A High-Gain Directive Superstrate Antenna for 60-GHz Applications

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***Abstract*-A high-gain aperture coupled antenna with superstrate structure for 60 GHz communication is proposed. Unprinted dielectric slab acts as superstrate is added above the antenna in order to increase the gain performance. Then, the effective radiated area and transmission line model are used to further enhance the gain. The maximum simulated gain of the antenna with superstrate structure can achieve 15.2 dBi at 60 GHz and is more than 13 dBi all over the 60 GHz band (from 57 to 66 GHz). From simulated results, the radiation patterns are found to be broadside all over the frequency band.**

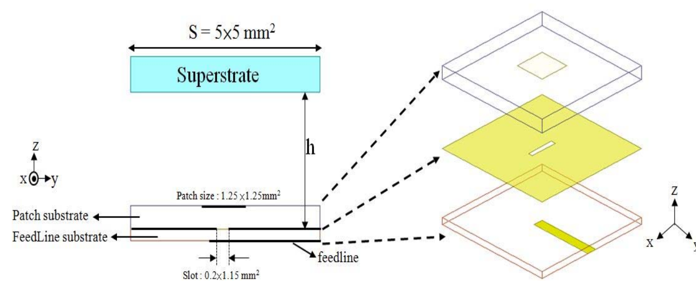
I. INTRODUCTION

Recently, the wide unlicensed frequency band around 60 GHz for wireless short-range communications are receiving a lot of attention [1]. The availability of several GHz bandwidths in the unlicensed 60 GHz band represents a great opportunity for ultra-high speed short-range wireless communications. For this communication, the data rate of short distance can be realized in multi-Gbps which is 40–100 times faster than today's WLAN systems. However, since the electromagnetic (EM) wave in the 60 GHz range critically suffers from the attenuation due to the oxygen absorption, the high signal attenuation caused by the absorption of oxygen molecules can be compensated for by using high-gain antennas. It is reported that conventional antenna arrays are used for high-gain applications. But in all these cases to achieve high gain, arrays of large number of elements are used, which increases the size of the antenna [2]. Besides, the complicated feeding network makes difficulty in design of array antennas.

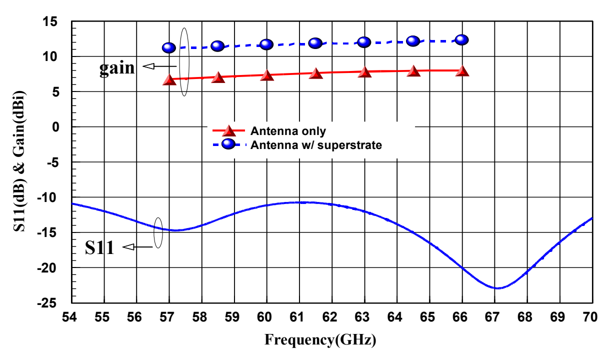
In this paper, a high-gain directive antenna with superstrate structure for 60 GHz communication is proposed. The simulated results show that the antenna has maximum gain of 15.2 dBi, stable response within 57–66 GHz.

II. SUPERSTRATE ANTENNA CONFIGURATION

Figure. 1 (a) shows the lateral view and 3D view of an aperture coupled patch antenna with superstrate. The slot is optimized to 0.2×1.15 mm^2 for maximum coupling with a feeding line length of 2.7mm. The patch size with 1.25×1.25 mm^2 on a substrate RT/Duroid5880 with relative permittivity ε_r =2.2 and thickness 0.508mm. The feedlines are printed on a RT/Duroid 6002 substrate with relative permittivity ε_r =6.15 and thickness of 0.254mm. The material used for the superstrate is RT/Duroid6010 with relative permittivity ε_r =10.2 and dimension of $5\times5\times0.787$mm^3. The distance between superstrate and antenna ground is optimized to 3.1 mm for better gain performance. Ansoft HFSS, an FEM-based solver, is used to calculate simulation results. The simulated return loss and comparison of gain with and without superstrate are shown in Fig. 1 (b). It can be seen that the enhancement of gain is about nearly 4 dB and more than 11 dBi within 57–66 GHz.



(a)



(b)

Figure 1. (a) Structure of antenna (b) Simulated results

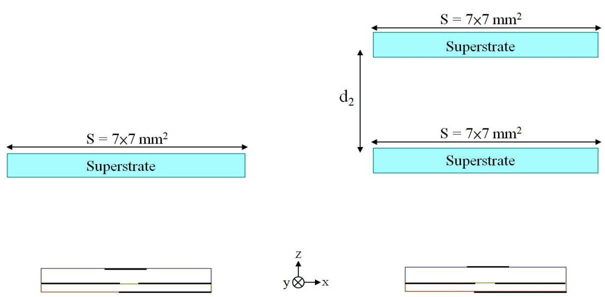
III. FURTHER GAIN ENHANCEMENT

A. *Effective Radiated Area*

In the previous section, one superstrate above antenna is added to realize gain enhancement of about 4 dB. In order to increase the gain performance, we enlarge the transverse size of superstrate to achieve larger effective radiated area. The illustrated structure is plotted at Fig. 2 (a), the transverse size is increased from 5x5 mm^2 to 7x7 mm^2 where the designed parameters of antenna remain the same. The simulated results of gain within 57–66 GHz are displayed in Fig. 3. It can be observed that gain enhancement about 1–2 dB within the desired band after we extend the dimension of superstrate which results from the extension of effective radiated area of superstrate.

B. Transmission Line Theory

In this section, we use the transmission line model [3] to further realize gain improvement. For the purpose of gain enhancement, a second layer of superstrate is added above the first one. These two superstrates are of the same dielectric constant and with same thickness. The distance, e.g., d_2, between two superstrates can be calculated by using transmission line model which was discussed in [3]. Fig. 4 illustrates the schematic of transmission line model. According to the general formula of input impedance described in [4], the annotation η_1 on Fig. 4 represents the input impedance seeing between first superstrate and antenna toward to the antenna. η_4 represents the input impedance seeing between two superstrates toward $+z$ axis, and so on. Then from resonance condition $\eta_2+\eta_3=0$, we can derive the value of d_2 equal to 4.06 mm. Hence, we place the second layer of superstrate with the evaluated distance d_2 as displayed in Fig. 2 (b). The comparison of simulated results is shown in Fig. 3, where the result within 57–66 GHz is presented. It can be seen that the performance of gain-enhanced about 1.5–2 dB is achieved after the second layer of larger superstrate is added. The detailed comparison of gain enhancement is given in Table I. Figure 5 shows the 2D radiation pattern of the antenna loaded with two layers of larger superstrate.



(a) (b)

Figure 2.The arrangement of superstrate antenna

(a) With one larger superstratr (b) With double superstrate

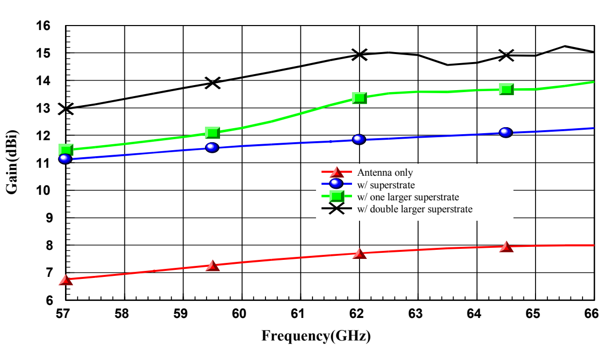


Figure 3. Comparison of simulated gain vs. frequency

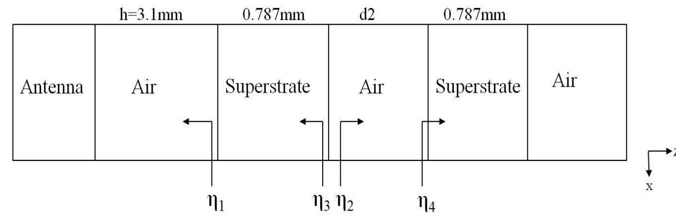
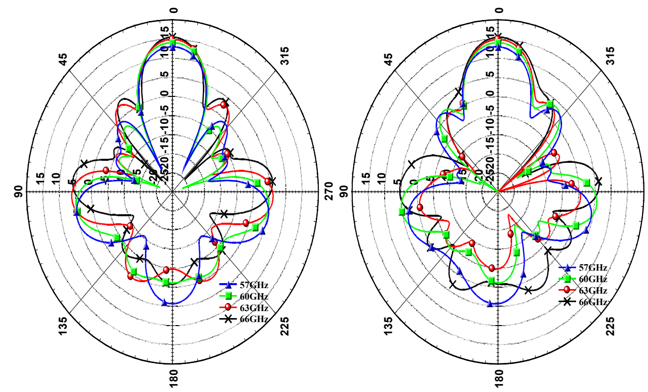


Figure 4. Illustration of transmission line model



(a) (b)

Figure 5. 2D radiation pattern.

(a) radiation pattern of xz plane (b) radiation pattern of yz plane

TABLE I
COMPARISON OF PEAK GAIN IMPROVEMENT

	Maximum Gain (dBi)	Improvement (dB)
Antenna only	7.9	
w/ one superstrate	12.2	4.3
w/ one larger superstrate	13.9	6
w/ double larger superstrate	15.2	7.3

IV. CONCLUSION

In this paper, a high-gain directive antenna for 60 GHz communication is proposed. For the purpose of high gain performance, theory of effective radiated area and transmission line model are introduced to realize gain enhancement. From simulation results, the gain is significantly improved by 6.2–7.3 dB, compared to the case of antenna only, pushing the final gain up to 13–15.2 dBi within the desired band of 57–66 GHz. It can seen that the maximum gain of 15.2 dBi is achieved with characteristics of stable and flat gain response.

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