Design and Implementation of A Filtenna with Wide Beamwidth for Q-Band Millimeter-Wave Short Range Wireless Communications

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***Abstract*-An integrated millimeter wave filtenna is proposed for Q-band indoor short range wireless communications (IEEE 802.11aj). Comprising of a substrate integrated waveguide (SIW) filter and a printed angled dipole with a reflector, the proposed filtenna performs a bandpass response over 43.5-47GHz and the wide beamwidth larger than 120°in main cuts. The proposed filtenna and its counterpart without the filter are simulated, fabricated, and measured. By comparing the measured return loss and radiation patterns between the filtenna and the original antenna, it is concluded that the performance of the filtenna is kept nearly no change within the operating frequency band while the out of band signal is effectively filtered.**

***Keywords*-Angled dipole, Filter, Wide Beam-Width, Filtenna, Substrate integrated waveguide(SIW).**

I. INTRODUCTION

With the rapid development of communication technology, demand for high speed data transmission with limitations of allowed power and available frequency spectrum leads to the development of millimeter-wave (mmW) short range wireless communications. In China, the millimeter wave high data rate transmission standard called as Q-LINKPAN was proposed in 2010 and get adopted as 802.11aj (45GHz) by IEEE802.11 Working Group in 2012[1]-[3]. The spectrum of 43.5-47GHz in Q-band is proposed for the next generation WPAN application, supporting the ultra high speed access and interconnection among a variety of wireless terminals in the indoor environment.

Filtennas working at mmW band have been reported in literatures[4]-[6]. Usually, these filtennas exhibit sharp transmission characteristics due to the SIW filter contribution, which is expected for mmW communication systems.

According to the demand of indoor short-range wireless communication, the corresponding access devices need to provide complete indoor coverage. We propose to use a structure of printed angled dipole with reflector to realize a type of access-point antenna with beamwidths of 120° in two main cuts for the indoor application demand of IEEE 802.11aj (45GHz) standard[7].

In this paper, Q-band filtennas consisting of a five-order SIW inductive window filter and a printed angled dipole with reflector are designed, fabricated and measured. The measured results agree well with simulations.

II. DESIGN OF THE SIW FILTER

SIW filters possess the advantages of low loss, high power capability, high efficiency, high Q-factor and low cost[8]-[12].

Considering the selectivity requirement, a five-order SIW inductive window filter with five inline SIW cavities for 43.5~47GHz is designed. The geometry of the five-order SIW inductive window filter is shown in Fig. 1. The corresponding parameters are shown in Table 1. Fig. 2 shows the simulated S-parameters of five-order SIW inductive window filter.

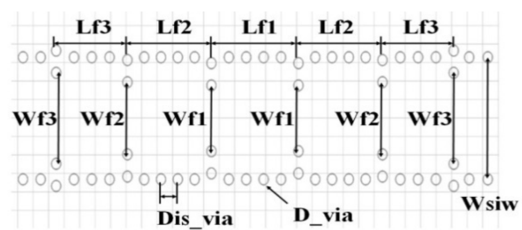

Figure 1. The geometry of five-order SIW inductive window filter

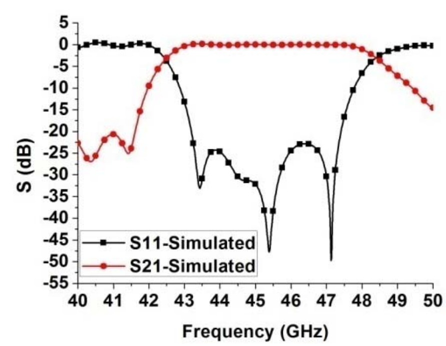

Figure 2. The simulated S-parameters of the five-order SIW inductive window bandpass filter

Table 1The parameters of the five-order SIW filter(in mm)

Parameters	Values	Parameters	Values
Lf1	2.81	Wf1	1.78
Lf2	2.71	Wf2	1.95
Lf3	2.3	Wf3	2.46
D_via	0.3	Wsiw	3.3
Dis_via	0.6		

III. DESIGN OF THE FILTENNA

Based on the design of the printed angled dipole with reflector fed by SIW-CPW transition and SIW-RWG transition, Q-band filtennas consisting of a five-order SIW filter and the original angled dipole antenna are designed.SIW is used as the feed line, which provides differential feed and a tight integration with the reflector.

The SIW-CPW transition can achieve fine impedance matching by adjusting the slot length and the bending angle of CPW into SIW[13]. Meanwhile, the SIW-RWG transition can achieve fine impedance matching by adjusting the joint cavity size and the air window size connecting SIW and RWG[14]. The RWG uses the standard rectangular waveguide: WR19, whose size is 4.775mm*2.388mm, and the test flange is the UG-383.

In the design the substrate of Rogers 5880 with permittivity of 2.2 and the thickness of 0.508mm is used for designing and implementing the filtennas.Fig.3 shows the geometry of filtennas fed by SIW-CPW transition. Fig. 4 shows the geometry of filtennas fed by SIW-RWG transition.

The length of SIW filter is about 15mm, and the whole size of the filtennas are 20mm*34.2mm fed by SIW-CPW and 30mm*48.4mm fed by SIW-RWG. The optimized physical parameters of filtennas fed by SIW-CPW transition are shown in Table 2. The optimized physical parameters of filtennas fed by SIW-RWG transition are shown in Table 3. The parameters of the five-order SIW inductive window filter are adjusted slightly to make the fabrication available. All optimized parameters are got from CST software[15].

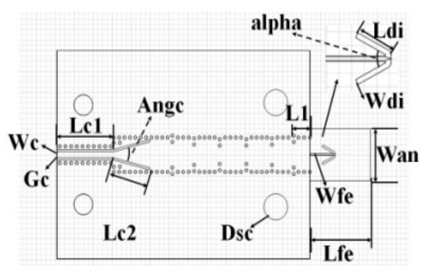

Figure 3. The geometry of filtennas fed by SIW-CPW transition

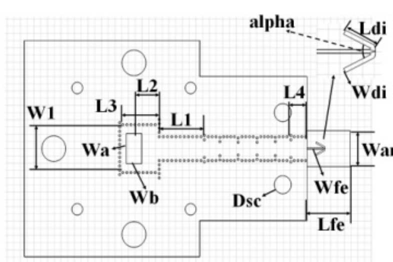

Figure 4. The geometry of filtennas fed by SIW-RWG transition

IV. ANTENNA MEASUREMENTS

The photos of the filtennas and the original antennas without filters prototypes are shown in Fig. 5 and Fig. 6, which are fabricated with standard PCB process.

Table 2 The optimized parameters of filtenna fed by SIW-CPW transition(mm)

Parameters	Values	Parameters	Values
alpha(°)	55	Dsc	2.5
Ldi	1.35	Angc(°)	28
Wdi	0.2	Wc	0.6
Wan	5	Gc	0.2
Wfe	0.17	Lc1	6
Lfe	2.4	Lc2	3.9
L1	1.9		

Table 3 The optimized parameters of filtenna fed by SIW-RWG transition(mm)

Parameters	Values	Parameters	Values
alpha	55	Wa	4.2
Ldi	1.35	Wb	2.3
Wdi	0.2	W1	6.64
Wan	5	L1	6.7
Wfe	0.17	L2	3.75
Lfe	2.4	L3	5.86
Dsc	2.5	L4	2.4

|S11| of four antennas are simulated and measured with vector network analyzer, and as shown in Fig. 7 and Fig. 8, well agreement between the simulated and measured results is achieved.

Fig. 7 shows the simulated and measured |S11| of printed angled dipole with reflector and the corresponding filtenna both fed by SIW-CPW transition. The measured impedance bandwidth of printed angled dipole with reflector fed by SIW-CPW transition for $|S11| \leq$ -10dB is 43.25-48.5GHz. The measured impedance bandwidth of the corresponding filtenna fed by SIW-CPW transition for $|S11| \leq$-10dB is 43.15-47.4GHz. It can be seen that the impedance bandwidth of two antennas covers the band 43.5GHz-47GHz. And integrating filter with the original antenna steepens the |S11| curve due to the signals out of the band being suppressed effectively.

Fig.8 shows the simulated and measured |S11| of printed angled dipole with reflector and the corresponding filtenna both fed by SIW-RWG transition. The measured impedance bandwidth of the printed angled dipole with reflector fed by SIW-RWG transition for $|S11| \leq$-10dB is 43.3-47.2GHz. The measured impedance bandwidth of the corresponding filtenna fed by SIW-RWG transition for $|S11| \leq$ -10dB is 43.35-47.1GHz. As pointed out above, it can be seen that the impedance bandwidth of two antennas covers the band 43.5GHz-47GHz, and integrating filter with the original antenna steepens the |S11| curve due to the signals out of the band being suppressed effectively.

Apparently the seamless integration of five-order SIW filter and the printed angled dipole with reflector will reduce the impact on antennas from the signals out of the band.

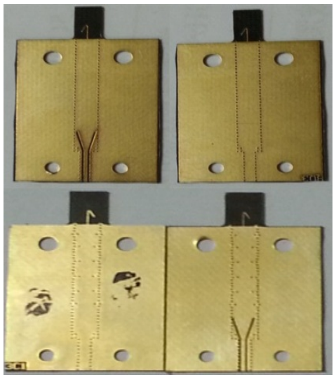

Figure 5. The photos of the filtennas and the original antennas without filters prototypes fed by SIW-CPW transition

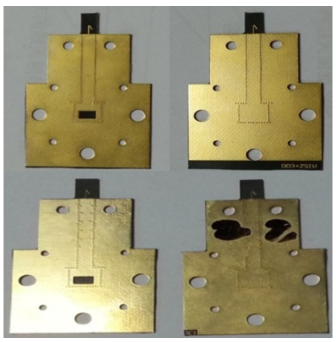

Figure 6. The photos of the filtennas and the original antennas without filters prototypes fed by SIW-RWG transition

The radiation patterns of four antennas are measured in the anechoic chamber. Fig. 9 shows the measured and the simulated radiation patterns of printed angled dipole with reflector and the measured radiation patterns of the corresponding filtenna both fed by SIW-CPW transition at E-plane (x-y plane) and H-plane (y-z plane) at 45.25GHz. Fig. 10 shows the measured and the simulated radiation patterns of printed angled dipole with reflector and the measured radiation patterns of the corresponding filtenna both fed by SIW-RWG transition at E-plane (x-y plane) and H-plane (y-z plane) at 45.25GHz.

Some metallic screws for fixing antennas in measurement and feeding transitions may have some little effect on radiation patterns. It can be seen that integrating filter just affects the radiation pattern of the radiation element slightly. The simulated 3-dB beamwidth of printed angled dipole with reflector fed by SIW-CPW transition in E-plane and H-plane is 135.8 degree and 126.1 degree. The simulated 3-dB beamwidth of corresponding filtenna fed by SIW-CPW transition in E-plane and H-plane is 138.5 degree and 120.2 degree. The simulated 3-dB beamwidth of printed angled dipole with reflector fed by SIW-RWG transition in E-plane and H-plane is 144.3 degree and 130 degree. The simulated 3-dB beamwidth of corresponding filtenna fed by SIW-RWG transition in E-plane and H-plane is 143.8 degree and 127.1 degree.

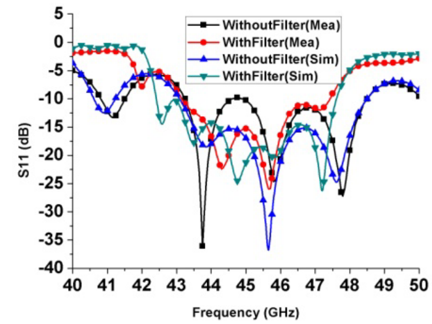

Figure 7. The simulated and measured |S11| of printed angled dipole with reflector and the corresponding filtenna both fed by SIW-CPW transition

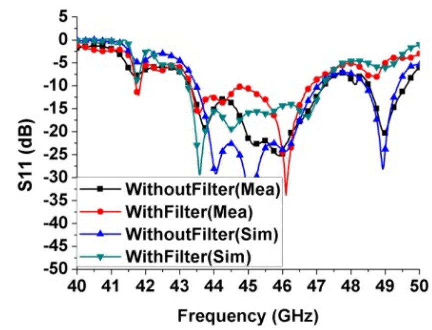

Figure 8. The simulated and measured |S11| of printed angled dipole with reflector and the corresponding filtenna both fed by SIW-RWG transition

Table 4 shows the measured gains and the simulated gains of the four antennas of 43.5, 45.25 and 47GHz.

The measured gains of the printed angled dipole with reflector fed by SIW-CPW transition varies from 5.34 to 5.76 dBi. The measured gains of the corresponding filtenna fed by SIW-CPW transition varies from 4.1 to 5.28 dBi. The measured gains of the printed angled dipole with reflector fed by SIW-RWG transition varies from 4.4 to 6.06 dBi. The measured gains of the corresponding filtenna fed by SIW-RWG transition varies from 4.04 to 5.34 dBi.

Table 4 The measured gains and the simulated gains of the four antennas

	Fed by SIW-CPW				Fed by SIW-RWG			
Gain(dBi)	Original		Filtenna		Original		Filtenna	
Freq (GHz)	Mea	Sim	Mea	Sim	Mea	Sim	Mea	Sim
43.5	5.76	6.1	4.1	5.4	4.4	5.61	4.04	5.04
45.25	5.34	6.07	5.27	5.7	6.06	6.38	5.34	5.35
47	5.49	6.37	5.28	6.1	5.73	5.83	5.13	5.44

V. CONCLUSION

In this paper, the filtennas operating at 43.5GHz-47GHz band for Q-Band Millimeter-Wave short range wireless communication are designed, simulated and measured. Compared with the angled dipole with reflector, the performance of the filtenna is kept nearly no change within the operating frequency band while the out of band signal is effectively filtered. It can be seen that the designs, based on SIW technology, features of lightweight, compact size, low cost, and easy integration. It is believed that the filtennas presented in the article are promising for mmW ultra-throughput access and interaction requirements.

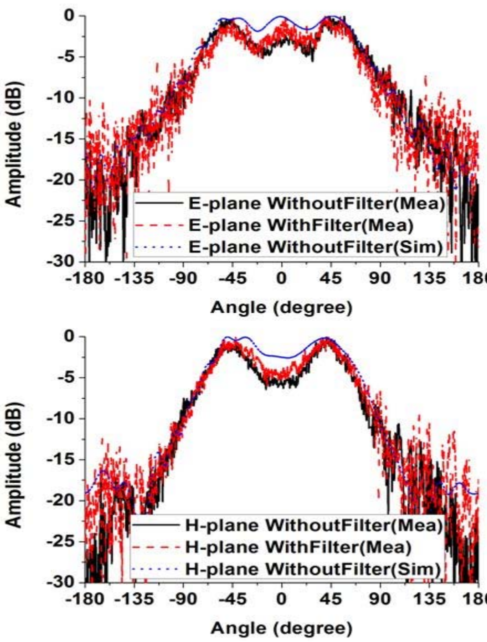

Figure 9. The measured and the simulated radiation patterns of printed angled dipole with reflector and the measured radiation patterns of the corresponding filtenna fed by SIW-CPW transition

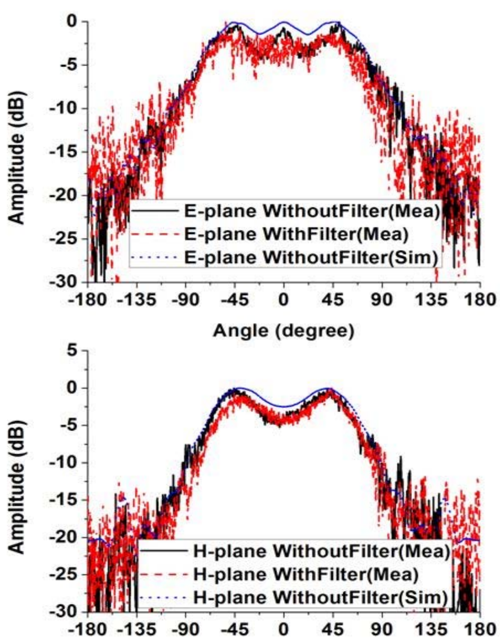

Figure 10. The measured and the simulated radiation patterns of printed angled dipole with reflector and the measured radiation patterns of the corresponding filtenna fed by SIW-RWG transition

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