# Bridging the Gap between Technology and Usability for Portable Brain Trauma Scanning Device

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***Abstract*— A portable medical scanning system for head trauma detection and monitoring is being developed. The technologies considered and developed are ultra-wideband radar (UWB radar) and magnetic induction tomography (MIT). We needed to find out the exact usage scenarios of these kinds of systems to determine exactly where and how these could be put in practice in the healthcare field in general. We identified the necessity for this technology with the projected capabilities and limitations known to be in the intensive care unit.**

***Keywords—UWB; Radar; Biomedical monitoring; Medical Imaging; Hematoma***

## I. Introduction

Patients with head injury often need rapid care for survival. The condition needs to be analyzed quickly and often monitored as well to apply the correct care procedures. Modern medical scanners in hospitals are able to do the job but there are frequently cases where head injuries still need better diagnostics. In many cases a portable or less obstructive brain scanner would be very useful. Therefore we started to investigate technologies and also the exact need for this capability. Our aim was to find the market niche and bring together the design from usage perspective with the technological reality.

Technology for scanning was investigated with UWB (ultra wide band) radar technology and a working prototype was built. At the same time the hospital setting was investigated, doctors and emergency personnel were interviewed to pinpoint the best place for the scanning technology in the whole healthcare system from paramedics emergency dispatch teams to intensive care and radiology departments. The most likely place for the usage of the device was found to be the intensive care unit (ICU) the most important reason being that the patient would need to be moved to radiology as seldom as possible.

Common diagnostics methods for head injuries are CT (computed tomography [1]) and MRI (magnetic resonance imaging [2]), both of which lack mobility, are expensive, do not provide real time results and cannot be used for continuous monitoring. However, head injuries need urgent treatment and there is need to evaluate and monitor development of stroke condition as early as possible, preferably in real time. Ultrasound diagnostics devices provide real time results and are portable but ultrasound cannot penetrate the bone which makes it impossible to diagnose brain damages. There are many research programs ongoing to develop portable device for detection and monitoring of intracranial hemorrhage, based on bioimpedance, radio frequency or optical detection methods. One example is Infrascanner (infrascanner.com) which is based on differential infrared light absorption of the injured versus the non-injured part of brain.

The detection method which has given promising results in simulation [3] is based on UWB radar. UWB radar generates short pulses which are radiated through the antenna towards the body. Electromagnetic energy propagating through the body is reflecting back from the tissue interfaces due to the different relative dielectric constant of the organs. That attenuated and reflected energy from the organ boundaries is received by the antenna and boundary location is calculated based on time difference of transmitted and received signal [4]. Brain tissue and hematoma permittivity difference is sufficient to detect reflected signal from hematoma area.

## II. Materials and Methods

Main building blocks of UWB radar are ultrashort impulse generator, UWB antennas, receiver, timing circuit and DSP unit. Impulse lengths are in the range of tens of picoseconds up to a nanosecond while EM energy is spread over wide microwave range usually from 3 to 10 GHz. Ultra short impulses allow to achieve good spatial resolution. Receiver is mainly based on correlation or sampling gate architectures. Timing circuit is used to determine reflection location based on time of flight of the generated pulse.

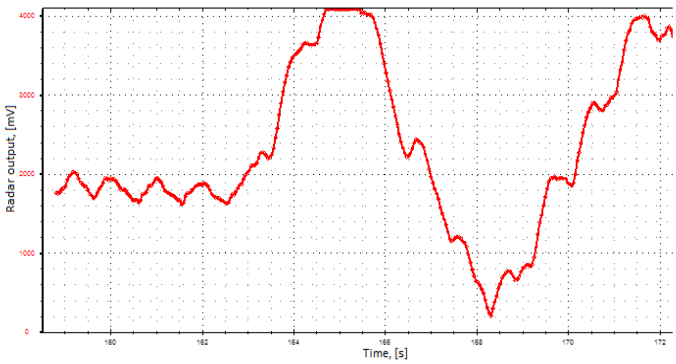


Fig. 1. Radar signal of heartbeat while holding the breath and then in a deap breathing cycle.

Prototype was built to test UWB radar main components and to get empirical information about antenna performance and reflected signal levels. Impulse generator of the prototype was based on SRD diode [5] and the achieved impulse length was 480 ps. Radar was able to detect respiration and heartbeat from the distance of 1 m, radar output signal is shown on Fig.1.

Spatial resolution was in the range of 3 cm due to relatively long impulse length and analog timing circuit which caused high jitter. It was not sufficient for hematoma detection. We are planning to use SiGe IC based impulse generator and timing circuit based on digital technology in the next prototype. The target is to generate impulse with the length less than 100 ps and have timing circuit resolution under 10 ps. Long term target is to investigate tomography possibilities with antenna array and SAR data processing algorithm to be able to detect hematoma and evaluate recovery progress.

It was estimated that this device could detect the need for secondary CT / MRI scan. Following research inclusive of interviews with ICU doctors and nurses as well as observations in ICU approved this use case. After taking into consideration all needs and limiting factors of UWB radar and MIT, many possible interface concepts were analyzed. The best head-gear candidates are as follows:

First the “radar headphones” Fig.2 row 1 represent the concept where antenna is moving around the head with electric motors. Pros about this concept: patient can move the head, it is easy to install, takes little storage space, feasible in electronics and it can show the 3D image. From the cons side it does not allow to rest the back of the head, image refreshment takes about 2 to 3 min.

As a second concept Fig.2 row 2, there is a smart pillow, where the antennas are sinked to the surface of the pillow. Patient must be wearing a special hat with antennas attached to. In this concept two devices are needed - the smart pillow and a hat to attach the antennas. This concept has also strong pros, such as retracting sensors, pre-setup is possible, partially allows some head movement, has neck support, no weight on the head and can accommodate all head sizes. As a downside it needs bigger storage space in the hospital.

For the third possible concept Fig. 2 row 3, there is modular helmet, where antennas are inside the helmet, which will be wrapped around the head. In this concept the pros are it’s compact size, patient can move around with it. On the other hand it has limited space for electronics and wearing a helmet might be uncomfortable for some patients.

## III. RESULTS

UWB radar was able to differentiate two objects separated from each other by 3cm from the distance of 30cm. It is expected result considering radar impulse length.

We see our device fitting in ICU scenarios. The portable device can be used for monitoring patients brain health in ICU. Any abnormal changes can be brought to the doctors notice. It can eliminate the repeated visits to radiology department and thereby also reduce the cost of CT scans.

Fig. 2. Sensor interface concepts

## IV. CONCLUSION

UWB radar prototype for medical imaging system has been developed and several usage scenarios in hospital were considered. The best location for application in hospital was found to be the ICU.

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