



# An Efficient Breast Cancer Detection with Ultra wide Band Dielectric Resonator Antenna based Microwave Imaging Technique

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## Abstract:

In women with cancer, breast cancer is the most prevalent type of illness. Reduced mortality can be achieved with early detection. Microwave mammography, a non-invasive, safe replacement for mammography, is a promising development. The use of a miniature ultra-wideband dielectric resonator (UWB-DRA) antenna simulation in CST Microwave Studio allows for the detection of breast cancer. The operating frequency in empty space is approximately 3.548GHz. Breast model tumour cells can be detected by the newly developed UWB-DRA antenna-based MWI, opening the door to potential human life structures. 16 x 20mm made up the antenna. The ground plane and patch can be modified slightly to boost bandwidth. On efficiency and gain, it has a remarkable impact. As the time slot lengthens, the main lobe gain rises, the skin effect is offset, and the radiation properties are enhanced. The side lobe level falls as well.

**Keywords:** Breast cancer, Microwave mammography, Ultra-wideband (UWB) antenna, ground plane, antenna.

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## Introduction:

Given that breast cancer is one of the most prevalent malignancies in women, successful treatment significantly depends on early identification [1], [2]. Among the most often utilised clinical imaging and diagnostic procedures for this purpose are magnetic

resonance imaging (MRI), ultrasound scanning, and nuclear medicine [3]. The basis for X-ray mammography is the use of ultra-high frequency radiation (10PHz–10EHZ), which spreads along the area being examined. We have therefore developed a painful test that compresses the breast in order to



diagnose it with ionising radiation. Other disadvantages include a small dynamic range, poor contrast, and textured pictures that make it challenging to detect extremely minor abnormalities in women with implants or surgical scars [4]. The high spatial resolution and significant storage capacity requirements are another drawback.

The goal of ultra-wideband (UWB) frequency-domain microwave imaging is to take advantage of genetic variations between healthy and cancerous breast tissue. Radar-

based microwave imaging (RBMI) technology is based on monostatic and multistatic radars [5]. Breast Tissue Anchor Antenna Array for Multi-Static RBMI Each antenna in the array sends out the signal once and then receives it again from the reflected signal. Consequently, it is a time-consuming and challenging procedure [6]. Reconstruct higher resolution breast images with high data rates for tumour identification by using the two primary beamforming methods, Delayed Summation (DAS) and Delayed Multiplication and Sum (DMAS) [7].

Figure 1 illustrates how breast cancer incidence and mortality today rise with age. As they get closer to 80, women experience a drop in occurrence.

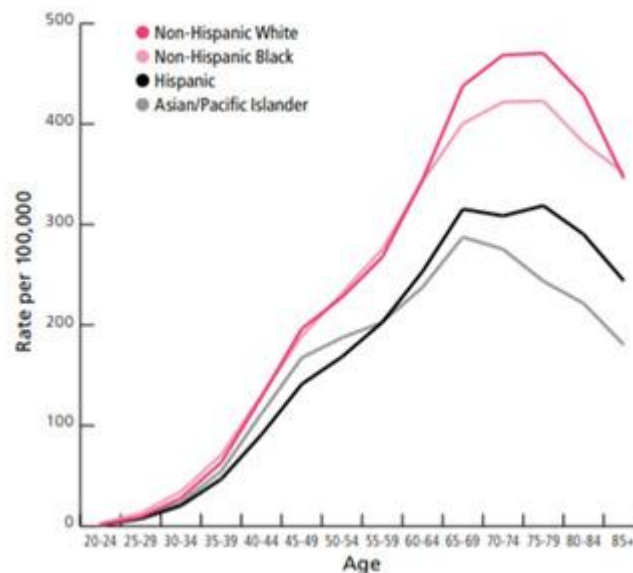


Fig 1: Rate of increase of breast cancer

The simplest method for detecting breast cancer in this situation is X-ray mammography. Because of thick fibrous tissue and the potential for incorrect breast cancer diagnosis, mammography is less sensitive than it once was [9]. These issues cause X-ray mammography to frequently yield false positive and false negative readings, allowing the patient to have surgery. Additional imaging methods include computed tomography, ultrasonography, and magnetic resonance imaging. The most often used kind of mammography is X-ray mammography. The aforementioned eISSN1303-5150

screening methods, however, have a limited level of selectivity and are unable to deliver crucial details on changes to molecular structure [10].

The specificity and sensitivity of finding things lodged in the breast have been improved using a novel approach termed microwave imaging [11,12]. Traditional approaches have drawbacks, which this new technique fixes. Microwave imaging technologies frequently employ ultra-wideband (UWB) techniques [13,14]. For noise reduction below tolerable limits, imaging systems often employ brief



pulses in the sub-nanosecond range. The capacity of UWB signals to identify objects with dimensions greater than the Rayleigh limit is another crucial characteristic [15].

To identify cancers deeper within the tissue using microwave imaging techniques, one antenna element [16] is insufficient [17]. In order to increase the resolution of microwave images, more antenna elements might be used. In order to categorise human breasts, image resolution turns out to be crucial. Antenna components are affixed to the human chest's borders. Between the antenna components, there is a small gap. The breast border is therefore covered by a tiny antenna element with the highest element count in order to improve image resolution. The hardest approach to measure return loss in free space, on the other hand, is through small antenna designs that directly interact with biological tissue [18,19]. As a result, we will construct a modest directional antenna using FR4 material for this investigation. Antenna gain and directivity can both be

increased with 2x2 element antenna arrays [20].

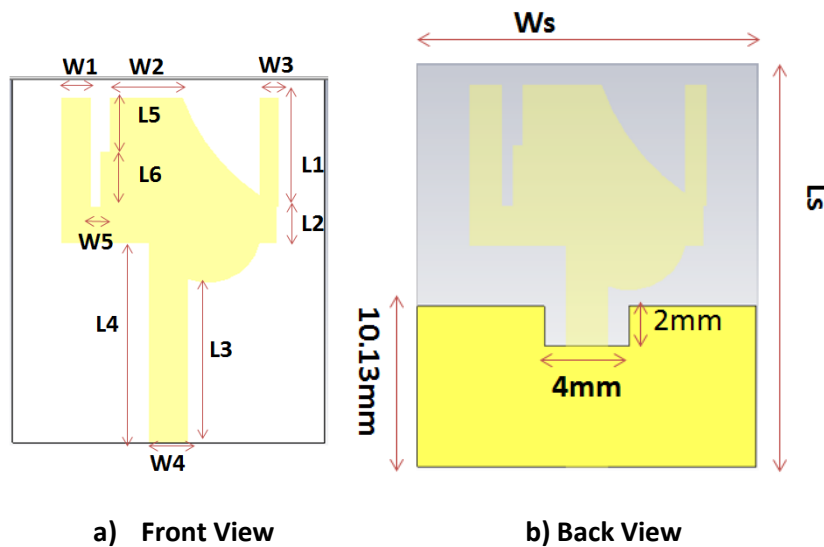
**Methodology:**

Microwave imaging applications' use of small UWB antennas is covered in this section.

**UWB-DRA antenna design:**

Antenna structure for UWB is shown in Figure 2. Increased bandwidth and less return loss have been major goals of antenna design. With a relative permittivity of 4.3, the FR4 antenna plate is used to create the antenna.  $W_s \times L_s$  are the dimensions of the substrate, which has a 1.6 mm thickness.

This plane is initially severed at the ground plane, therefore extending the antenna's bandwidth. To expand the antenna's bandwidth, you can also chop out portions of the ground plane. Another rectangular slot is then made in the patch plane, increasing the bandwidth once again. The ground plane and patch both have 0.035mm of thickness.



**Fig 2: Configuration of the miniaturized antenna (a) Front view (b) Back view**

**Table 1: Dimension of the Antenna**

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
Ls	20	L1	6
Ws	16	L2	2
W1	1.5	L3	8.9

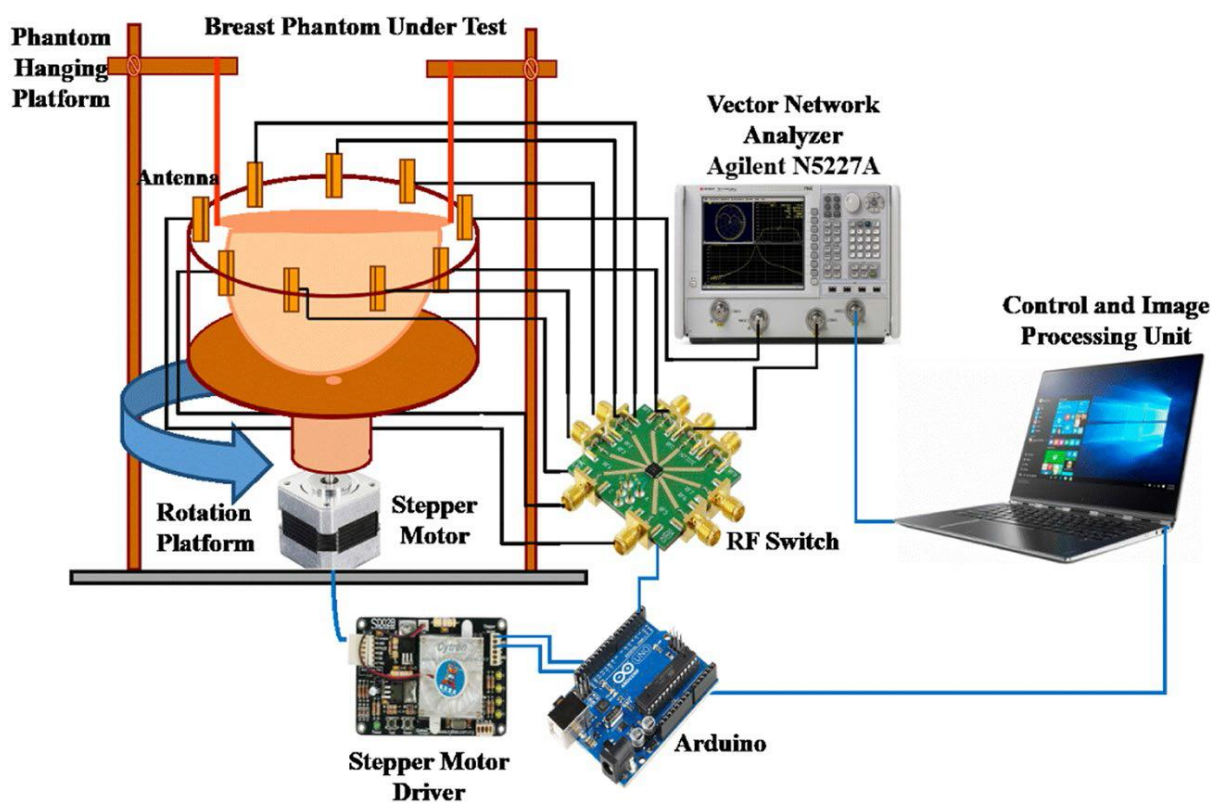


W2	3.71	L4	11
W3	1	L5	3
W4	2	L6	3
W5	0.5		

**Microwave Imaging System:**

Figure 3 depicts the proposed imaging systems architecture as well as additional parts. Nine antenna arrays make up the MIS that was created. An image reconstruction, signal processing, and port RF switching software for a laptop running MATLAB. A clear, round ABS plastic container with movable sides houses the antenna. SD02B stepper motor's control is mounted on a plastic container. With the aid of a suspended platform, the phantom is positioned inside the antenna array and scanned there. Don't

go closer than 2 cm to the model than the installed antenna. To spin the array 0 to  $2\pi$  around the breast model in polar coordinates, the mechanical rotation stage can use stepper motors. With the help of a coaxial connection, the antenna is linked to the RF switch. In the frequency domain, Port 1 of the VNA produces and transmits a microwave signal to the phantom. Switching the receive antennas on the PC using the Agilent E8358A (VNA) and a MATLAB application allowed us to collect the backscattered signals that were picked up by the eight receiver antennas. For a total of 360° covered by 50 identical sites, backscatter data (S21, S31, S41,... S81) were gathered at every 7.2° rotation.



**Fig 3: The diagram and different components of the proposed breast imaging system**



All of these components, along with the electronic machine circuits necessary for data collecting, are managed by the PC-controlled Arduino Uno system, which is connected to your computer through USB. The data is processed to look for cancer using imaging algorithms that rebuild mammography from the collected data. The safety of patients and people was not taken into account in this investigation. The breast model is set inside an antenna array, which enables the breast tissue to both absorb and reflect microwave signals. The complete imaging system is calibrated at operational frequencies using the Agilent 85052D calibration kit to minimise air interference.

The current section of the paper follows UWB DRA employing FR4 lossy substrate (dielectric constant  $[\epsilon_r] = 4.4$ , thickness  $(h) = 1.57$  mm), and alumina ( $\epsilon_r = 9.8$ ,  $h = 4$  mm). Employ similar. The single-base RBMI system sensor that is being suggested With overall measurements of  $20 \times 15 \times 5.64$  mm<sup>3</sup>, the proposed antenna comprises a copper feed network. CST MWS V017 was utilised in the design and simulation of the planned DRA. To determine the starting dimensions of a dielectric resonator (DR) supplied using a microstrip line feeding strategy, the proposed DRA uses a dielectric waveguide model of the FR4 slab. It was planned (equation 1).

$$f_{mnl} = \frac{c}{2\pi\sqrt{\epsilon_r}} \sqrt{k_x^2 + k_y^2 + k_z^2}$$

The wavenumber on the x, y, and z axes, respectively, are denoted by  $k_0 = 2\pi f$ ,  $k_x = m\pi/a$ ,  $k_y = n\pi/b$ , and  $k_z = l\pi/2d$ . The DRA has three dimensions, denoted as a, b, and d. The three DRA values are as follows:  $a = 8$  mm,  $b = 8$  mm, and  $d = 4$  mm. By replacing  $m = n = l =$

1,  $k_x = 0.392$ ,  $k_y = 0.392$ ,  $k_z = 0.392$ ,  $c = 3108$  m/s, and  $\epsilon_r = 9.8$  in Equation 1, one may find the resonance frequency of  $f_{111}$ . Receive  $f_{111} = 10.4$ GHz. The fundamental formulas (2) and are used to determine the FR4 substrate's substrate size (3).

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$$L_s = 6h + L$$

$$W_s = 6h + W$$

where the board height is 1.57 mm, and  $L = W = 8$  mm (i.e. optimised DR length and width, respectively).  $17.4 \times 17.4$  mm<sup>2</sup> are the predicted substrate dimensions in equations (2) and (3), while the optimum dimensions, which excite the 10.6 GHz frequency, are  $15 \times 20$  mm<sup>2</sup>.

To offer a 50 impedance match for the suggested antenna, which is mounted on top of the FR4 board, the copper feed is tailored for a "I" shape ( $t = 0.035$  mm). Using Equation 4, one may get the microstrip feed antenna's width  $w$ .

$$Z_0 = \frac{120\pi/\sqrt{\epsilon_{ff}}}{\frac{w}{h} + 1.393 + 0.667\ln(\frac{w}{h} + 1.444)}$$

Where  $\epsilon_{ff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ \left( 1 + 12 \frac{h}{w} \right)^{-1/2} \right]$

$W$ ,  $Z_0$ ,  $h$ , and  $ff$  in Equation 4 stand for the width, impedance, substrate height, and effective relative permittivity of the antenna, respectively. If  $Z_0=50\Omega$ ,  $h=1.57$ mm,  $\epsilon_r=4.4$ , and  $\epsilon_{ff}=15.07$  values are used in formula 4,

$w=3.3$ mm, or the microstrip line's width, is calculated. Additionally, to enhance impedance matching outcomes, two rectangular stubs are joined to the top and bottom of the feeder. The ground

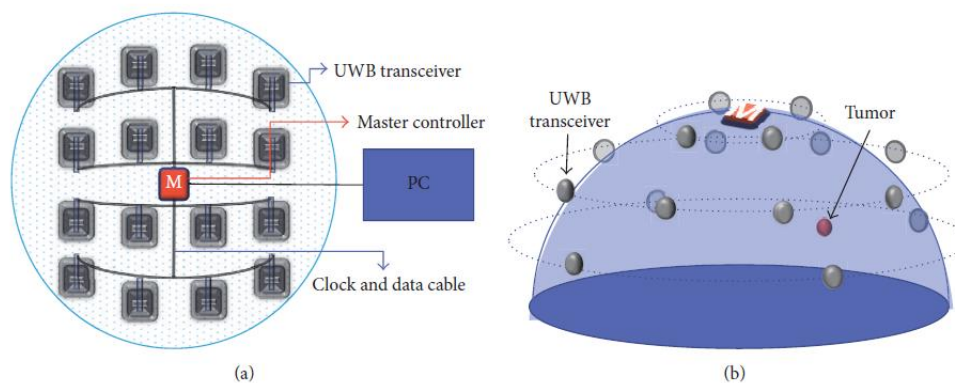


construction is flawed, the tread has reduced, and there are grooves in it. The substrate's base receives it after deposition. By doing so, the cubic DR structure is able to exhibit the appropriate UWB properties. For usage as a sensor in suggested biomedical applications, the final DRA was tuned. Copper-related material is depicted in black, FR4 is represented by grey, and DR is represented by pale yellow. The optimum parameter values for the proposed antenna's different sediments are displayed in Table 1 for your reference.

### Result and Discussion:

We suggest a time-domain measurement-capable instantaneous microwave imaging system. A host controller and a UWB-DRA transceiver make up the system. Figure 1 depicts the set-up of our formerly suggested time-domain microwave breast imaging system. A main controller is located in the

centre of a 3D hemisphere that is surrounded by UWB-DRA transceivers. Instead of high-speed oscilloscopes and precise pulse generators, we employ CMOS transceiver chips. The primary controller also functions as a switch matrix. We achieved a sampling rate of 28.2 Gs/s by using the equivalent time sampling technique at a sampling frequency of 1.76 GHz. The host controller's single system clock powers all 16 transceivers at once. The whole scan time is greatly decreased to 1.32 seconds thanks to the transceiver's single UWB pulse transmission while the other receivers simultaneously receive the signal at a sampling rate of 1.76 GHz. Over 10 seconds are covered by the frequency domain system. Fast scan periods are crucial to obtaining a good breast image since patient movement during measurement can result in artefacts in the collected images.

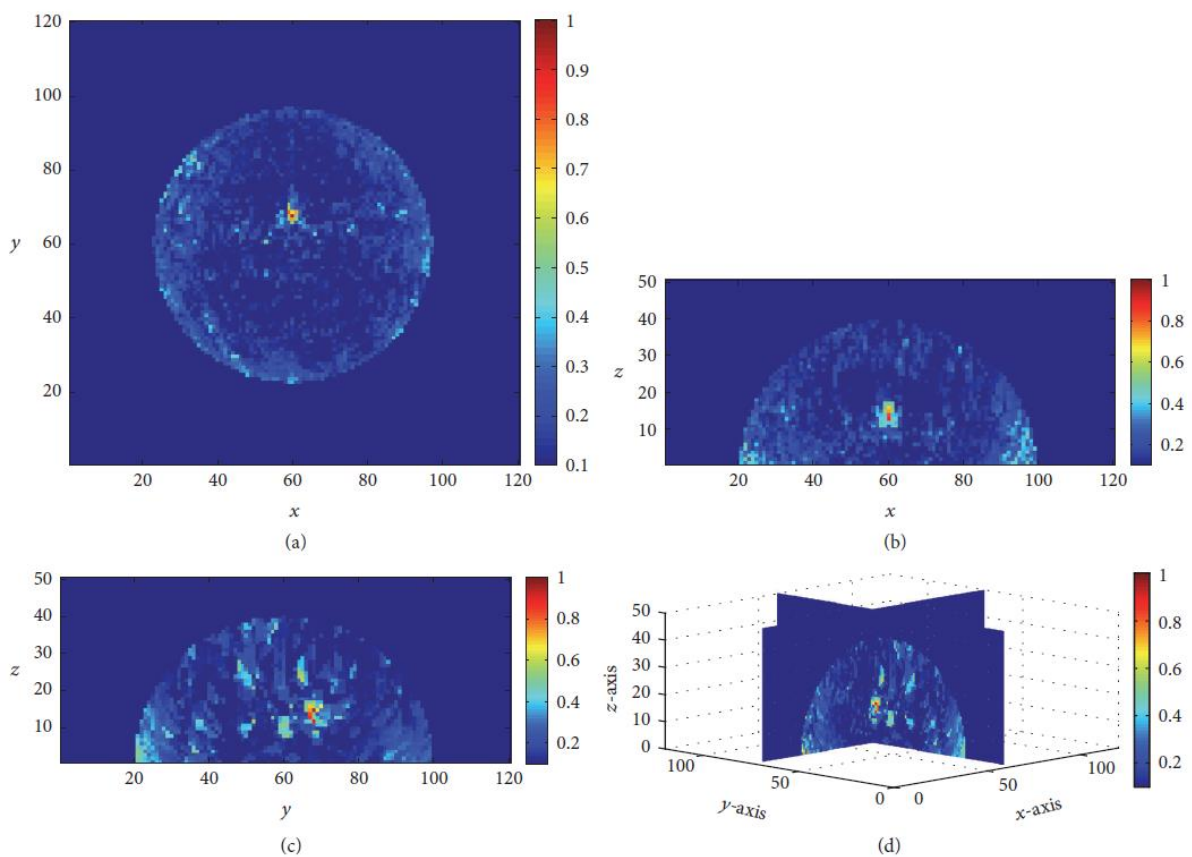


**Fig 4: Breast cancer imaging system with 16 UWB transceivers. (a) Configuration of UWB-DRA transceivers and master controller and (b) location of UWB-DRA transceivers with a 3mm radius tumor inside**

Figure 5 displays the results of all potential noise sources, including clock skew ( 1 percent + 5ps), clock jitter, 2mm thick skin, fat, and tumours with a 3mm radius in 3D hemispheres. Using white noise, the sculpted breast model's contours were restored after 1000 measurements (1.6 ps). The tumour was

situated at  $x = 70$ ,  $y = 60$ , and  $z = 17$  in a breast model with an 84 mm diameter. A modulated Gaussian pulse with a pulse width of 0.3 ns and a frequency of around 6 GHz is broadcast using the UWB-DRA antenna mounted along the breast model.





**Fig 5: Cross-sectional images of restored breast model with 1,000 measurements, (a)  $x$ - $y$  plane,  $z = 17$ , (b)  $x$ - $z$  plane,  $y = 70$ , (c)  $y$ - $z$  plane,  $x = 60$ , and (d) 3D image**

**Table 2: Comparison of the different measurements system with the proposed system**

Reference	and frequency band	Types of antenna	Experimental test with mimic of breast phantom	Type of imaging technique	Conclusion
[21]	20 × 20 (7-12 GHz)	Stair case DRA	Not done	Multistatic	complicated size, unknown tumour location, and unknown tumour size
[22]	30 × 30 (3.47-9.62 GHz)	H-shaped DRA	Not done	NA	tumour location and size cannot be determined
[23]	30 × 30 (24-27 GHz)	4 line fed rectangular DRA	not done	Monostatic	the provision of circularly polarised DRA While having a high gain,



					biological applications should not be used. Since the structure is complicated
[24]	NA(2-12 GHz)	Tapered slot line antenna	Done	NA	intricate and essential structure Coupling Immersion
[25]	NA (2.4-4.7 GHz)	Microstrip patch antenna	Done (petroleum jelly + wheat flour)	Monostatic	These were the procedures used in the antenna experiments. Tumor of considerable size (radius: 6.5mm) focus on primarily. instead of the tumor's size, deep tumour detection
<b>Proposed Method</b>	20 × 15 (4.3-12.6 GHz)	Cubical-shaped DRA	Done (gelatin + petroleum jelly)	Monostatic	a little DRA that can find tumours in the right places and of the right sizes.

**Conclusion:**

The goal of this mission is to design, create, and employ a novel portable UWB antenna-based microwave imaging system that can be utilised to detect breast cancers in real time. For microwave imaging, a large pulse envelope peak side-slit UWB directional Vivaldi antenna is proposed. The antenna's tapered slot design offers excellent gain and good directivity. A UWB compact antenna with few patches and ground alterations to increase bandwidth is designed and simulated in this research. By constructing an array of 2x2 elements, essential characteristics like gain and directivity can be improved. Consider varied element spacings when examining

antenna arrays. Comparing the results to conventional nonlinear inverse scattering methods from a quantitative perspective and in terms of computing burden, the results are quite encouraging. Each measurement takes 1.32 seconds of equivalent time sampling to transfer from the time domain clock to the 1.76 GHz sampling clock. Thus, by shortening measurement periods, it is possible to minimise artefacts brought on by patient movement.

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