Design of a compact dualband quasi-isotropic antenna

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A dualband quasi-isotropic antenna is presented. It is based on the split-ring-resonators (SRRs), which provide a quasi-isotropic radiation pattern with an electrically small size. For the dualband operation, the SRRs are placed orthogonally to reduce the mutual coupling between the elements. A folded dipole structure is applied to the SRR, therefore, the input impedance at each band can be easily tuned. Both simulated and measured results are presented. The results show dualband operation (792 and 1124 MHz), high efficiency (higher than 86 and 85.5%), compact size ($ka = 0.47$ at 792 MHz), moderate gain deviation (4.42 and 5.76 dB) with simple direct feed.

Introduction: The quasi-isotropic antenna has attracted attention because of its uniform radiation in all directions. Several recent studies have suggested the way to design quasi-isotropic antennas [1–4]. These designs include a dielectric resonator with small ground plane [1], four monopoles with sequential feeding network [2], and two crossed dipoles with different lengths [3]. The design proposed in [4] is a compact quasi-isotropic antenna that uses the folded dipole and split-ring resonator (SRR), which is widely used to miniaturise the electrical size of the microwave components [5–10].

In this Letter, a dualband quasi-isotropic antenna is described by implementing SRRs orthogonally and applying the folded dipole structure. Unlike the conventional quasi-isotropic antennas, which operate at a singleband, the proposed antenna provides dualband operation within a compact size.

Design of the dualband quasi-isotropic antenna: The proposed antenna configuration is described in Fig. 1*a* with parameter values. For better understanding of the suggested antenna structure, it considered as two separate parts, the horizontal (*xz*) and vertical (*yz*) elements. The horizontal element is based on the SRR, which provides a quasi-isotropic radiation pattern by simultaneously exciting an electric dipole ($\hat{x}$) and perpendicular magnetic dipole ($\hat{y}$). The folded dipole structure is then applied to the SRR, which is a folded split ring resonator (FSRR), to enhance the radiation performances of the antenna. The input resistance can be easily controlled by adjusting the width ratio (w_2/w_1) of the FSRR, while the resonance frequency is tuned by changing the radius (r) and the gap (g) of the FSRR.

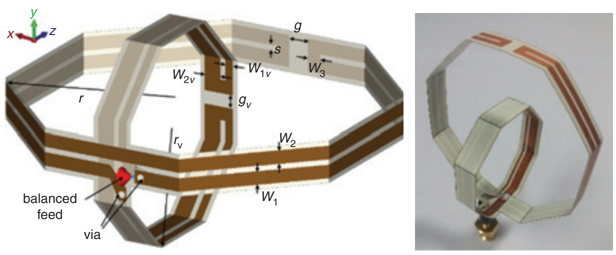

Fig. 1 *Configuration of proposed antenna.* $W_1 = W_2 = 2$, $W_{1v} = 0.8$, $W_{2v} = 3$, $W_3 = 2$, $r = 28$, $g = 3$, $r_v = 18.4$, $g_v = 0.7$, $s = 0.8$ *(unit: mm)*

a Geometry of antenna
b Perspective view of fabricated antenna

The design of the dualband quasi-isotropic antenna using FSRRs should be considered the mutual coupling between the elements. Since the SRR can be regarded as the equivalent electric dipole and magnetic dipole, having orthogonal equivalent dipoles for each element would significantly reduce the mutual coupling. Therefore, the additional FSRR element is implemented vertically. The additional FSRR element is, thus, implemented vertically for the high band operation. This results in elements that can resonate independently at each band.

The proposed antenna is fabricated on the flexible substrate, Rogers ULTRALAM 3850, with 4 mils thickness, $\varepsilon_r = 2.9$, $\tan\delta = 0.002$. The horizontal element is etched on the front surface of the substrate while the vertical element is etched on the reverse side. The development figure is then folded and soldered. The 50-ohm balanced feed is connected to both FSRRs through via holes, and a ferrite bead is used to prevent the current from flowing on the outer conductor of the coaxial cable. The proposed antenna also can be fabricated using two planar printed circuit boards (PCBs) for mechanical stability.

Simulated and measured results of the proposed antenna: Fig. 2 shows the simulated current distribution at each resonance using the CST full electromagnetic (EM) simulator. It indicates that each element resonates at its own frequency, with little coupling, as intended. In Fig. 3*a*, the simulated and measured reflection coefficients are depicted. The measured resonant frequencies are 792 and 1124 MHz, with the fractional bandwidths of 2.8 and 1.8%, respectively. The measured total radiation efficiency across the bandwidth is higher than 86% at the low band (LB) and 85.5% at the high band (HB), as described in Fig. 3*b*. The measured gains are 1.8 dBi (LB) and 2.33 dBi (HB), which are higher than simulated gain results. These differences might arise due to the measurement environments, which distort the uniform radiation pattern.

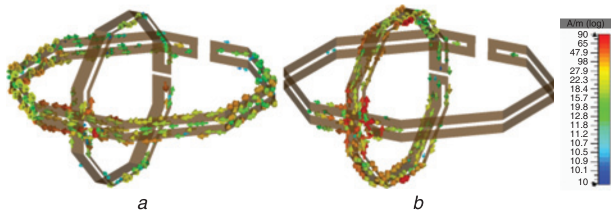

Fig. 2 *Simulated current distribution of proposed antenna*

a LB resonance
b HB resonance

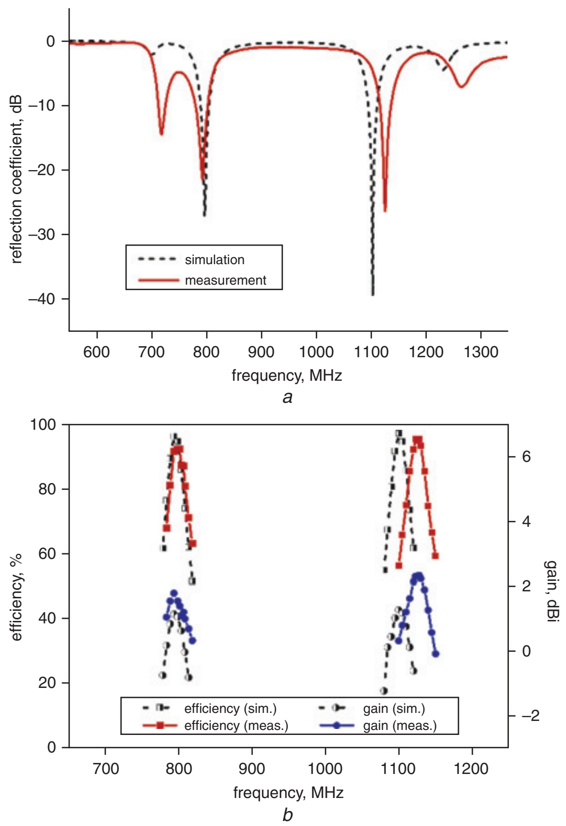

Fig. 3 *Simulated and measured results of proposed antenna*

a Reflection coefficient
b Total radiation efficiency and realised gain

The radiation patterns are plotted in Fig. 4 for both the LB and HB resonances. The radiated electric field of the equivalent electric dipole and magnetic dipole can be verified from the theta and phi components in Figs. 4*a* and *d*. The measured results generally agree with the simulated results, although small discrepancies arise due to fabrication and measurement tolerance. The performances of the proposed quasi-isotropic antenna are compared in Table 1. As shown in the table, the suggested work can provide a quasi-isotropic pattern at dualband, while other studies support singleband operation. To the best of the author's knowledge, no previous work has proposed a dualband quasi-isotropic antenna. In addition, the designed antenna shows an electrically small size and moderate gain deviation, which indicate the uniformity of the radiation pattern.

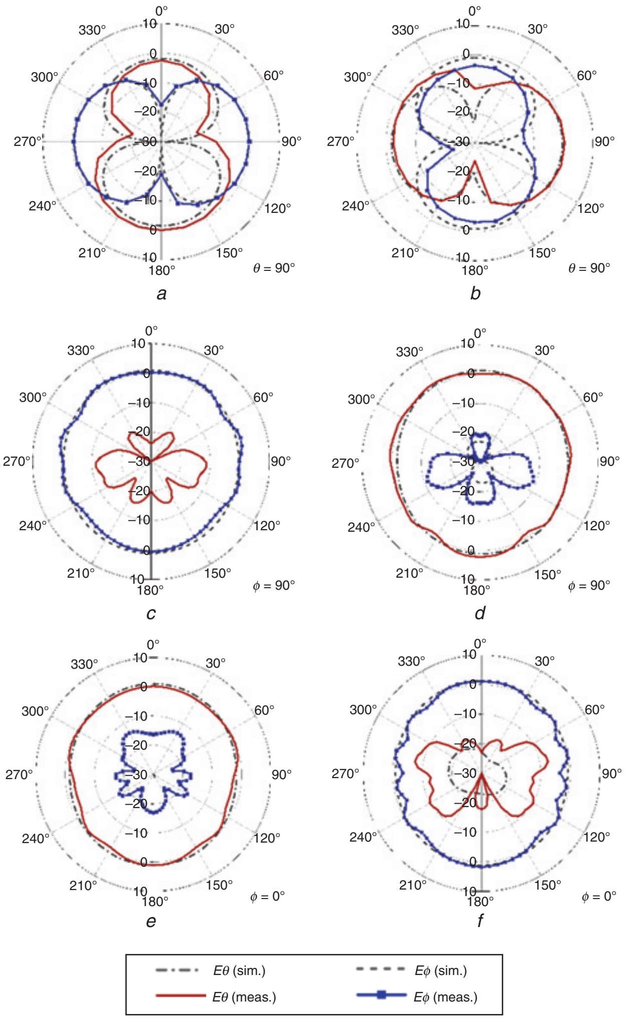

Fig. 4 *Simulated and measured polar patterns of proposed antenna*

a xy-plane at LB resonance
b xy-plane at HB resonance
c yz-plane at LB resonance
d yz-plane at HB resonance
e xz-plane at LB resonance
f xz-plane at HB resonance

Table 1: Performance comparisons of the measured results with recent works

Ref.	Operation band	Electrical size (*ka*)	Gain deviation (dB)		Fractional bandwidth (%)	
[1]	singleband	1.05	5.60		6.9	
[2]	singleband	1.63	5.75		20.8	
[3]	singleband	1.16	6.64		11.0	
[4]	singleband	0.41	5.20		1.8	
This work	dualband	0.47	LB	4.42	LB	2.8
			HB	5.76	HB	1.8

Conclusion: This work is the first demonstration of a dualband quasi-isotropic antenna. The FSRRs are implemented orthogonally to reduce mutual coupling between the elements at each band. The simulated and measured results generally correspond. The input resistance and the resonance frequency of the antenna can be easily controlled by changing the design factors of each FSRR element. The proposed dualband quasi-isotropic antenna has high efficiency, compact size, and simple direct feeding, therefore, it represents a promising candidate for use in modern wireless communication systems.

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One or more of the Figures in this Letter are available in colour online.

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