LIFE DETECTION SYSTEM

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Submitted By

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INDEX

1. INTRODUCTION

A new sensitive microwave life-detection system which can be used to locate human subjects buried under earthquake rubble or hidden behind various barriers has been constructed. By advent of this system the world death rate may decrease to greater extent as large percentage of death occur due to earth quake. This system operating at 1150 MHz or 450 MHz can detect the breathing and heartbeat signals of human subjects through an earthquake rubble or a construction barrier of about 10-ft thickness. Previous methods for searching and rescuing human victims buried under earthquake rubble or collapsed building debris were the utilization of dogs, or seismic or optical devices. These devices are not effective if the rubble or debris covering the human victims is thicker than a few feet, especially for the case when the victims are completely trapped or too weak to respond to the signal sent by the rescuers.

FINDER which stands for Finding Individuals for Disaster and Emergency Response is a Life Detection System. In the wreckage of a collapsed Textile Factory and another building in the Nepalese village of chautara, four men were rescued, two from each building, in one of the hardest-hit areas of the 7.8 magnitude earth quake on April 25. This technology detected the men’s presence even though they were buried under about 10 feet of brick, mud, wood and other debris. FINDER sends a low-powered microwave signal -- about one-thousandth of a cell phone's output -- through rubble. It looks for changes in the reflections of those signals coming back from tiny motions caused by victims' breathing and heartbeats. In tests, FINDER has detected heartbeats through 30 feet of rubble, or through solid concrete. The technology evolved from JPL's efforts to develop low-cost, small spacecraft radios, using signal processing developed to measure small changes in spacecraft motion.

Besides natural disaster settings, the device could be used to find people lost in a forest, trapped in a burning house or buried in the wreckage of a collapsed building. There are many potential uses in medicine as well: A device based on FINDER could monitor the vital signs of someone who is trapped in a car or quarantined with an extremely contagious disease such as Ebola. In these situations, first responders could measure a patient's heartbeat without having to physically touch them. The next generation of this technology could combine FINDER with robotics and even small autonomous flying vehicles to get closer to victims and examine a wider area.. FINDER exemplifies how technology designed for space exploration has profound impacts to life on Earth.

FIG 1.1 FINDER

2. PRINCIPLE OF OPERATION

The basic physical principle for the operation of a microwave life-detection system is rather simple. When a microwave beam of appropriate frequency (L or S band) is aimed at a pile of earthquake rubble covering a human subject or illuminated through a barrier obstructing a human subject, the microwave beam can penetrate the rubble or the barrier to reach the human subject. When the human subject is illuminated by a microwave beam, the reflected wave from the human subject will be modulated by the subject's body movements, which include the breathing and the heartbeat. If the clutter consisting of the reflected wave from stationary background can be completely eliminated and the reflected wave from the human subject's body is properly modulated, the breathing and heartbeat signals of the subject can be extracted. Thus, a human subject buried under earthquake rubble or hidden behind barriers can be located.

2.1. INTRODUCTION TO MICROWAVES

Microwaves are electromagnetic waves with wavelengths ranging from as long as one meter to as short as one millimeter, or equivalently, with frequencies between 300 MHz (0.3 GHz) and 300 GHz. This broad definition includes both UHF and EHF (millimeter waves), and various sources use different boundaries. In all cases, microwave includes the entire SHF band (3 to 30 GHz, or 10 to 1 cm) at minimum, with RF engineering often putting the lower boundary at 1 GHz (30 cm), and the upper around 100 GHz (3mm). The advantages of microwaves are ,

- Increased bandwidth availability (1 GHz-103 GHz).
- Improved directive properties.
- Transmitter /receiver power requirements are very low.

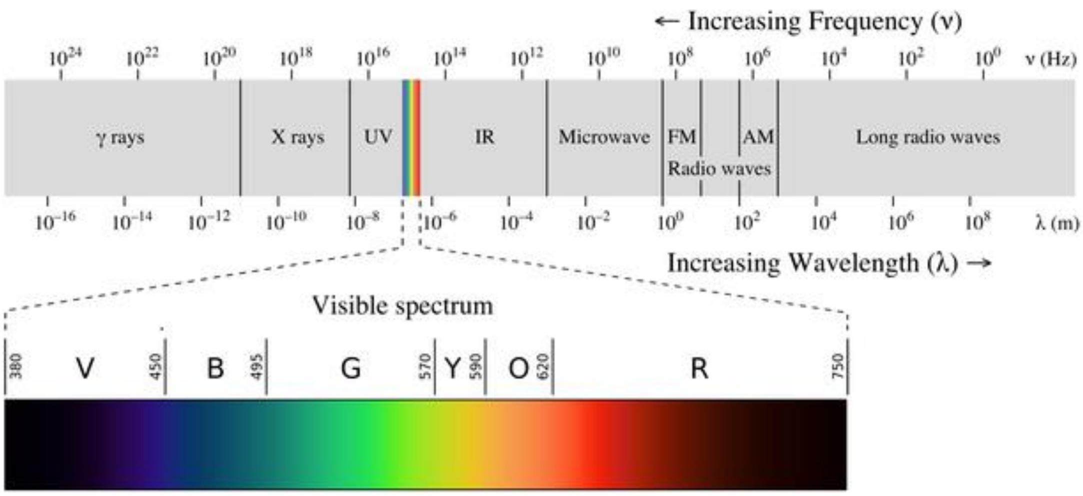

FIG 2.1.1 Electro Magnetic Spectrum

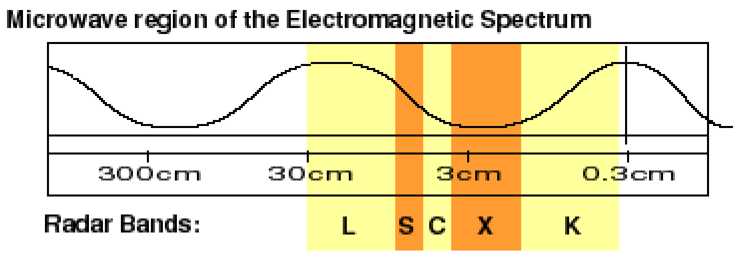

FIG 2.1.2 Microwave region of Electromagnetic Spectrum

Standard Radar Frequency Letter-Band Nomenclature(IEEE Standard 521-1984)		
Band Designator	Frequency (GHz)	Wavelength in Free Space (centimeters)
L band	1 to 2	30.0 to 15.0
S band	2 to 4	15 to 7.5
C band	4 to 8	7.5 to 3.8
X band	8 to 12	3.8 to 2.5
Ku band	12 to 18	2.5 to 1.7
K band	18 to 27	1.7 to 1.1
Ka band	27 to 40	1.1 to 0.75
V band	40 to 75	0.75 to 0.40
W band	75 to 110	0.40 to 0.27

FIG 2.1.3 Microwave Bands

2.2 MAJOR COMPONENTS OF THE CIRCUIT

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 microwave controlled clutter cancellation system, which creates an optimal signal to cancel the clutter from the rubble.
- A dual antenna system, which consists of two antennas, energized sequentially.
- A laptop control which controls the microprocessor and acts as the monitor for the output signal.

2.3. WORKING FREQUENCY

The frequency of the microwave falls under two categories, depending on the type and nature of the collapsed building. They are,

- L (or) S band frequency say 1150 MHz
- UHF band frequency say 450 MHz

An electromagnetic wave of 450 MHz is difficult to penetrate layers of reinforced concrete slabs with imbedded metallic wire of 4-in spacing. Through a series of experiment, we selected the operating frequency of 1150 MHz for the second system with the goal of penetrating such earthquake rubble. After the construction of the 450-MHz and the 1150-MHz systems and an extensive series of experiments, we found that an EM wave of 1150 MHz can penetrate a rubble with layers of reinforced concrete slabs with metallic wire mesh easier than that of 450 MHz . However, an EM wave of 450 MHz may penetrate deeper into a rubble without metallic wire mesh than that of 1150 MHz . The basic circuit structures of the 450-MHz and the 1150-MHz microwave life-detection systems are quite similar and they are operated based on the same physical principle.

3. SYSTEM DIAGRAM

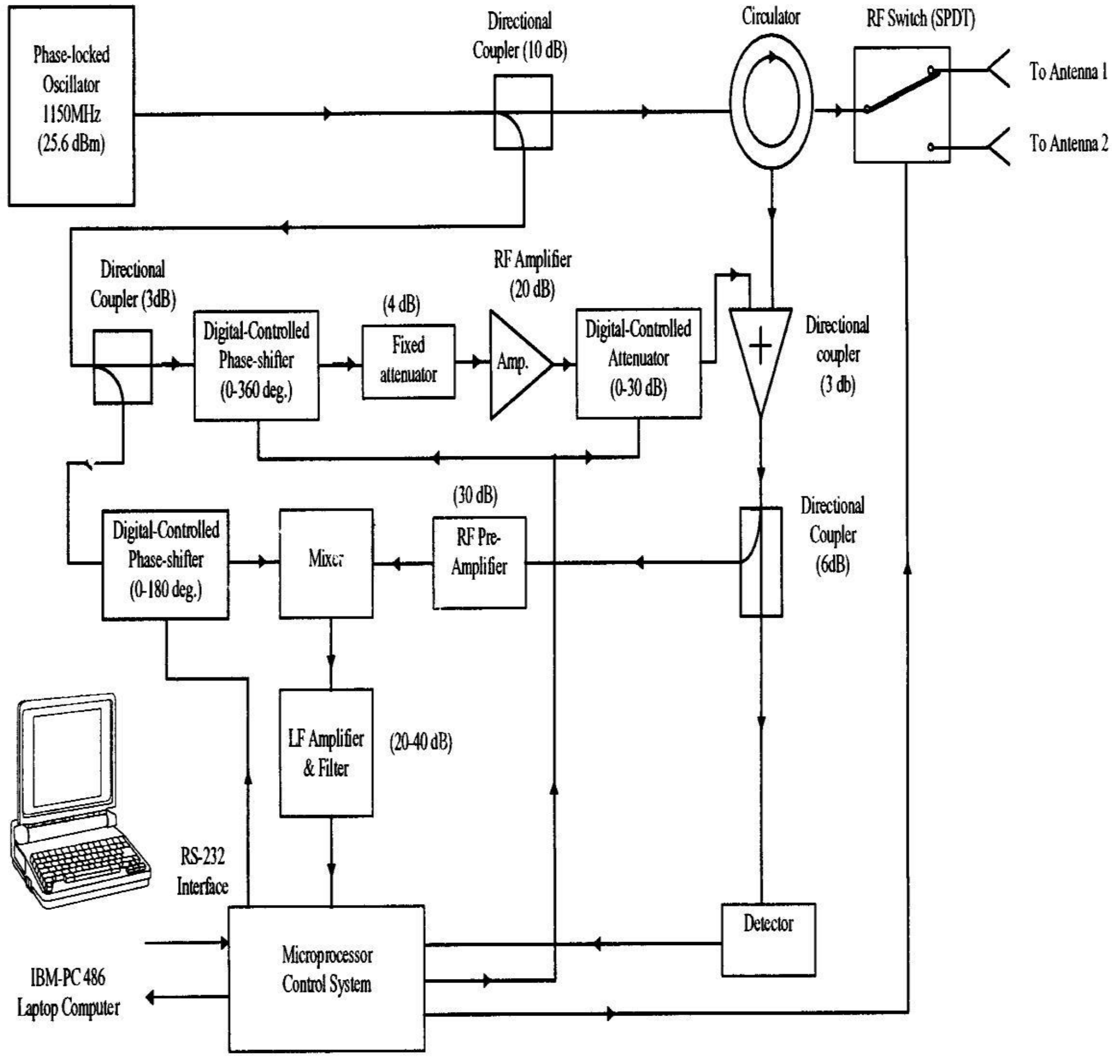

FIG 3.1 Schematic Diagram of 1150MHz Microwave-Life detection System

3.1 CIRCUIT DESCRIPTION

The circuit description is as follows:

3.1.1 PHASE LOCKED OSCILLATOR:

A phase-shift oscillator is a simple electronic oscillator. It contains an inverting amplifier, and a feedback filter which 'shifts' the phase of the amplifier output by 180 degrees at a specific oscillation frequency. The filter produces a phase shift that increases with frequency. It must have a maximum phase shift of considerably greater than 180° at high frequencies, so that the phase shift at the desired oscillation frequency is 180°. Here the phase locked oscillator generates a very stable electromagnetic wave say 1150 MHz with output power say 400mW.

3.1.2 DIRECTIONAL COUPLER:

Directional couplers are four-port circuits where one port is isolated from the input port. Directional couplers are passive reciprocal networks. All four ports are (ideally) matched, and the circuit is (ideally) lossless. A directional coupler has four ports, where one is regarded as the input, one is regarded as the "through" port (where most of the incident signal exits), one is regarded as the coupled port (where a fixed fraction of the input signal appears, usually expressed in dB), and an isolated port, which is usually terminated. If the signal is reversed so that it enter the "though" port, most of it exits the "input" port, but the coupled port is now the port that was previously regarded as the "isolated port". The coupled port is a function of which port is the incident port. Waveguide couplers couple in the forward direction (forward-wave couplers); a signal incident on port 1 will couple to port 3 (port 4 is isolated). Micro strip or strip line coupler are "backward wave" couplers.

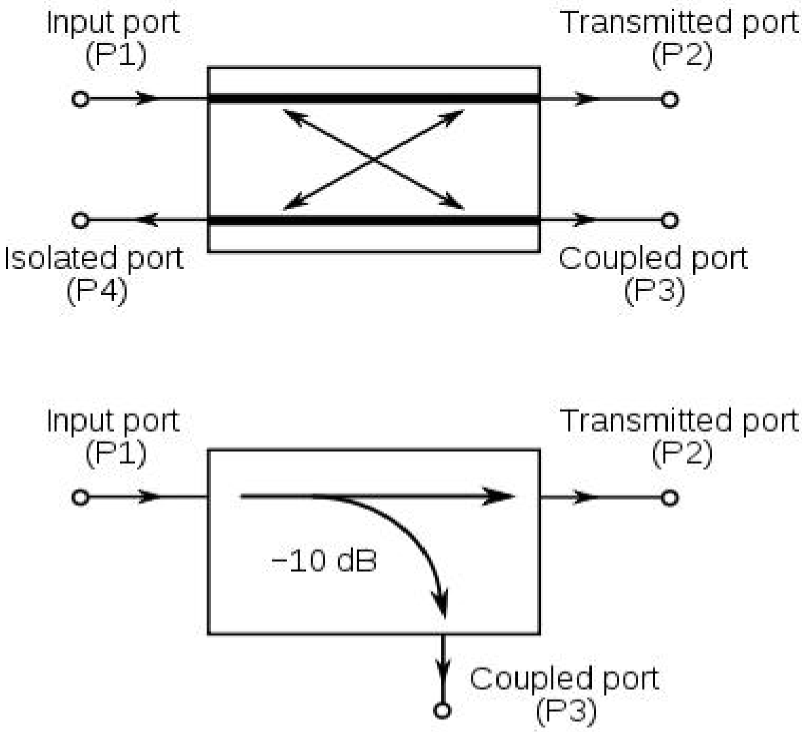

FIG 3.1.2.1 Two common couplers for directional couplers

The micro wave life detection system uses four directional couplers: two 3dB, one 6dB and one 10 dB directional coupler.

3.1.3 CIRCULATOR:

A circulator is a ferrite device (ferrite is a class of materials with strange magnetic properties) with usually three ports. The beautiful thing about circulators is that they are non-reciprocal. That is, energy into port 1 predominantly exits port 2, energy into port 2 exits port 3, and energy into port 3 exits port 1. In a reciprocal device the same fraction of energy that flows from port 1 to port 2 would occur to energy flowing the opposite direction, from port 2 to port 1.

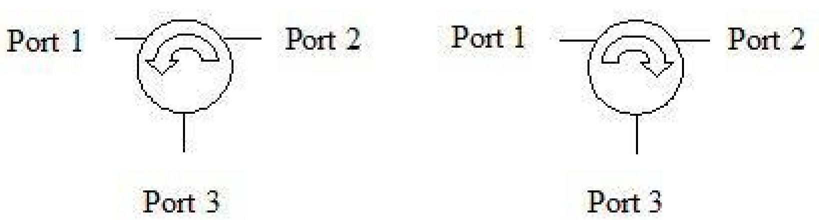

FIG 3.1.3.1 CCW and CW circulators

The selection of ports is arbitrary, and circulators can be made to "circulate" either clockwise (CW) or counter clockwise (CCW). A circulator is sometimes called a "duplexer", meaning that is duplexes two signals into one channel (e.g. transmit and receive into an antenna).In microwave life detection system there are two antennas. The antenna can perform two functions simultaneously with the help of a circulator, which separates the radiating EM wave from the received EM wave.

3.1.4 ANTENNA SYSTEM:

The dual antenna system has two antennas, which are energized sequentially by an electronically controlled microwave single-pole double-throw (SPDT) switch. The SPDT 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. Each antenna acts separately. Each antenna simultaneously acts as the radiating element and the receiving element. It radiates EM wave through the earthquake rubble to reach the trapped human subjects and at the same time it receives the reflected EM wave from the rubble and the human subjects.

3.1.5 CLUTTER CANCELLATION SYSTEM:

The clutter cancellation unit consists of

1. A digitally controlled phase shifter
2. A fixed attenuator
3. A RF amplifier
4. A digitally controlled attenuator.

3.2 WORKING OF LIFE DETECTION SYSTEM

The schematic diagram of the 1150-MHz microwave life-detection system is shown in Fig. 3.1. A phase-locked oscillator generates a very stable EM wave at 1150 MHz with an output power of 400mW(25.6 dBm). This wave is fed through 10-dB directional coupler and a circulator before reaching a radio-frequency (RF) switch, which energized the dual antenna system sequentially. The 10-dB directional coupler branches out one-tenth of the wave (40 mW) which is then divided equally by a 3-dB directional coupler. One output of the 3-dB directional coupler (20 mW) drives the clutter cancellation circuit and the other output (20 mW) serves as a local reference signal for the double-balanced mixer.

3.2.1 CLUTTER CANCELLATION OF THE RECEIVED SIGNAL:

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 combined with the received signal from the antenna, via the circulator, in a 3-dB directional coupler, the large clutter from the rubble is completely cancelled, 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 is passed through a 6-dB directional coupler. The 1/4 of this output is amplified by a RF preamplifier (30 dB) and then mixed with a local reference signal in a double-balanced mixer. The other 3/4 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. When the settings of the digitally controlled phase-shifter and attenuator are swept by the microprocessor control system, the output of the microwave detector varies accordingly. The minimum detector reading corresponds to the right settings for the digitally controlled phase-shifter and attenuator. These settings will be fixed for subsequent measurements.

3.2.2 MICROPROCESSOR CONTROL UNIT:

The algorithm for the antenna system and the clutter cancellation system are as follows:

3.2.2.1 ANTENNA SYSTEM:

1. Initially the switch is kept in position 1 (signal is transmitted through the antenna1).

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.

3.2.2.2 CLUTTER CANCELLATION SYSTEM:

1. Send the signal to the rubble through antenna 1.

2. Receive the signal from the rubble through antenna 2.

3. Check the detector output. If it is within the predetermined limits go to step 5.

4. Otherwise send the correction signal to the digitally controlled phase shifter 1 and attenuator and go to step 1.

5. Check the sensitivity of the mixer. If the optimum go to step 7.

6. Otherwise send the correction signal to the digitally controlled phase shifter 2 to change the phase and go to step 1.

7. Process the signal and send it to the laptop.

3.2.3 DEMODULATION OF THE CLUTTER CANCELLED SIGNAL:

- At the double balanced mixer, the amplified signal of the reflected wave from the person's body is mixed with the local reference signal.

- The phase of the local reference signal is controlled by another digitally controlled phase shifter 2 for an optimal output from the mixer.

- The output of the mixer consists of the breathing and heartbeat signals of the human plus some avoidable noise.

- This output is fed through a low frequency amplifier and a band pass filter (0.4 Hz) before displayed on the monitor.

- The function of the digitally controlled phase shifter 2 is to control the phase of the local reference signal for the purpose of increasing the system sensitivity.

- The reflected signal from the person’s body after amplification by the pre-amplifier is mixed with the local reference signal in a 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.

3.3 EXPERIMENTAL RESULTS

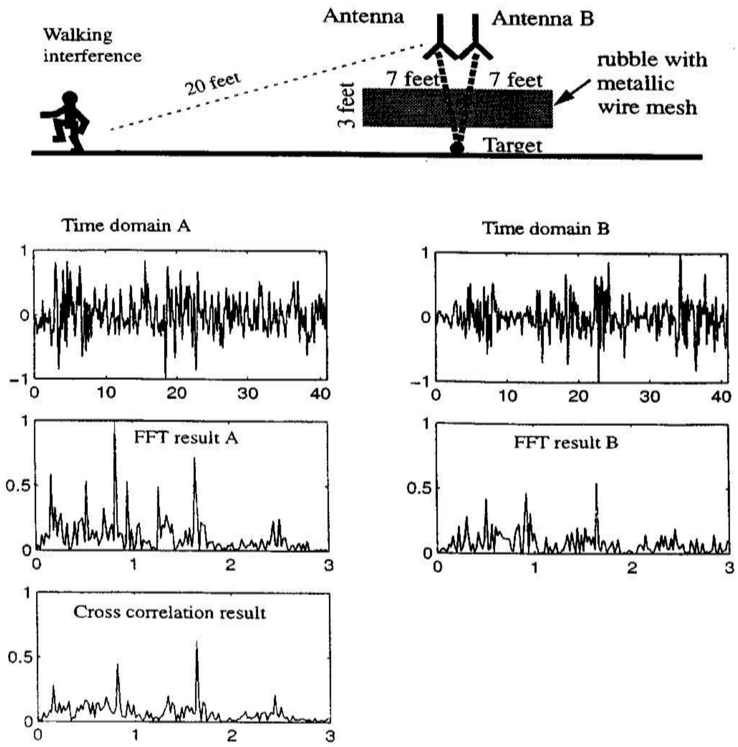

FIG 3.3.1 Heartbeat signals measured by two reflector antennas

Figure 3.3.1 Heartbeat signals measured by two reflector antennas while a human operator was walking near the rubble. Both time-domain and FFT results are shown. The cross-correlation result of the two sets of results shows the heartbeat frequency and its harmonic, while the interference signal created by the operator nearly disappear. The 1150-MHz life-detection system was used.

Figure 3.3.1 shows the heartbeat signals measured by reflector antenna A and reflector antenna B both placed 7 feet above the target when a human operator was walking near the rubble, about 20 feet from the antenna. The walking human subject created a large interference signal in the outputs of antenna A and antenna B showing both in their time-domain results and the FFT results. When those two sets of signals were cross correlated, the heartbeat signal of 0.8 Hz and its second harmonic of 1.6 Hz appeared while the interference signal nearly disappeared. From this result, we can conclude that the dual-antenna system of the 1150-MHz can be used to reduce the interference noise created by the system operators moving near the rubble as well as the background noise.

3.4 ADVANTAGES AND DISADVANTAGES

3.4.1 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, minimum interference with other devices is expected.
- No need to use heart beat and the breathing sensor. Our interest in just to observe the minute movement of the victim.

3.4.2 DISADVANTAGES

- System 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.

4. CONCLUSION AND FUTURE SCOPE

A new sensitive life-detection system using microwave radiation for locating human subjects buried under earthquake rubble or hidden behind various barriers has been constructed. This system operating at 1150 or 450 MHz can detect the breathing and heartbeat signals of human subjects through an earthquake rubble or a construction barrier of about 10-ft thickness. The location of the person under the rubble can be known by calculating the time lapse between the sending time, Ts and receiving time, Tr. Since it will not be possible to continuously watch the system under critical situations, an alarm system has been set, so that whenever the laptop computer system processes the received signal and identifies that there is a human being, the alarm sound starts. The possible shortcoming of this system is the effects of the background noise created by the environment and operators. A sophisticated signal processing scheme may further improve the system performance. In future, depending upon the developing such technology, if the system is enhanced 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.

5. REFERENCES

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