**Quantum Microwave Medical Imaging**

Microwave imaging for cancer detection is an expanding area of technology research. A number of researchers have targeted new microwave imaging technologies towards breast cancer screening [1] and it is believed that screening for other cancers could benefit from advances in microwave imagining and quantum sensing as well

**Current Technologies**

Medical imaging can be achieved by a number of different technologies today. These include Magnetic Resonance Imaging (MRI) systems, X-Ray based devices and Ultrasound machines. Each of these technologies provide highly beneficial diagnostic information to medical practitioners and their patients but each one also has limitations. In addition to these technologies we are also going to consider the emerging field of Terahertz (THz) imaging technologies as well. We will review some on the key limitations of these technologies to aid in identifying where a quantum based microwave imaging solution can be beneficial.

**Magnetic Resonance Imaging**

MRI systems offer the medical profession an excellent, non-invasive method to visually investigate a multitude of systems within the human body. MRI visualization form part of many medical investigate protocols and have been in use for many years. MRI is a powerful tool for medical diagnosis but still has a number of limitations to its application. These limitations are size and complexity, long scan time, noise during scan, exclusion of patients and limited application to the chest region[2].

This size and complexity of an MRI system cannot go un-noticed. These systems are large, technically complex systems that require dedicated real estate and specialized personal to operate and maintain them. These aspects require large upfront and ongoing investments for the overall MRI solution to deliver benefits.

MRI systems require long scan times in order to construct an image. This long image acquisition time exposes the image to motion artifacts that can decrease the overall image quality. This limits the usefulness of MRI systems for some medical applications.

During the operation of the MRI system the current within the gradient coils will change rapidly and these can produce acoustic noise up to 112db depending on the machine. This is noise is a not only a nuisance but also heightens patient anxiety during operation and can even cause hearing damage if protective measures are not taken.

Patients with metal implants may be excluded from MRI scanning. A metal implant will exert its own magnetic field and distort the nearby area making a certain diagnosis difficult or impossible.

The MRI system are routinely used in the diagnosis of cardiovascular disease and other conditions involving the upper chest area. However, diagnosis is limited to specific conditions due to low proton density in the lung which result in low signal to noise ratio and the fast signal decay due to susceptibility artifacts at air-tissue, as well as cardiac and respiratory motion artifacts reduce image quality

**X-Ray Technology**

X-Ray technology has been used by the medical profession for many years. It is a widely used imaging solution for multiple applications and is understood by many medical practitioners. A main drawback of x-ray images is that they present a 2D image of a 3D structure with foreground obscuring background or background showing through and obscuring the foreground. Also, the contrast difference between different parts of the body or different parts of an organ can be poor thus providing limited insight[3]. Great care must be taken when using an x-ray image as patient expose to the x-ray source is itself presents a danger to the patient and operator alike[4]. Similar to MRI systems an x-ray system is large and require upfront and on-going investment in real estate, expertise and consumables to deliver value.

**Ultrasound Technology**

Like X-ray and MRI the use of ultrasound imaging systems is a standard diagnostic solution used in the medical profession. The applications of ultrasound imaging include obstetrics, cardiology, ophthalmology and general abdominal imaging**5**. Ultrasound imaging uses diagnostic frequencies of 1-30MHz resulting in 2mm X 2mm image resolutions. Ultrasound cannot penetrate bone or air filled cavities in the body. This limits its usefulness for the head, lungs and intestines. Other technical factors limit the data acquisition rate and resolution achievable with ultrasound based technologies.

**Terahertz Technology**

Terahertz (THz) medical imaging is rapidly improving due to the increase of transistor operating frequencies. Even though there is significant interest in THz technologies, the difficulty of generating THz signals makes this spectrum mostly unused. Terahertz photons energies are rather low thereby preventing them from breaking chemical bonds or ionizing molecules and atoms. This make THz imaging harmless for living organisms, unlike x-ray and UV ray higher energy photons. Unlike optical imaging methods, THz radiation is not scattered by tissues. Relatively small wavelengths of THz signals enable high resolution imaging whereas the high absorption rates by substances, such as water, make them useful for investigating soft tissues. These properties of THz radiation make them useful in various medical applications, such as non-invasive cancer detection, ex-vivo spectroscopy and imaging of tissues, in-vivo examination of tissue via spectroscopy [6].

**Microwave Imaging**

Microwave Imaging (MWI) offers low implementation and operational cost, ease of use, user friendliness and are low health risk to patients. The technology exploits the dielectric contrast between different tissues to create images using radar-based or tomographic imaging techniques. A key initial application was the detection of breast tumors but brain imaging is now a key area of research and the number of potential applications being explored is growing. Research is now being conducted into the application of MWI to the detection of pulmonary edema, skin cancer, intracranial hemorrage and a number of other areas [7].

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