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Design and Analysis of Triangle Patch Microstrip Antenna Array For 5G Applications

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Abstract: This paper presents the design and analysis of a triangular patch microstrip antenna array intended for fifth-generation (5G) wireless communication applications. The design specifications in the approved project report target an operating frequency of 8 GHz in the 5G millimeter-wave bands n257/n261. The proposed structure uses an equilateral triangular radiating patch on Rogers RT/duroid 5880 substrate and a 1×4 linear array with a corporate feed network. The report specifies a relative permittivity of 2.2, substrate thickness of 0.508 mm, copper thickness of 0.035 mm and a 50 fi input. The supplied simulation figures include S-parameter, VSWR, gain, three-dimensional radiation and surface-current plots. Their frequency axes and labels indicate approximately 3.5–6 GHz and about 4.75 GHz, respectively, and are not treated as verified 28 GHz simulation results. In addition, photographs of the fabricated antenna connected to a Vector Network Analyzer (VNA) and the measured S11 display are included. The VNA photograph shows a marker reading of 29.2275 GHz and −10.01 dB; this is reported as the displayed marker reading, not as a confirmed resonant frequency or complete bandwidth measurement.

Keywords: Triangular microstrip patch, antenna array, 5G, 8 GHz, Rogers RT/duroid 5880, return loss, VSWR, radiation pattern.

I. INTRODUCTION

The growth of fifth-generation wireless communication has increased the demand for antennas that support high-frequency operation, directional radiation and compact integration. Microstrip patch antennas are widely used because they have a low profile, light weight and can be fabricated using printed-circuit techniques. A typical microstrip antenna consists of a conducting patch, a dielectric substrate and a ground plane. Radiation occurs mainly due to fringing fields at the patch edges.

Among common patch geometries, the triangular patch offers a compact radiating structure. However, a single patch can have limited gain and bandwidth. Combining multiple elements into an array can increase gain and directivity and can provide a more focused radiation pattern. Array design also requires attention to element spacing, mutual coupling, feed-network losses and impedance matching.

This work follows the approved project report, which specifies a triangular patch array for 8 GHz 5G applications. The available result figures are also retained from that report. Their frequency indication is discussed separately so that the design target is not confused with the frequencies shown in the plots.

II. RELATED WORK

Earlier studies have investigated triangular microstrip patches for digital television, WLAN, 5.8 GHz ISM-band communication, 5G wireless systems and X-band arrays. Arza and Rohmah studied a linear array of triangular patch elements for digital television [1]. Sotyohadi et al. examined bandwidth optimization of a triangular patch for 2.4 GHz WLAN [2]. Chakraborty et al. reported a triangular-slot microstrip patch for wireless communication [3]. Other work considered 5G microstrip antennas [4], slot techniques for triangular patches [5], and comparisons of triangular 4×4 and 2×2 arrays [6]. Circularly slotted triangular patches have also been investigated for 5.8 GHz ISM applications [7], while different feeding techniques for slotted triangular patches were studied in [8]. A modified triangular patch for 5G Sub-6 GHz applications is described in [9].

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The present project focuses on a 1×4 triangular array with a corporate feed and a stated 8 GHz design target. The cited works provide context for triangular patch geometry, array configuration, feeding and bandwidth considerations.

III. DESIGN SPECIFICATIONS

The design values below are transcribed from the approved project report. They describe the intended design target and are not inferred from the result plots.

TABLE I DESIGN SPECIFICATIONS

Parameter	Value
Operating frequency	8 GHz
Application band	5G mmWave (n257/n261)
Substrate	Rogers RT/duroid 5880
Relative permittivity (εr)	2.2
Loss tangent (tan δ)	0.0009
Substrate thickness	0.508 mm
Copper thickness	0.035 mm
Patch shape	Equilateral triangle
Feed type	Microstrip line feed
Input impedance	50 fi
Array configuration	1×4 linear, corporate feed
Target return loss	Below −10 dB (VSWR < 2)

IV. ANTENNA DESIGN AND METHODOLOGY

A. Triangular Radiating Element

The proposed radiating element is an equilateral triangular microstrip patch. The approved report gives an initial side length of approximately 4.47 mm and a corresponding triangle height of approximately 3.87 mm for the stated 8 GHz design on RT/duroid 5880. These are starting dimensions and the report notes that final values are tuned during simulation.

B. Substrate and Feeding Network

Rogers RT/duroid 5880 is selected for its low relative permittivity and low loss tangent. A microstrip line feed is used, with a 50 fi input impedance. The corporate feed network uses 50 fi, 70.7 fi quarter-wave transformer and 100 fi branch-line sections. The quarter-wave transformer impedance is stated as 70.7 fi for matching a 100 fi branch to a 50 fi source.

C. Array Configuration

The array is specified as a 1×4 linear arrangement. The initial element spacing is $\lambda_0/2$, approximately 5.36 mm at the stated 8 GHz design frequency. The report explains that equal path lengths are used in the corporate feed so that the four elements are excited in phase. Under ideal conditions, four elements can provide an approximate 6 dB gain increase over one element before feed-network losses.

D. Simulation Workflow

The report describes full-wave electromagnetic simulation using a solver such as CST Microwave Studio or ANSYS HFSS. The stated setup includes a 24–32 GHz sweep, a 50 fi waveguide port, open/radiation boundaries, adaptive mesh refinement, and far-field and surface-current monitors at 8 GHz. The parametric study varies patch side length, substrate thickness, dielectric permittivity, feed position, element spacing and number of elements.

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E. Flow Chart

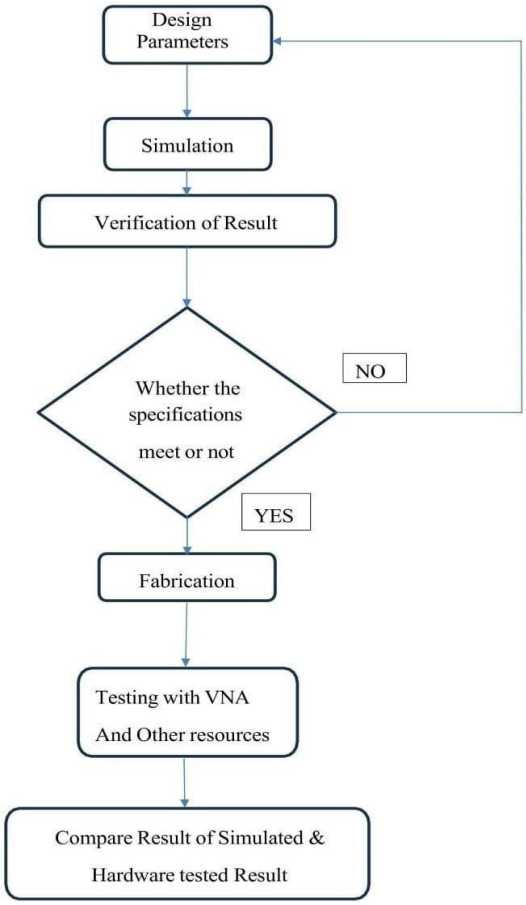


Fig. 1 Flow chart of triangular microstrip patch antenna array design and analysis, based on the approved project workflow.

The workflow begins with design parameters, followed by antenna simulation and verification. If the specifications are not met, the design is modified and simulated again. If they are met, the process proceeds to fabrication, VNA testing and comparison of simulated and hardware-tested results. The report presents fabrication and VNA testing as subsequent workflow stages.

V. SIMULATION OUTPUTS AND OBSERVATIONS

The following five figures are reproduced from the Results chapter of the approved project report (printed pages 33–34). The figure labels and plotted frequency information are retained. The plots are treated as simulation outputs supplied in the report; no additional measurements or numerical values have been generated for this paper.

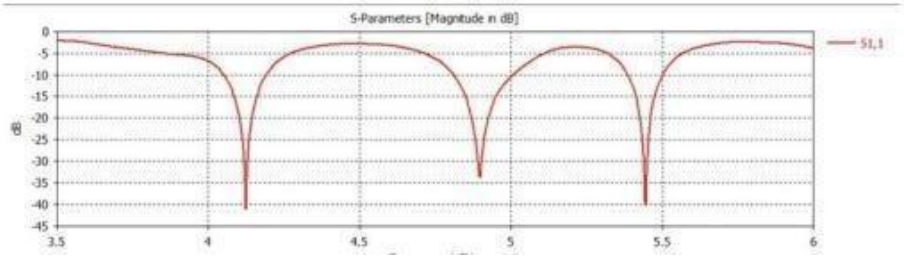


Fig. 2 S-parameter (S11) response reproduced from the approved report.

The S-parameter graph shows the magnitude response over an approximately 3.5–6 GHz frequency span, with multiple minima visible in the plotted response. The figure does not show a 28 GHz sweep.

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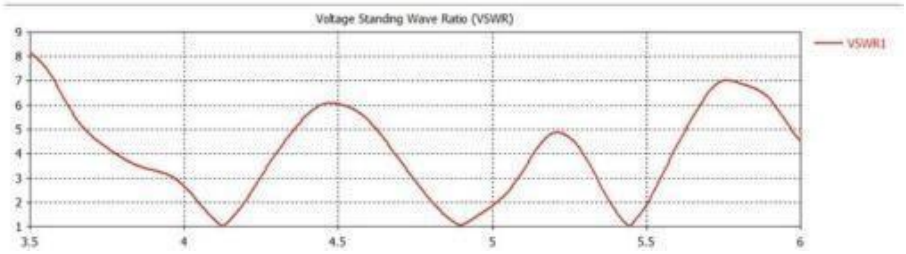


Fig. 3 VSWR response reproduced from the approved report.

The VSWR plot shows the variation of standing-wave ratio across the displayed frequency range. The target specified in the design table is VSWR below 2; the graph is presented as supplied without assigning unreported exact values.

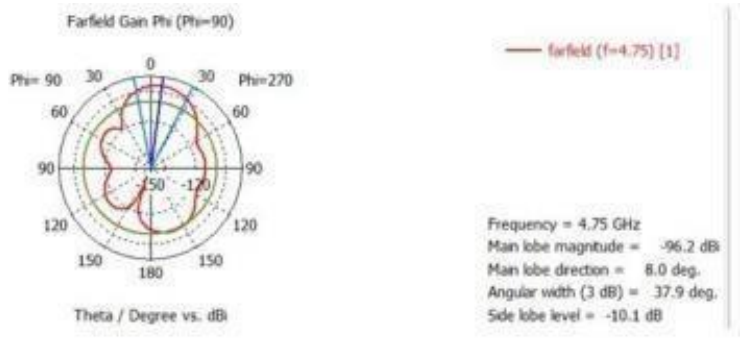


Fig: Gain

Fig. 4 Gain pattern output labelled at approximately 4.75 GHz in the approved report.

The gain figure is labelled at approximately 4.75 GHz. It provides the far-field gain-pattern output included in the project report. No 8 GHz gain value is claimed from this figure.

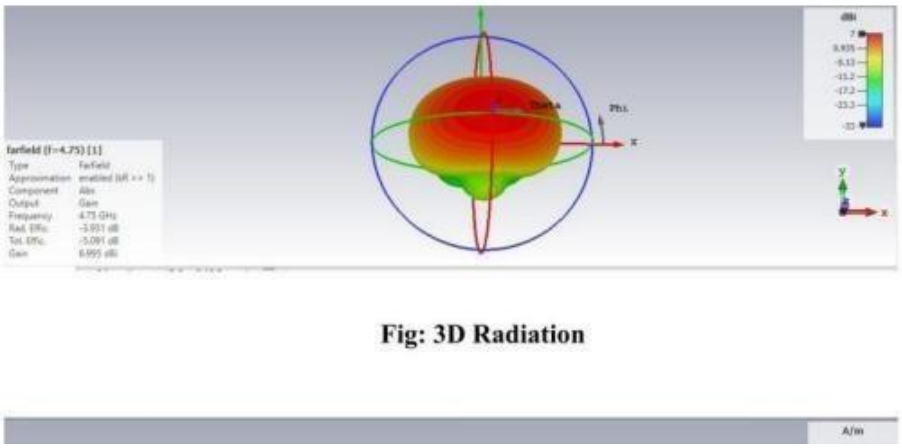


Fig: 3D Radiation

Fig. 5 Three-dimensional radiation pattern reproduced from the approved report.

The 3D radiation plot is labelled at approximately 4.75 GHz and illustrates the simulated spatial radiation distribution shown in the report.

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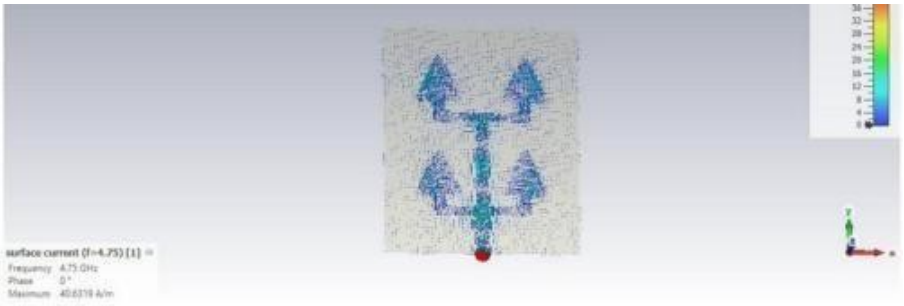


Fig: Surface Current Distribution

Fig. 6 Surface-current distribution reproduced from the approved report.

The surface-current plot is also labelled at approximately 4.75 GHz. It shows the current distribution over the antenna structure at the frequency indicated in the source figure.

VI. EXPERIMENTAL OBSERVATION AND VALIDATION STATUS

The fabricated triangular patch array was connected to an Anritsu Vector Network Analyzer (VNA) for an S11 measurement. Figure 7 shows the antenna connected to the measurement instrument, while Fig. 8 presents a closer view of the VNA display. The instrument screen identifies the trace as S11 (log magnitude) and shows a frequency span from 24 GHz to 30 GHz. The displayed marker reads 29227.500000 MHz (29.2275 GHz) at −10.01 dB. This value is the reading at the selected marker position in the supplied photograph; it should not be interpreted as the resonant frequency or the full impedance bandwidth without examining the complete trace and measurement data.

The photographs provide visual evidence of the hardware connection and the S11 measurement display. The exported VNA point-data files are also analysed below to report the measured S11 and VSWR values over the recorded frequency sweeps. The gain file contains three frequency-value pairs and is reported separately; its units are interpreted as GHz and dB based on the supplied project context.

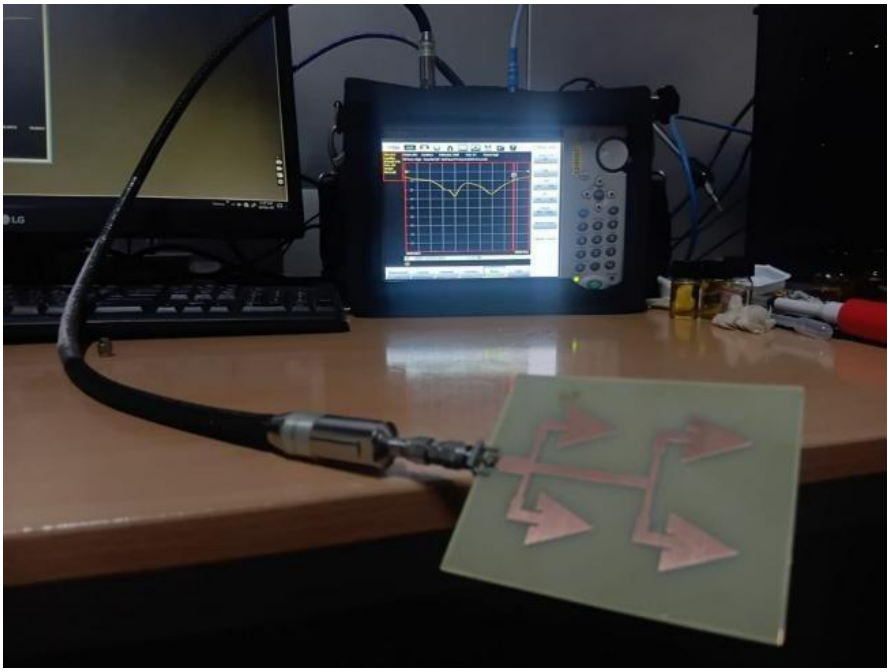


Fig. 7 Fabricated triangular patch antenna array connected to the VNA for S11 measurement.

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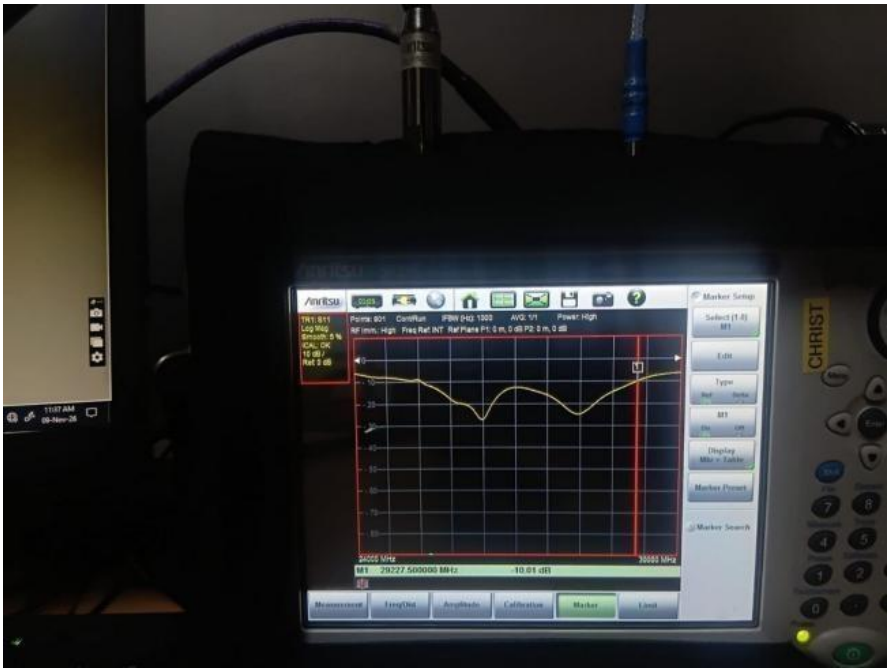


Fig. 8 Close-up of the VNA S11 display showing the marker reading at 29.2275 GHz and −10.01 dB.

Measured VNA Results and Data Analysis

The VNA data files supplied for this paper contain two S11 sweeps and one VSWR sweep. The millimeter-wave S11 and VSWR files cover 24–30 GHz, while the lower-frequency S11 file covers 3–6 GHz. The key readings extracted from the marker records and point data are summarised in Table II. The minimum values in the point-data traces are distinguished from the marker readings.

At the design frequency of 8 GHz, the closest recorded point is 27.9975 GHz. At this point, the measured S11 is approximately −23.190 dB and the corresponding VSWR is 1.147. At the separate marker position of 29.2275 GHz, the S11 marker is −10.026 dB and the VSWR marker is 1.919. These are distinct frequency points and are reported separately.

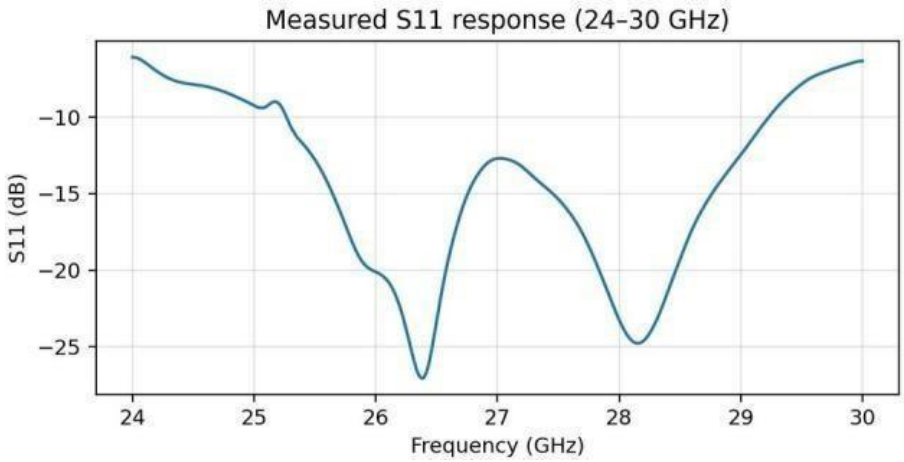


Fig. 9 Measured S11 response over the 24–30 GHz sweep, plotted from the supplied VNA data.

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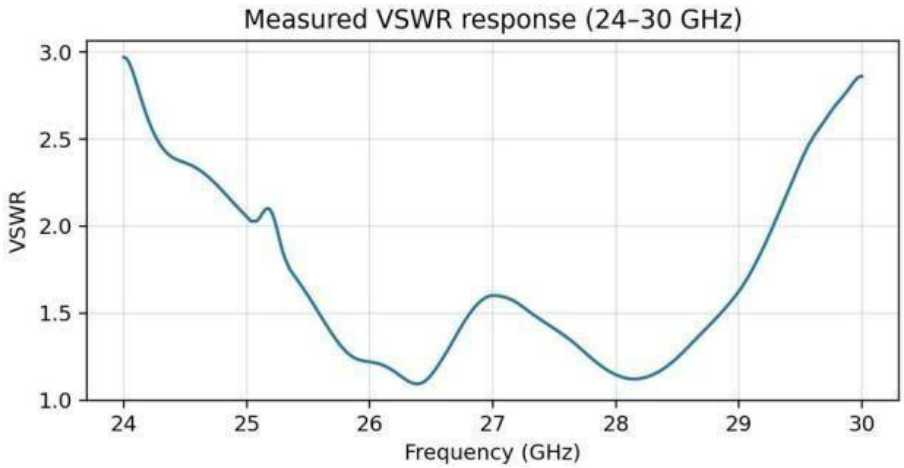


Fig. 10 Measured VSWR response over the 24–30 GHz sweep, plotted from the supplied VNA data.

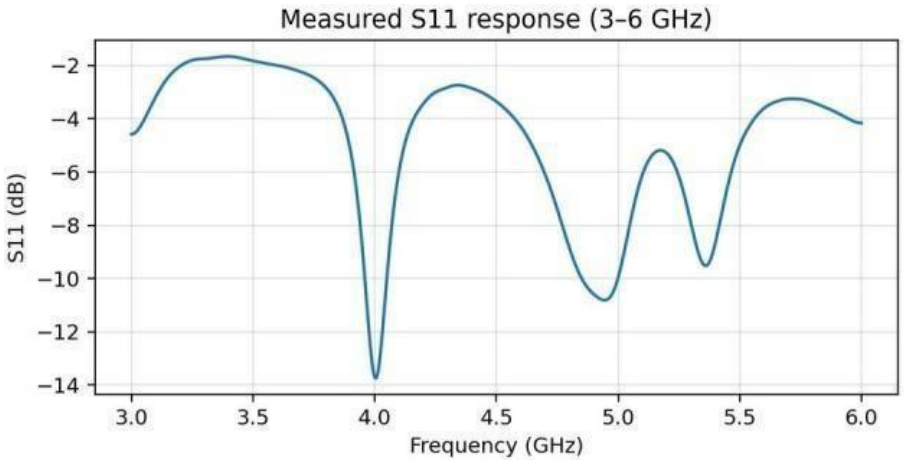


Fig. 11 Measured S11 response over the 3–6 GHz sweep, plotted from the supplied VNA data.

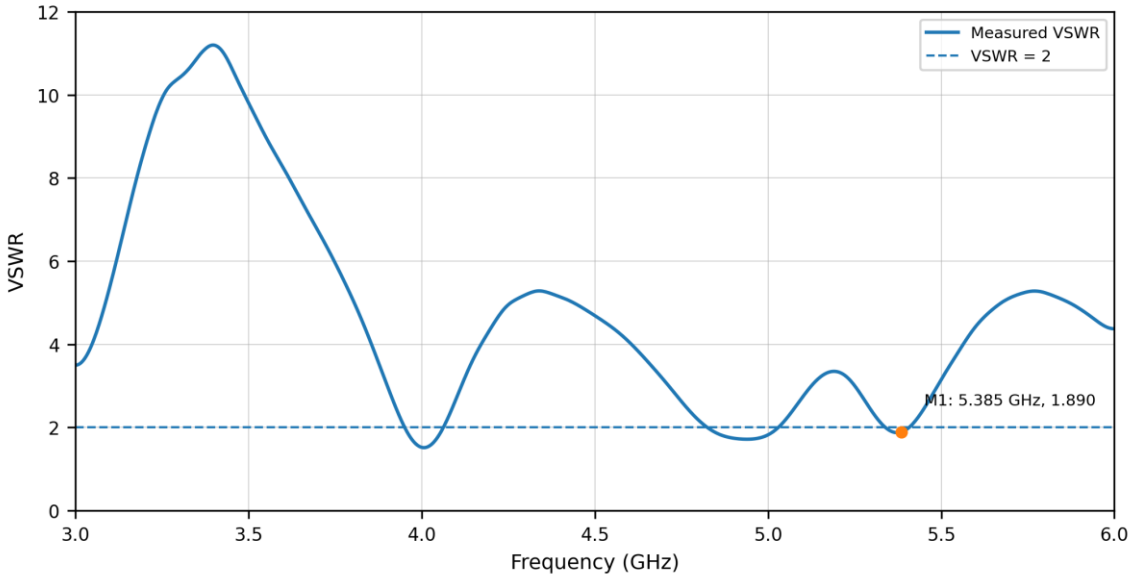


Fig. 12 Measured VSWR response over the 3–6 GHz sweep, plotted from the supplied VNA data.

The 3–6 GHz VSWR trace reaches a minimum of approximately 1.515 at 4.005 GHz. The supplied marker M1 is at 5.385 GHz with a VSWR of approximately 1.890. The dashed line indicates the VSWR = 2 reference level.



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The gain data file contains the following three frequency-value pairs, interpreted as frequency in GHz and gain in dB:

4.0 GHz – 11.00 dB; 4.9 GHz – 10.82 dB; and 5.3 GHz – 10.44 dB. These values are reproduced as supplied and are not extrapolated to 28 GHz.

TABLE II MEASURED VNA READINGS

Frequency	Value	Source / note
29.2275 GHz	−10.026 dB	VNA marker (S11)
26.385 GHz	−27.055 dB	Minimum in exported S11 point data
29.2275 GHz	1.919	VNA marker (VSWR)
26.385 GHz	1.093	Minimum in exported VSWR point data
4.905 GHz	−10.630 dB	VNA marker (S11, 3–6 GHz)
4.005 GHz	−13.745 dB	Minimum in exported S11 point data (3–6 GHz)
4.0 GHz	11.00 dB	Gain data file
4.9 GHz	10.82 dB	Gain data file
5.3 GHz	10.44 dB	Gain data file

VII. CONCLUSION

This paper has presented the design specifications, methodology, simulation outputs and experimental VNA results for a triangular patch microstrip antenna array intended for 5G applications. The supplied 24–30 GHz VNA data show an S11 minimum of approximately −27.055 dB and a VSWR minimum of approximately 1.093 at 26.385 GHz. At 27.9975 GHz, close to the 28 GHz design target, the measured S11 is approximately −23.190 dB and VSWR is approximately 1.147. The marker at 29.2275 GHz records S11 of −10.026 dB and VSWR of 1.919. A separate 3–6 GHz S11 sweep and three supplied gain data points are also reported. These measured data provide experimental evidence; further repeat measurements and radiation-pattern testing can be used for more complete hardware validation.

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