Self-shielded Wideband Yagi Antenna with Rectangular Horn for 60 GHz Unlicensed Band

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Research Article

Keywords:

Posted Date: April 25th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1429232/v1

Self-shielded Wideband Yagi Antenna with Rectangular Horn for 60 GHz Unlicensed Band

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Abstract

This paper presents a self-shielded Yagi antenna with a rectangular horn for the 60 GHz unlicensed band. The rectangular horn is used for the isolation from the other electronics around the antenna. For the self-shielded Yagi antenna with a rectangular horn, a 28.5 % impedance bandwidth, a 33.3 % 3 dB-gain bandwidth, and a 12.7 dBi peak gain are achieved. To the best of the authors' knowledge, the proposed 60 GHz self-shielded antenna shows the widest bandwidth characteristics among those that have been reported.

Keyword: rectangular horn, Yagi antenna, self-shielded antenna, 60 GHz, self-shielded switched-beam antenna, wide-band

1. Introduction

Based on the range from 57 GHz to 64 GHz, the 60 GHz millimeter-wave frequency has been allocated as the unlicensed band in countries over the world for high data-rate wireless communications [1-2]. As a number of applications such as IEEE802.11ad WLAN, uncompressed video streaming, mobile-distributed computing, and wireless gaming have been realized, 60 GHz antennas have become a promising research topic [3-10]. In order to implement the mobile gadgets which adopt the 60GHz, the antenna should be isolated for the other components in the gadgets. In [3], the Yagi antenna can be self-shielded through the addition of metal shields at the upper and bottom sides; however, this design suffers from a large antenna volume due to a low coupling efficiency. In [4], a Yagi antenna that is enclosed with a conical-horn antenna is presented; here, a high gain and good aperture-efficiency characteristics are achieved, but it suffers from a narrow bandwidth due to the proximity effect of the cutoff plane [4].

In this paper, a self-shielded wide-band Yagi antenna with rectangular horn for 60 GHz-band applications are introduced. The proposed self-shielded antenna reveals an improved gain, a wide bandwidth, symmetrical radiation patterns, a wide impedance bandwidth, as well as self-shielded characteristics. Furthermore, the gain and radiation patterns are immune to the change of the operating frequencies within the band. This paper is organized as follows. In section II, the design and measurement of the self-shielded Yagi antenna with the rectangular horn is described. The proposed antenna is compared and discussed, and a conclusion is given is section III.

2. 60 GHz Self-shielded Yagi-antenna Design and Measurement with Rectangular Horn

The geometries of a single Yagi-antenna for the 60 GHz band are shown in Fig. 1. A teflon substrate of an 80 um thickness, a dielectric permittivity (εr) of 2.2, and a metal thickness (t) of 18 um was chosen. For the single Yagi-antenna element, the micro-strip line is used for feeding, and the coplanar waveguide with a ground line is formed at the feed point for probing. The dimensions for the single-antenna element are summarized in Table I.

To isolate the antenna from other electrical component, horn antenna is the one of the promising structure, and this antenna is basically fed by waveguide. In [6], the Yagi antenna is used as the mode exciter for the waveguide, and it shows the maximum insertion loss of - 0.4 dB at the edge frequency. This structure was then applied for the 60 GHz frequency. The detailed design flow is explained in [8]. For the self-shielded Yagi antenna, the aperture $(= W_H \times H_H)$, flare angle, and shape of the horn dominantly affect the gain and the bandwidth characteristics of the self-shielded Yagi antenna. In this section, the way that the parameters are determined for a desirable antenna structure is investigated.

In this design, a rectangular-horn structure is used rather than a rectangular box, two metal planes, or a conical horn to increase bandwidth and antenna gain(see Fig. 2). With the presence of the rectangular horn, the antenna gain is increased rather than adding top and bottom metal planes or rectangular box. Moreover, with the presence of the rectangular horn, the impedance will change slowly over the frequency band and fabrication is easier than that of a conical horn due to the proximity of the cutoff plane [4]; for this reason, the bandwidth of the rectangular horn is broader than that of the conical horn.

To determine the optimum aperture of the self-shielded Yagi antenna, a parametric analysis is conducted. In Fig. 3 and Fig. 4, the simulated realized gain and the E- and H-plane HPBW (half-power beam width) of the self-shielded Yagi antenna for various WH and HH are plotted. By increasing the width of the horn antenna (WH), the realized gain is increased and the E-plane HPBW is decreased, while the H-plane HPBW is maintained. Alternatively, by increasing the height of the horn antenna (HH), the realized gain is increased, the H-plane HPBW is decreased, and the E-plane HPBW is maintained. This is a basic operation characteristic of the horn antenna and is explained in [7]; therefore, the self-shielded Yagi antenna operates like a typical horn antenna.

Flare angle is one of the important parameters for the horn antenna. For a typical horn antenna, the flare angle is designed from 20 deg. to 35 deg. ($20° \leq 2\psi \leq 35°$)[7]. Parametric analysis for various LH was conducted for this study to optimize the self-shielded Yagi antenna. In Fig. 5, the simulated E- and H-plane beamwidths and realized gains of the self-shielded Yagi antenna for various LH are plotted. In the case of 9 mm, which corresponds to a flare angle of 20 deg., the bandwidth and realized characteristics are optimized in terms of peak gain and gain variation in the 60GHz frequency band(57-64GHz).

3. Result

Figure 6 shows the fabricated self-shielded Yagi antenna. This antenna was measured from the 50 GHz to the 70 GHz. A detailed explanation regarding the measurement is described in [5].

1) Impedance Bandwidth

Figure 7 plots the simulated and measured impedance characteristics of the self-shielded Yagi antenna. The simulated and measured impedance (- 10 dB) bandwidths are 24.5 % (from 50 GHz to 64.7 GHz) and 28.5 %(from 50 GHz to 67.1 GHz), respectively.

2) Gain

Figure 8 shows the simulated and measured realized gain characteristics of the self-shielded Yagi antenna. The simulated and measured peak gains are 13.3 dBi (at 67 GHz) and 12.7 dBi (at 63 GHz), respectively. The simulated and measured 3 dB-gain bandwidths are 19 GHz (51GHz to 70GHz) and 20 GHz (50GHz to 70GHz) respectively. In the 60GHz unlicensed frequency band(57 - 64GHz), the measured gain is very flat; the difference between the measured peak gain and the lowest gain is only 0.6dB.

Figure 9 shows the simulated and measured radiation patterns at 57 GHz, 60 GHz, and 64 GHz. The simulated and measured HPBW is 40deg at 57, 60, and 64GHz. The measurement results are in sound agreement with those of the simulation. Ref. [8] describes about 60GHz E-shape patch antenna, and the measured radiation pattern of E-shaped antenna is fluctuated over the radiation anagle. That's because the reference horn antenna sense the radiated field reflected from the probe. That implies the E-shaped patch antenna is not electrically isolated from the probe. However, the measured radiation pattern of the proposed antenna is smooth over the radiation angle. This results shows the proposed antenna is electrically isolated from other electrical component.

4. Conclusion

In this paper, a 60 GHz self-shielded Yagi antenna for which a rectangular-horn antenna is used are presented. To isolate the antenna from the other electrical components, the Yagi antenna is enclosed by the rectangular horn. For the self-shielded Yagi antenna with the rectangular horn, a 28.5 % impedance bandwidth, a 33.3 % 3 dB-gain bandwidth, and a 12.7 dBi peak gain were achieved with a size of $290\ \mathrm{mm}^3$. The performances of the proposed antenna and the other previously reported 60 GHz self-shielded antennas are listed in Table II. To the best of the authors' knowledge, the proposed 60 GHz self-shielded antenna shows the widest bandwidth characteristics among the previously reported 60 GHz self-shielded antennas.

Funding This work was supported by Hanyang University, Ansan, Republic of Korea (Grant numbers 202200000000980). Author Tae Hwan Jang has received research support from Hanyang University, Ansan.

Declarations

Conficts of Interest The authors declare no conficts of interest.

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Figures

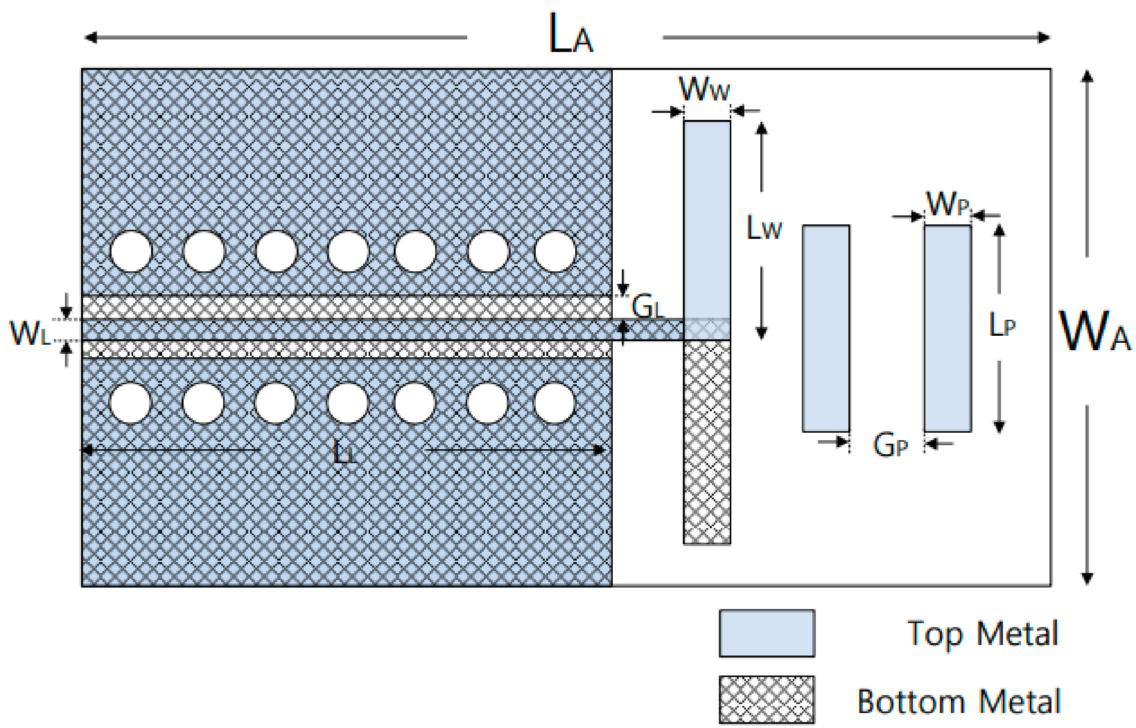


Figure 1

Geometry of single Yagi-antenna element for 60 GHz

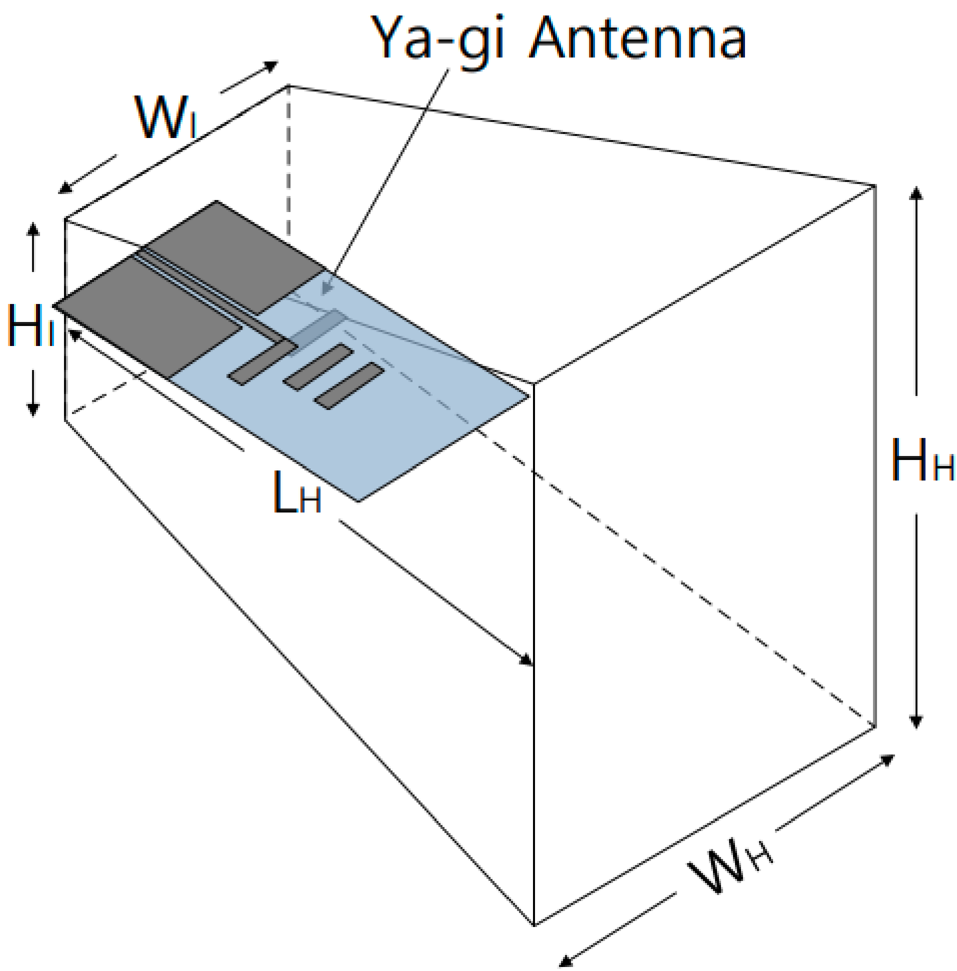


Figure 2

Geometry of self-shielded Yagi antenna for 60 GHz

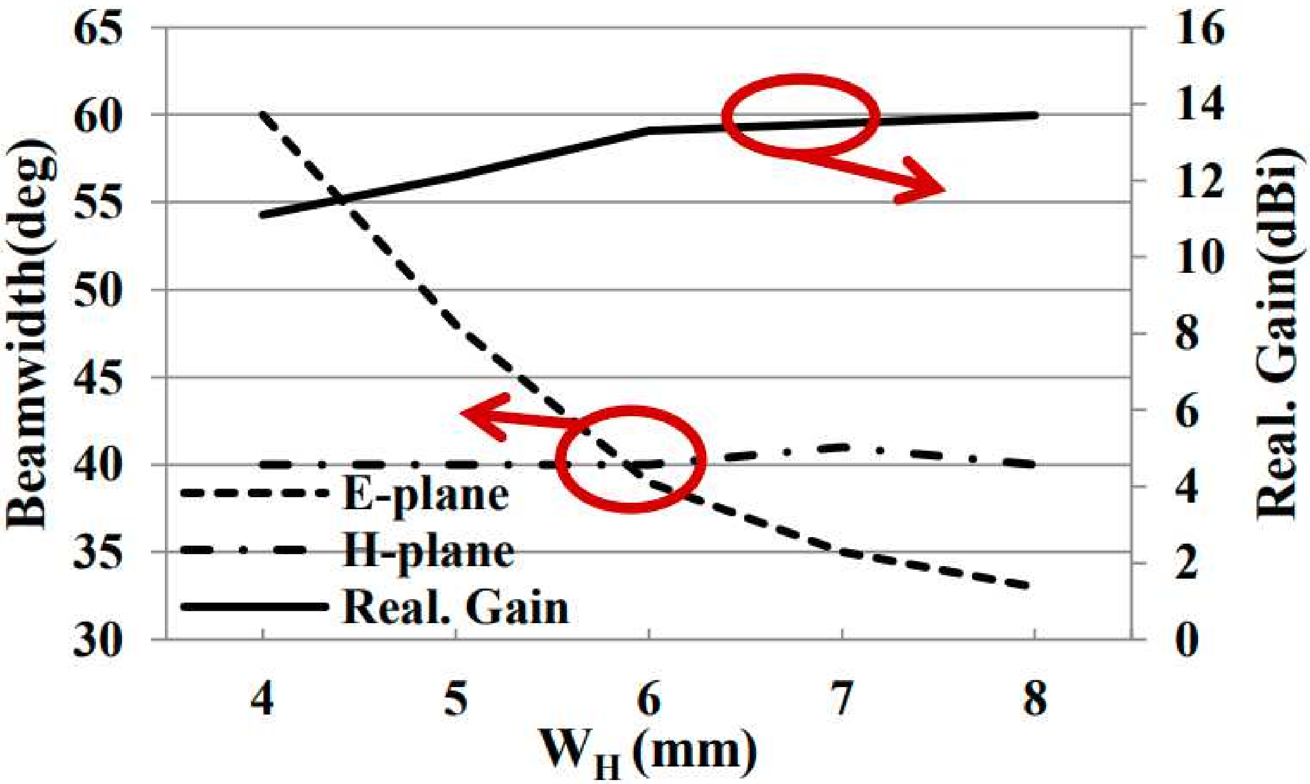


Figure 3

Smulated E- and H-plane HPBW and realized gain of the 60 GHz selfshielded Yagi antenna for various WH (at 60 GHz)

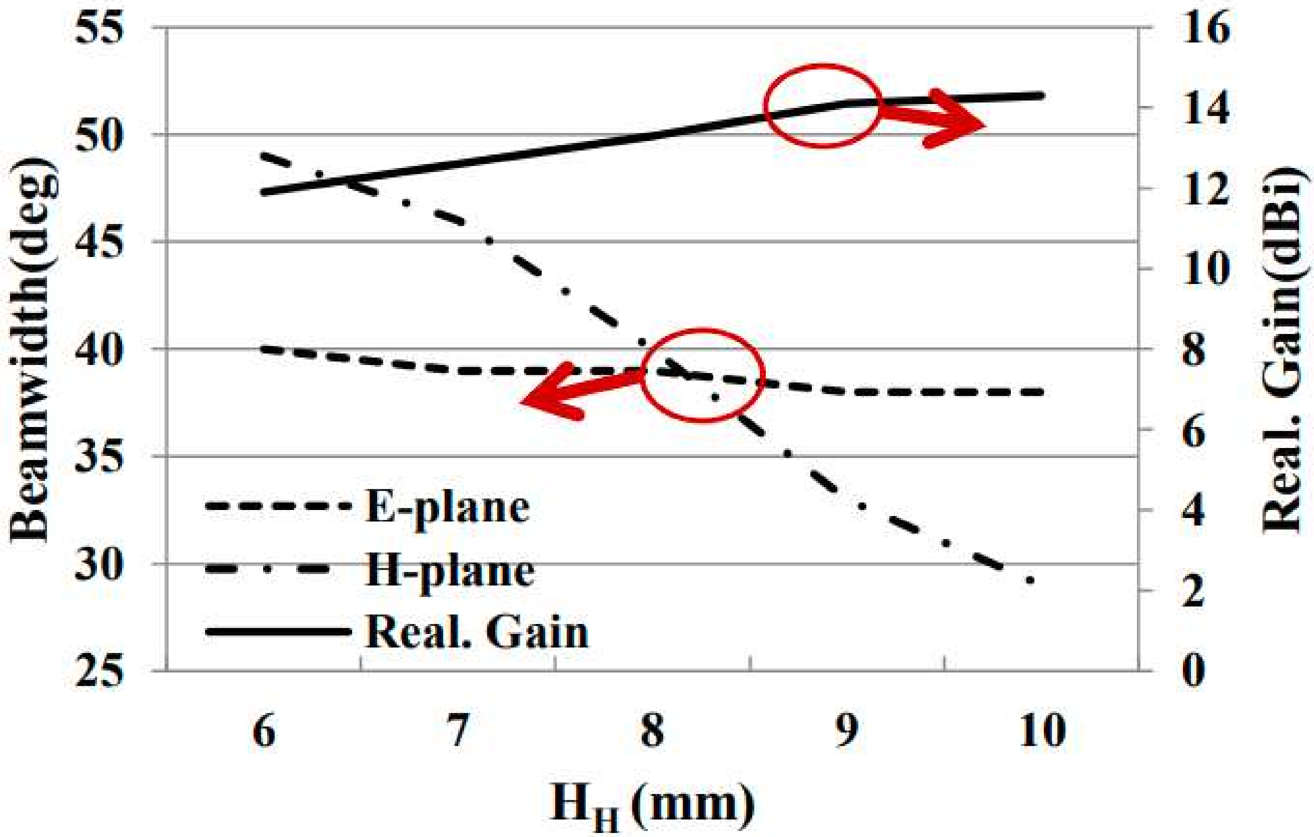


Figure 4

Simulated E- and H- plane HPBW and realized gain of the 60 GHz selfshielded Yagi antenna for various HH (at 60 GH

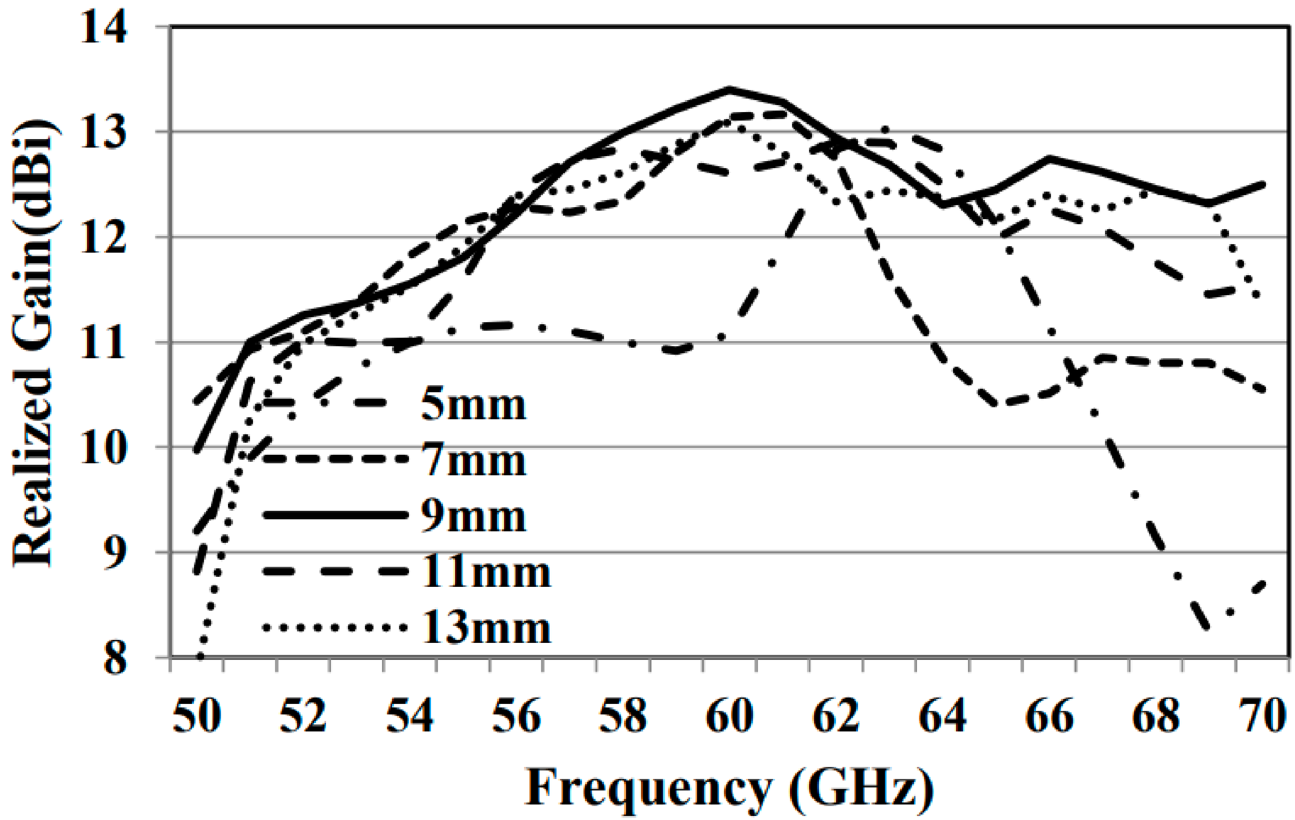
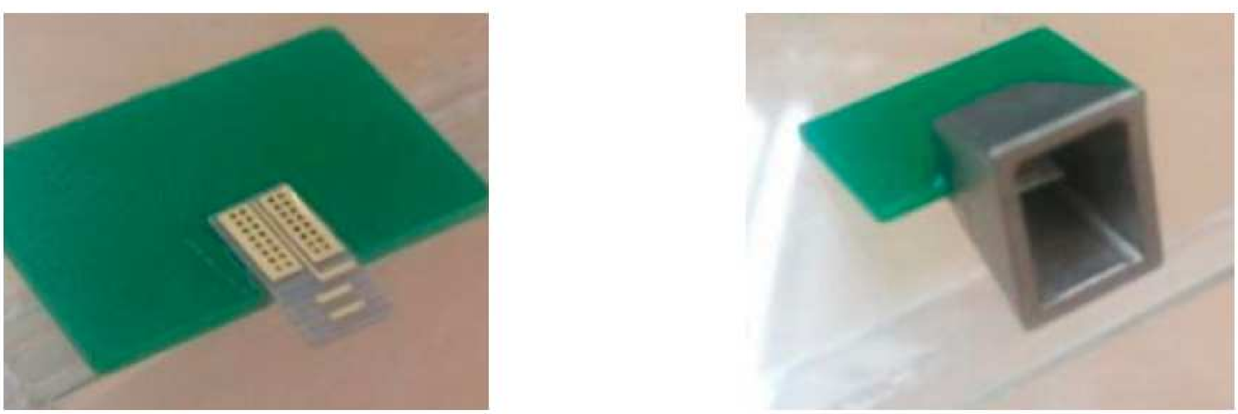


Figure 5

Simulated E- and H- plane beamwidth and realized gain of the 60 GHz selfshielded Yagi antenna for various LH.



(a) (b)

Figure 6

Fabricated 60 GHz self-shielded Yagi antenna: (a) without rectangular horn (b) with rectangular horn (proposed)

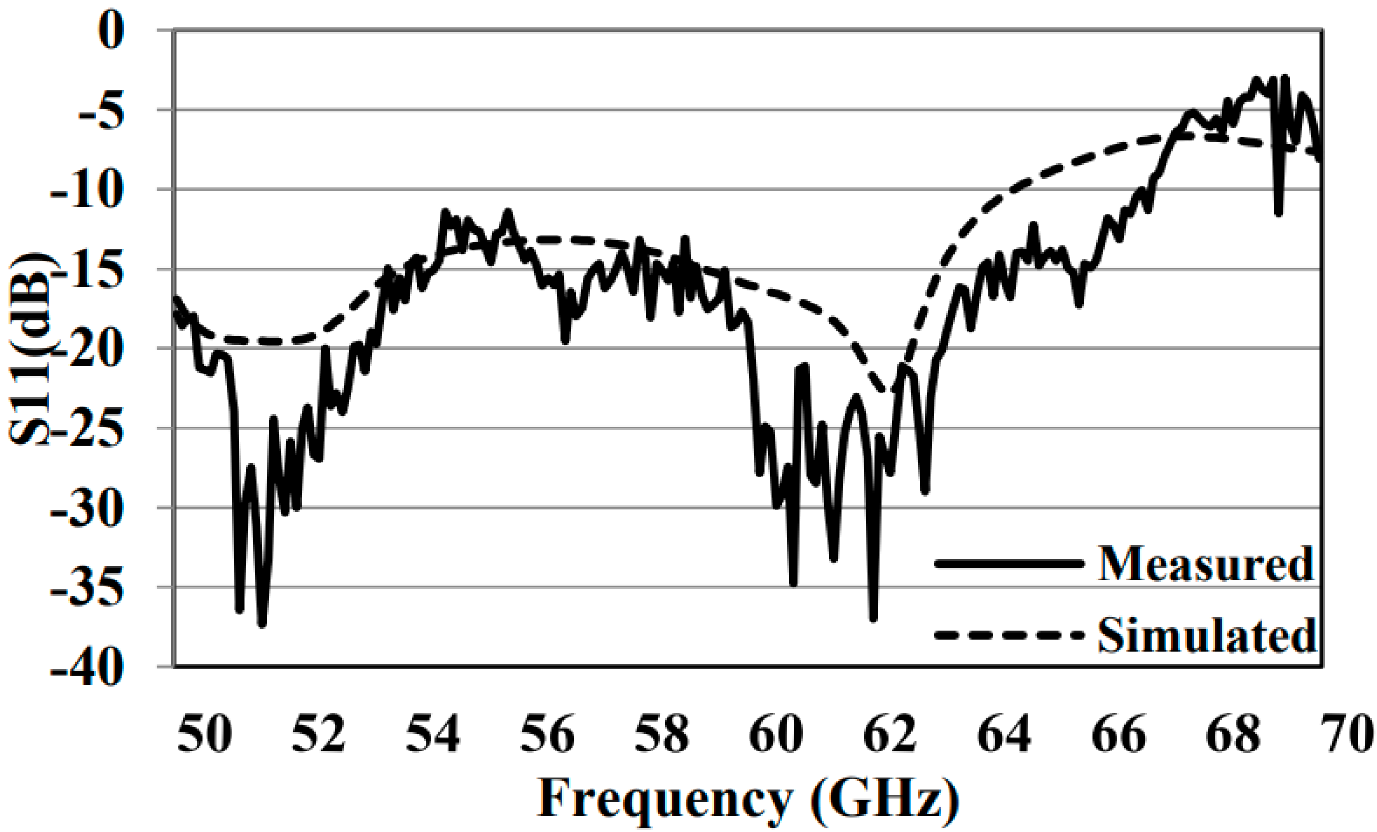


Figure 7

Simulated and measured S11 of the 60 GHz self-shielded Yagi antenna

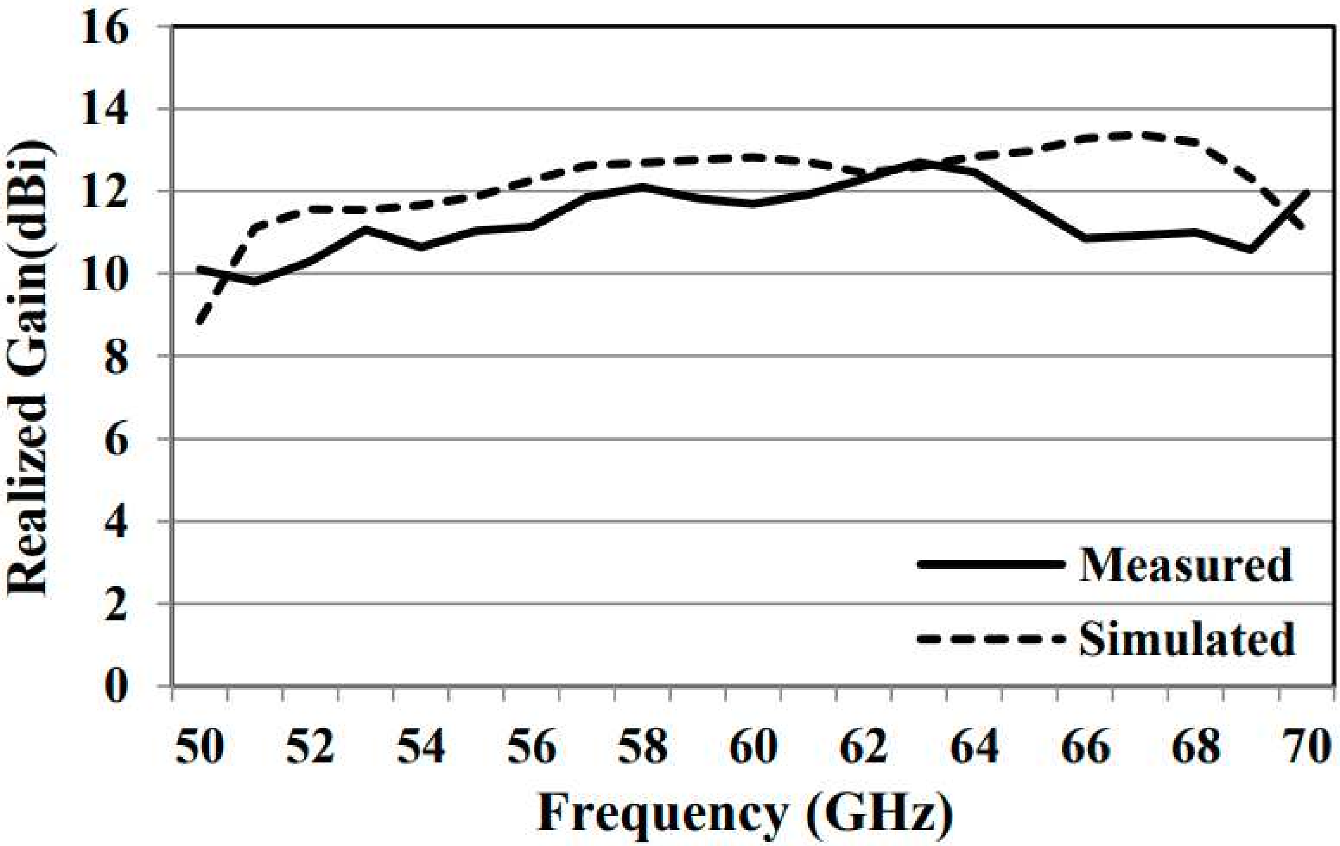


Figure 8

Simulated and measured realized gains of the 60 GHz self-shielded Yagi antenna

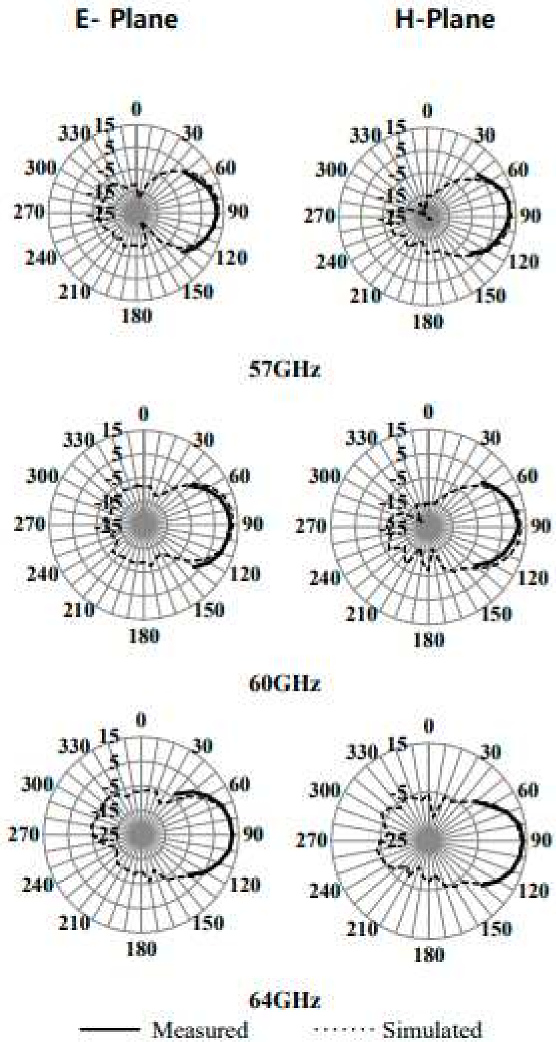


Figure 9

The simulated and measured radiation patterns of the 60 GHz self-shielded Yagi antenna.