Investigation on Various antenna design techniques for Vital Signs Monitoring

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Abstract*—There have been a wide range of research activities to develop non-contact methods for vital signs monitoring. Various types of antennas have been investigated and successfully utilized covering wide range of frequencies. Different frequency band ranges such as MedRadio: 401-402 MHz and 405-406 MHz for narrow band less than 100kHz, Medical Implant Communications Service (MICS): 402-405 MHz for bandwidth less than 300kHz, Industrial Scientific-Medical (ISM): 902-928MHz, 2.4 to 2.4835 GHz, 5.725 to 5.875 GHz, for bandwidth more than 500kHz, UWB: 3.1 to 4.9 GHz or 6 to 10.6 GHz, and Millimetre-wave (MMW) 30 to 300GHz frequencies have been used in antennas design. Designing an antenna for radar-based sensor system used on vital sign monitoring is a challenging task, as the antenna needs to fulfill several fundamental requirements, such as optimized characteristics in frequency-and time-domains, small size and low profile, good frequency propagation. In this work, we present a review on the various antenna design techniques for vital signs monitoring.

***Keywords*—Vital signs; heart rate; respiration rate; antenna structure; frequency band.**

I. INTRODUCTION

Remotely non-contact monitoring of vital signs using Doppler radar is a more convenient way to check the vitality signs of a person as compared to the traditional vital sign monitoring devices, such as electrocardiogram (ECG), pulse oximetry and capnography, because these traditional devices need direct sensors plantation on the subject body as well as they consume comparatively much longer implementation time to start the measurements [1].

Most of the review papers on radar-based sensor system for vital signs detections have been reported, however the reported review papers doesn't focus on antenna design part, and recent years many types of antennas with different structure, good antenna performance, designed at different frequencies band have been reported [5-14], therefore there is a need to review this part of the sensor as it play a crucial role on the sensors performance.

Remote vital signs monitoring system leads to several potential applications not only in hospital applications, but also in searching for survivors after earthquake [2]. In addition, during catastrophes such as avalanche, typhoon, and tsunami which cause the building collapse or other accidents resulting in people trapped, remotely vital signs equipment will be needed to search people who are buried as quickly as possible, also can be used in security and defence sectors [3].

Radar-base sensor systems for vital signs detection involve several parts; antenna is one part of the sensor to operate. However designing of an antenna for vital signs detections is a challenging task as antenna needs to fulfill several fundamental requirements.

In the recent years, many research has been conducted to improve the accuracy of the remote vital signs monitoring by employing various antenna techniques and using different frequencies bands as in Fig.1, most of the reported practical work based on Doppler radars for remote vital signs detections are working at microwave frequency of Industrial Scientific-Medical (ISM), UWB and Millimetre-wave (MMW) band because of its small wave length, that can easily detect a small movement displacement as that of heart beat rate [4].

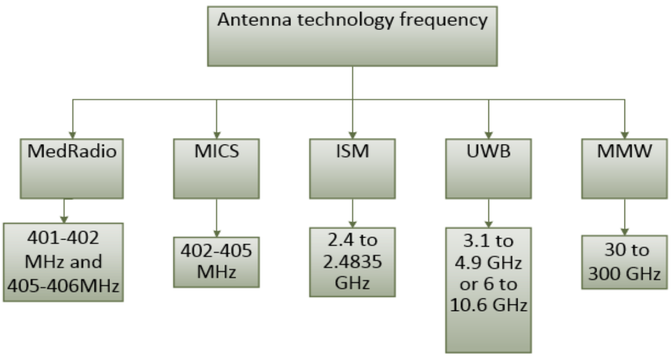

Fig 1. Different frequencies technology and their frequency ranges.

Our paper review will analyse the research development of various antenna techniques, and antenna performance designed for vital signs applications.

II. VARIOUS ANTENNAS TECHNIQUES

With an increase of different frequency band used on Radar system for vital signs detection, an increasing number of antennas, with different structures and features, have been developed, and some of the reported antenna structure for vital signs monitoring with different structure are shown in Fig 2.

A. Microstrip Antennas:

A microstrip antenna consists of a radiating patch with an electrically large ground plane separated by a dielectric material. The typical patch size is $\lambda_o/2$, where λ_o is the wavelength at the dielectric substrate. For the radiation patch, different shapes have been tested, with the rectangular and the circular patch is most commonly used. Rectangular antennas normally have lineal polarization. Microstrip antennas display a high quality factor, so their bandwidth is limited to about 5–10% of the resonant frequency.

B. Slot Antennas

The slot element is made by eliminating the pertinent metal on the metallic side, with a typical size $\lambda o/2$. The most common shapes in slot antennas are rectangular and ring. H. Cheng et al. have tested a rectangular slot antenna integrated with a resonator structure based on an alumina substrate. A miniature C-shape slot antenna loaded with a shorting post and a high efficiency and compact rectenna (rectifying antenna) based on an annular ring slot antenna for circular polarization in the Industrial Scientific-Medical (ISM) band also have been developed for vital sign detection.

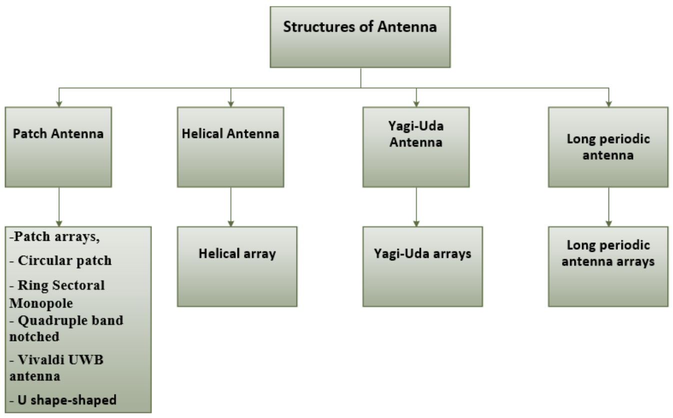

Fig 2. Summarized block for antenna techniques design for vital sign detections.

C. Dipole antennas

Dipole antennas consist of two radiating elements (arms of the antenna), fed in opposite phases. The antenna arms can be located on the same side of the substrate or on different sides. Depending on the location of the arms, different kinds of feeding schemes can be found; the most used being coplanar waveguide lines, quarter length lines balun or direct feed by soldering the coaxial connector on top and bottom sides of the substrate. For sensor applications, dipole antennas have been mainly used not only on-body communication but also in network communication nodes.

D. Monopole antennas

Monopole antennas consist of only one resonant element directly fed with a transmission line. With an appropriate design procedure some monopole antennas can provide a wider bandwidth than dipole antennas. This behavior makes monopole antennas suitable for compact and wideband applications.

E. Arrays antennas

Some sensor applications require high gain antennas in order to enlarge the communication distance or to concentrate the radiation beam onto a specific point. In these cases, arrays of planar antennas are considered for providing very directive antennas. The main disadvantage of arrays is the final size of the antenna, so high frequency applications like radar are the typical uses.

F. Helical antennas

Helical antennas is another basic, simple, and practical configuration of an electromagnetic radiator that of a conducting wire wound in the form of a screw thread forming a helix. In most cases the helix is used with a ground plane. The ground plane can take different forms. Typically the diameter of the ground plane should be at least $3\lambda/4$. However, the ground plane can also be cupped in the form of a cylindrical cavity or in the form of a frustrum cavity.

III. ANTENNAS ANALYSIS AS DEPLOYED IN VITAL SIGNS DECTION

Table. 1 lists a summary of some of the antenna that have been reported for vital signs monitoring, showing their resonating frequencies, band width, antenna size, antenna gain, return Loss S11 and its references papers**.**

Table 1. Some of the antenna that has been reported for vital signs monitoring.

Antenna type		**Antenna Size (mm)**	**Resonant Freq.** (GHz)	**Antenna Gain (dBi)**	**Antenna Band Width (GHZ)**	**Return Loss S11 (dB)**
Patch Antenna	2 x 2 patch antenna array[5]	0.52 × 0.58	5.8	10.77	0.001	- 26
	2 × 4 slot array Antenna [6]	25 × 24	2.4	12.2	0.21	-
	4 by 5 elements Array Antenna [7]	5 X10	24	17.1	1	-
	6 × 2 patch elements [8]	-	60	13.9	4.62	-
	2-by-2 patch arrays	-	5	9	-	-
	Planar Inverted F Antenna (PIFA) [9]	63 × 34	1.914 &2.45	-	-	−25.60 & −30.38
Helical Antenna	Axial-Mode [10]	8-turn	2.4	9.80	-	-
	Helical Arrays Antenna [11]	-	2.457	31	-	
	Dual helical antenna[12]	4 –turns	2.460 & 2.510	-	-	-
Yagi-Uda Antenna	Yagi patch [13]	120x80	2.45	8.96	50	-22.87
	Yagi antenna[14]	-	2.4	7.7	-	-22.7

Patch antenna as in the Table. 1 shows a remarkable trend on antenna designs that have reported for vital signs application by having many types of patch antenna structure with different frequencies. Frequency bands around 2.4GHz, 5.8GHz, 24GHz and 60GHz and good antenna gain around 9dBi to 17dBi with a return loss less than -10dB have reported on this type of antenna, and almost cover the whole range of frequencies that have been proposed to be used in vital signs detection such ISM, UWB and MMW.

Helical antenna with different model design such as axial-model have also reported for vital signs detection, the frequency band at 2.4GH, 2.46GHz and 2.5GHz with different number of turns, good antenna gain with return loss value less than -10dB have been reported as can be seen in Table 1.

Yagi-Uda antenna structure have also proposed for vital signs detections, the frequency ranges around 2.4GHz and 2.45GHz, good band width around 50MHz, antenna gain of around 8dBi and return loss less than -10dB have been report as can be in Table 1.

From the Table.1, antenna design for vital signs detection should consider the frequency that is to be used in designing, as an antenna play a crucial role for the sensor to operate, recently millimetre-wave frequencies have shown interest for many researchers on antenna design for a remote vital signs monitoring. The main motives of MMW frequencies include (i) improvement in the detection accuracy by employing shorter wavelength of the signal, (ii) smaller form factor for the device compactness and (iii) possibility of more subject focused signal transmission and reception to avoid the interference from the unwanted side reflections.

IV. Conclussion

This article presents a review on various antennas that have been reported on vital signs monitoring. Designing an antenna for Doppler radar plays a crucial role in vital sign monitoring. The antenna should be designed in such a way that it only focuses the radiation beam on the subject and should have an adequate gain to maintain a required signal to noise ratio.

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).

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