Microwave Based Life Detection System for Post-Disaster Rescue Operations

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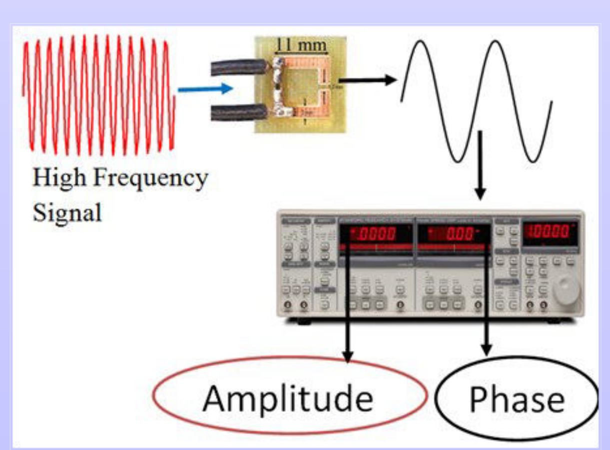
Introduction

Currently, rescue teams rely on sniffer dogs, CO_2 detectors, and thermal imaging cameras to detect people trapped under rubble/snow due to an earthquake/avalanche. However, all these techniques have limitations in case the person is unconscious and unresponsive.
To improve life detection in case of disasters, efforts are being made to develop a portable non-contact microwave based system to detect breathing and heartbeat for search and rescue operations.
The basic physical principle of a microwave based life detection system is that transmitted microwaves undergo phase modulation due to the pulse or respiration of the human being. These phase modulated microwaves are then reflected back and by measuring their phase and amplitude, the frequency and amplitude of heartbeat and respiration can be determined.

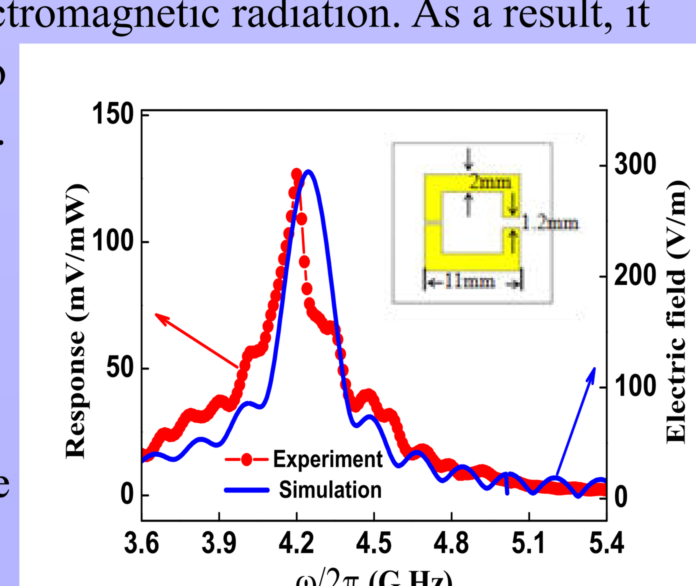
Innovation for Sensitivity Enhancement

- A **split ring integrated sensor** is used to convert the high frequency reflected signal to a low frequency signal by interference between the reflected and reference microwaves. The split ring integrated sensor is operated at resonance in order to enhance its sensitivity.
- The phase and amplitude of the down converted signal is then measured in real time by a lock-in amplifier with high sensitivity.



What is a Split Ring Resonator?

A split ring resonator is a meta material that can be oriented such that it is excited by both the electric and magnetic fields of the incident electromagnetic radiation. As a result, it produces a strong induced current that enables it to either enhance or oppose the incident radiation [3]. Hence, at resonance a split ring based sensor can provide high sensitivity for measurement.
The split ring resonator used for our experimental purpose was fabricated using the CST software, and had a square loop made of copper on a FR-4 substrate with a Schottky diode placed between the gap. This split ring resonator has a resonant frequency at 4.2 GHz as shown by the experimental and simulated results on the right.



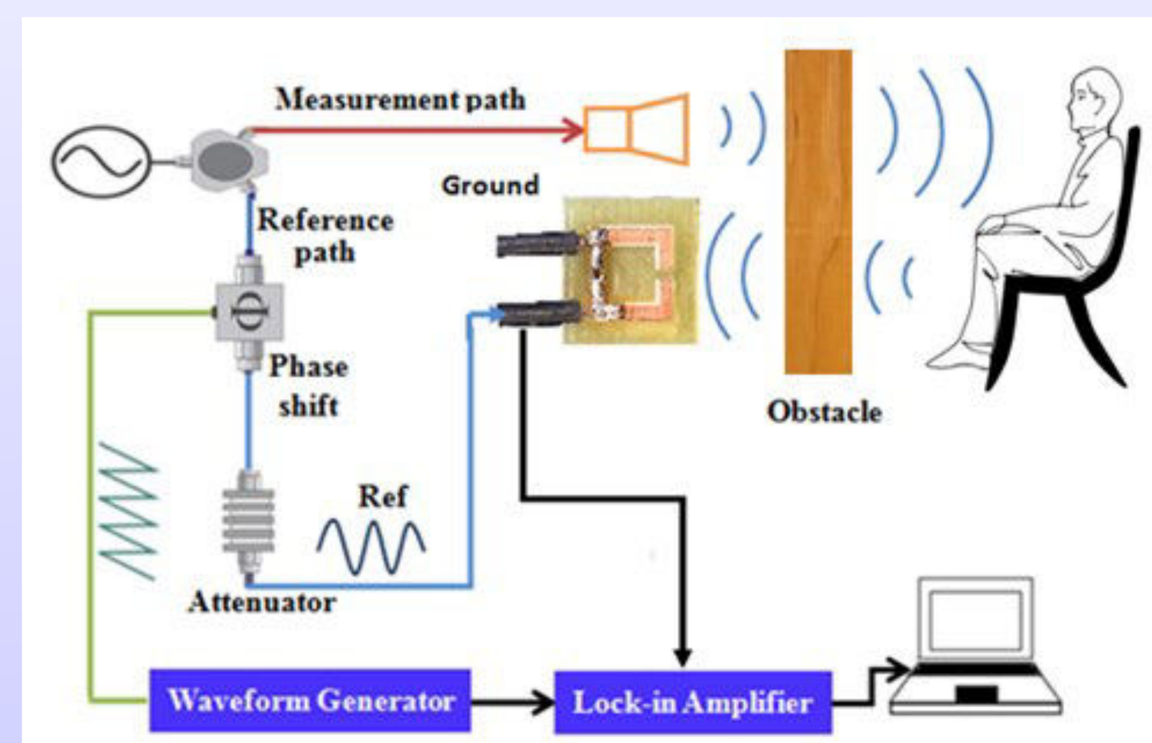
Theoretical Model

If we assume the displacement of the chest due to breathing and/or heartbeat to be given as z(t) = Asin(f t) where A is the amplitude of oscillation of the chest and f is the frequency of breathing or heartbeat. Then the phase modulation of the reflected microwaves (with wavelength λ) due to the periodic movement of the chest is given by

$$\Delta\varphi = \frac{A \times 8\pi}{\lambda}$$

We can measure this phase difference using a lock-in amplifier using a phase resolved sensor technique as developed by Yao et al [5]. The frequency of oscillation can then be determined by performing a Fast Fourier Transform (FFT) on the phase data to convert it from time domain to frequency domain.

Experimental Setup

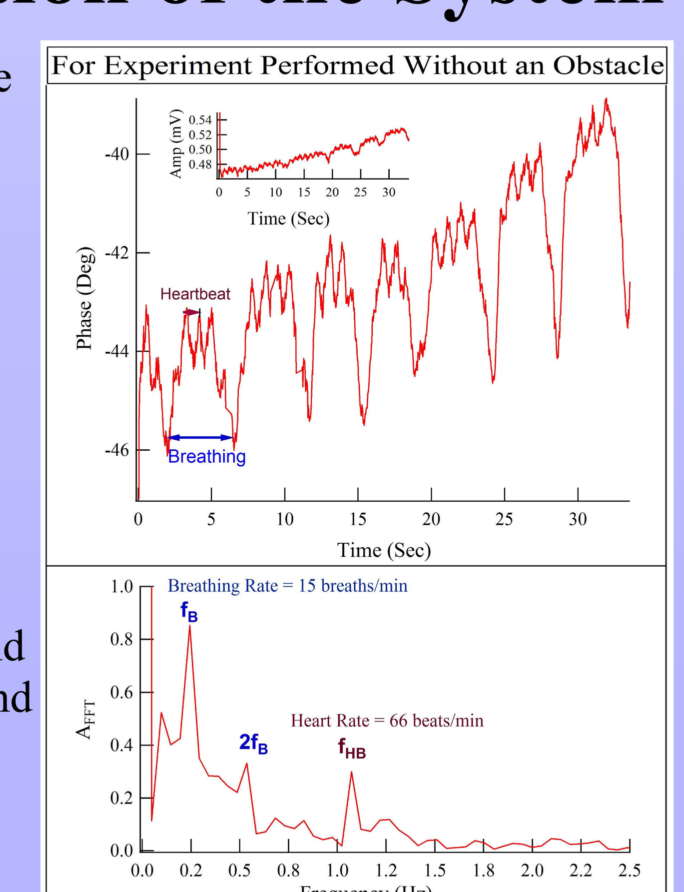


The above figure shows the experimental setup used to measure the frequency and amplitude of heartbeat and respiration of the test subject with an optical obstacle (piece of plywood) placed between the subject and the microwave sensor and transducer. The waveform generator controls the phase shifter and introduces a phase difference between the reflected and reference microwaves that undergo interference at the sensor.

Displacement Resolution of the System

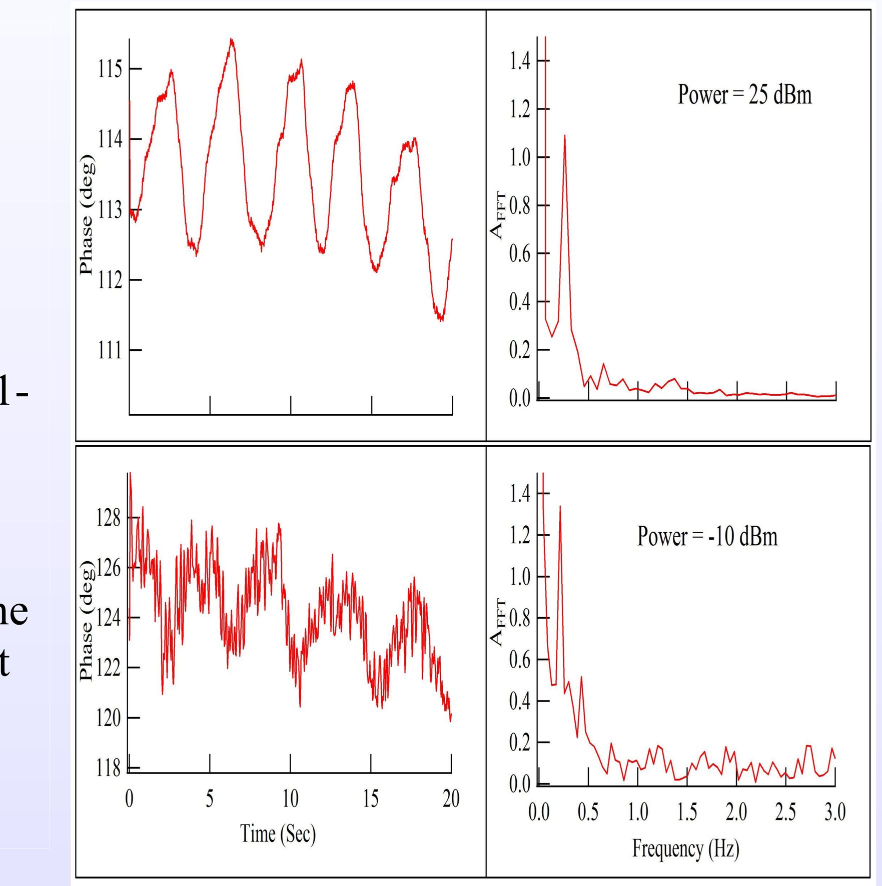
The results obtained from the plots shown on the right can be summarized as follows:-

- The inset shows the plot of amplitude of the reflected microwaves, which shows the breathing signal.
- The plot of phase data shows the heartbeat signal superimposed on the breathing signal.
- **The phase data has a resolution of 0.5° which corresponds to a displacement of 50 µm.**
- The displacement of chest due to breathing and heartbeat is calculated to be (2.4 ± 0.8) mm and (0.3 ± 0.1) mm respectively.



Sensitivity and Microwave Power Dependence

- Right panel shows the phase data and the corresponding FFT results obtained at different microwave powers.
- Signal noise decreases as the microwave power increases.
- For microwave power between (0.1-1.0) Watt the phase data clearly shows the breathing signal.
- It is estimated that at 1 W microwave power, we can detect the breathing frequency even if the test subject is **40 m** away from the microwave sensor and transducer.



Conclusions

Non-contact microwave based life sign detection system has been successfully developed using a split ring integrated solid state sensor.

- This system has a resolution of 50 µm for measuring chest displacement due to breathing and heartbeat.
- The current experimental setup has the ability to detect breathing and heart rate at a distance of up to 40 m between the test subject and the microwave transducer.

Future Work

A portable system can be designed for practical applications in area of search and rescue operations due to the small size and high sensitivity of the split ring integrated solid state sensor.

Acknowledgments

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References

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