# APPLICATIONS OF RADARS IN MEDICINE

PRESENTED BY
DR. HUSHAM J. A. AL-QAIYSI

DEPARTMENT OF COMMUNICATION & COMPUTER ENGINEERING

CIHAN UNIVERSITY / ERBIL

# ABSTRACT

Ultra-wideband radar (UWB) holds great promise for a variety of medical applications. This seminar presents demonstration of the feasibility of using ultra-wideband sensors for detection of internal injuries, monitoring of respiratory and cardiac functions, and continuous non-contact imaging of the human body. Sensors are low-power, portable, and do not require physical contact with the patient. They are ideal for use by emergency responders to make rapid diagnosis and triage decisions. In the hospital, vital signs monitoring and imaging application could improve patient outcomes. In this seminar an overview of ultra-wideband radar technology is discussed as well as the key design tradeoffs. Examples are given on ongoing research in applying ultra-wideband technology to the medical field.

**Contents :**

# INTRODUCTION

- *In this seminar, an Ultra Wide Band (UWB) radar system is proposed in an attempt to take a medical image of each human body layer.*
- *In fact, this system consists of sending an electromagnetic pulse and analyzing the echo reflected by the human body tissue.*
- *In order to realize this system, the parameters which enable us to optimize the functionality of our radar are computed.*
- *Indeed, a frequency range is fixed , incident angle, pulse repetition frequency, the power and the antenna deployed by the UWB radar system in medicine. As well as, a human body model is presented in order to have practical results.*

# A UWB radar system offers many benefits over continuous wave radars:

- Due to a very high down-range resolution, a target can be precisely located;
- A large bandwidth allows a better separation be-tween targets and a clutter;
- It possesses a good immunity against a multipath interference, which is very strong within buildings and collapsed buildings;

# A UWB radar system offers many benefits over continuous wave radars (Continue):

- This system can be used in the medical application.
- The electromagnetic pulses generated by the UWB radar are able to explore human body. Then, the human body layer has got electric characteristics which make differentiate between each echo reflected by the human body structure.

# Ultra-wideband Basics



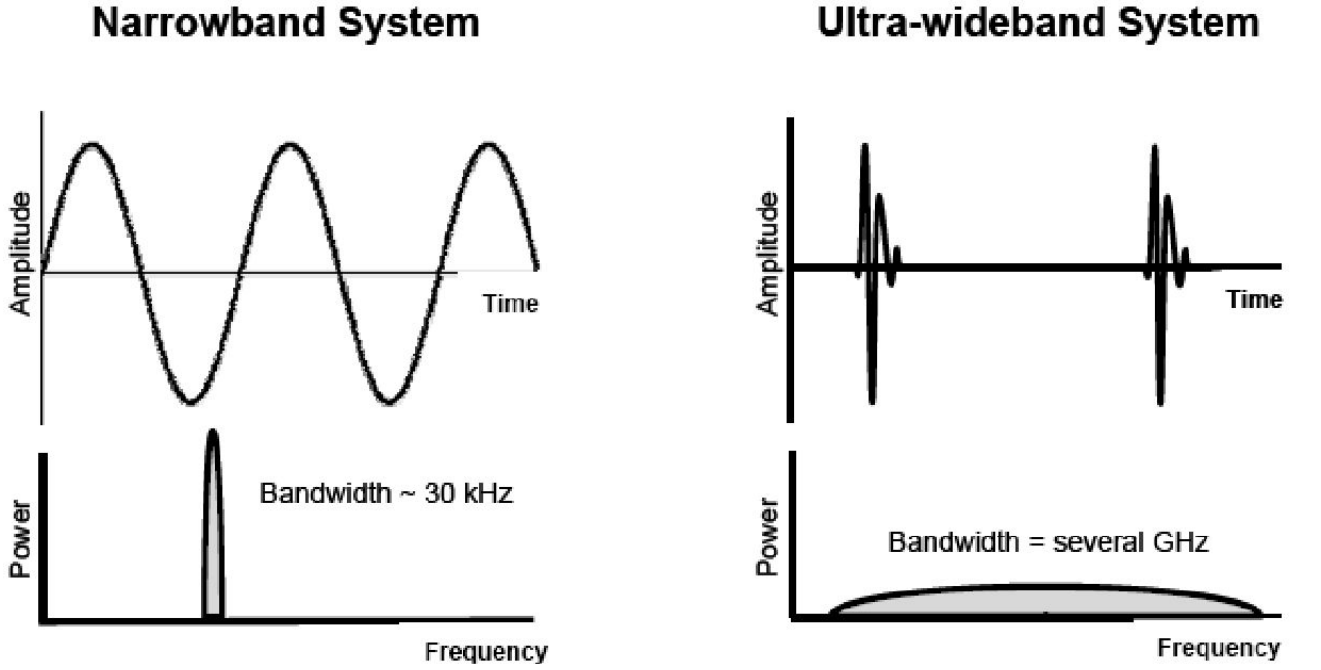



Figure 1: Narrowband vs. UWB in Time and Frequency Domain

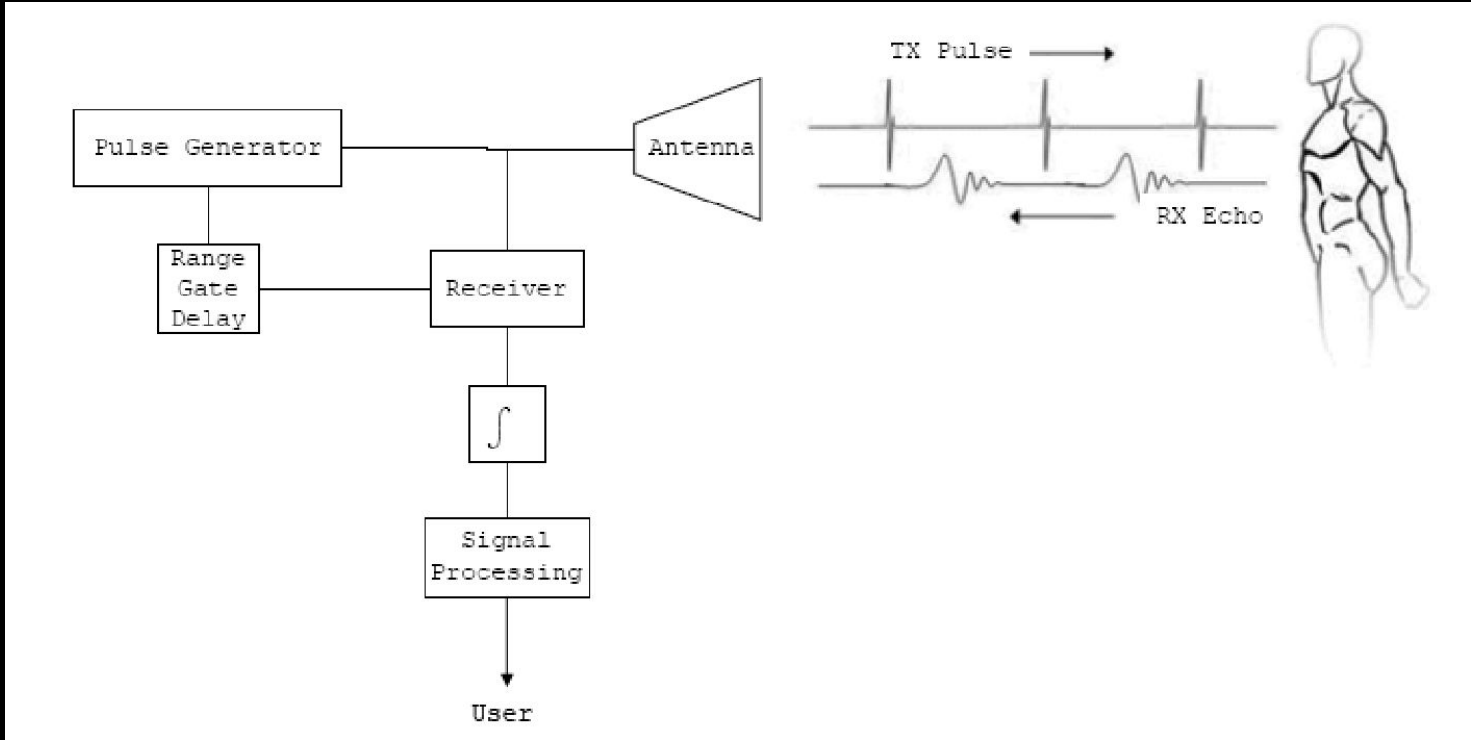
# Ultra-wideband Advantages

- UWB signals are capable of penetrating a great variety of materials, including plastic, wood, rubber, sheetrock, dry soil, glass, and concrete.
- Biological materials including skin, muscle, fat, and bone can also be penetrated.
- Non-invasive, non-contact, and non-ionizing.
- Low power, portable, and low cost.

# SENSING WITH ULTRA-WIDEBAND

- A family of ultra-wideband sensors known as micro-power impulse radar (MIR) was developed.
- MIR sensors are safe for medical use, since UWB signals are non-ionizing and emitted power is very low.
- In a typical MIR sensor used for medical applications, peak transmit power is 60 milliwatts and average transmit power is 25 microwatts.

# Micro-power Impulse Radar (MIR) Sensor Block Diagram



# Imaging with Ultra-wideband Sensor Arrays



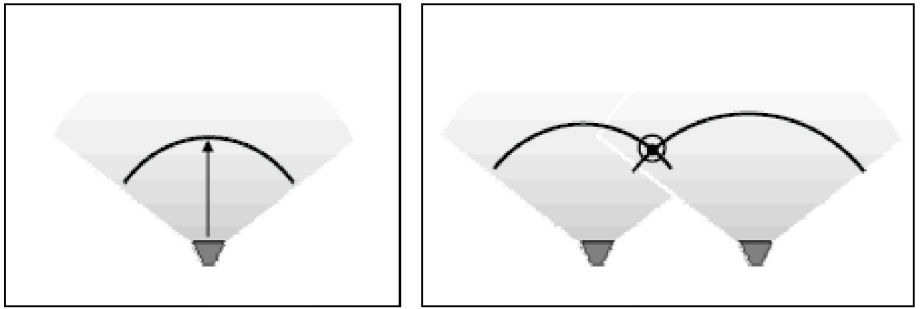


Figure 3: 1-D vs. 2-D positioning

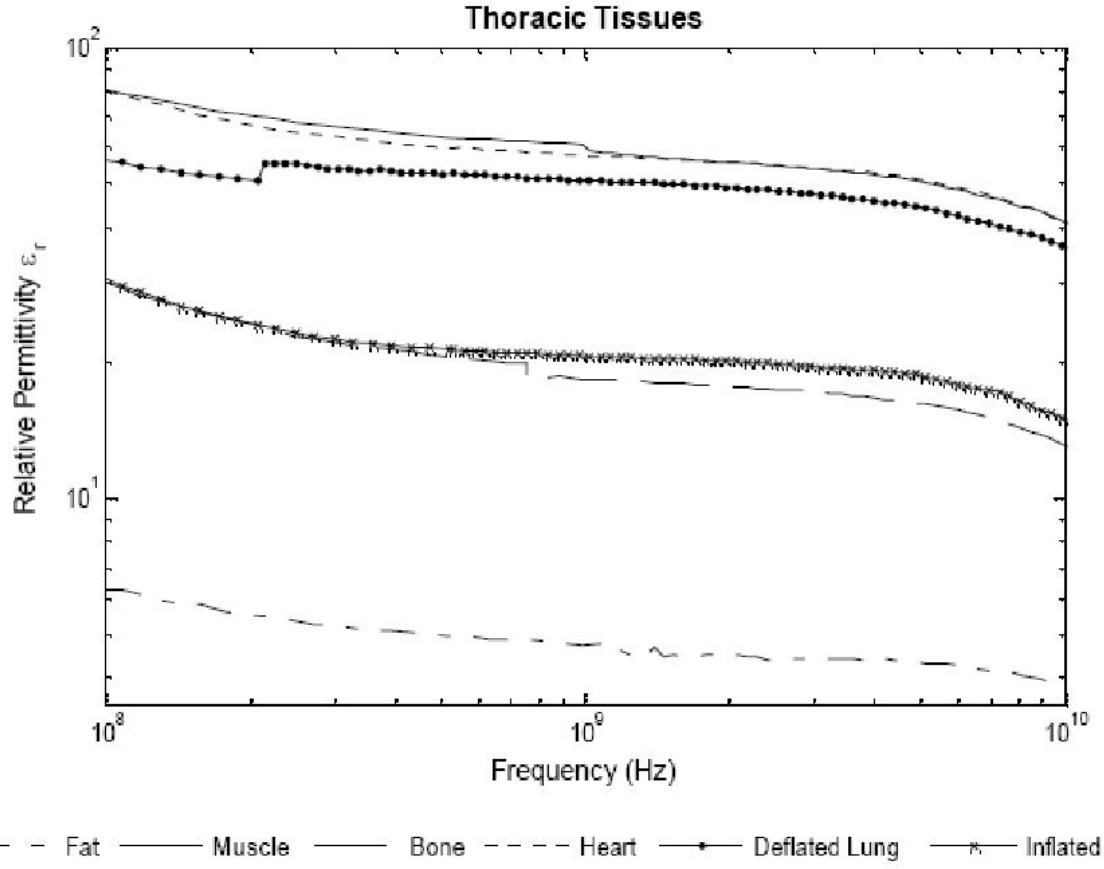
# Ultra-wideband Radar for Biological Sensing

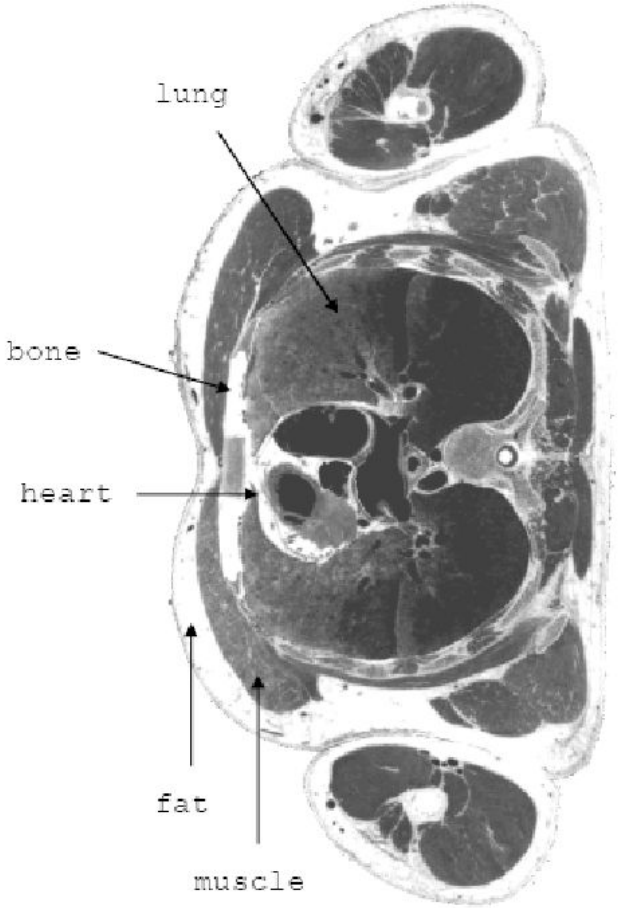
$$E_t = \tau \cdot E_i \qquad \text{and} \qquad E_r = \Gamma \cdot E_i ,$$

$$\tau = \frac{2 \cdot \sqrt{\varepsilon_{r1}}}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}}$$

$$\Gamma = \frac{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}}$$

- **$\varepsilon r_1$ and $\varepsilon r_2$ are the relative permittivities of the two mediums.**
- **By detecting ultra-wideband reflections, sensors can determine the presence or absence of abnormalities at tissue boundaries and monitor their motion.**


Thoracic Tissues
Relative Permittivity $\varepsilon_r$
$10^2$
$10^1$
$10^8$
$10^9$
$10^{10}$
Frequency (Hz)
Fat
Muscle
Bone
Heart
Deflated Lung
Inflated Lung


lung
bone
heart
fat
muscle

# Design Variables and Tradeoffs

- **Frequency Content of UWB Signals**
  - ✓ A large bandwidth is beneficial, because many materials can be penetrated while achieving good spatial resolution.
  - ✓ A very large bandwidth, however, can reduce the signal to noise ratio (SNR).
- **Power**
  - ✓ A large peak signal power is important for obtaining good penetration through materials and long operating distances.
  - ✓ A major drawback, however, is a reduction in the efficiency of high power pulse generation circuits.

## ❖ Pulse Repetition Rate

- ✓ UWB systems measure the time of flight for pulses to reflect off of a target.
- ✓ The pulse repetition rate must be slow enough to allow reflected pulses to return to the receiver; otherwise, transmitted pulses would interfere with received signals
- ✓ Receiver Window Size: Choosing a small window allows greater spatial resolution and better sensitivity to small movements, however, faster sampling circuits are required.

## ❖ Receiver Integration Time

- ✓ Instead of examining the received signal from a single pulse, which will be obscured by a number of noise sources, many pulses can be observed, one after another.

# MEDICAL APPLICATIONS OF UWB RADAR



## Hematoma Detector

- ✓ Patients having unrecognized intracranial injuries may develop permanent brain damage, severe disability, or death. Early diagnosis and treatment of intracranial hematomas is essential for improving patient outcomes.

- ✓ The current method used to identify intracranial hemorrhage is computed tomography (CT). Delay in neurosurgical intervention can result in irreversible brain injury or death.

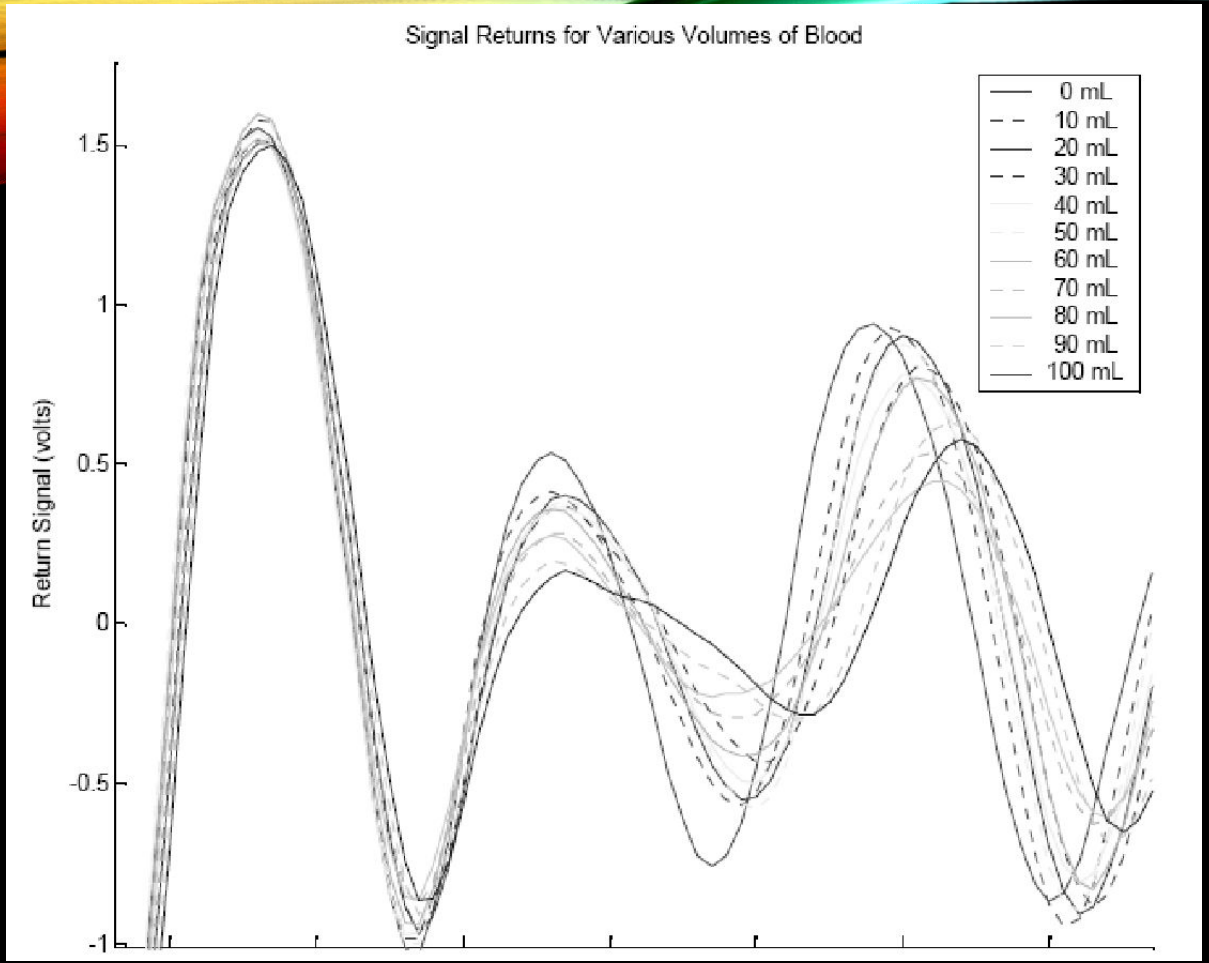
- ✓ A portable, hand-held hematoma detector could be of use for traumatic brain injury patients in the field to properly triage victims and minimize unnecessary delays before definitive medical intervention.

# Prototype

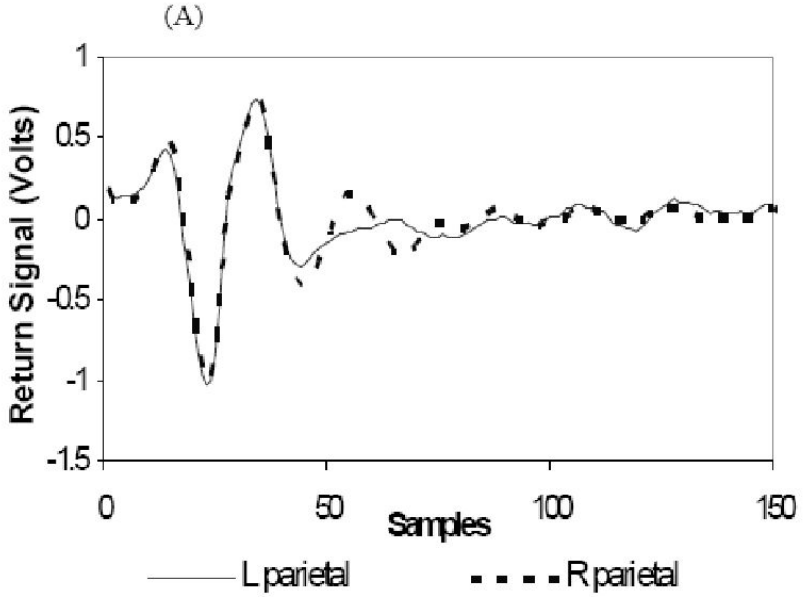



## Handheld Hematoma Detector

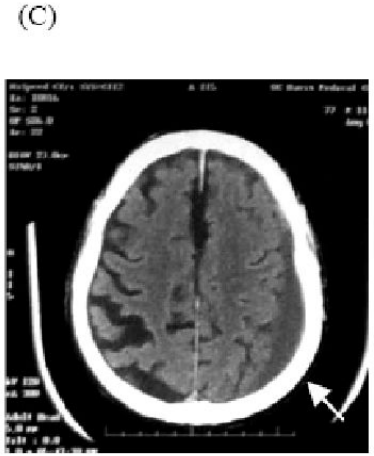
Key specifications are a center frequency of 2 GHz, a 200 ps pulse width, a 2 MHz pulse repetition rate, an average power density of less than 0.001 mW/cm2, and a peak power density of 2.5 mW/cm2, measured at a distance of 1cm.




**MIR signals from phantom hematoma**








**Patient with Chronic Subdural Hematoma – (A) MIR scan (B) CT axial (C) MRI coronal**

# Experiments Results

- Ultra-wideband radar imaging has potential to be a viable patient monitoring technology.
- Key advantages that satisfy specific application needs not addressed by MRI or CT include real-time imaging of moving organs, inexpensive hardware, and portability.

UWB radar images of human volunteers. Female (left) Male (right)

# CONCLUSIONS

- Ultra wideband radar is a flexible technology that can be adapted to a variety of medical applications.
- A suite of Micropower Impulse Radar technologies have been developed at Lawrence Livermore National Laboratory(University of California).
- Prototype devices have the ability to detect internal tissue boundaries, monitor motion, and produce images without direct contact with a patient. They are low-power, safe, portable, and inexpensive.
- The hand-held form factor, low power requirement, and rapidly generated results make this detector suitable for use in remote areas, where CT and MRI imaging systems are unavailable.
- Unlike CT and MRI systems, ultra-wideband radar could be used for continuous, real-time monitoring over extended time periods.

# Thank You ……