Printed Square Quadirifilar Helix Antenna (QHA) for XM Satellite Radio Receiver

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***Abstract*— In this paper, a new printed square quadrifilar helix antenna (QHA) with circular polarization (CP) applied for XM Satellite Radio is proposed. To improve the radiation efficiency of QHA, the optimum matching method considering both the reflection coefficients at each feeding port and the mutual coupling coefficients between each antenna is used. The measured results show that the proposed antenna has a 3-dB beam-width of more than 150° and a front-to-back ratio of more than 15 dB. Also, the proposed antenna shows the peak gain of about 0 dBic and the axial ratio less than 2 dB in a targeted frequency band. The center frequency is designed at 2.335GHz.**

I. Introduction

XM Satellite Radio (XM) is the service in the United States and Canada providing pay-for-service radio, analogous to cable television. In mobile satellite radio applications like XM, the design of the suitable antenna is one of the most important factors for receiving signals properly from satellites. The antenna is expected to cover as many service areas of satellite radio as possible with high rejection of the multipath and cross polarized signals.

Circularly polarized (CP) patch antennas have been widely used for satellite communication applications because of its broad beam-width and good circular polarization characteristic. However, as the size of ground plane is reduced, the CP patch antenna exhibits high backward radiation [1]. This means that the antenna has lesser forward radiation and receives more noise from the bottom.

The quadrifilar helix antenna (QHA) invented by Gerst has been studied extensively over the past several decades [2]-[5]. QHA is consisted of four helices equally spaced on a cylinder and each helix is connected to a feed network of equal amplitude with relative phases of 0°, 90°, 180° and 270°. This antenna is suitable for mobile satellite radio receiver antenna because of its broad CP beamwidth and low backward radiation regardless of reduced ground plane size. Recently, the size of the QHA gets smaller for the use in handheld mobile devices. As the size of QHA is reduced, the mutual coupling between each helix antenna is increased.

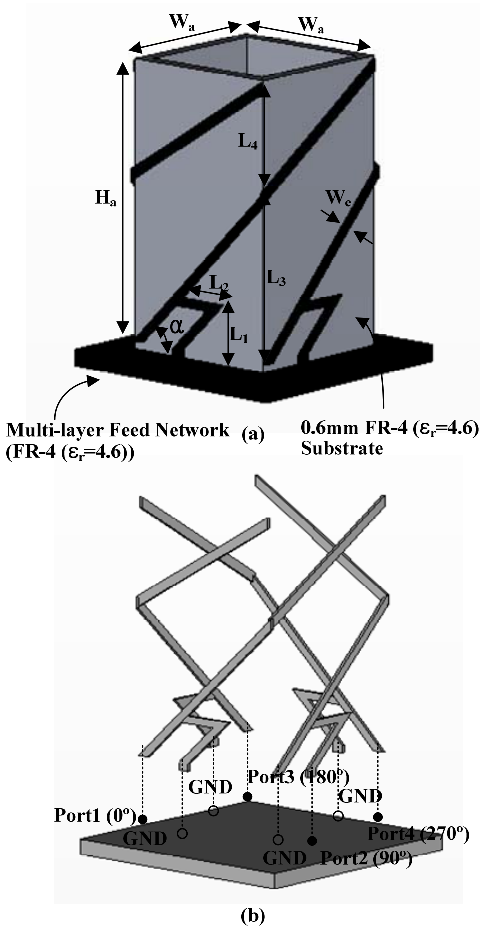

Fig. 1 The geometry of the proposed quadrifilar helix antenna in (a) and feeding port structure of antenna with short-stub in (b)

For a compact 4-port feed antenna like the conventional QHA, thematching method considering reflection coefficient and the mutual coupling coefficient can only be optimized if the input impedance is very low. But it is hard to design the feed network of very low input impedance in realty.

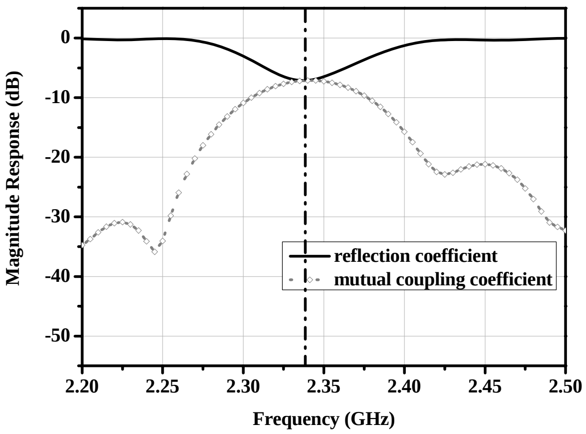

Fig. 2 Simulated input impedance matching result between the reflection coefficient and the mutual coupling coefficient of the proposed antenna

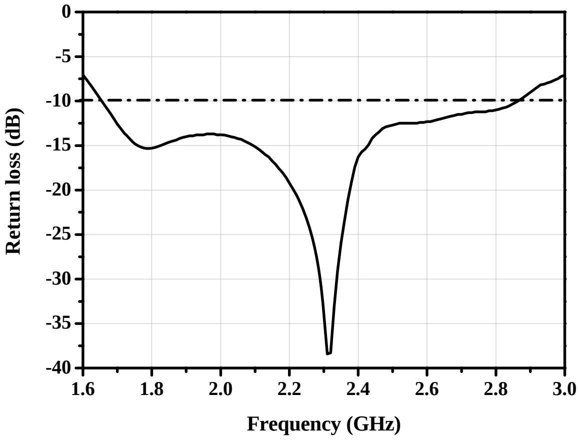

Fig. 3 Measured return loss for the proposed antenna

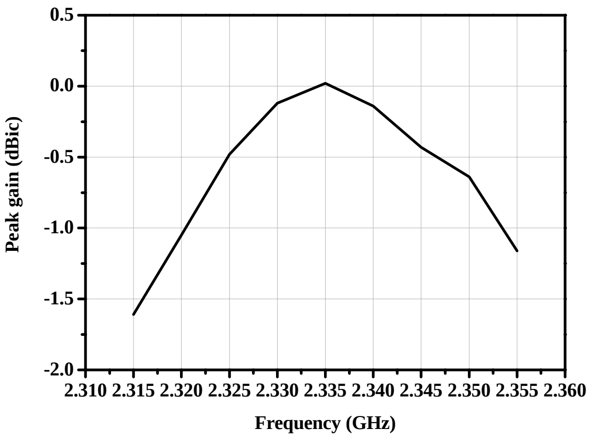

Fig. 4 Measured peak gain for the proposed antenna in XM frequency range

In this paper, we propose the compact printed square QHA using short-stub connected to the ground with left-hand circular polarization (LHCP) for XM satellite radio application. As the short–stub is used, the matching condition considering both the reflection coefficient and the mutual coupling coefficient can be optimized regardless of high input impedance. This matching condition makes the design of antenna simpler and the improvement for the radiation efficiency of QHA easier.

II. Design of Printed Square QHA

Fig. 1 shows the geometry of the proposed compact square printed QHA for XM Satellite Radio application. The antenna is grounded above the multi-layer FR-4 substrate (thickness of 0.6mm, relative permittivity of 4.6 and size of 15×15 mm^2). On the grounded substrate, the feed network is implemented to generate four equal amplitude signals with relative phases of 0°, 90°, 180° and 270° for circularly polarized waves. Each helix monopole antenna of QHA is also printed on a FR-4 substrate. Each helix has a length of 26 mm, width (W_e) of 0.5 mm and pitch angle (α) of 45° to resonate in XM frequency band. The width (W_a) of a square antenna is 10 mm and height (H_a) is 17 mm.

To improve the radiation efficiency of the antenna, the reflection coefficient and the mutual coupling coefficient among the ports must be considered for matching [6]. By using and adjusting short-stub feed line in each helix, the matching condition can be simply obtained. The height of the matching line (L_1) and distance between helix and matching line (L_2) the are chosen to be 3.5 mm and 3 mm for good matching and radiation efficiency, respectively. Fig. 2 shows that the reflection coefficient and the mutual coupling coefficient of the proposed antenna are matched in the XM frequency range.

III. Experimental Results

Fig. 3 shows the measured return loss. The center frequency of proposed antenna is about 2.335 GHz and return loss at the center frequency is about -38dB. The bandwidth of about 1.1 GHz (1.7~2.8GHz) is observed due to the wide bandwidth characteristic of the feed network.

Fig. 4 shows the measured peak gain in the XM frequency range. The measured peak gain is about 0 dBic with the measured radiation efficiency of about 40% at the center frequency of 2.335 GHz. Since the frequency band of XM (2332.5~2345MHz) is located in 3-dB gain bandwidth, the proposed antenna produces a stable gain property of less 1dBic in the XM band. The 3-dB gain bandwidth is about 100 MHz.

Fig. 5 shows the measured radiation pattern of the proposed antenna at 2.335 GHz in x-z direction. The half power beam width (HPBW) is about 140°. As the proposed antenna has a broad beamwidth, it can possibly cover many satellites over the hemisphere. The front-to-back ratio is more than 15dB and thus the antenna filters out the noise and unwanted signals from the bottom of the antenna.

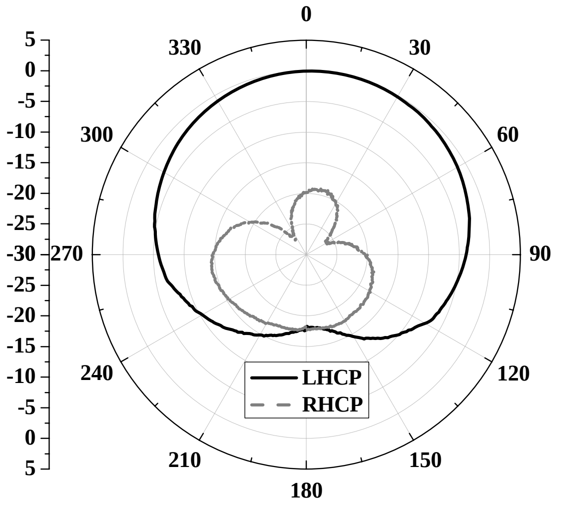

Fig. 5 Measured radiation pattern for the proposed antenna in x-z direction (at 2.335 GHz)

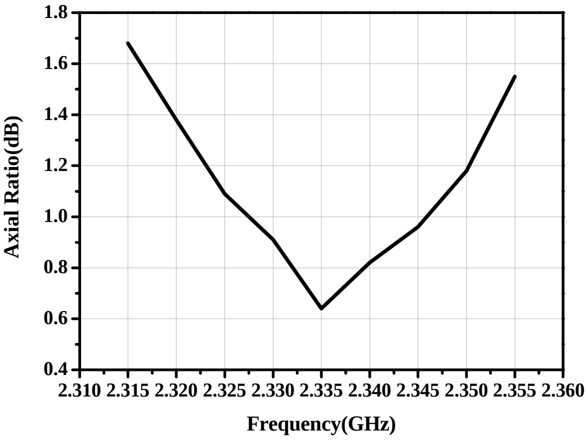

Fig. 6 Measured peak Axial Ratio (AR) for the proposed antenna in XM frequency range

Fig. 6 shows the measured peak axial ratio (AR) in the XM frequency range. The measured AR of the proposed antenna is less than 1 dB in the XM band. That is, the proposed antenna has a good CP performance.

Fig. 7 shows the measured axial ratio radiation pattern in x-z direction at 2.335 GHz. According to the measured result, 3-dB axial ratio beamwidth is about 150°. The proposed antenna with good CP wave radiation characteristic rejects unwanted cross polarized and multi-path signals effectively. Fig. 8 is the picture of the fabricated printed QHA for XM satellite radio receiver.

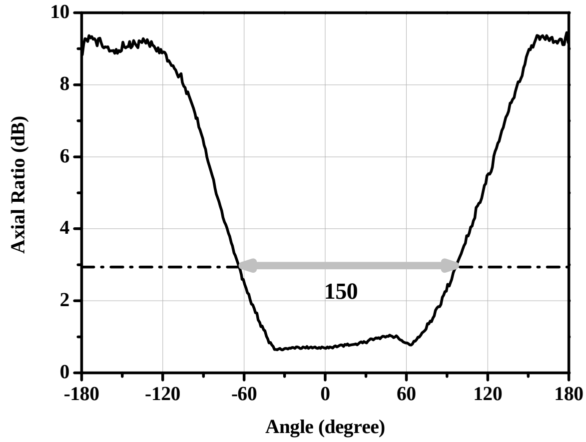

Fig. 7 Measured Axial Ratio radiation pattern (at 2.335 GHz)

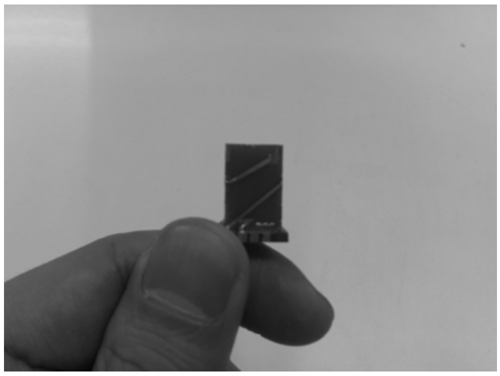

Fig. 8 The implemented proposed QHA antenna

IV. CONCLUSIONS

A new printed square quadrifilar helix antenna for XM satellite radio receiver has been presented and verified. The measurement results show that the proposed antenna is well-matched to the optimum matching condition considering both the reflection coefficient and the mutual coupling coefficient among the ports. The proposed antenna has a good circularly polarized radiation performance. The measured results show that the proposed antenna has a 3-dB beam-width of more than 150°, a front-to-back ratio of more than 15 dB, a peak gain of about 0 dBic and an axial ratio less than 2 dB in a targeted frequency band. The proposed antenna can be utilized for many applications in XM satellite radio.

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