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Dual-Polarized Annular Ring Patch Antenna for 2.4 GHz Doppler Radar

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Abstract

A 2.4 GHz dual-polarized antenna for a Doppler radar is studied. The proposed dual-polarized antenna using a stacked annular ring patch with two co-centric gap-coupled feed lines and a 90° hybrid exhibits fairly good performance of 22 dB isolation at a center frequency of 2.4 GHz. Using a 90° hybrid, a right-handed circular polarization for the transmitter and a left-handed circular polarization for the receiver are implemented. The gain of the designed antenna is about 0 dBi over operating frequencies. The antenna size including a ground plane is only 40×40 mm^2.

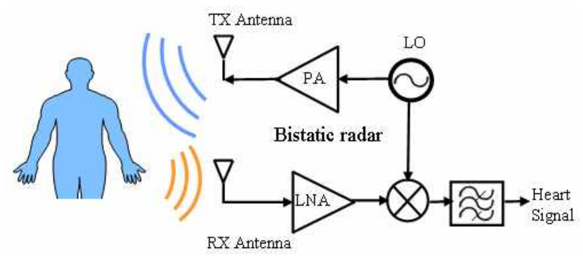
Key words: Doppler Radar, 2.4 GHz, Dual-Polarized, Hybrid, Isolation, Annular Ring, Microstrip Antenna.

Ⅰ. Introduction

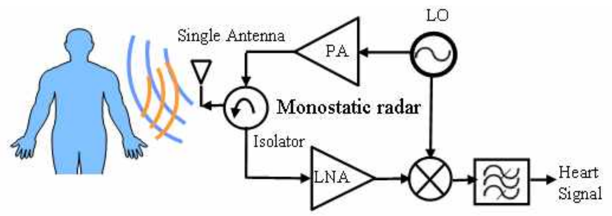
Doppler radar sensing of heart and respiration rates is a promising technique for healthcare applications. Typically, Doppler radar transmits a continuous-wave(CW) signal and demodulates the signal reflected off a target. According to Doppler theory, a human chest wall that has a periodic time-varying position will reflect the phase-modulated signal in proportion to the position of the chest wall. By demodulating this phase modulated signal, the heart and respiration rates can be obtained[1].

Because Doppler radars transmit and receive a signal at the same time and at the same frequency, good isolation between the transmitter(TX) and receiver(RX) circuit is very important for the proper detection of weak vital signals. The two main choices for Doppler radar are bistatic and monostatic configurations as shown in Fig. 1. The bistatic configuration uses separate TX and RX antennas, while the monostatic configuration uses a single antenna with some type of radio frequency(RF) isolator. However, the bistatic configuration has a size problem because antenna is the largest component in the Doppler radar. Therefore, to reduce the size of the radar, a monostatic configuration is preferred[2].

The monostatic radar, on the other hand, has a TX leakage problem. The large leakage signal from the TX can reduce the sensitivity of the radar and even saturate the RX. Therefore, an RF isolator such as a large ferrite circulator or a directional coupler with a TX leakage cancellation technique should be used to reduce the level of TX leakage. These methods, however, increase the complexity of the radar and show some additional power losses due to the RF isolator[3].



(a) Bistatic Doppler radar



(b) Monostatic Doppler radar

Fig. 1. Comparison between bistatic Doppler radar and monostatic Doppler radar.

In this letter, we propose a 2.4 GHz dual-polarized antenna for a Doppler radar. Using the dual-polarized antenna, additional power losses in the circulator or directional coupler can be resolved[4]. The proposed antenna consists of a stacked annular ring patch antenna with two co-centric gap-coupled feed lines and a 90° hybrid, which are fabricated on a low cost printed circuit-board. Details of the proposed antenna design and obtained performances are described.

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Ⅱ. Antenna Design

To achieve compact size at a frequency of 2.4 GHz, an annular ring stacked patch antenna is used. When operated in its fundamental mode, TM_{11}, this antenna is smaller than other shape patch antennas[5] The antenna has three FR-4(ε_r=4.4) layers, including a cover layer. The 90° hybrid and feed line circuits are printed on the bottom layer and a ring-shaped strip conductor is stacked between a substrate layer and a cover layer. A cover layer and a thick substrate between the radiating patch and the ground plane are needed to operate throughout the entire 2.4 GHz industrial, scientific, and medical(ISM) band. The heights of the substrates of the proposed antenna are determined to satisfy the bandwidth requirements.

The feeding probe is located at an optimum location to improve the impedance matching. The large probe inductance, arising from the thick substrate and cover layer, for the two probe feeds is tuned out by embedding a co-centric gap-coupled slot around each feed in the radiating patch.

Fig. 2 shows a top view of the annular ring stacked microstrip antenna. The antenna is stacked between a 3.2 mm thick FR-4 substrate and a 1 mm cover layer. The dimensions of the antenna are determined by an HFSS-TM simulator. The proposed antenna exhibits a compact size of 40×40 mm^2 including a ground plane.

The operating principle of the proposed dual-polarized antenna is as follows. A 90° hybrid coupler is used as a polarizer and a duplexer for a Doppler radar. The TX signal inputs at one input port of the 90° hybrid coupler

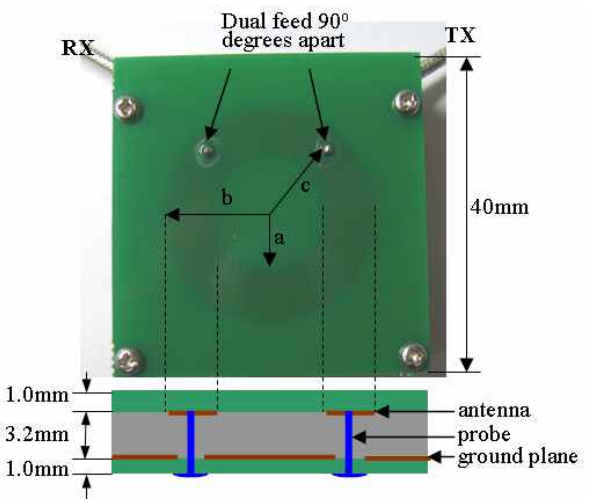
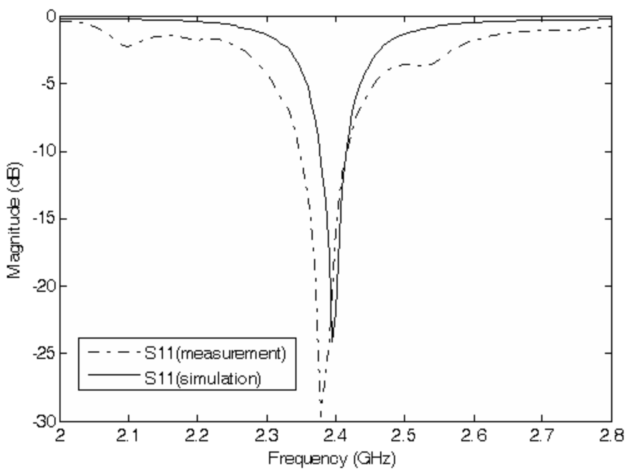


Fig. 2. The photograph of the dual-feed circularly polarized annular ring stacked patch antenna(a=7.1 mm, b=13 mm, c=10.7 mm).

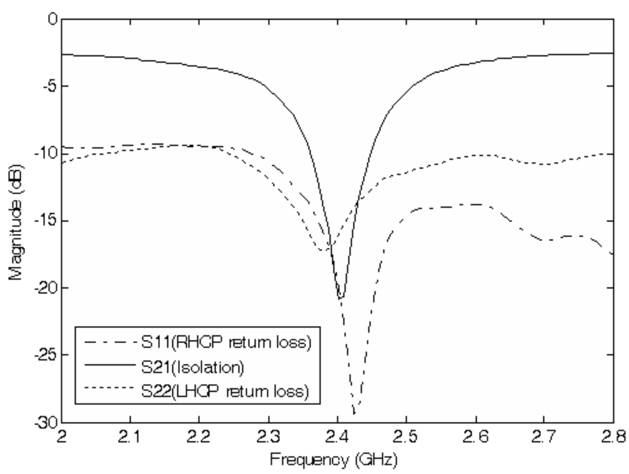
and the RX signal at the other. Two gap-coupled probe feeds placed in orthogonal directions are used for excitation of the proposed antenna. Because of the 90° phase difference between feeding lines, a right-handed circular polarization(RHCP) antenna is formed at the TX, whereas a left-handed circular polarization(LHCP) antenna is formed at the RX. As a result, two differently polarized antennas can be established within a single antenna without additional power losses.

Ⅲ. Measurement Results

The proposed 2.4 GHz dual-polarized antenna for Doppler radar has been fabricated and experimentally analyzed. First, a single probe-fed annular ring stacked microstrip antenna without a 90° hybrid was measured. The measured return loss of an antenna itself is shown in Fig. 3(a). The measured −10 dB bandwidth of the antenna



(a) Linear polarization



(b) Circular-polarization

Fig. 3. Measured S-parameter of annular ring stacked patch antenna.

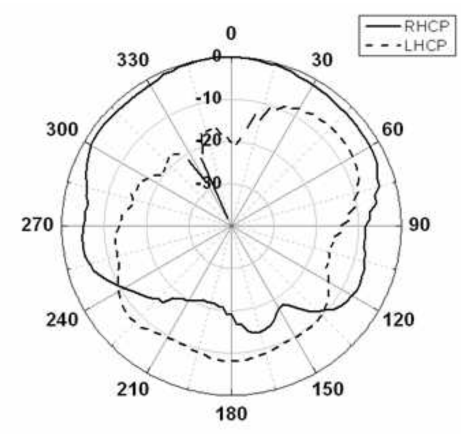


Fig. 4. Measured radiation pattern of annular ring patch antenna.

is about 70 MHz at the center frequency of 2.4 GHz.

Next, a circularly polarized antenna with a 90° hybrid was measured. The 90° hybrid(Anaren Xinger 1P603S) was fabricated on the opposite side of the patch across the ground plane. As shown in Fig. 3(b), the circularly polarized antenna shows the wideband reflection coefficient owing to the wideband characteristics of the 90° hybrid. Moreover, the isolation of the antenna is about −22 dB at 2.4 GHz. However, the isolation is drastically decreased outside of the −10 dB bandwidth of the antenna due to the narrow bandwidth of the antenna itself.

The radiation pattern of RHCP by the TX port at 2.4 GHz is shown in Fig. 4. A good RHCP radiation and low cross-polarization level of −20 dB for the TX port are observed. Similarly a good LHCP radiation and low cross-polarization level are also observed for the RX port. The maximum gain at 2.4 GHz is about 0 dBi toward the normal direction of the patch in both cases. The half-power beam-widths of the RHCP and LHCP are 140° and 132°, respectively.

Ⅳ. Conclusions

A 2.4 GHz dual-polarized antenna for Doppler radar was designed and implemented in a printed circuit-board. The fabricated antenna consists of a stacked annular ring patch antenna fed with two gap-coupled probe feed lines and a 90° hybrid coupler. The return loss and isolation characteristics are excellent in the 2.4 GHz frequency band. The proposed design has a simple structure, and can be fabricated at a very low cost. The compact size of 40×40 mm^2 enables the proposed antenna to be easily integrated with a portable Doppler radar.

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