A Compact, Low-Profile Dual-Band Patch Filtering Antenna for Off-Body Communications

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***Abstract*—A compact dual-band filtering antenna operating in the 5.0-GHz WiFi and 5.8-GHz ISM bands for wearable applications is investigated. The proposed filtering antenna is composed of a rectangular patch that etched with two pairs of rectangular slots and two notch ring slots. In addition, a set of curved parasitic patches with metallic pins are placed inside the two notch ring slots. Four rectangular slots and the curved parasitic patches generate three radiation nulls at the edges of lower and upper bands, and in the middle of the two working bands, leading to an enhanced suppression level in the stop-band. The proposed filtering antenna has the dimensions of 41.5 mm×33.9 mm×1.524 mm with a simulated in-band gain of about 6.5 dBi. Due to the merit radiation patterns with the front-to-back ratios of more than 15 dB, the proposed filtering antenna is suitable for the off-body communications.**

***Keywords*—Dual-band, filtering antenna, off-body communications, radiation nulls.**

I. Introduction

Filtering antenna with uniform gain curve has attracted increasing interest in recent years. On one hand, its overall size can be considerably reduced due to the fact that it integrates the two discrete passive devices, namely antenna and filter, into a single component. On the other hand, the integrated design of filter and antenna can decrease the insertion loss. Based on above-mentioned benefits, varieties of filtering antennas have been developed. A printed planar filtering antenna is realized by combining an inverted-L dipole and a series of parallel coupled microstrip lines [1]. The design is based on the filter synthesis approach by taking the antenna radiator as the last stage resonator of the filter. However, due to the insertion loss of the filter, the radiation efficiency and gain of antenna are degraded. Another filtering antenna's design concept which embedding the filter into the antenna's feed network is proposed in [2]. A unidirectional filtering antenna consisting of a printed rectangular loop with two gaps is obtained [3]. A novel dielectric resonator filtering antenna is designed in [4]. In addition, some filtering antennas have achieved good performance such as dual-band filtering operation [5]. However, due to bulky size and high profile, the filtering antennas mentioned above are not suitable for the body-centric communication. A co-designed filtering antenna applying for wearable devices is demonstrated in [6], whereas it still has a multi-layer configuration.

In this paper, a compact low-profile dual-band patch antenna with filtering characteristics is introduced. The proposed antenna without extra filtering circuit takes on a sharp band skirt and good selectivity in the boresight gain response. Through etching some slots and attaching the parasitic patches in rectangular patch, the performances of dual-band and three radiation nulls are achieved. Since no extra filtering circuit in antenna configuration, the design is compact. The following sections give detailed configuration and simulated results of the proposed antenna.

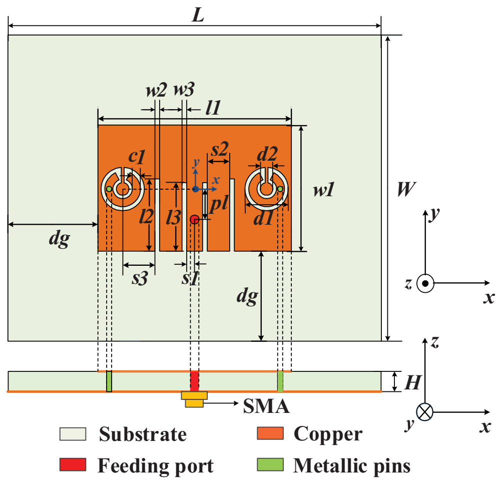


Fig. 1 Geometry of the dual-band patch filtering antenna.

II. Theory and Design

Fig. 1 shows the geometry of the proposed dual-band patch filtering antenna. The topology is symmetric around the *y*-axis of the radiating patch. As illustrated in the figure, the dual-band filtering antenna is manufactured on a Rogers RO4232 substrate with a dielectric constant of 3.2, a loss tangent of 0.0018, and a thickness of *H*. A compact rectangular radiator is printed on the dielectric substrate, the radiator has two pairs of rectangular slots and double curved parasitic patches. The feeding port is placed on the distance *pl* from the center of the rectangular radiator. The two pairs of rectangular slots on both sides of the feeding port induce two radiation nulls at the band-edges of antenna gain curve. Furthermore, the two curved parasitic patches are connected to the bottom ground plane by two metallic pins, simultaneously generating the

TABLE I
OPTIMIZED ANTENNA DIMENSIONS

Symbol	*L*	*W*	*l*1	*l*2	*l*3	*w*1
Value (mm)	41.5	33.9	21.5	8	7.6	13.9
Symbol	*w*2	*w*3	*s*1	*s*2	*s*3	*c*1
Value (mm)	0.3	0.2	0.9	2.5	4.1	0.88
Symbol	*dg*	*d*1	*d*2	*pl*	*H*	
Value (mm)	10	4.6	1.8	3.8	1.524	

TABLE II
ELECTRICAL PARAMETERS OF HUMAN TISSUES

Human tissues (thickness)	5.0 GHz		5.8 GHz	
	ε_r	σ (S/m)	ε_r	σ (S/m)
Skin (1.5 mm)	39.6	3.57	38.62	4.34
Fat (10.5 mm)	5.03	0.242	4.95	0.29
Muscle (39.2mm)	50.13	4.24	48.99	5.2

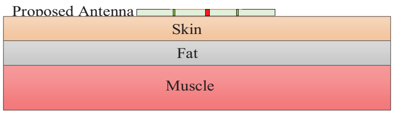


Fig. 2 Multilayer tissue model

second operation band and the third radiation null. The location of the radiation nulls can be tuned by adjusting the length and the position of the rectangular slots. The radiation nulls give rise to a sharp band-edge roll-off in the gain response. The process of designing and optimizing is conducted with the aid of ANSYS HFSS *v*.14. The final dimensions of the proposed antenna are listed in Table I.

III. RESULTS

To evaluate the antenna performance on the human body, the proposed antenna is put on the multilayer tissue model which consists of skin, fat, and muscle layers, as shown in Fig.2. The electrical parameters and thickness of human tissues are listed in Table II. With reference to Fig. 3, the proposed antenna can operate at two modes, i.e. 5.0-GHz WiFi band is assigned for data transmission while 5.8-GHz ISM band is for a wake-up pulse. As described in Fig. 3, the realized gain of antenna is attained about 6.5 dBi at 5.0-GHz WiFi band and 5.8-GHz ISM band. With reference to the gain curve, the three radiation nulls are below –17 dBi. The simulated far-field radiation patterns of the proposed dual-band patch filtering antenna on the multilayer phantom are simulated and depicted in Fig. 4. The front-to-back ratios (FBR) in dual bands are better than 15 dB and could be further big through enlarging the size of the ground plane. Due to the strong radiation in the opposite direction of human body, the proposed antenna has the potential in the off-body communications.

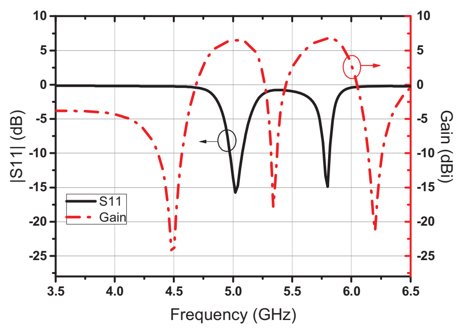
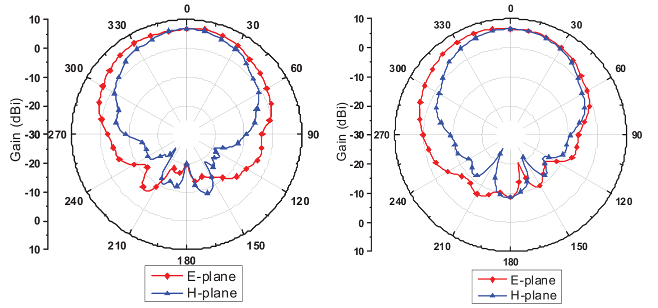


Fig. 3 Simulated reflection coefficients and gain



(a) (b)
Fig. 4 Simulated radiation patterns at (a) 5.0 GHz and (b) 5.8 GHz

IV. CONCLUSIONS

A compact low-profile dual-band patch filtering antenna for off-body information transmission has been designed. Compared to traditional filtering antenna, since only a layer of the substrate is used, a low profile is achieved. The two pairs of rectangular slots and a pair of parasitic patches with metallic pins engender three radiation nulls at 4.5, 5.34 and 6.2 GHz, respectively, that are observed at the band-edges of the boresight gain responses, resulting in the 5.0-GHz WiFi and 5.8-GHz ISM bands with a high selectivity, a sharp band shirt in stop-band, an average gain of about 6.5 dBi, and an FBR of more than 15dB. Therefore, the proposed filtering antenna is fit for being placed on the body surface to communication with outside devices, such as nearby base stations and wearable equipment on the other human bodies.

In future works, the prototype of the proposed dual-band patch filtering antenna will be fabricated and measured to verify the theoretical analysis.

ACKNOWLEDGMENT

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