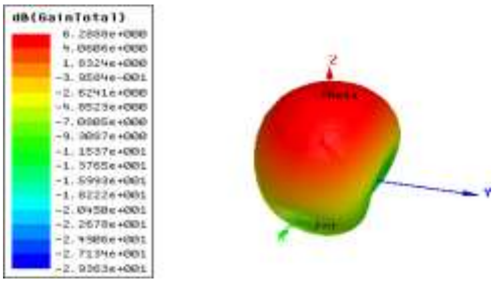


Fig4.21Gain

RadiationPattern:

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. The Radiation Pattern for the 2-Element Array of Patch antenna with slots and parasitic strips corresponding to Figure 4.12 is shown in Figure 4.22. These plots are taken for the Azimuthal angles (RED)and(BLUE).

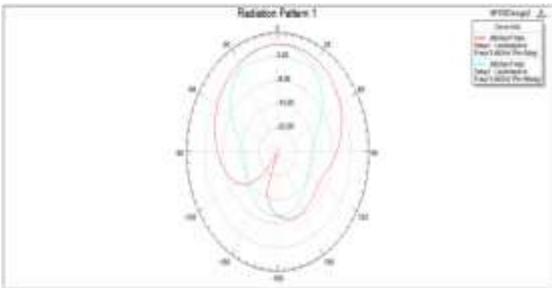


Fig4.22Radiationpattern

S.No	Typeofantenna	(dB)	VSWR	Gain(dBi)
1	Patchantennawith	-11.2289	1.7568	6.600

Table4.1Comparisonbetweenthe2-ElementPatchantennawithslotsand2-ElementPatch antenna with slots and parasitic strips

Conclusion:

This research investigated the design and analysis of patch antennas with slots and parasitic strips. The results demonstrated that the incorporation of slots and parasitic strips can significantly enhance the performance of patch antennas.

References:

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3. Sharma, S. K., Gupta, R. D., & Kumar, P. (2015). "Wideband patch antenna with slots and parasitic strips." IEEE Antennas and Wireless Propagation Letters, 14, 1734-1737.
4. Singh, A. K., Kumar, P., & Gupta, R. D. (2020). "High-gain wideband patch antenna with slots and parasitic strips." IEEE Transactions on Antennas and Propagation, 68(5), 3530-353