Abstract of the Research Work

Design, Analysis and Application of UWB Vivaldi Antenna for Microwave-Based Breast Cancer Diagnosis System

The scientific rationale for doing this work is owing to the statistical data observed in 2017 which shows that breast cancer has ranked number one cancer among Indian females with age standardized incident rate of 25.8 for every 100,000 women and mortality rate of 12.7 among 100,000 women. The main causes for this detected hike are due to insufficient screening, diagnosis of the tumor at extremely developed stage and inaccessibility of appropriate medical facilities. The current screening techniques in progress for breast imaging are Mammography, MRI, Ultrasound, and Positron Emission Tomography.

The Mammography is a widespread screening method which is fast technique and utilize X-rays to create the breast images. However, it has few shortcomings such as: It involves a compression of the breast during examination which causes the tissues to overlap and produce a false positive result which leads to recalls and further examination. Also, it is not useful in diagnosing cancer in women with dense breast tissues.

The second commonly used screening technique is the breast MRI which uses the radio waves and the strong magnetic field to take the inside images of the human body. The downsides of MRI

screening are that it is expensive, requires use of contrast liquid for imaging and moreover the examination takes more time (range from 20 minutes to 90 minutes, sometimes even more) and very slight movement can cause distorted images.

An another painless and less radiation exposure imaging technique is Ultrasound Imaging technique which uses ultrasound waves (2.5 MHz-15 MHz) to see the internal body structure. Ultrasound imaging is not affected by the density of breast tissue and does not require contrast material. Despite the advantage, it has low resolution and does not differentiate malignant and benign tumor.

Yet another newest imaging modality is PET that involves radioactive tracers which is either swallowed or inhaled or given through a vein. In PET the harmful radiation is less, but the use of radioactive tracer's means, it is not advisable for pregnant women and diabetics patient.

The above listed shortfall of the current diagnostic tools leads to develop a new imaging technique called as Microwave-Based Imaging. Microwave based Imaging (MWI) is an emerging technique that exploits the functional and physiological information encoded in dielectric properties to distinguish and characterise the different tissues and or pathologies. It is like CT, MRI, and Ultrasound, etc but uses electromagnetic radiation in the frequency band of 1 GHz-10 GHz to reconstruct the dielectric properties of an organ under test. In

microwave imaging system, the OUI is illuminated by an ultra-wideband pulse from an antenna or from an antenna array, and later the backscattered signals from the OUI are received and recorded to pre-process and reconstruct the OUI images.

Compared to the existing imaging modalities, the MWI system offers many rewards such as: It is inexpensive, non-ionizing, and non-destructive imaging procedure to assess the pathological conditions of bio-tissues for the clinical analysis and for the medical intervention, It has the ability to offer functional imaging without the use of contrast agents, it can be effectively used for the detection of biological anomalies like tumor at an early curable stage and, It reconstructs the complex permittivity of the imaging object unlike other imaging modalities. The main issue in MWI system is to efficiently recover the information carried by the sensitive microwaves. In such systems, the antenna array design is known to have a direct impact on quality of the images which are reconstructed using either quantitative or qualitative imaging methods.

The proposed research work aims to:

I. Design and fabricate the Vivaldi antennas with compact geometry and with enhanced performance features such as ultra-wide bandwidth, better gain, high front to back ratio, better group delay with flat delay characteristics over operating bandwidth, reduced E plane beam squint and high-fidelity factor.

II. Design MWI prototype comprising arrays of proposed Vivaldi sensor and the tumor embedded breast model and analyze the system's ability in non-invasive diagnosis of breast tumor.

III. Efficiently process the scattered signals received by the receiving sensor array and transform the signals to produce the images using a quantitative image reconstruction algorithm with help of the MATLAB software.

IV. Validate whether the proposed compact antennas and the deployed array setup are suitable to construct a device that can detect breast tumor.

Summary of Results:

The main objective of this thesis is to design and analyse the effectiveness of the proposed antennas and the antenna array configuration for MWI systems. The proposed Vivaldi antenna with hemicylindrical slots and Directors (VAHCSD) exhibits all the required characteristics for an MWI system such as simple geometry of size 49×48.5×0.8, UWB operation, Peak gain of 9.5 dB, unidirectional radiation pattern, fidelity factor of 0.9557 and flat group delay with a small variation of +0.5ns. In the work II, size of VAHCSD design has been reduced and radiation characteristics have been enhanced further by introducing a new circular tapered Vivaldi antenna with director. Compared to VAHCSD geometry, the geometry of CTVAD has been reduced by 26.38% at same time

0.5dB-1dB gain increment has achieved in the low frequency band. In addition, the CTVAD antenna exhibits good pulse handling ability and time domain performance. Later, the applicability of proposed VAHCSD and CTVAD structure for breast imaging is demonstrated using a breast phantom embedded with a single tumor of high permittivity. A two-system made of 20-element antenna placed in two levels as a circular array configuration surrounding the breast phantom have been proposed. The evaluation on the SAR results shows that the CTVAD structure and VAHCSD structure have low SAR over the desired operating bandwidth, which confirms that the designed structure can be utilized to use in the microwave imaging systems. The frequency domain analysis presented herein is a proof of concept to validate the ability of proposed array configuration in identifying a tumor like inclusion. The application of DMAS algorithm in our proposed microwave imaging system consistently demonstrate better clutter suppression and accurate localization of tumor.

Publications:

1. Swathiga Guruswamy, Ramya Chinniah, Kesavamurthy Thangavelu, "*A Printed Compact UWB Vivaldi Antenna with Hemicylindrical slots and Directors for Microwave Imaging Applications*", Elsevier AEU-International Journal of Electronics and Communications,2019, Vol.110, October 2019.

2. Swathiga Guruswamy, Ramya Chinniah, Kesavamurthy Thangavelu, "*Design and Implementation of Compact Ultra-Wideband Vivaldi Antenna with Directors for Microwave-Based Imaging of Breast Cancer*", Springer-Analog Integrated Circuits and Signal Processing,2021,1-14 (Accepted for Publication)

3. Swathiga Guruswamy, Ramya Chinniah, Kesavamurthy Thangavelu,"*A Small UWB Tapered Antenna Design for Microwave Imaging System*" International Journal of Latest Engineering and Management Research (IJLEMR), 2021, Vol.6,1-3.

4. Swathiga Guruswamy, Ramya Chinniah, Kesavamurthy Thangavelu, "*A Novel Microwave-Based Imaging System Design and Analysis for Breast Tumour Detection*" Journal of Xidian University, 2021,Vol.15,302-308.