Miniaturized High Gain Slot Antenna with Single-layer Director

Hongjuan Han, Ying Wang*, Xueguan Liu and Huiping Guo
School of Electronic Information Engineering, Soochow University, 215006, Suzhou, China

Abstract- **In this paper, a three-layered slot antenna with compact size and high gain is proposed at 5.4 GHz for WiMAX(5.2~5.8 GHz) applications. Simulated gain of 12dBi and measured gain of 10.48dBi are achieved and the impedance bandwidth is 22.59%. The efficiency is measured of 97.23%. Measured and simulated results are in good agreement. The overall size of the antenna is 100×100 ×21.5 mm³.**

Index Terms- **slot antenna, high gain, broad bandwidth, high efficiency and WiMAX.**

I. INTRODUCTION

The IEEE 802.16 Working Group has established a standard known as WiMAX (Worldwide Interoperability for Microwave Access). WiMAX has three operating frequency bands, which range from 2.4-2.8 GHz, 3.2-3.8 GHz, and 5.2-5.8 GHz, respectively. Nowadays researches are focusing on miniaturization of the antennas for wireless communications. Antennas for wireless communications are required to exhibit characteristics such as high gain, compact size, high efficiency, low cost, wide bandwidth and so on. Classical Yagi antenna consists of a reflector, a driver and several directors, which has been very popular due to its simplicity as well as its customizable high gain (Gain of a traditional Yagi antenna with three directors can be optimized to 9dBi) [1]. In order to realize a gain of 12dBi, 10 directors are required in [2]. Several microstrip-Yagi or quasi-Yagi antenna structures have been reported in [3]-[6], which have high gain and high front-to-back (F/B) ratio. However, these antennas have narrow bandwidth and large size. A multilayer-stacked microstrip Yagi antenna is presented in [7] and two slot Yagi antennas are proposed in [8]-[9]. In [7], multilayer-stacked microstrip Yagi antennas are proposed. High gain of 11dBi and 10.28dBi can be achieved respectively with adopted four layers of directors for dipole and dual polarization applications. In [8] and [9], the proposed slot Yagi antenna operates at 10 GHz with high gain, narrow bandwidth and large size. Obviously there is an increased demand of antennas with compact size, broad bandwidth and high gain. In this paper, a novel slot Yagi antenna is presented. The proposed antenna is designed for the WiMAX band of 5.2-5.8GHz and detailed discussion is given in the following sections.

II. PRELIMINARY ANTENNA STRUCTURE

The preliminary structure of a slot antenna, named Design 1, is shown in Fig. 1, which consists of a slot, noted as a driver in the following sections and a ground noted as a reflector. In order to achieve good F/B ratio and higher gain for this preliminary structure, the size of the reflector is optimized to 100 ×100mm². Dimensions of this structure are given in Table 1. The antenna is designed on a 1.5mm-thick FR4 substrate with dielectric constant (εr1) of 4.4. Compared S_{11} between simulation and measured results are shown in Fig.2. The center frequency of the preliminary structure is 5.8 GHz. The measured and simulated bandwidths are 5.32-6.32 GHz and 5.4-6.18 GHz respectively. Fig. 3 shows the simulated radiation patterns of phi=0˚and phi=90˚ at 5.8 GHz. It is noted that the radiation pattern is not acceptable for practical use due to its large side lobes on the direction of theta=±40˚ as shown in Fig. 3.

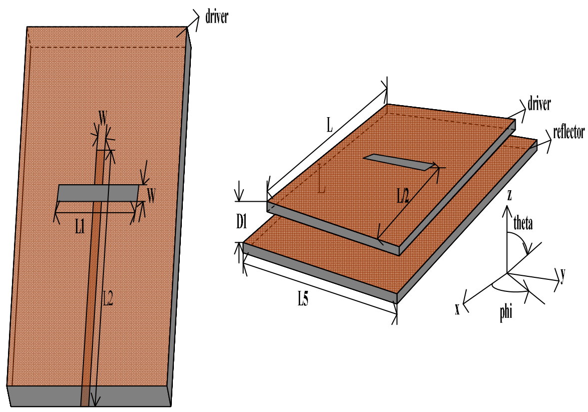

Fig. 1. 3D view of the preliminary structure rectangular

TABLE 1
PARAMETERS OF ANTENNA

Symbol	Value	Unity
H	1.5	mm
L	60	mm
L1	36	mm
L2	38	mm
L3	55	mm
L4	13.75	mm
L5	100	mm
W	3	mm
D1	13.5	mm
D2	6.5	mm
εr1	4.4	/
εr2	2.5	/

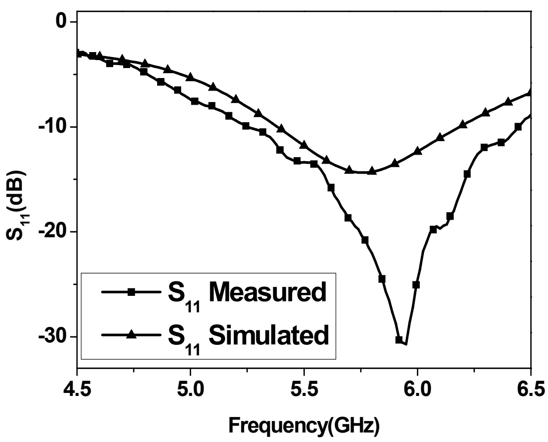

Fig. 2. Measured and simulated S_{11} of basic slot antenna

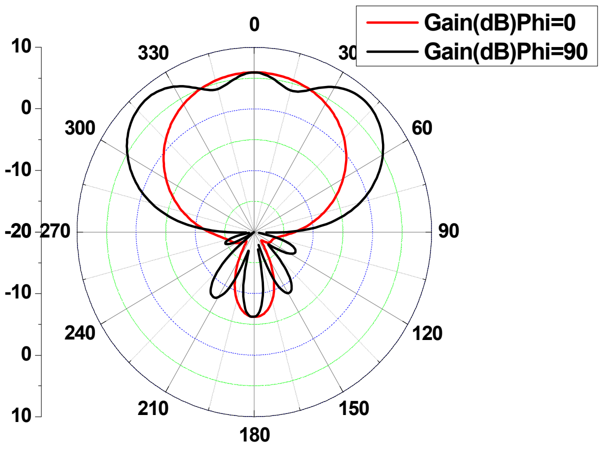

Fig. 3. Simulated radiation pattern of basic slot antenna

III. Proposed Slot Antenna With Single Layer Director

In order to improve the radiation pattern of the preliminary structure for practical use, a single-layer director with 1, 3 or 5 slots is added on the top of the preliminary structure as shown in Fig. 4 and Fig. 5. As noted in [7], three to four layers of directors are required to achieve high gain. Only one director layer is required to achieve a gain as high as shown in [7]. High performance and compact size are achieved. The optimized distance between two slots is 13.75mm, which is close to $\lambda/4$. The size of the director layer is $60(L)\times60(L)mm^2$ and the distance from the director to the driver is D_2. The director is designed on the substrate with $\varepsilon r2$ of 2.5 and loss tangent of δ =0.001. All the parameters are listed in Table 1, where D_1=13.5mm (0.243λ), D_2=6.5mm (0.117λ), L_2=38mm (0.647λ), L_3=55mm (0.989λ) and L_4=13.75mm (0.243λ). The overall height of the proposed antenna is 21.5mm.

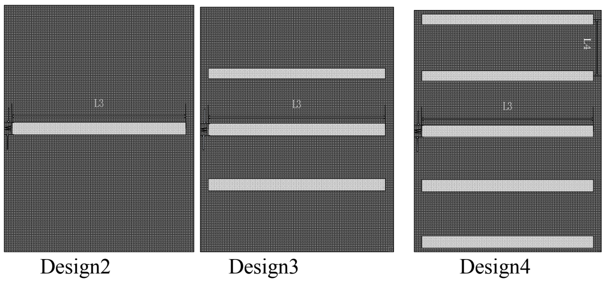

Fig. 4 Structures of the proposed single layer director

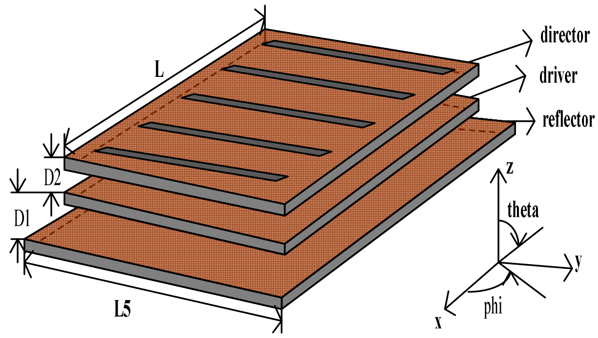

Fig. 5 Structure of the proposed antenna (Design4)

TABLE 2
THE SIMULATED RESULTS OF THE ANTENNA WITH DIFFERENT DIRECTOR

Number of slot in the director	Frequency (GHz)	Bandwidth (GHz)	Gain (dB) Z Axis	Size of the antenna (mm^3)
1	4.7	0.06	7.45	100*100*21.5
3	5.4	1.06	11.86	100*100*21.5
5	5.4	1.14	11.98	100*100*21.5

IV. Results And Discussions

Performance of the proposed slot antenna with single-layer director is given in Fig. 6- Fig.12. Simulated results of the proposed antenna with one, three and five slots in the director are compared in Table 2. Photograph of the fabricated preliminary structure and the proposed slot antenna with single layer director are given in Fig. 8 and Fig. 9. Comparison between simulated and measured results is shown in Fig. 10, Fig. 11 and Fig.12, which shows good agreement. The proposed design is discussed as following:

a) As shown in Fig. 3 and Fig. 7, director layer with slots helps to reduce the side lobe and improve the radiation pattern. The main lobe focuses on the orthogonal direction of the director layer (theta= 0°).
b) The proposed slot antenna with five slots in the single-layer director has a simulated bandwidth of 20.7% and measured bandwidth of 22.59%, which exhibit wide

band characteristics. However, the bandwidth of the antenna with one slot in the director is only 1.3%.at 4.7GHz as shown in Fig.6. Bandwidth enhancement can be achieved by increased number of slots.

c) As listed in Table 2, gain in the orthogonal direction of the slot antenna could be greatly improved from 5.94dBi (without single-layer director) to 12dBi (with five slots in the director). The measured gain is 10.48dBi at 5.4GHz.

d) As shown in Fig.11, the simulated and measured efficiency of Design4 can be up to 84.5% and 97.2% at 5.4GHz, while the simulated and measured efficiency of design1 are 80.2% and 78.9% at 5.4GHz. Efficiency has been improved with the single-layer director.

e) Fig. 12 presents the simulated and measured *xoy* plane and *yoz* plane radiation patterns of Design4. Good agreement between the measured and simulated radiation patterns has been achieved. The maximum simulated and measured gains are 12dBi and 10.48dBi respectively.

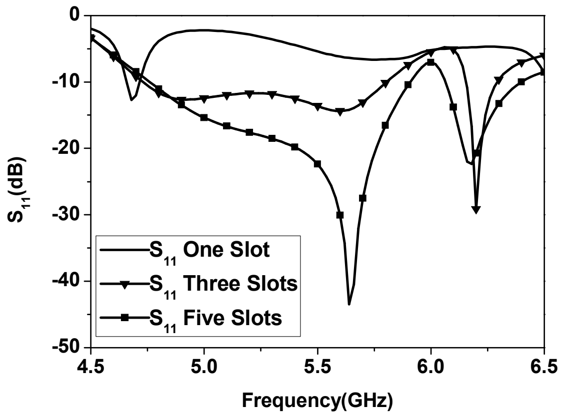

Fig. 6 Comparison of simulated S_{11} for 1, 3 and 5 slots in the Single-layer director

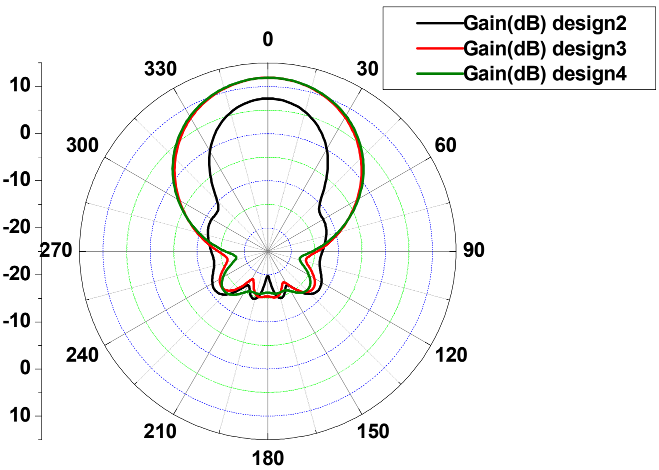

Fig. 7 (a) Simulated radiation patterns (phi=0˚) for Design2, Design3 and Design4

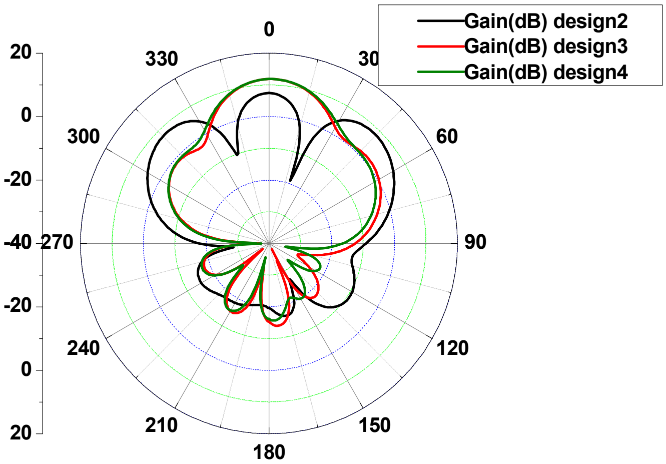

Fig. 7 (b) Simulated radiation patterns (phi=90˚) for Design2, Design3 and Design4

Fig. 8. Photograph of the preliminary structure

Fig. 9. Photograph of the proposed slot antenna with single-layer director

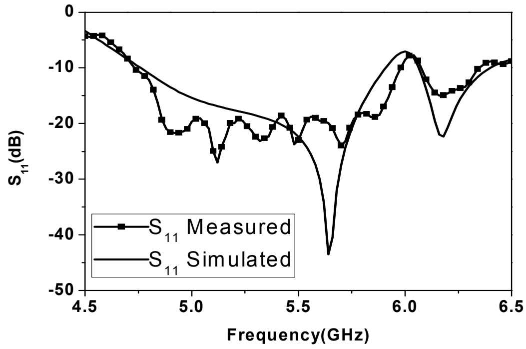

Fig. 10. Simulated and measured S_{11} of the proposed slot antenna with five slots in the director

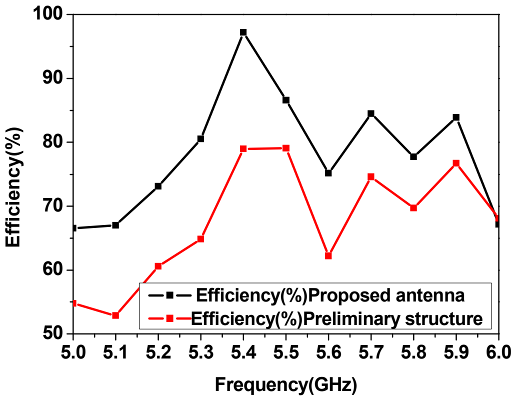

Fig. 11. Measured efficiency for the preliminary slot antenna and the proposed antenna (Design 4)

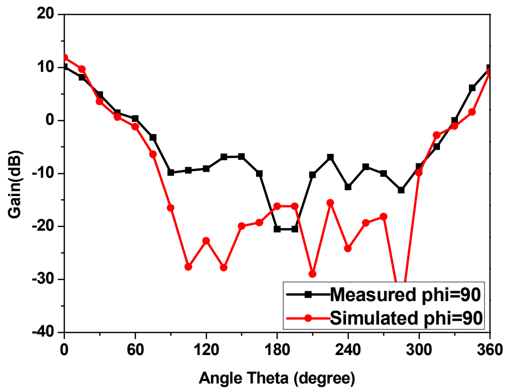

Fig. 12 (b) Measured and simulated radiation patterns of Design4 in *yoz* plane at 5.4GHz

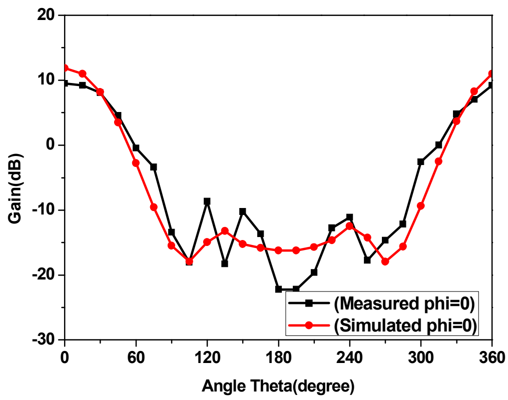

Fig. 12 (a) Measured and simulated radiation patterns of Design4 in *xoz* plane at 5.4GHz

V. CONCLUSION

In this paper, a novel slot antenna with single-layer director is proposed. By adding a director layer with five slots on the top of the basic slot antenna, main lobe of the radiation pattern is shifted to the orthogonal direction theta=0° instead of theta=±40°. Good performance with gain of 12 dBi and efficiency of 97.2% is achieved at 5.4GHz for WiMAX applications. The overall optimum size of the proposed antenna is only $80\times80\times21.5$ mm^3. Bandwidth has also been enhanced up to 22.59% compared to 17.24% for a basic slot antenna. Good agreement between simulated and measured results is achieved.

ACKNOWLEDGMENT

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