DESIGN OF RECTANGULAR METASURFACE ANTENNA FOR WIRELESS COMMUNICATION DEVICES

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Abstract— **Metasurfaces are the opposite of metamaterials in thickness and height, but they also feature sub wavelength characteristics. Compared to metamaterials, metasurfaces are less bulky due to their lower dimensions. Metasurfaces hold considerable potential for use in wireless communication because of their exceptional ability to manipulate electromagnetic waves. This article started off with the goal of creating rectangular printed antennas before moving on to the creation and use of metasurface superstate for use on top of rectangular patch antennas. When a metasurface superstate is applied to patch antennas, improvements are shown in the antenna's properties, including gain, VSWR and S11. This article mostly concentrated on enhancing the antennas' gain, and it was found that adding the superstate increased the gain by an average of 1 dB. The Metasurface Superstate Antennas are constructed using FR-4 Material and operate at 2.4 GHz and 5.2 GHz frequencies. As the metasurfaces market takes up again after a slow few years, there are currently around 25 metasurfaces product developers globally who have garnered over $300 million in recent funding. Applications utilizing these frequencies, including mobile phones, Bluetooth, Wi-Fi, WLAN, and Zigbee, are served by the proposed Metasurface Antenna.**

Keywords **–Metasurface Antenna, Rectangular Patch Antenna, FR-4, Wireless Communication Devices**

I. Introduction

Metasurfaces are flat or two-dimensional (2D) metamaterials with thicknesses less than one wavelength. Because they are lightweight and simple to fabricate, they are extensively studied and used in electromagnetic applications. Metasurfaces are unique materials with the ability to block, absorb, concentrate, distribute, or steer microwave through visual frequencies at both normal and oblique incidence in space as well as at grazing incidence on the surface. Metasurfaces are artificially thin layers consisting of small inclusions regularly placed in a dielectric host material. They can be applied to obtain unusual space wave transmission and reflection properties, or they can be utilized to modify the dispersion characteristics of guided or surface waves. Metasurface Technology has received a significant deal of interest from the scientific community and has been put to many various uses. Surface wave (SW) can be used to simulate a desired aperture field radiating through a leaky wave (LW) effect when it interacts with modulated, locally periodic boundary conditions (BCs) imposed by a metasurface. The conventional metasurface structure is lightweight, complicated, and has a low profile. Additionally, building it with typical printed circuit board techniques is simple. Moreover, the feeding element is integrated into the MTS plane, removing the need for redundant feed configurations, sub-reflectors, and unnecessary projection.

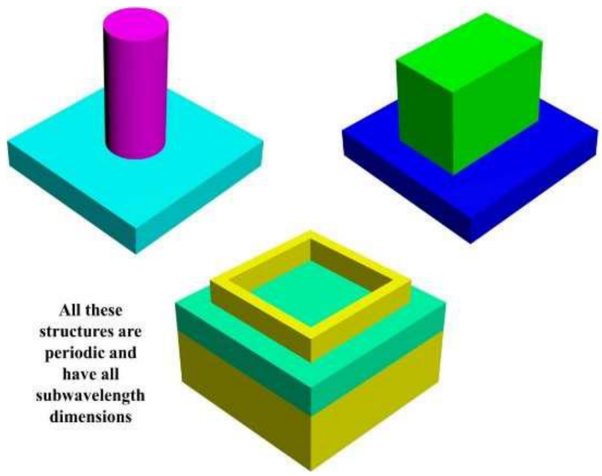

Figure 1: Different Metasurfaces

Over the past ten years, Metasurface (MTS) Antenna Design has emerged and changed dramatically, becoming a major advancement in the area. Thousands of sub wavelength patches of various sizes or metallic strips printed on a grounded dielectric substrate are the usual components of metasurface antennas operating at microwave frequencies. It is convenient to use metalized pin textures in place of patch textures in some millimeter and sub millimeter wave applications. The interactive SW interprets the texture as a continuum as long as the wavelength of the elements implementing the IBCs is modest. The individual components of the texture work like pixels in a black-and-white print image; the grayscale effect is produced by altering the size of the pixel-elements inside a regular lattice. Metasurface antennas are lightweight, low-cost, intricate, and have a compact profile. Since the feeding structure is integrated into the metasurface plane, no external protrusions, backup feed systems, or sub reflectors are needed.

II. Antenna Design

Rectangular Patch Antenna is made up of a metallic ground plane on one side of the non-conductive substrate panel and a radiating metallic patch on the other. The dimension L is approximately equal to a half wavelength and is defined as half the free space wavelength (λ) divided by the square root of the effective dielectric constant (ε) of the board material. The wavelength must be significantly less than half due to the radiation fringing from the ground plane and the two opposite patch edges that are L apart. Two additional edges do not radiate if the feed is on the centerline. Because it is engraved on the board on the same side as the patch and other component traces, the microstrip feeder is convenient. The usage of the rectangular printed antenna design in HFSS is demonstrated in Figure 2 below. The measurements of the printed rectangular antenna are substrate's dimension is 58.94 x 35.9 mm, its thickness is 1.6 mm, and its material is FR4 epoxy. The patch's measurements are 12.56 x 17.56 mm. The patch operates at 5.2 GHz.

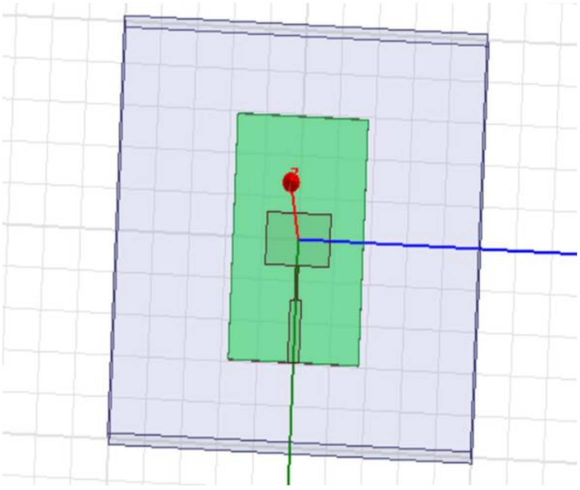

Figure 1: Rectangular Patch Design in HFSS

Improving the antenna's performance characteristics, especially its gain, is the main objective of the work. The Rectangular Printed Antenna uses a Metasurface Superstate to achieve this. A superstate on top of the antenna can only be used as intended after determining the dimensions of a unit cell. Using 3X 1 Unit Cells, we have presented the Metasurface Superstate. The parameters of the proposed metasurface cell are as follows: the substrate measures 58.94 x 35.9 mm, the thickness is 1.6 mm, the superstate height is 13.72 mm, and the unit cell measures 5.76 x 1.92 mm.

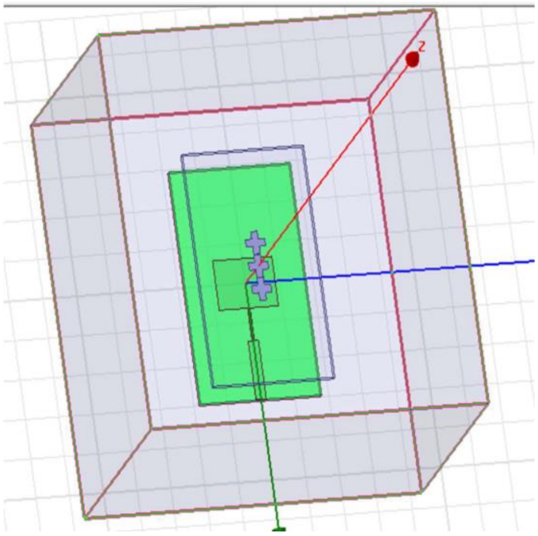

Figure 2: Proposed 3x1 Metasurface Antenna

III. Fabrication Model of Proposed Antenna

Figure 3: Fabricated 3x1 Metasurface Antenna (a) Top View (b) Side View

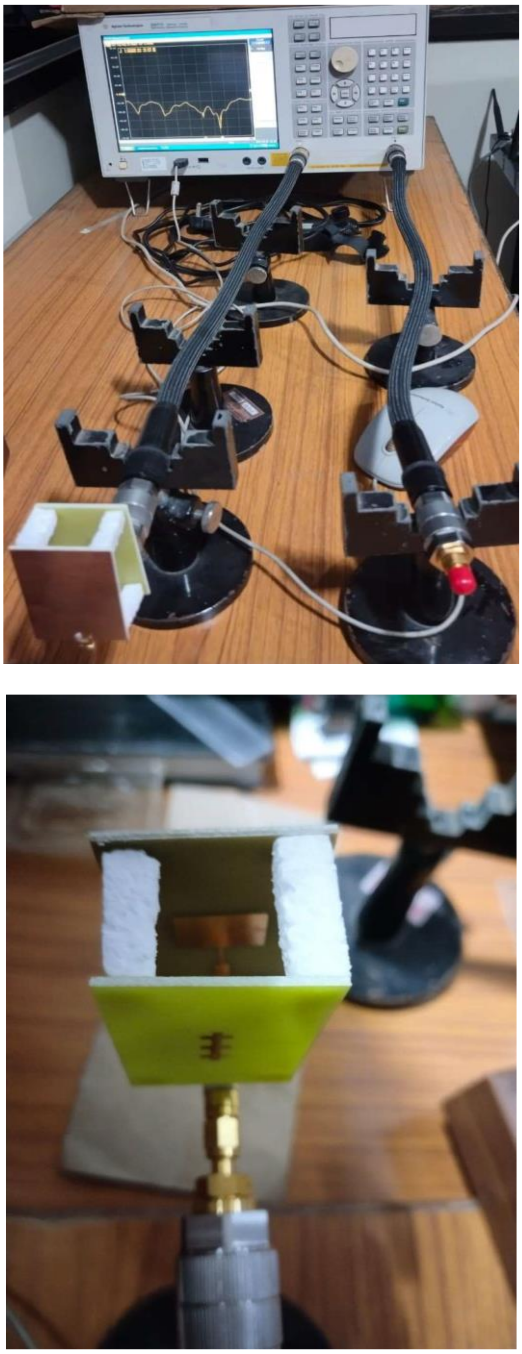

Figure 4: Fabricated Antenna setup with Vector Network Analyzer

Proposed Metasurface Antenna has a dielectric constant of 4.4 and is made using FR-4 Substrate. These models are examined using a vector network analyzer following construction.

IV. Simulated & Measured Results

a) S11 (Reflection Coefficient)

The amount that indicates how much of a wave is reflected by an impedance discontinuity in the transmission channel is known as the reflection coefficient (S11). It is the ratio of the incident wave's amplitude to the reflected waves. S11 of the HFSS designed 3x1 Metasurface Antenna, which correlates to Figure 3, is shown in Figure 6. At 2.4 to 5.2 GHz, the proposed 3x1 Metasurface Antenna Simulated Return loss is 11.72 dB.

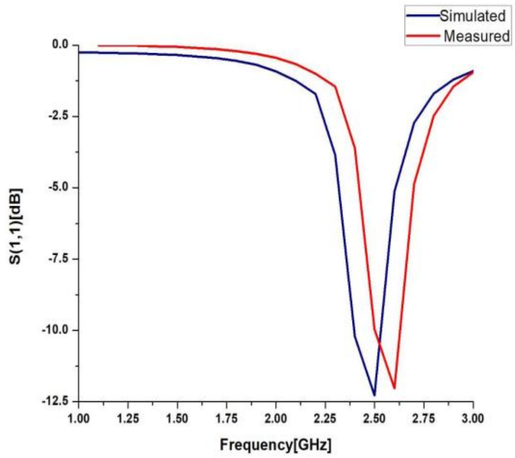

Figure 5: S11 of Proposed 3x1 Metasurface Antenna

b) Gain

The power that an antenna transmits in a certain direction as comparison to an isotropic antenna is indicated by its Antenna Gain. This specification outlines the maximum signal strength that an antenna in a given direction is capable of sending or receiving. In accordance with Figure 3, Figure 7 shows the gain of the HFSS designed 3x1 Metasurface Antenna. The estimated gain of a 3x1 metasurface antenna at 2.4 to 5.2 GHz is 6.17 dB.

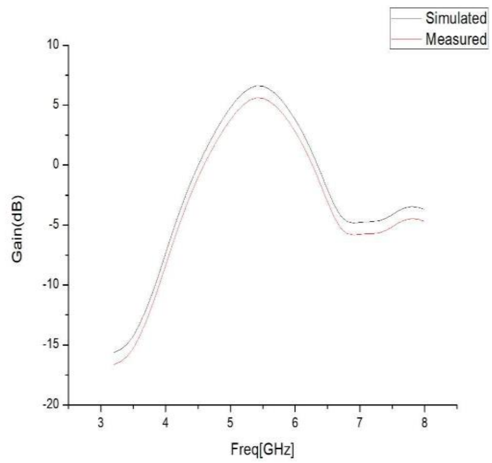

Figure 7: Gain of Proposed 3x1 Metasurface Antenna

c) VSWR

Voltage Standing Wave Ratio is a measurement of the degree of mismatch between an antenna and the feed line that connects to it. A VSWR value of less than two is considered suitable for the majority of antenna applications. One could characterize the antenna as having a "Good Match." Thus, when an antenna is said to be poorly matched, it typically indicates that the frequency of interest has a VSWR value greater than 2. Figure 8 displays the VSWR of the HFSS-designed 3x1

Metasurface Antenna, which corresponds to Figure 3. The proposed 3x1 Metasurface Antenna's measured and simulated VSWR is 1.7 dB at 2.4 to 5.2 GHz.

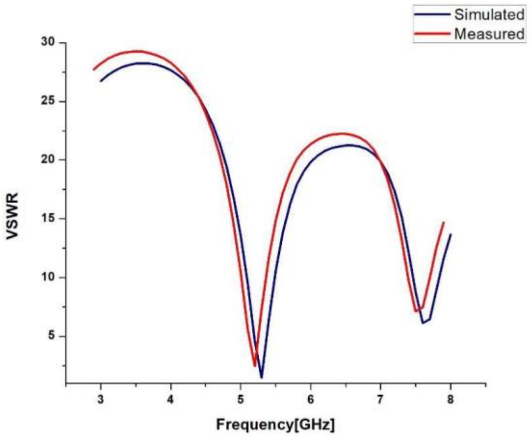

Figure 8: VSWR of Proposed 3x1 Metasurface Antenna

V. RESULT ANALYSIS

The reference articles are related to Metasurface Antennas and compare the sizes of antennas, S11 and antenna gain. Antenna Gain in the proposed work is higher than that of Metasurface Antennas, which acted as the reference.

Table 1: Comparison table of existing Metasurface Antenna's gain with proposed work

Ref	Size of Antenna (mm)	S11 (dB)	Gain (dB)
[1]	40 × 40 × 1.6	-29	3.6
[2]	40 × 40 × 1.6	-28	3.5
[3]	0.33 × 0.33 × 0.04	-10	5.29
[4]	34.5 × 28 ×4	-10	5.8
[5]	29.79 × 12.5 × 4.16	-14	6.12
Proposed Work	**13.72 × 5.76 × 1.92**	**11.72**	**6.17**

VI. CONCLUSION

The main goal of the paper is to improve the performance characteristics of the antenna, specifically its gain. Thus, Proposed 3x1 Metasurface Superstate is used on top of the antenna using the same unit cell. This article analyzes the performance of rectangular microstrip antennas with and without superstate using both manufactured and simulated data. Out of all these antenna configurations, the proposed metasurface superstate antenna has the highest return loss and gain (11.22 dB and 6.17 dB). The Proposed metasurface superstate antennas have a frequency range of 2.4 GHz–5.2GHz. Numerous applications including mobile phones, Bluetooth, Wi-Fi, WLAN and Zigbee employ the proposed Metasurface Antenna. Metasurface antennas have low power consumption and small size as their key advantages, and further advancements in this field can assist to increase the efficiency of antennas in various applications. High gain can be obtained from the microwave structures of those with metasurface superstates.

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