Non-Contact Vital Signs Monitoring in Broiler Chickens

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Abstract: Measuring the heartbeat and respiration of animals continuously can provide valuable information about their health status. Respiratory-related diseases are very common in the poultry industry and unfortunately, there is no non-contact respiratory monitoring system for measuring the breathing rate and heart rate of the broiler chicken. In this letter, we explored and tested the feasibility of utilizing a 24 GHz on-shelf Radar module for monitoring the vital signs (breathing rate and heart rate) of broiler chickens. A signal processing approach has been developed to extract vital signs of broiler chicken from Radar-captured signals. The experiment was carried out on three different normal broiler chickens with the age of 25-30 days, weight 1.18-1.6 Kg where a 24-GHz radar module was mounted at a distance of 0.2 meters above the chest surface of the chicken, and this particular experiment was repeated for twenty times. We also used a reference ECG module (Biopac System) for extracting the breathing rate and heart rate of the broiler chicken and compared the accuracy of our proposed system. Experimental results demonstrated that the radar measurement closely matches the Biopac ECG acquisition module measurement and showed an accuracy of 96% for a short-scale study.

Introduction: 40% of the total protein consumed globally comes from broiler chickens [1]. The poultry industry is one of the largest and fastest-growing industries for the need for protein consumption [2]. According to the "Poultry Global Market Report 2022," this particular industry has a $350.87 billion market value and a 10.1% yearly growth rate [3]. Unfortunately, there is not that much importance in monitoring the health status of broiler chickens. Due to Virulent Newcastle Disease (known as Ranikhet), about 32.5% of broiler chickens die annually, and the mortality rate of broiler chickens due to this disease is around 80-100% [2]. It has been proven in the study that the virulent Newcastle disease affected broiler chicken breathing rates, and heart rates became faster than normal broiler chickens [4]. Sudden Death Syndrome (SDS), Chronic Heart Failure (Hypoxemia, Ascites) are also heartbeat-related diseases in broiler chickens [5]. Monitoring vital signs such as heart rate and breathing rate of broiler chickens can provide valuable information on the health status of the chicken [6]. Traditional methods of vital signs monitoring of chickens are all contact-based means a sensor needs to be placed on the body surface, which is uncomfortable, and sometimes skin irritation also takes place. For example, one of the common techniques for monitoring breathing rate and heart rate is an electrocardiogram (ECG) which is directly related to the skin contact of the body surface of a broiler chicken [7]. As all the traditional method of monitoring the vital signs of broiler chicken is contact-based so, it is not possible to monitor vital signs continuously. Thus, an innovative non-contact sensing technology is required for continuous monitoring of different vital signs such as breathing rate and heart rate. Prior research demonstrated the feasibility of utilizing frequency-modulated continuous wave (FMCW) radar for vital signs monitoring of cows [8], and ultra-wideband (UWB) radar for vital signs monitoring of cats, dogs [9], and continuous wave (CW) radar for vital signs monitoring of aquatic animals such as fish [10]. However, to the best of our knowledge, none of the work is focused on utilizing CW radar for vital signs monitoring of

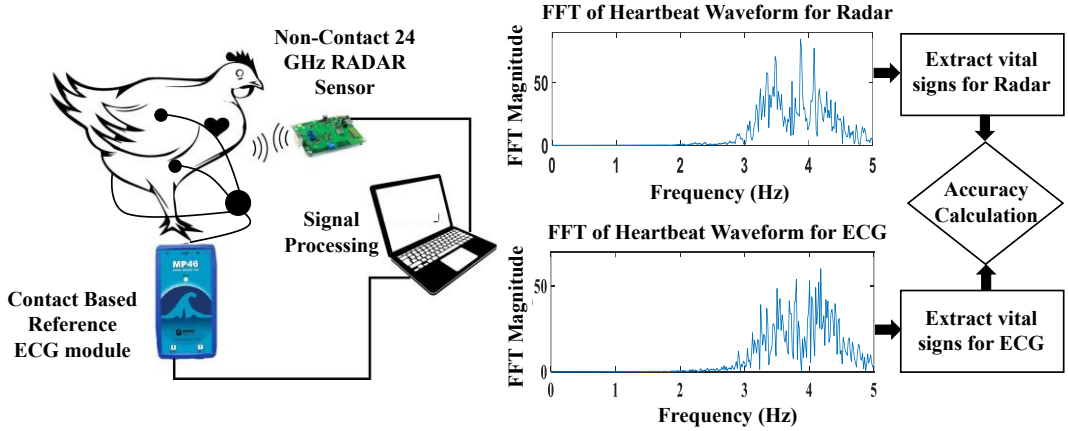

Fig. 1 *Block diagram of the proposed system. The system consists of a 24-GHz radar module and reference sensor (Biopac EGC system). After capturing data using both types of sensors, the result was compared with the Radar extracted vital signs and Biopac extracted vital signs.*

broiler chickens. In this work, we focused on utilizing a 24-GHz continuous wave (CW) Radar module for extracting the vital signs of broiler chickens. The goal of this research effort is to demonstrate the efficacy of Radar technology for monitoring the vital signs of broiler chickens without attaching any electrodes to the body surface of the chicken. A signal processing approach has been designed in Matlab to handle radar data for extracting reliable vital signs (BR, HR) of broiler chickens. The graphical abstract of our proposed system is shown in Figure 1. Here a non-contact 24 GHz CW Doppler radar transmits an electromagnetic signal. This signal is being reflected from the broiler chicken. The reflected signal is received by the radar transceiver. Then the reflected signal is processed in Matlab software and the developed algorithm extracts the heart rate and breathing rate spectrum. To test the feasibility and accuracy of our proposed non-contact radar system, we also used a contact-based Biopac ECG acquisition system as a reference and then compared it with the radar-captured

Experimental Setup and Data Acquisition: According to the Doppler theory, the phase change of the reflected signal is directly proportional to the tiny movement of the chest surfaces of the broiler chicken due to cardio-respiratory activities [6]. The 24GHz CW radar module, named KLC-1a radar transceiver, was connected to the X1 channel of the ST100 starter kit, and a USB cable was inserted between the ST100 and the laptop, which supplied power to the radar module from the computer. The ST100 Staterkit is the core controller of the radar system, which communicates with the KLC-1a radar module via a channel and receives raw radar data in real-time [11]. The KLC-1a transmits a signal of a 24 GHz carrier frequency and receives the reflected signal from the broiler chickens with a delay. The received signal is digitally converted to a time domain signal. The ST100 stater kit channels are associated low-noise amplifier, so the signal is received in a controlled way. We performed this experiment on Three broiler chickens. At the time of our experiment, the weight of those chickens was 1.18kg to 1.60kg, and the age range was 25 days to 30 days. The chickens were conscious when the experiment was going on. The KLC-1a radar module was placed in a line-of-sight alignment with the broiler chicken's heart position. The distance between the broiler chicken's heart and the KLC-1a radar module was 18cm. We recorded signal data repeatedly for each broiler chicken. For each chicken, we recorded data 20 times. Each time we record data for 1 minute so that we can analyze this data for more breathing cycles of the broiler chicken. An interval of 2-10 minutes was given for recording each data. The data was recorded when the broiler chicken was held tight at the time of recording data so that it can not move. This animal study performed in this work was approved by the Ethical Review Committee of the Faculty of Biological

(a) (b)

Fig. 2 *(a) Experiment conducted on a broiler chicken using a Radar system (basically KLC-1a antenna mounted on ST 100 Starterkit) where the broiler chicken is placed 18 cm distance from the module (b)* Data collection using the ECG system where the three electrodes are connected to the different parts of the broiler chicken through electrode pads

Sciences, University of Dhaka (Project number: 201). Fig. 2 illustrates the data recording process of monitoring the vital signs of broiler chickens.

Results: We collected data from broiler chickens using 24-GHz radar. The data was recorded more than 20 times for each broiler chicken with 1 minutes window. We filtered the collected data to remove the background noise signal and extract the heartbeat waveform. This signal is filtered by using a Butterworth bandpass filter. The frequency range of the Butterworth bandpass filter was 3.3 Hz to 4.4 Hz for heartbeat extraction. We filtered the signal collected by RADAR and the BIOPAC ECG system irrespectively. Figure 3 illustrates the heartbeat waveform extracted by the Radar module and Biopac ECG acquisition system.

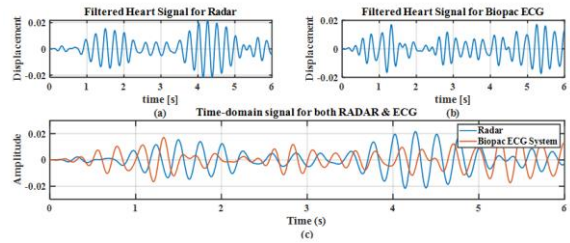

Fig. 3 (a) Filtered heartbeat waveform from RADAR captured signal (b) Filtered heartbeat waveform from BIOPAC ECG system(c) Heartbeat waveforms drawn together both from Biopac ECG system and Radar.

After filtering the heartbeat waveform in the time domain we performed the fast Fourier transform (FFT) to extract the heartbeat from the radar-captured and Biopac ECG acquisition system. From Figure 4, we can see that the

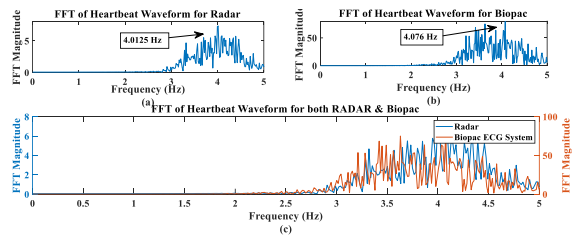

Fig. 4. *FFT spectrum (a) from Radar (b) Biopac ECG acquisition system (d) both Radar and Biopac.*

heartbeat in frequency is 4.0125 Hz which is 240.75 beats per minute using the Radar module, and the heartbeat in frequency is 4.076 Hz, which is 244.54 beats per minute using the Biopac ECG acquisition module. The extracted heartbeat waveform from the Radar and Biopac ECG acquisition system is closely matched. Table-I illustrates the summary of twenty measurements of the same broiler chicken where the highest error rate was 3.96%.

***Table I:* Results for Heart Rate measurement collected from the same Broiler Chicken**

Sample No	Heart rate from ECG (Hz)	Heart rate from Radar (Hz)	Heart rate ECG (BPM)	Heart rate from Radar (BPM)	Percentage of error (%)
Sample 1	4.20	4.16	252.55	249.87	1.06
Sample 2	4.07	4.09	244.78	245.92	0.46
Sample 3	3.63	3.59	218.30	215.97	1.06
Sample 4	4.17	4.29	250.63	257.59	2.77
Sample 5	4.17	4.17	250.68	250.32	0.14
Sample 6	4.07	4.12	244.65	247.68	1.24
Sample 7	3.88	3.91	233.16	234.81	0.70
Sample 8	3.52	3.54	211.68	212.41	0.34
Sample 9	4.07	4.01	244.57	240.75	1.56
Sample 10	4.18	4.22	251.20	253.44	0.89
Sample 11	3.84	3.81	230.65	228.90	0.75
Sample 12	3.76	3.74	225.84	224.65	0.52
Sample 13	4.17	4.12	250.74	247.26	1.39
Sample 14	3.58	3.58	215.31	214.99	0.15
Sample 15	3.99	3.99	239.56	239.76	0.08
Sample 16	3.96	3.90	237.61	234.18	1.44
Sample 17	3.85	4.00	231.48	240.53	3.90
Sample 18	3.63	3.72	218.17	223.21	2.31
Sample 19	3.41	3.47	204.86	208.63	1.84
Sample 20	4.19	4.12	251.85	247.26	1.82

Conclusion: In this letter, we investigated the feasibility of utilizing non-contact 24-GHz radar sensors for monitoring the vital signs of Broiler chickens. To the best of our knowledge, this is the first report on using Radar sensing technology for monitoring the heartbeat of a broiler chicken. We also compared the accuracy of heartbeat calculations from the Radar signal and the Biopac ECG acquisition module. Our short-scale repetitive measurements indicate that the accuracy of the proposed Radar system is almost 96% in comparison with the Biopac ECG acquisition system. A large-scale study in a poultry farm for a variety of broiler chicken species remains our ongoing work.

References:

1. B. Sharratt and B. Auvermann, “Dust pollution from agriculture,” in *Encyclopedia of agriculture and food systems*, vol. 2, MA, Elsevier Academic Press Cambridge, 2014, pp. 487–504.
2. M. S. Rahman, M. G. Rabbani, M. J. Uddin, A. Chakrabartty, and M. Her, “Prevalence of Avian Influenza and Newcastle Disease Viruses in poultry in selected areas of Bangladesh using rapid antigen detection kit,” *Arch. Clin. Microbiol.*, vol. 3, no. 1: 3, pp. 1–8, 2012.
3. Research and markets, “No TitlePoultry Global Market Report 2022.” [Online]. Available: https://www.prnewswire.com/news-releases/poultry-global-market-report-2022-301584528.html
4. D. E. Swayne, “Pathobiology of H5N2 Mexican avian influenza virus infections of chickens,” *Vet. Pathol.*, vol. 34, no. 6, pp. 557–567, 1997.
5. B. Lupiani and S. M. Reddy, “The history of avian influenza,” *Comp. Immunol. Microbiol. Infect. Dis.*, vol. 32, no. 4, pp. 311–323, 2009.
6. X. Hui and E. C. Kan, “No-touch measurements of vital signs in small conscious animals,” *Sci. Adv.*, vol. 5, no. 2, p. eaau0169, Feb. 2019, doi: 10.1126/sci-adv.aau0169.
7. P. Kneis and R. Siegmund, “Heart rate and locomotor activity in fish: Correlation and circadian and circannual differences inCyprinus carpio L.,” *Experientia*, vol. 32, no. 4, pp. 474–476, 1976.
8. S.-A. Tuan, D. J. A. Rustia, J.-T. Hsu, and T.-T. Lin, “Frequency modulated continuous wave radar-based system for monitoring dairy cow respiration rate,” *Comput. Electron. Agric.*, vol. 196, p. 106913, 2022.
9. P. Wang *et al.*, “Non-contact vital signs monitoring of dog and cat using a UWB radar,” *Animals*, vol. 10, no. 2, p. 205, 2020.
10. N. Hafner, V. Lubecke, D. Garmire, A. Ohta, G. Sasaki, and J. Drazen, “DOPPLER RADAR SENSING OF FISH PHYSIOLOGICAL MOTION,” Ph.D Dissertation, University of Hawaii at Manoa, 2012.
11. [online] https://rfbeam.ch/product/k-lc1a-radar-transceiver/