Research Article

A MODERN MICROWAVE LIFE DETECTION SYSTEM FOR HUMAN BEING BURIED UNDER RUBBLE

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ABSTRACT

“Thousand of persons killed as a cause of earthquake”. The above words aren’t the headlines of the newspaper but such news come after the disaster destroyed the field. The disaster in the New York City at ‘World Trade Center’ claimed lives of more than 5000 people. It was said if survivors has been found and rescue earlier the numbers of victims have been lower. There is no end to the number of lives lost as the result of such disasters as landslides, collapsed tunnels and avalanches.

The microwave life detection system is develope for the search and rescue of victims trapped under the rubble of collapsed buildings. The proposed system utilizes L-band frequency which is able to detect respiratory and heart fluctuations. The operation principle is based on Doppler frequency shift of the electromagnetic wave reflected from the buried victim. The schematic diagram of microwave Transmitting/Receiving (T/R) and clutter cancellation subsystem are included in this report. In this report various parts of a microwave life detection system such as antenna, directional coupler, and splitter has been discussed. By advent of this system the world death rate as a cause of an earthquake may decrease to greater extent.

KEYWORDS Life under rubble, modulation due to body oscillations, Doppler shift, dual antenna system, clutter signals.

1. INTRODUCTION

Most of the victims of earthquake or other natural disasters in the various parts of the worlds are trapped under rubble of the collapsed buildings. A detection of the victims can save his life. As in the radar application, the phase of the incident wave can be changed due the body vibrations. Depending upon this fact “A Revolutionary System to Detect Human Being Buried under the Rubble” used to trap the buried victims under earthquake rubble or collapsed buildings by the utilization of microwave radio frequency has been design.

1.1 Need of life detection system over conventional system

Existing ways to detect the human being under the earthquake rubble and collapsed buildings are utilization of the dogs, optical devices and acoustic life detectors and the rescue robot [1]. But the dogs can detect the dead persons and this occupies the precious time which can be utilize to detect alive victims. Also, the optical devices have a limited number of degree of freedom, require expert operators and cannot be used in inaccessible area. Acoustical detectors such as geophones are simple to understand but they require quiet working environments, a condition difficult to reach especially in critical situations [2]. The Rescue Robot can navigate deep into the rubble to search for victim by the use of temperature sensor but they are unable to trap once they go out of range.

Information about the location of buried person would be of great value for the rescue personnel, since it would help to reduce the time of operation and thus, help to save more lives. There is a need to construct a life detection system which can detect buried victims under earthquake or building debris most efficiently and as possible in short time. Such kinds of problems have been efficiently solved considering continuous wave or ultra wideband radars which offer good localization and spatial accuracy.

In rescue mission and also in some surveillance operations there is not only the need of detect life signals but also the identification of people in a given area, to facilitate rescue team operations in case of emergencies. This task can be complied with through the wall surveillance techniques.

1.2 Principle of Working:

The principle of detection is firstly, microwave is sent through rubble to detect vital signs of life. Microwave is having the property to penetrate through barriers and would reflect back from some objects. These objects include humans. When the beam hits the body, the signal reflected with an additional modulation created by movement of heart and lungs. So, the reception of modulated signals shows the presence of alive human inside the rubble.

With the modulated signal there are some signal (commonly known as clutter signal) which are reflected from the immobile object such as rubble or debris. Thus in order to maintain a high sensitivity for this application, the clutter wave reflected from the rubble or the surface of the ground has to be cancelled as thoroughly as possible. For this an automatic clutter cancellation system is used. A microwave life detection system operated on the radio frequency was proposed in the 1985 [3]. This system detects the body oscillations occur due the breathing and heartbeat fluctuations. The system includes the additional subsystem to cancel the unwanted signals receive from the motionless objects such as rubble.

1.3 Frequency Bands:

The microwave life detection system can works on different range of frequencies from L-band (2GHz) to X- band (10GHz). But X-band microwave is unable to penetrate deep into the rubble. It can penetrate rubble up to 1.5 ft in the thickness (5 layers of bricks)
while L-band can penetrate the rubble of about 3 ft in thickness (10 layers of bricks)\(^{[5]}\). Due to the fact that lower frequency will be more capable of detecting vital signs through very thick rubble, so frequency of an electromagnetic wave needs to be in the L-band or S-band range. For this reason, a microwave life detection system which operates on the L-band frequency. This system is supposed to quite efficient to trap the breathing and heartbeat signals of victims who are completely trapped and too weak to respond.

**2. LITERATURE REVIEW**

Images of events causing damage in which people have been trapped or buried under rubble serve as constant reminders of the vulnerability of the places where we live and work. To conduct rapid rescue operations, emergency forces all over the world need timely information on the exact position of people trapped or buried under rubble, information on the risk of collapse of debris and standardized intervention procedures as well as information on the state of the victims’ health.

**2.1 History**

Collapse of man-made structures, such as buildings and bridges, occur with varying frequency across the world. In such a case, survived human beings are often trapped in the cavities created by collapsed building material. The concept of microwave life detection system was emerged with the development in the systems for rescue operation. Initial dogs were used to detect presence of human then acoustic detectors and robot radar come into existence. But these systems are having major drawbacks. The history of “Revolutionary System to detect Human Being Buried Under the Rubble” starts with K. M. Chen who brings out the concept of detection of buried victims using microwave beam in 1985\(^{[4]}\). After the detailed study of microwave signals and Doppler’s effect, Ku Mem chen had been proposed including the basic principle for the operation of life detection system in 1991\(^{[5]}\). A Low Power Hand-Held Microwave Device for the Detection of Trapped Human Personnel by W. S. Haddad in 1997\(^{[6]}\). The device, called the Rubble Rescue Radar (RRR) incorporates Micropower Impulse Radar technology which was developed at Lawrence Livermore National Laboratory over the few years. In 2003 P. K. Banerjee and A. Sengupta proposed the basic block diagram for the clutter cancellation system. In 2004, there was a concept of three band radar system proposed by M. Bimpas\(^{[7]}\).

The researcher put their effort to study the various effect various bands of microwave signals and depending upon this, a system which detect human being with ka-band with double sidebands have been proposed, in 2006. It states that a short wavelength of ka-band increases the sensitivity of antenna which will detect the small body vibration \(^{[8]}\). A paper on ‘An X-band microwave life detection system’ has been presented by Huey Ru in 2007. In this paper author present the idea of detecting human being located behind the wall using a microwave signal \(^{[9]}\). The phase change of a reflected microwave signal will provide the precious information about the buried victim’s heartbeat as well as breathing \(^{[10]}\).

A rescue radar system is proposed by M. Donelli in 2011. In radar system a SAW oscillator is used to generate 10GHz frequency signals. While receiving through patch antenna the signal is process by the ICA (Independent Component Algorithm)\(^{[2]}\).

**3. MATERIAL AND METHOD**

This section includes detail description of block diagram of “Revolutionary System to Detect Human Being Buried under the Rubble.” Also with this there is explanation of various parts of microwave system. The working of clutter cancellation system is included in this section.

**3.1 Block Diagram :**
The microwave life detection system has four major components. They are a microwave circuit which generates, amplifies and distributes microwave signals to different microwave components. A dual antenna system, which consists of two antennas, energized sequentially. A microwave controlled clutter cancellation system, which creates an optimal signal to cancel the clutter from the rubble.

**3.1.1 A Microwave Circuit:**
The microwave circuit in the fig.2 consists of phase locked oscillator, directional couplers and circulator. The phase locked oscillator is used to generate a very stable electromagnetic wave of 2GHz range. The SAW (Surface Acoustic Wave) oscillator can generates 1150 MHz frequency with output power 400mW.

Power dividers and directional couplers are passive devices used in the field of radio technology. They couple part of the transmission power in a transmission line by a known amount out through another port, often by using two transmission lines set close enough together such that energy passing through one is coupled to the other. In microwave life detection system 10 dB and 3dB couplers are used. 10dB coupler is used to divide the power into 1/10\(^{th}\) and 9/10\(^{th}\) part while 3dB coupler divides power into two equal parts.
Fig. 2. Schematic diagram of the 1150-MHz microwave life-detection system.

Fig. 3 Flow chart for antenna system
3.1.2 Antenna:
The dual antenna system has two antennas, which are energized sequentially by an electronically controlled microwave single-pole double-throw (SPDT) switch. The switch turns on and off at a frequency of 100 Hz which is much higher than the frequency range of the breathing and heartbeat signals between 0.2 Hz and 3 Hz. Thus, we can consider that the two antennas essentially sample their respective objects at the same time. In this dual-antenna system, the two antenna channels are completely independent. The algorithm and flowcharts for the antenna is as follows:

1. Initially the switch is kept in position 1 (signal is transmitted through the antenna 1)
2. Wait for some predetermined sending time, Ts
3. Then the switch is thrown to position 2 (signal is received through the antenna 2)
4. Wait for some predetermined receiving time, Tr
5. Go to step 1
6. Repeat the above procedure for some predetermined time, T.

3.1.3 A Clutter Cancellation Circuit:
In any remote sensing instrument the clutter caused by undesirable objects surrounding the detectable subject must be cancel to the optimum level. The clutter canceller forms the heart of life detection system. It consists of Programmable Phase Shifters, Programmable Attenuator, a RF Amplifier a Microprocessor based control unit.

3.1.3.1 Canceller Operation:
The clutter signal is passed through a detector as shown in fig. 4 which outputs a DC voltage of few tens mV. Then it is amplified by an operational amplifier and fed to A/D converter whose outputted to the Port A of microprocessor. The output port C and port B are connected to the phase attenuator and phase shifter respectively. The controller uses different combination of attenuation and phase shifting to achieve optimum level. The clutter cancellation circuit consists of a digitally controlled phase-shifter (0–360°), a fixed attenuator (4 dB), a RF amplifier (20 dB), and a digitally controlled attenuator (0–30 dB). The output of the clutter cancellation circuit is automatically adjusted to be of equal amplitude and opposite phase as that of the clutter from the rubble. Thus, when the output of the clutter cancellation circuit is mixed with the received signal from the antenna, via the circulator, in a 3-dB directional coupler, the large clutter from the rubble is completely canceled, and the output of the 3-dB directional coupler consists only of the small reflected wave from the subjects body. This output of the 3-dB directional coupler consists of a RF preamplifier (30 dB) and then mixed with a local reference signal in a double-balanced mixer. The other 3/4ths of the output is detected by a microwave detector to provide a dc voltage, which serves as the indicator for the degree of the clutter cancellation.
At the double-balanced mixer, the amplified signal of the reflected wave from the subject’s body is mixed with a local reference signal. The phase of the local reference signal is controlled by another digitally controlled phase-shifter (0 – 180°) for an optimal detection of respiratory rate and t is the time. When these two inputs are mixed in the double-balanced mixer, the output of the mixer consists of the breathing and heartbeat signals of the human subject plus unavoidable noise. This output is fed through a low-frequency (LF) amplifier (20–40 dB) and a bandpass filter (0.1–4 Hz) before being displayed on the monitor of a laptop computer. The function of a digitally controlled phase-shifter (0 – 180°) installed in front of the local reference signal port of the double balanced mixer to control the phase of the local reference signal for the purpose of increasing the system sensitivity.

The local reference signal is assumed to be \( A_L \cos (\Theta t + \Phi_L) \) where \( A_L \) is the amplitude and \( \Phi_L \) are the phase, respectively. While the other input to the mixer, the reflected signal from the human subject, is assumed to be \( A_r \cos (\Theta t + \Phi_r + \Delta \Phi(t)) \) where \( A_r \) is the amplitude and \( \Delta \Phi(t) \) the phase, respectively, and \( \Delta \Phi(t) \) is the modulated phase due to the body movement of the human subject. \( \Theta \) is the angular frequency and \( t \) is the time. When these two inputs are mixed in the double-balanced mixer, the output of the mixer will be

\[
A_r A_L \cos (\Phi_r - \Phi_E - \Delta \Phi(t))
\]

From this expression of the mixer output, it is easy to see that

If \( \Phi_L - \Phi_r = (n + \frac{1}{2}) \pi \), \( n = 0, 1, 2, \ldots \)

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The system has a minimum sensitivity because \( \frac{\partial}{\partial t} (-\Delta \Phi(t)) \cos (\Phi_r - \Phi_E - \Delta \Phi(t)) = \sin (\Phi_r - \Phi_E - \Delta \Phi(t)) \). \( \Delta \Phi(t) \) is usually a small phase angle perturbation created by the body movement of the human subject. \( \Phi_E \) is the constant phase associated with the reflected signal from the human subject and it cannot be changed \( \Phi_L \). is the phase of the local reference signal and it can be controlled by the digitally controlled phase-shifter (0 – 180°). In the operation, the phase-shifter will automatically shift \( \Phi_E \) in such a way that \( \Phi_L - \Phi_r \) is nearly \((n + \frac{1}{2}) \pi \) to attain a maximum system sensitivity.

The microprocessors control circuit and the LF amplifier/filter circuit of the microwave life-detection system are described in detail elsewhere.

4. MODULATION

The microwave beam incident into the rubble gets phase modulated due to body vibration. The phase modulation is occurs according to the Doppler Shift. The use of Doppler radar was demonstrated for detection of respiratory rate \(^{[10]}\), and heart rate \(^{[9]}\), using commercially available waveguide X-band Doppler transceivers.

4.1 Doppler Shift Effect:

When a source generating waves moves relative to an observer, or when an observer moves relative to a source, there is an apparent shift in frequency. If the distance between the observer and the source is increasing, the frequency apparently decreases, whereas the frequency apparently increases if the distance between the observer and the source is decreasing. This relationship is called Doppler Effect (or Doppler Shift) after Austrian Physicist Christian Johann Doppler (1803-1853).

By the Doppler Effect, microwave beam reflected from a moving surface undergoes a frequency shift proportional to the surface velocity. If the surface is moving periodically, such as the chest surface of person due to breathing, this can be termed as a phase shift proportional to the surface displacement. If the movement is small compared to the wavelength, the system will mixed received signal with transmitted signal which gives output proportional to the body oscillation of human subject. Fig.5 illustrates this concept. Internal body reflections are greatly attenuated and will not be considered here. We assume that a continuous wave (CW) radar system transmits a signal of frequency \( f \). The actual working of Doppler shift starts with reflected beam from a target at a distance \( d \), with a time-varying displacement given by \( x(t) \).

![Fig. 5. Vital signs remote monitoring Doppler radar system](image-url)

Doppler radar shown in Fig. 5 is a single channel, direct conversion, CW radar. Major limitations of the single channel configuration is detection sensitivity to target position due to a periodic phase relationship between the received signal and local oscillator, resulting in “optimum” and “null” extreme target positions.

5. RESULT

A several experiments are performed with the life detection system. Various layers of bricks were used to simulate the thickness W of rubble or barrier and the distance between the victim and the barrier of rubble D was a variable parameter for the experiment. In the graphs, the heartbeat signal (when the human subject holding his breath), the breathing signal, and the background noise were include. Firstly, the heartbeat and breathing signals were detected for each position. When the thickness of this wall increases to eight layers (about 90 cm), the performance of the L band life-detecting system became marginal. For the distance D =16 m, the
system was marginal. Fig.6 to Fig.12 is the Fast Fourier Transform (FFT) of the time-domain signal, which shows the frequency components of the time-domain signal. Fig.7 to Fig.9 show the same result performed on the same distance D for the different thickness as shown respectively. The frequency domain FFT results show the peaks of heartbeat signal (0.8 Hz to 2.5 Hz) and breathing signal (0.2 Hz to 0.5 Hz). Other small peaks are probably due to noises or the second harmonic of the breathing signal. When all these result were compared it is found that the amplitude of the breathing signal is becoming smaller with the increase of the wall’s thickness. The heartbeat signal peak also decreases with the increase of the wall’s thickness. Fig.10 to Fig.12 show the FFT results behind the same wall. The distance (D) is 4m, 8m and 12m accordingly. It can be concluded from the result, thickness affects breathing signal whereas distance D affects heartbeats signals. The L band system performs better enough for remotely buried victims signals. Our experiments prove that a buried victim can be efficiently detected using lower band frequency.
Fig. 8 Frequency spectrum of breathing and heartbeat, D=1m, W=48cm

Fig. 9 Frequency spectrum of breathing and heartbeat, D=1m, W=60cm

Fig. 10 Frequency spectrum of breathing and heartbeat, D=4m, W=24cm
DISCUSSION
This section includes the advantages, disadvantages, application and future scope of the life detection system.

6.1 Advantages
- Remote life sensing could be a powerful tool in applications where it is not desirable to disturb a subject’s physiological and/or emotional state during detection or in other situations where access to the subject is limited.
- The frequency 2.45 GHz i.e. L-band frequency and this is free for use by commercial applications, so we expect a minimum interference with other devices during our tests.
- No need to use heart beat and the breathing sensor. Our interest in just to observe the minute movement of the victim.

5.2 Disadvantage:
- Project is expensive but once it is implemented the expenses can be reduce lower extend.
- The L- band frequency is unable to penetrate more metal like structure but it can penetrate over 10 layers of bricks.
- The involvement of clutter signal may destroy the vital information of life signs. But if the proper demodulation is used one can receive the vital signs efficiently.

5.3 Future Scope :
In future, depending upon the developing such technology, if we can enhance the system so that it will able to detect number of victims buried under the respective rubble. Then rescuer will prefer area with more number of victims. Eventually, our system can save more lives.
CONCLUSION
A life-detection system with a microprocessor-based automatic clutter cancellation subsystem can be invented for special rescuing robots. This system can operate at 2-G Hz and it will be used remotely to detect the breathing and heartbeat signals of alive subjects through rubble or some other barriers about 3ft in thickness. The microprocessor-based automatic clutter-canceling increases the efficiency of system. The clutter canceller uses an adjustable attenuator and phase shifter to cancel the transmitting power leakage from the circulator and background reflection clutter to enhance the detecting sensitivity of the weak vital signals.

We believe that through the development of similar and related techniques for life detection system, it will be possible to overcome the current fundamental problems in detecting buried victims and save many precious lives.

ACKNOWLEDGEMENT
The authors would like to thanks Dr. P. V. Ingole for idea of such life detection system and Miss S. S, Thakare for providing the guidance. We are gratefully acknowledging the support of all the IEEE paper on life detection system.

REFERENCE