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Extended hemispherical integrated lens antenna for V-band application (Poster Communications)

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Abstract

In this paper, we examine the performance of a dipole antenna as a feed for a hemispherical printed plastic lens for MM-wave applications at 60 GHz. ABS M-30 plastic is used to achieve this goal by printing layers to create the desired model. Electromagnetic simulations indicate that the proposed extended lens antenna has cross-polarization of less than -16 dB for 60 GHz applications. The proposed antenna's design process is described in detail throughout this paper.

Introduction

- For feeding lens structures, unidirectional, wide band, and compact structures are promising candidates.
- As a result of the use of a high relative permittivity material, however, fabrication is expected to be costly, and analyzing these lenses will limit their implementation.
- Various lenses have covered the mm-wave spectrum with unidirectional and bidirectional beam launchers. Still, their major drawbacks include high cross-polarization, narrow impedance bandwidth, and difficulty in fabrication.

In this design, we propose using a directive antenna to direct radiation in a broadside direction onto the plastic lens.

As a result of this strategy, the impedance-matching bandwidth can be maintained. In addition, an extended portion of the radiation pattern for increased gain is tipped in the broadside direction over the operating frequency band.

In the proposed plastic-printed object, a hemispherical lens structure increases antenna gain up to 17 dBi. A MakerBot Replicator 2 is used to 3D print the ABS-based plastic lens with a relative permittivity of $\epsilon_r=2.7$ and a loss tangent of 0.006. By inserting a plastic lens on top of a directive antenna, we demonstrate that bandwidth enhancement, matching improvement, and gain increase are noticeably obtained for V-band applications.

Lens Antenna Design

The entire antenna design is defined as follows (Figs. 1 and 2):

- A low-thickness dipole antenna with a maximum gain of 4.8 dBi operating at 55 GHz is designed on Rogers RO5870 ;
- The spherical lens is a transmissive device that focuses an electromagnetic beam using refraction. Therefore, the refractive index of the designed lens for the final performance of the lens to focus and tilt the primary beam is an essential factor.
- A spherical lens with ABS plastic is designed on the top of the dipole antenna to increase the antenna gain and tilt beam by 50 deg in the boresight direction.
- To find the best focus point to obtain a maximum gain enhancement, low X-polarization, and low side lobe level (SLL) in the $-z$ plane for the dipole antenna, the center position of the lens should be analyzed with simulation 0.1mm in $-y$ axis direction from center of lens;
- The extended part of the lens with R/n height is added to tilt the total beam in the broad side direction, R is the radius of the lens; n is the refractive index of the lens and extended part material;
- it is observed that the total impedance bandwidth over the operating band increases as the plastic lens is embedded. Thus, we have full impedance bandwidth for lens antenna at V-band frequencies.

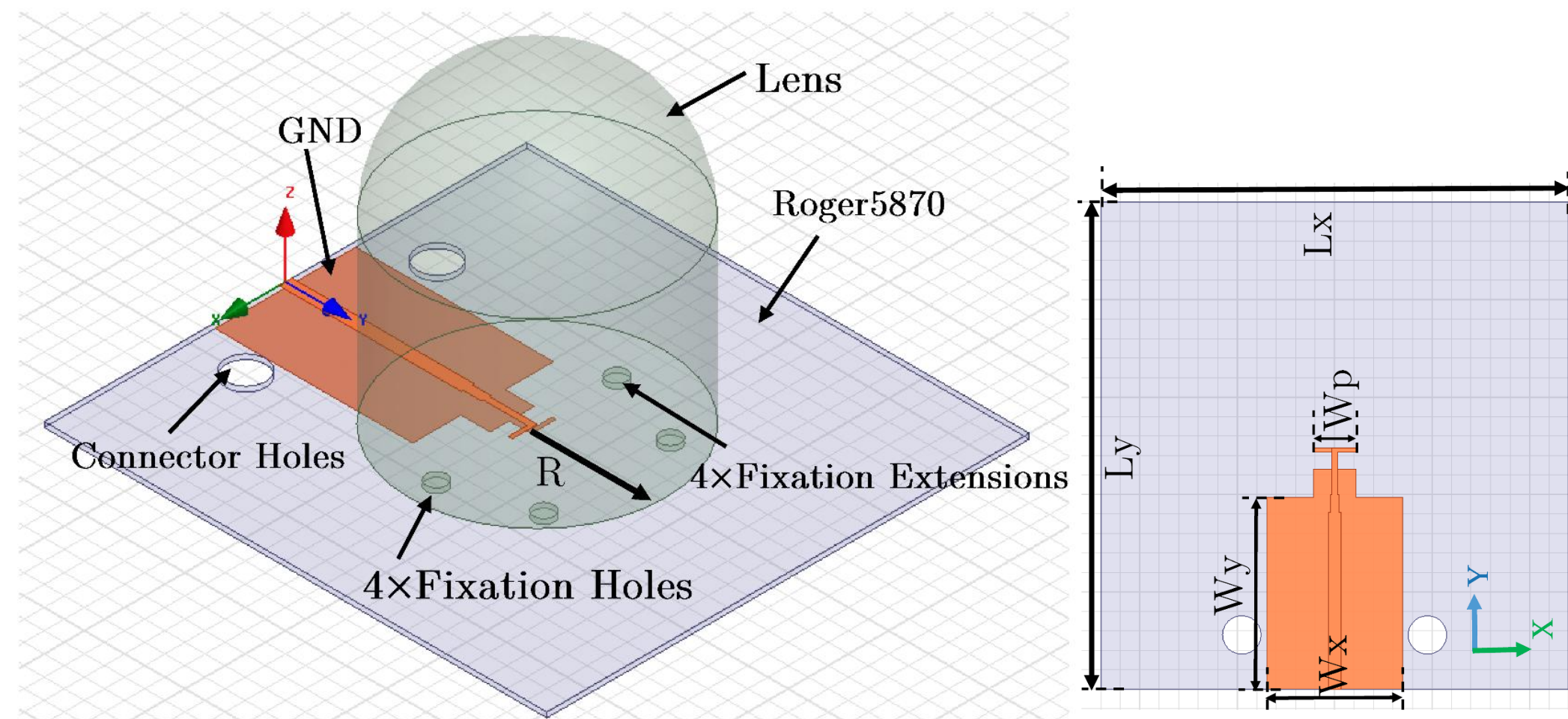


Fig 1. Geometry of the proposed dipole antenna and integrated lens antenna.

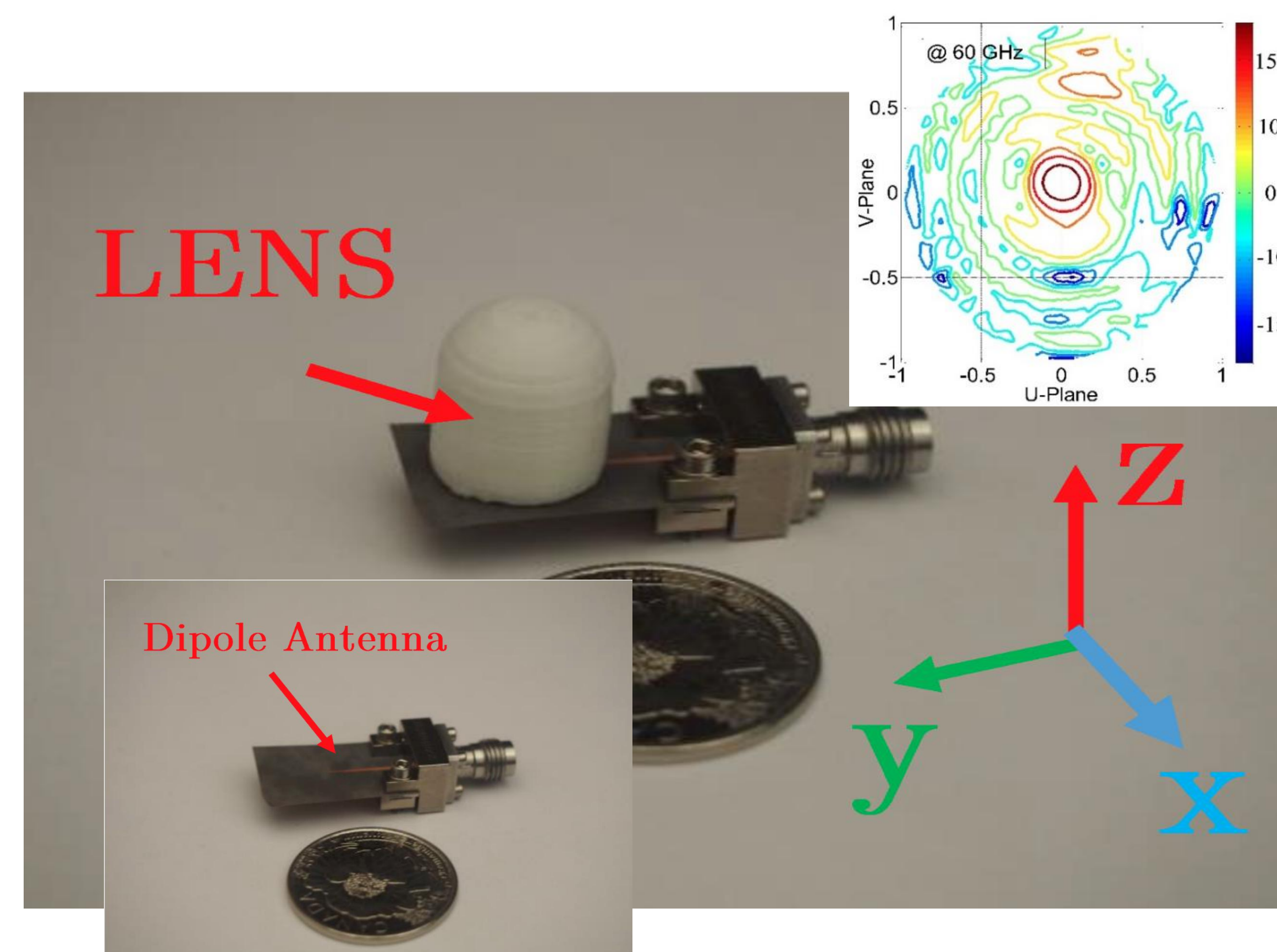


Fig 2. Fabricated Dipole antenna and Realized ABS plastic lens,

Beam-tilting Mechanism

- In this analysis, using a high refractive index material will cause the radiated EM waves to refract in a predefined direction.
- Snell's law predicts a tilting mechanism in those structures because of using two media via distinct refractive indices.
- This concept is feasible in designing the proposed lens antenna to tilt the primary beam in the elevation plane. Unlike the metamaterial lens with higher refractive indexes with 2-D scanning abilities (Azimuth and Elevation Planes).
- A compilation of a homogeneous lens with a constant refractive index can provide 3D beam-scanning up to the position of the wave source. Higher gain enhancement in a predefined direction is possible, as analyzed in previous works.
- In this prototype, a microstrip dipole antenna on a Roger 5870 substrate with a relative permittivity of $\epsilon_r=2.2$ is considered a quasi-TE source of ray launcher that emits EM rays.
- Then, an extended lens with a high relative permittivity material compared to the substrate relative permittivity is used on the top of the radiation source. This lens tilts the primary beam in the elevation plane.
- Each radiated ray from the dipole source will result in different phase shift angles because of the effective path length of the antenna aperture. Then the ellipticity of the hemispherical lens is used for the concentration of rays in the elevation plan.
- by changing the dipole antenna position as a radiation source the e on the x-axis, beam scanning capability of the proposed antenna in a broadside direction between ± 45 deg is feasible.

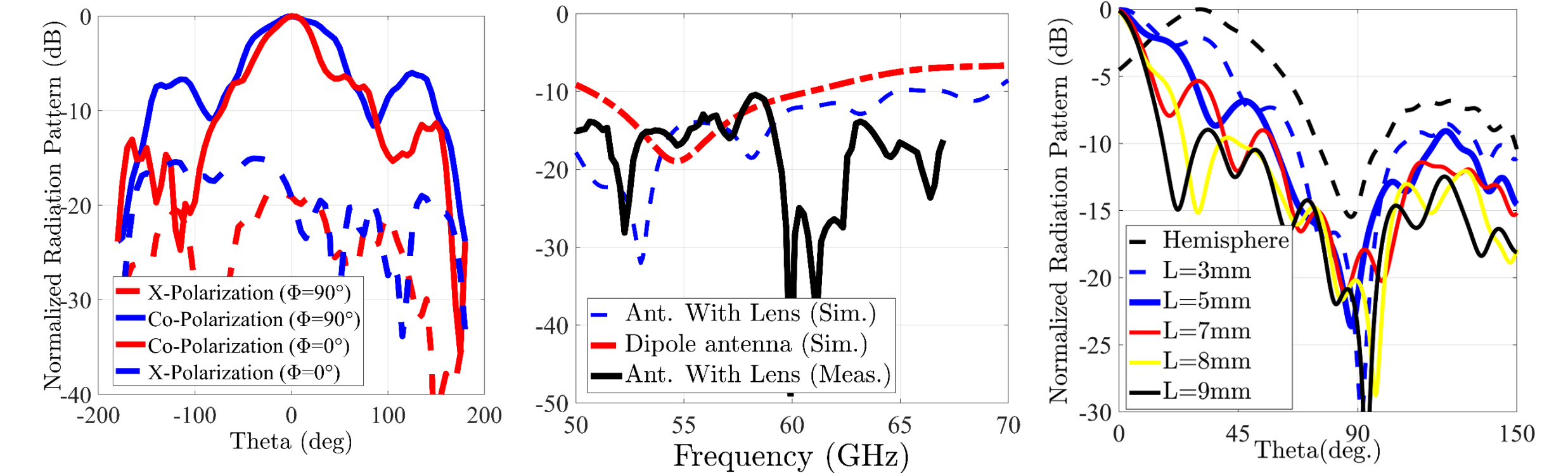


Fig 3. Measured and simulated results for the dipole antenna with and without lens

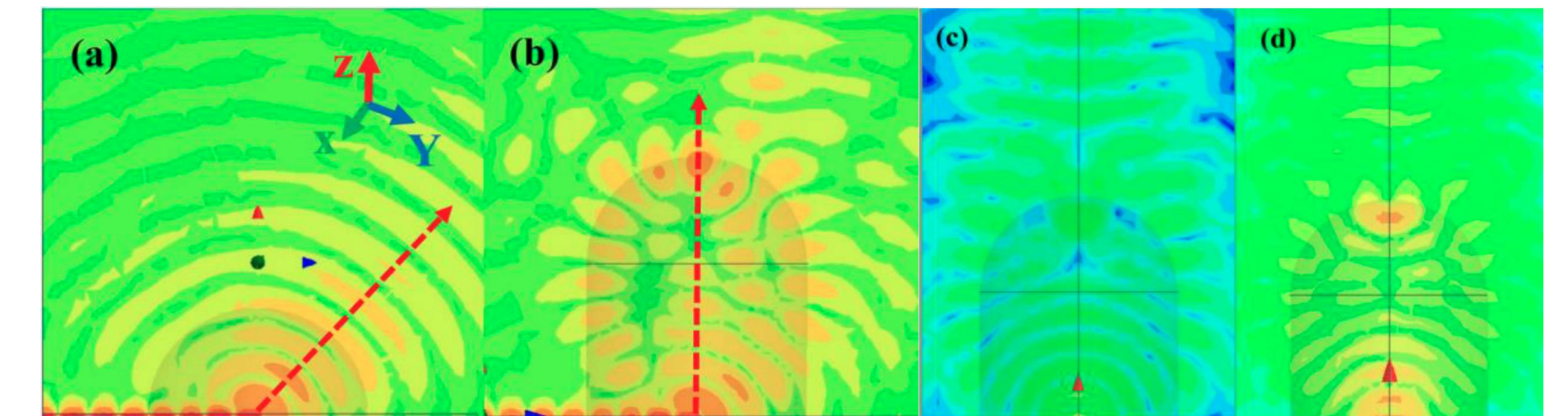


Fig 4. Near-field E-field distribution for (a) hemispherical, (b) Extended; and (c), (d) E- and H-field distribution with WR-15 excitation, respectively;

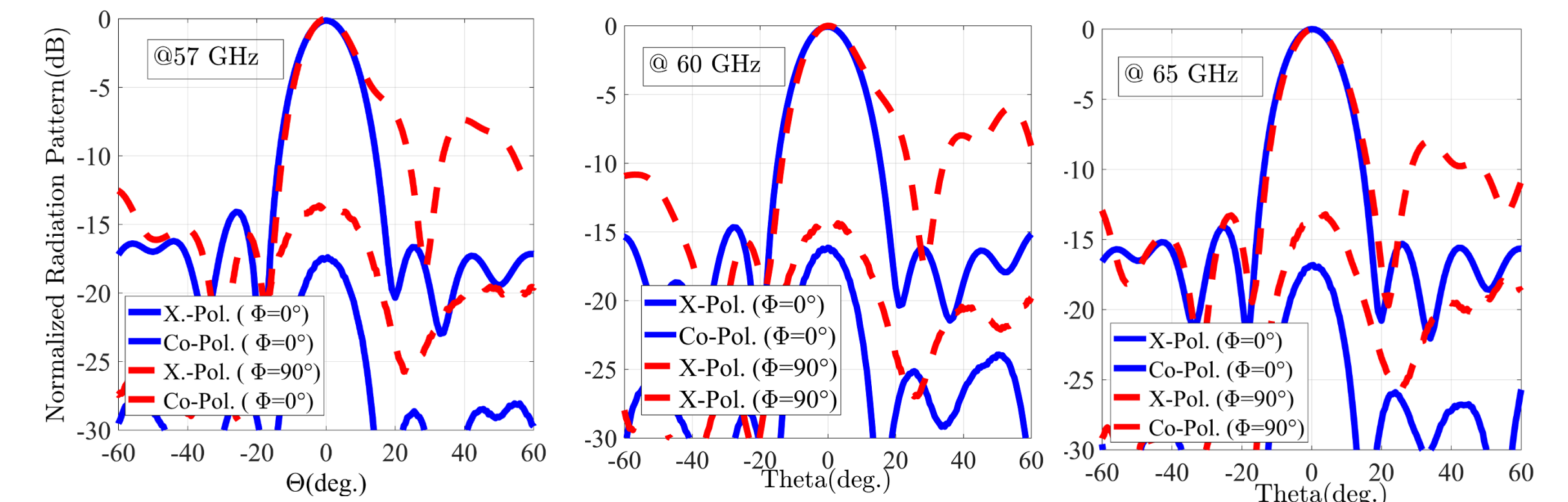


Fig 5. Normalized measured 2-D gain patterns for integrated Lens antenna for $\Phi=0$ deg and 90 deg at 57, 60, and 65 GHz.

Results and Discussion

- Fig.1 shows the prototype of the integrated lens antenna. The simulation results of the antenna with integrated lens for impedance matching validate the design over the operating band 50-70GHz, as shown in Fig.2.
- The photograph of the realized dipole and lens antenna with a 1.85-mm end-launch Southwest Connector is shown in Fig.2a.
- The Near-field distribution computed with the FEM method using Ansoft HFSS commercial software at 60GHz for the optimized shape hemispherical, extended hemispherical of the plastic lens with dipole beam launcher is shown in Fig.4.
- As shown in Fig. 4 (a) for the yz-plane cut, the boresight plane primary beam is tilted by 50deg in the broadside direction
- with controlling the spherical lens center point and extension part, the high gain in broadside radiation is accessible.
- The simulated E- and H-plane radiation patterns at 60GHz for dipole antenna are shown in Fig. 3.
- The near-field distribution for a similarly optimized lens with **WR-15** excitation at 60 GHz has a symmetrical radiation pattern as expected

Conclusions

- A 60GHz integrated hemispherical lens antenna using dipole antenna has been introduced. This lens structure has extended to a cylindrical part with the same material with ABS M-30. This layout can be constructed by a standard PCB process on Roger 5870.
- We showed that by extending the spherical lens and optimizing plastic lens parameters, an excellent impedance matching, and high gain could be obtained.
- The measured results illustrate that the lens antenna offers a good bandwidth and 16 dBi gain at 60 GHz.

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