A Printed Dipole Array Antenna for Non-contact Monitoring System

Qiancheng Liang, Ramadhani Selemani Mpanda
Sino-Dutch Biomedical and Information Engineering School, Northeastern University, Shenyang, China

Xin Wang, Jingjing Shi, Lisheng Xu*
Sino-Dutch Biomedical and Information Engineering School, Northeastern University, Shenyang, China
xuls@bmie.neu.edu.cn

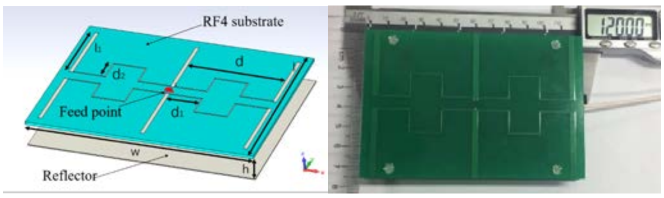
***Abstract*—A printed dipole array antenna with a reflector is presented for a non-contact monitoring system. It has a simple and novel structure with symmetrical array elements, as well as a small size of 120 mm × 35 mm × 12 mm. The proposed antenna is intended to operate at the frequency of 2.4 GHz, Industrial Scientific Medical (ISM) band, and the simulated and measured return loss matches well at the desired resonant frequency band, in which -10 dB bandwidth is 150 MHz (6.2%), covered from 2.35 GHz to 2.5 GHz. The maximum antenna gain reaches 10.8 dBi and the half-power beamwidth is 49°, which exhibit good performances required in a non-contact monitoring system. It should be a good candidate for providing a high quality vital sign detection with less environment influences.**

Keywords—non-contact detection; printed dipole array antenna; ISM band

I. INTRODUCTION

Human health monitoring has been a subject of extensive research since the number of elderly people living alone have grown rapidly as well as the young people who are over burden are more and more vulnerable to cardiovascular disease. Therefore, there are plenty of technologies used in human health monitoring and have made tremendous progress in small wearable sensors for vital sign detection [1]. However, the conventional wearable sensors still have unsolvable problems or limitations. For example, the conventional sensors need leads and to be attached to human body surface or clothes. This is inconvenient for the users who desire to move freely. Moreover, in the case of people who suffer from severe injury or burn, it is difficult for them to wear the sensors for further treatments. With the development of Doppler radar technology in medical care and healthcare, it is usually applied in a non-contact detection of respiration and heart rate to provide a new solution for human health monitoring [2]. As a key component in Doppler system, antenna design plays an important role in vital sign monitoring. The antenna should be designed in such a way that it focuses the radiation beam on the human subject and should have an adequate antenna gain to maintain a required signal quality [3]. The antenna with directional radiation beam can focus on the users when they are sleeping, driving or working. Usually, the gains of most antennas used in the acquisition of human vital signs are around 9 dBi [3-4]. On the other hand, microstrip dipole antennas are thought to be appropriate due to their embedment with on-chip devices, low profile, low cost and ability to make array to boost the antenna gain [5].

II. ANTENNA STRUCTURE



(a) (b)

Fig. 1. Printed dipole array antenna with symmetrical array elements and a reflector, (a) geometry model design; (b) top view of the fabricated antenna.

As shown in Fig. 1, the proposed microstrip printed dipole array antenna has a simple and novel structure with symmetrical array elements for attaining high antenna gain and a reflector to focus the radiation beam at a specific direction. The three dipole array elements are connected by a pair of meandered transmission lines to guarantee good impedance matching and maximum antenna gain. The transmission lines make up of three same lines in x-axis, and two same lines in y-axis, the length of them is d_1 and d_2, respectively. The feed point is at the middle dipole element. Each dipole array element has two arms in the same side of the substrate, and the length of each arm equals to $\lambda/4$, where λ indicates the wavelength at 2.4 GHz. The FR4 substrate with relativity of ε_r = 4 and thickness of h = 4 mm was used in this antenna which can shorten the wavelength compared to free space. Therefore, the corresponding theoretical value of radiation element l_1 can be described as

$$l_1 = \frac{1}{4}\lambda = \frac{c}{4f\sqrt{\varepsilon_r}} \quad , \qquad (1)$$

where c the velocity of light, f is the resonance frequency. A metal plate worked as antenna reflector is added to the back side of dipole array elements, with a distance of $h = \lambda/4$ from the FR4 substrate.

According to our simulation results, the gain of a single dipole array element with a reflector structure achieved to 5.07 dBi at the resonant frequency of 2.33 GHz. It possessed good directivity and can operate at the required frequency band, nevertheless, the gain of single element (5.07 dBi) is not sufficient enough for maintain good signal quality in a non-contact monitoring system.

In order to increase the antenna gain, it is common to combine several single radiating elements together. According to [6], it revealed that the distance d between each two adjacent dipoles is a main factor to influence the antenna gain, and the maximum gain will be found when $d = \lambda/2$ if the array has odd number of dipoles. To balance the requirement of antenna gain with size and power loss at transmission lines, we finally determined the printed dipole array antenna to have three single dipoles with a spacing of $\lambda/2$. Between each two dipoles, inversely symmetric meandered transmission lines were used to reduce the size of the antenna. The optimized geometrical parameters of this antenna after the simulations by CST are shown in Table. I.

TABLE I. GEOMETRICAL PARAMETERS OF THE ANTENNA

l_1	d	d_1	d_2	h	w	l
35 mm	51mm	17 mm	12 mm	12 mm	120 mm	75 mm

III. Antenna Performance

The printed dipole array antenna is measured using a vector network analyzer; Fig. 2 shows the simulated and measured S_{11} of the proposed printed dipole array antenna. It can be found that the simulated and measured -10 dB impedance bandwidths are in good agreement and cover the ISM frequency band from 2.35 GHz to 2.5 GHz (6.2%). The resonant frequencies appear at 2.4 GHz and 2.41 GHz, respectively, for the simulated and measured S_{11}. Some discrepancy observed between the measured result and simulated data may be caused by unexpected fabrication tolerance and measurement error.

Fig. 3 plots the simulated 3D radiation pattern for the proposed antenna at 2.4 GHz. It is obvious that the main lobe created by the metal reflector radiates the microwave towards z-axis direction. The simulated peak gain reaches 10.8 dBi in free space, and the half-power beamwidth is 49°. Both the high gain achievement and good angular width demonstrate its capacity and possibility for a non-contact monitoring application, for example, the sleep monitor.

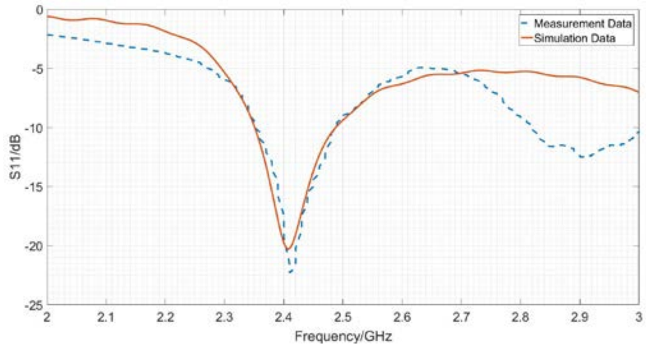


Fig. 2. Simulated and measured S_{11} of the proposed antenna.

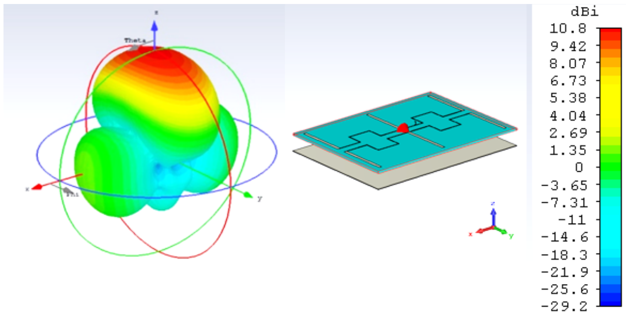


Fig. 3. 3D radiation pattern for the dipole array antenna at 2.4 GHz.

IV. Conclusion

A simple and novel printed dipole array antenna with a reflector has been designed and fabricated for a non-contact monitoring system. Three single dipoles connected with meandered transmission lines have been demonstrate to show its good radiation performance with maximum antenna gain of 10.8 dBi, and half-power beamwidth of 49°. The simulated and measured results match well at 2.4 GHz ISM band. The -10 dB impedance covered from 2.35 GHz to 2.5 GHz, and the bandwidth is 150 MHz (6.2%). It should be a useful and good candidate for providing a solution for non-contact vital sign monitoring.

Acknowledgments

The research reported here was, in part, supported by the National Natural Science Foundation of China (No. 61773110, No. 613740156, No. 1701096), and the Fundamental Research Funds for the Central Universities (No. N161904002, No. N172008008, No. N171904010).

References

[1] Alexandros Pantelopoulos, Nikolaos G. Bourbakis, “A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis,” IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), Vol. 40, pp. 1-12, Jan. 2010.

[2] M. S. Rabbani, M. S. Rabbani, “60 GHz microstrip antenna for remote vital sign monitoring in automobile applications,” Antennas, Propagation & RF Technology for Transport and Autonomous Platforms, Birmingham pp. 1-5, February 2018.

[3] Park, Zivin, C. Li, and J. Lin, “A Broadband Microstrip Antenna With Improved Gain for Noncontact Vital Sign Radar

Detection," IEEE Antennas & Wireless Propagation Letters. vol. 8, pp. 939-942, August 2009.

[4] Mattia V D, Petrini V, Pallotta E, et al. "Design and realization of a wideband antenna for non-contact respiration monitoring in AAL application," The 10th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications, Senigallia - Ancona, pp. 1-4, September 2014.

[5] Jain S K, Pawar S, "Characterization of Log Periodic Planar Dipole Array Antenna," IEEE International Conference on Industrial and Information Systems, Roorkee, pp. 43-48, December 2016.

[6] Drane, C, and S. Lele, "Gain enhancement for linear endfire arrays of dipoles fed by interconnecting transmission lines," Antennas and Propagation Society International Symposium IEEE, Seattle, vol 17, pp. 649-651, June 1979.