

A Pattern Reconfigurable Conformal mmWave Antenna for 5G Applications

Antonio Stroh, Matthew Sigda, Kevin Carbone, Dillon Baun, Md Abu Saleh Tajin, *Student Member, IEEE*,
Oday Bshara, Vasil Pano, and Kapil R. Dandekar, *Senior Member, IEEE*

Electrical and Computer Engineering

Email: {as4822, mjs643, krc95, dsb78, mt3223, ob67, vp93, dandekar}@drexel.edu

Drexel University, Philadelphia, PA 19104, USA

Abstract—We present a pattern reconfigurable conformal mmWave antenna at 28 GHz for 5G applications. Using a T-junction power divider and PIN diodes, eight 2×2 sub-arrays of microstrip patches are configured to radiate independently creating separate states capable of 360° of discrete coverage.

Index Terms—mmWave antenna, 5G, conformal antenna, reconfigurable antenna

I. INTRODUCTION

The cellular communications industry continues to experience increased capacity demands as more devices and data-intensive applications enter the market. To mitigate these capacity burdens, 5th generation (5G) millimeter wave (mmWave) cellular networks are simultaneously being developed and deployed to improve legacy infrastructure.

While the advantages of 5G are apparent, radiating at such a high frequency makes the wireless signal more sensitive to environmental conditions leading to higher attenuation and shorter propagation distance. To overcome the high attenuation, the wireless communications industry has been exploring high directivity antennas equipped with various beam steering methods to align the propagating signal in the direction of the receiver. While phased array antennas require accurate control of the feed amplitude and phase of each element, pattern reconfigurable antennas offer an alternative method for beam-steering by dynamically changing their radiation properties [1].

Conformal structures can enhance reconfigurable antennas by leveraging their geometry to provide beam steering. mmWave conformal, reconfigurable antennas have been designed using a variety of common antenna structures [2, 3]. We propose a pattern reconfigurable conformal antenna array that leverages a cylindrical shape to produce eight discrete states delivering 360° of beam steering. Each state consists of a 2×2 sub-array of patch antennas fed in parallel by microstrip transmission lines. PIN diodes switch between transmission lines to activate one state at a time. The antenna is designed for 28 GHz indoor, cellular environments and provides an average gain of 7.7 dBi and a -10 dB bandwidth of 815 MHz. The proposed conformal antenna is scalable, and the maximum gain can be increased by packing more patch antenna elements in a unit cell.

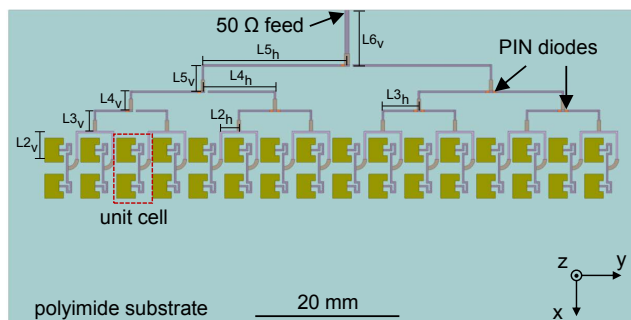


Fig. 1: Top view of the 2×16 planar antenna in state-1.

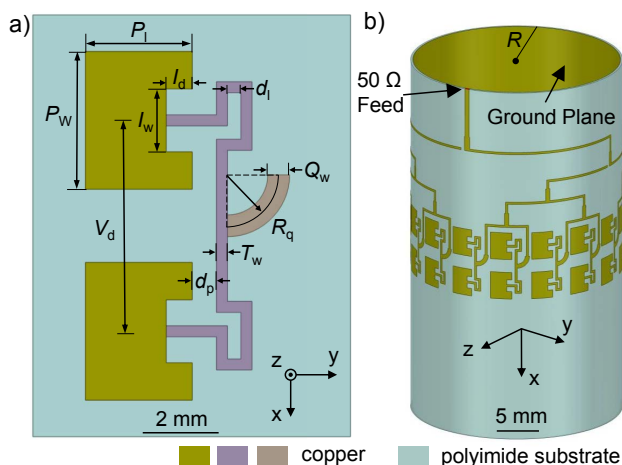


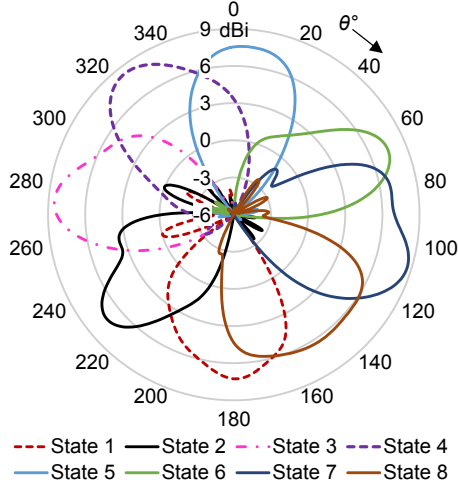
Fig. 2: a) Parameterized 2×1 unit cell, and b) an isometric view of 2×16 conformal antenna where $R = 13.6$ mm (right).

II. ANTENNA DESIGN AND SIMULATION

Using ANSYS high frequency structure simulator (HFSS), the conformal antenna was modeled by wrapping a 2×16 planar array (Fig. 1) around a cylindrical structure featuring an outer polyimide substrate layer of thickness 0.279 mm and an inner ground sheet (Fig. 2b). The 2×16 planar array (Fig. 1) was designed by cascading a 2×1 unit cell array (Fig. 2a). Each unit cell features two adjacent inset patches fed from a meandered transmission line used to ensure the length is an integer multiple of $\lambda/2$ (where λ = wavelength) for impedance matching. Current delivery to each unit cell is achieved using

TABLE I: List of HFSS design parameters.

param	Value (mm)	param	Value (mm)	param	Value (mm)	param	Value (mm)
P_w	3.60	T_w	0.28	R	13.6	$L4_h$	10.9
P_l	2.80	d_l	0.56	$L2_h$	2.82	$L4_v$	2.84
I_d	0.66	d_p	0.55	$L2_v$	4.20	$L5_h$	21.6
I_w	1.60	R_q	1.31	$L3_h$	5.50	$L5_v$	3.91
V_d	5.36	Q_w	0.55	$L3_v$	3.14	$L6_v$	8.08

Fig. 3: Gain plots for all eight antenna states where $\phi = 90^\circ$.

a T-junction corporate feed along with quarter-wavelength transformers to match the input and output impedance at each junction. While the initial impedance of the transmission line is 50Ω to match with a lumped port excitation at the top of the antenna, the impedance of the remaining transmission lines were chosen to be 75Ω to decrease the line thickness. With this decreased thickness, a $\lambda_0/2$ vertical and horizontal patch array spacing was used to mitigate grating lobes.

To achieve beam steering, two PIN diodes have been placed at each corporate feed junction to control which unit cells radiate, resulting in a total of 14 diodes. In an effort to increase gain, two adjacent 2×1 unit cells were chosen to be simultaneously active while the other cells remain off. Such a feeding method results in eight patterns. The conformal antenna geometry leaves enough space inside the cylinder to accommodate DC wires carrying control signals. The supporting cylinder structure can be fabricated with a 3D printer. Antenna performance is not affected by the cylinder structure since it resides under the conformal ground plane.

III. RESULTS AND DISCUSSION

Fig. 3 shows the simulated gains for all eight antenna states when $\phi = 90^\circ$. The maximum gain across the states range from 6.36 dBi to 8.64 dBi with an average of 7.70 dBi. The half power beamwidth (HPBW) ranges from 31.0° to 75.0° with an average of 46.4° . As shown in Fig. 4, the simulated antenna provides an average -10 dB bandwidth of 815 MHz. Considering the direction of radiation, gain magnitude, and

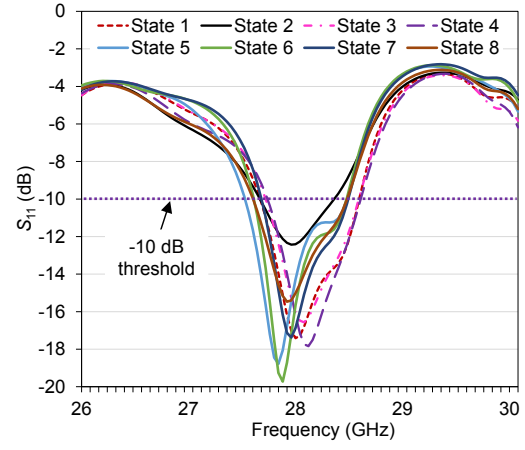
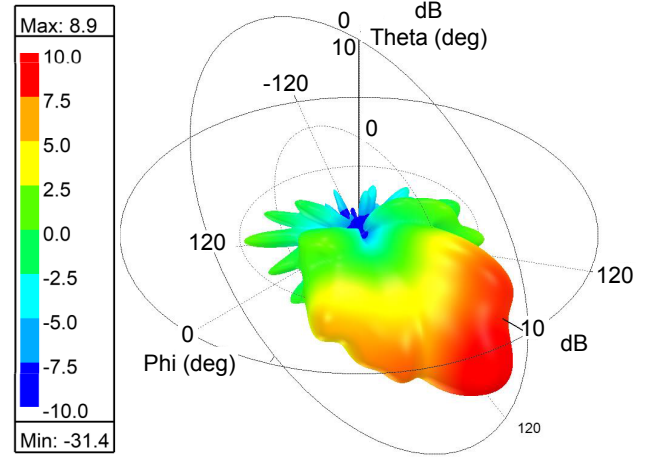
Fig. 4: Simulated S_{11} coefficient for all eight antenna states.

Fig. 5: 3D radiation plot of a single antenna state (state-7).

HPBW for each antenna state, the simulated 2×16 conformal antenna provides sufficient use from $\theta = 0^\circ$ to 360° , adequate for wearable applications subjected to dynamic environments. While these results project future applicability, a functioning prototype will be pursued to further validate the accuracy of the model and provide insight on design improvements.

ACKNOWLEDGEMENT

This research is supported by the National Science Foundation (NSF) under Grant CNS-1828236.

REFERENCES

- [1] C. Deng, D. Liu, B. Yektakhah, and K. Sarabandi, "Series-fed beam-steerable millimeter-wave antenna design with wide spatial coverage for 5g mobile terminals," *IEEE Transactions on Antennas and Propagation*, vol. 68, no. 5, pp. 3366–3376, 2020.
- [2] S. F. Jilani, M. O. Munoz, Q. H. Abbasi, and A. Alomainy, "Millimeter-Wave Liquid Crystal Polymer Based Conformal Antenna Array for 5G Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 1, pp. 84–88, 2019.
- [3] V. Semkin, F. Ferrero, A. Bisognin, J. Ala-Laurinaho, C. Luxey, F. Devillers, and A. V. Räisänen, "Beam Switching Conformal Antenna Array for mm-Wave Communications," *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 28–31, 2016.