

# A Novel 24GHz Microstrip Array Module Design for Bioradars

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**Abstract**—In this paper, a new millimeter-wave transmitting/receiving antenna module for bioradar sensors was proposed. This antenna was designed operating at 24 GHz for remote contactless evaluation of the human organism adaptation to physical and mental stress. This module was divided into two parts, both of which were implemented by a microstrip array antenna sub-module. The feed networks were also optimized for impedance matching to eliminate the signal self-mixing. This module had a dimension of 56×64 mm<sup>2</sup>, which made it easy to install on the roofs above the beds to monitor the heart movement activity and respiration pattern variability of burned patients or people in stress. The simulation results showed its good performance in bioradar applications.

**Keywords**—bioradars; microstrip array antenna; millimeter wave;

## I. INTRODUCTION

Bioradar is a product of biological and social progress[1-3]. Along with the development of human civilization and fast pace of life, health-related problems become the key issues in current society, especially in emergencies to detect life signs, a long term monitoring mental illness or monitoring mental health groups, as well as special medical care for burned patients or other critically ill patients who urgently require the non-contact care. The development of bioradars has brought opportunities. In current Chinese big cities, bioradars are in the great demands concerning with the increasing living pressures. Improving and promoting the development of bioradars can effectively release the pressure of these problems, and be more likely to provide medical care, to ease the conflicts between the doctors and patients, and to maintain social stability.

For bioradar sensors, the basic requirement is compact with high gains[4-5]. Huge volumes of bioradars may cause troubles in installations and mobility. Also, in order to acquire the weak signals scattered from human bodies, bioradars should be applicable to tiny movements of heart beats or respiration patterns. In such cases, the antenna for bioradar applications

can be implemented by using 24GHz signals with a group of microstrip arrays.

In this paper, we propose such a millimeter-wave microstrip array antenna module for bioradar sensors. Both high gains and low side lobe levels can be achieved by non-homogeneous weights for amplitudes excitation. Moreover, the feed networks are optimized for impedance matching. Furthermore, performance of this antenna is evaluated by numerical simulations. The results prove that this antenna module is applicable in the bioradar applications.

## II. ANTENNA STRUCTURES

Designing antenna for bioradars is different from other radar applications. First, application of short distance does not require high transmission power due to the health safety considerations. However, weak movements of human heart activity and respiration pattern variability desire high gain in receiving the signals scattered from the targets. Meanwhile, the beam should be narrow in order to avoid the disturbance from the neighbor targets. Considering all the factors in the practical applications, we propose such a configuration of the antenna. In this design, the transmitting antenna includes 24 elements for a narrow beam and the receiving antenna includes 48 elements for a large aperture areas. Figure 1-(a) shows the configuration of the proposed antenna module.

Each antenna element in this array is a single-patch antenna, depicted in Fig. 1-(b) and (c). A U-slot is arranged on both sides of the feed line. The feeding point can be changed by means of adjusting the depth of the slot. Moreover, the width of slot will also affect the impedance of the patch. Therefore, impedance matching can be realized by choosing the proper feeding point. Each patch is fed at the junction on the same plane of the feeding network by using a power dividing network. According to antenna array synthesis, adopting unequal current amplitude distribution instead of equal amplitude can efficiently reduce side lobe level.

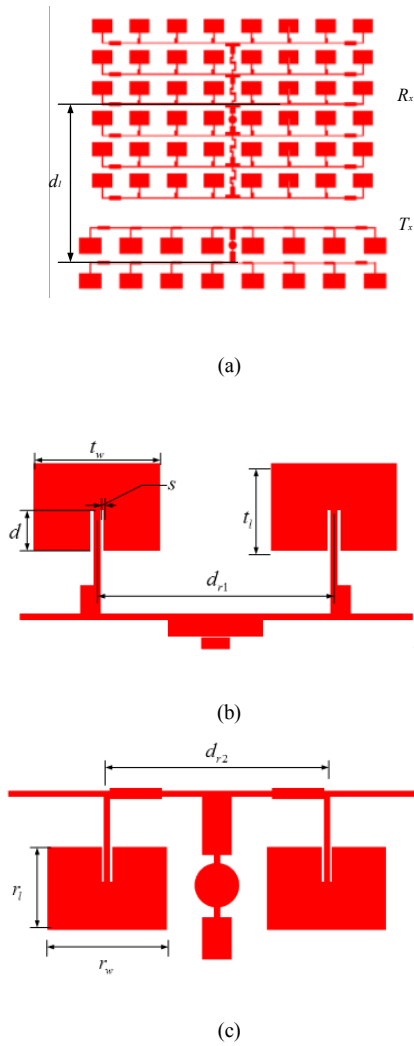


Fig. 1. Antenna configuration.

In this design, the antenna module was etched on a  $73 \times 64$  mm<sup>2</sup> FR-4 substrate,  $\epsilon_r = 3.55$ , having 1/2-oz copper cladding. Important parameters were shown in table 1.

TABLE I. ANTENNA CONFIGURATION

Parameters	Value (mm)
$s$	0.1
$d$	1.2
$t_w$	3.7
$t_l$	2.55
$r_w$	4.14
$r_l$	2.86
$d_{r1}$	7
$d_{r2}$	7.8
$d_l$	23.5

### III. PERFORMANCE EVALUATION

The performance of the proposed modules were analyzed by using numerical simulations in CST Microwave Studio for both transmitting antenna and receiving antenna sub-modules. Also, this design should take into account the elimination of self-mixing in order to recover the spectral details in the proximity of zero-frequency. To acquire the drawbacks caused

by this problem, the evaluation of the mutual coupling was analyzed.

#### A. Receiving antenna

Fig. 2 shows the return loss characteristics of this antenna module. The calculated bandwidth is 0.5 GHz over 24 GHz to 24.5 GHz for return loss less than -10 dB. Fig. 3-(a) to (f) respectively show the radiation patterns at 23.5GHz, 24GHz and 24.4 GHz on the E-plane and H-plane. The calculated antenna gain is 19.23 dB, 21.07 dB and 17.58 dB. Moreover, the side lobe level at 23.5GHz, 24GHz and 24.4 GHz for H-plane is -17.5 dB, -16.4 dB and -13.4dB respectively. And for E-plane, the result is -17.3dB, -12dB, -13.6dB.

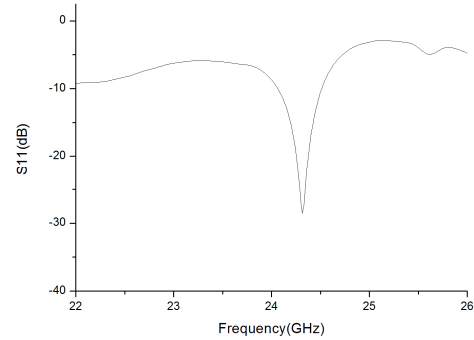


Fig. 2. Return loss characteristics for T1 antenna

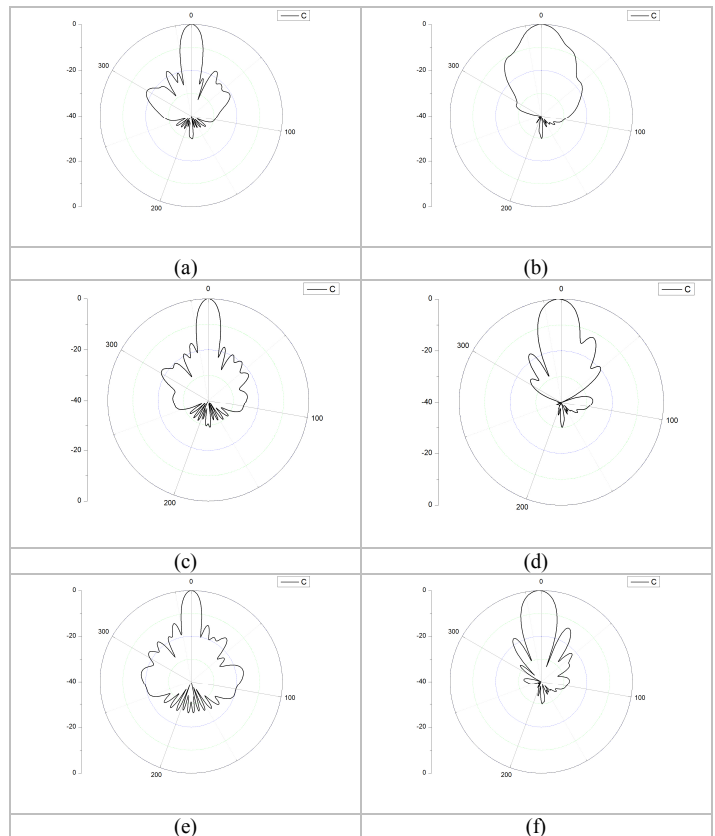


Fig. 3. Radiation patterns for Rx antenna (a) H-plane for Rx antenna at 23.5 GHz (b) E-plane for Rx antenna at 23.5 GHz (c) H-plane for Rx antenna at 24. GHz (d) E-plane for Rx antenna at 24 GHz (e) H-plane for Rx antenna at 24.4 GHz (f) E-plane for Rx antenna at 24.4 GHz

### B. Transmitting antenna

Fig. 4 shows the numerical return loss characteristics for the transmitting antennas. The calculated bandwidth is 0.6 GHz over 23.7 GHz to 24.3 GHz for return loss less than -10 dB.

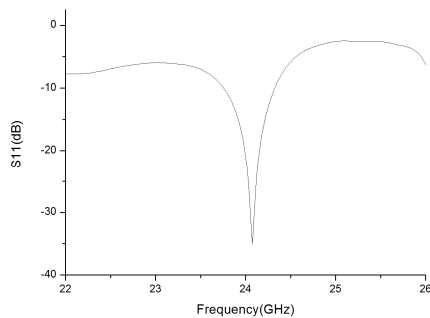


Fig. 4. Return loss characteristics for Tx antenna

Fig. 5-(a) to (f) respectively show the radiation patterns at 23.5GHz, 24 GHz and 24.4 GHz on the E-plane and H-plane. The reported gain for Tx is 15.77 dB, 17.15dB, 15.75 dB, and the side lobes are -16.7 dB, -16.7 dB and -14.5 dB on the H-plane. The side lobes are -26.7 dB, -13.7 dB and -10.5 dB on the E-plane.

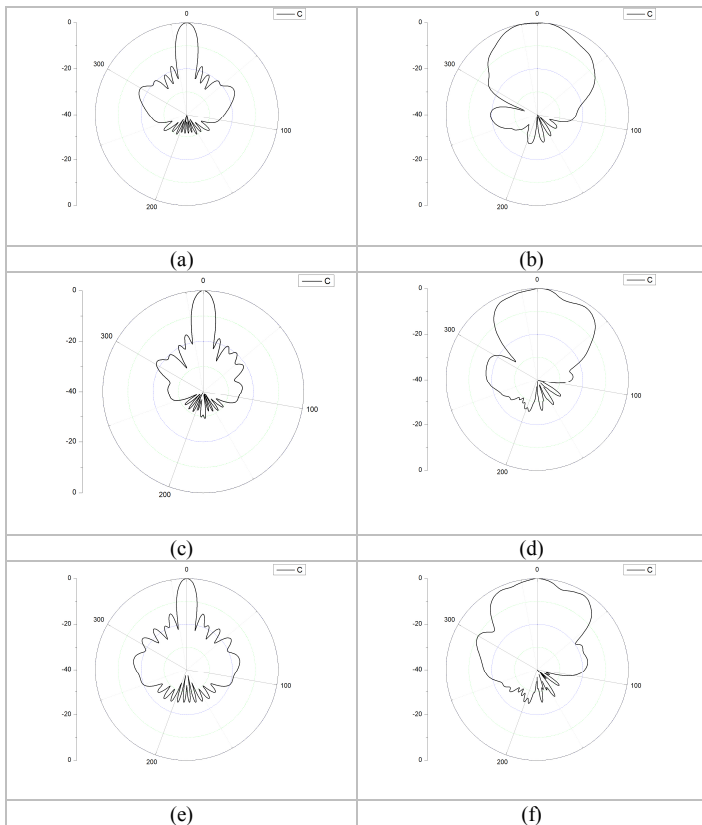


Fig. 5. Radiation patterns for Tx antenna (a) H-plane for Tx antenna at 23.5 GHz (b) E-plane for Tx antenna at 23.5 GHz (c) H-plane for Tx antenna at 24. GHz (d) E-plane for Tx antenna at 24 GHz (e) H-plane for Tx antenna at 24.4 GHz (f) E-plane for Tx antenna at 24.4 GHz

### C. Mutual coupling

The distance between the transmitting antenna and receiving antennas is dependent on the requirement of isolating the mutual coupling effects among the patch antenna elements and the beam-pattern distortion due to the position of each single-patch antenna as the feeder. Fig. 6 show the mutual coupling in the proposed antenna module. At 24 GHz, the mutual coupling between the transmitting antenna and the receiving antenna was below -35 dB, which provides good isolations between the transmitting antenna and the receiving antenna

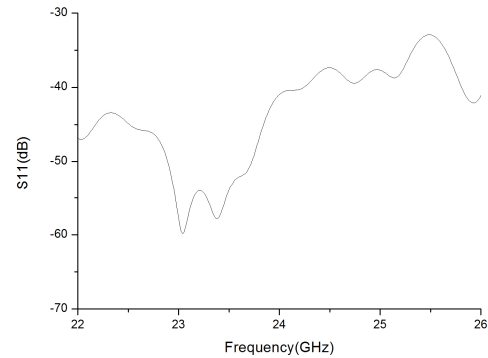


Fig. 6. Mutual coupling between antennas

## IV. CONCLUSION

This paper introduced a novel millimeter-wave antenna module design for bio-radar sensors. This module included one transmit antenna with 48 elements and two receive antennas. The transmitting antenna obtained 17.15dB gain and -16.7 side lobe level, and the receiving antenna gain exceeds 17dB. The simulation results have confirmed the feasibility of the initial antenna prototype. Future work will continue to increase the frequency band and further decrease the side lobe levels. We also wish manufacturing the prototype of this antenna for test in the anechoic chamber .

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