Cylindrical Microwave Imaging System with Extended Gap Ridge Horn Probes

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Abstract

In this paper, we present a cylindrical microwave imaging system based on a multi-frequency bi-focusing (MFBF) imaging technique using Extended Gap Ridge Horn antenna (EGRH) probe for medical applications. The proposed probe antenna is designed to operate between 0.5 GHz to 1 GHz and filled with a high permittivity material to have an impedance match to the human body. This system has been successfully simulated using CST Microwave studio.

1. Introduction

Over the last two decades, microwave imaging (MWI) for medical applications has been investigated as a novel and promising imaging and diagnostics technique for tumor detection, due to the multiple advantages such as its noninvasive, non-ionizing, and penetrating characteristics. However, designing antennas for medical application present some challenges that should be solved such as the overall size and good impedance matching in low frequencies to ensure the penetrations of the wave in human body. In the last years, many ultra-wide band antennas(UWB) have been proposed in the literature for medical applications and other radar based microwave imaging such as Vivaldi antenna [1, 2], printed patch antenna, Bow-tie antenna, Horn antenna and Extended Gap Ridge Horn antenna (EGRH)[3]. In this paper, we present a EGRH for microwave imaging, the antenna is filled with a material of permittivity $\epsilon_r = 50$ which similar to the average permittivity of human body. The simulated results obtained by CST Microwave studio are then processed in Matlab to reconstruct the image using (MFBF) algorithm that allows us to detect the position of the target.

2. Imaging System Design

The key component of the proposed system is the EGRH, inspired from [3], depicted in Figure 1. The antenna consist of a double ridge waveguide that has a cut-off frequency close to $0.5GHz$. The technique of inserting ridges in the waveguide compared to the simple wave-guide of the same dimensions lowers the cutoff frequency and increase the cutoff frequencies of the next two higher modes to get an antenna that operate in ultra-wide band [4]. In our design $f_c{<}0.5GHz$, the EGRH feed with a coaxial cable of 50Ω by connecting the inner conductor of the coaxial to the lower ridge in the waveguide, then an horn with exponential ridge is added to the double ridge waveguide to match the antenna to the imaging area,and finally the antenna is filled with a material of $\epsilon_r = 50$ to match the impedance with human body. The imaging system of figure 2 contains 8 EGRH displayed as a circular array of antennas along a cylinder with circumference radius of $100mm$ where the EGRH of figure 1 constitutes the basic element of the array, where one antenna works as transmitter and the other antennas receive the scattered signals; The principal step of microwaves imaging is getting the specific target response from the data, this process must be applied before starting the reconstruction of the image by simulating the model with the target and without the target. As result we get two matrices of 8*8 elements of scattered signals, with and without target. By using the equation 1 we get the target response, this direct problem is solved by the numerical software tools CST.

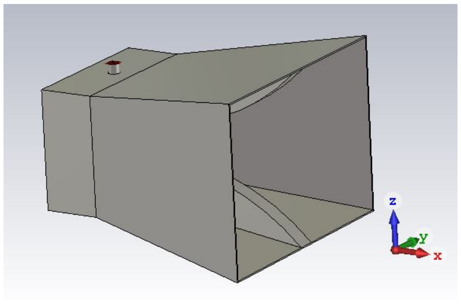

Figure 1: Simulated EGRH antenna.

$$T_{targetresponse} = S_{target} - S_{notarget} \tag{1}$$

The S parameters result of the simulation are imported for processing in Matlab using an (MFBF) algorithm of image reconstruction (inverse problem) based on equation 2 from [5].

$$I(x_f, y_f) = \sum_{T_i} \sum_{R_j} E(\rho_{T_i}, \rho_{R_j}) * \frac{\sqrt{\rho_{R_j - f}}}{e^{-j*k*\rho_{R_j - f}}} * \frac{\sqrt{\rho_{T_i - f}}}{e^{-j*k*\rho_{T_i - f}}} \tag{2}$$

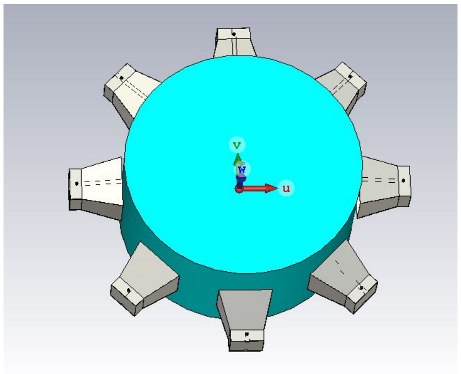

Figure 2: Microwave imaging system.

3. Results and discussion

The system in figure 2 has been simulated using the numerical software tools CST to test the performance of the (MFBF) algorithm developed, we inserted a metallic cylinder of radius 5mm as target in three different positions: ($x = 0mm$ & $y = 0mm$) figure 3, ($x = 50mm$ & $y = 0mm$) figure 4, and ($x = 50mm$ & $y = 50mm$) figure 5. To have a better accuracy on the detection of the target we used UWB signals to reconstruct the image, the addition of the phase and amplitude of each frequency which has the same amplitude and phase at the position of target we get as result an image with a size very close to the actual size of the target for tree different positions.

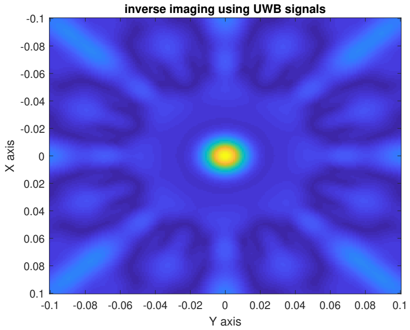

Figure 3: Target at the center.

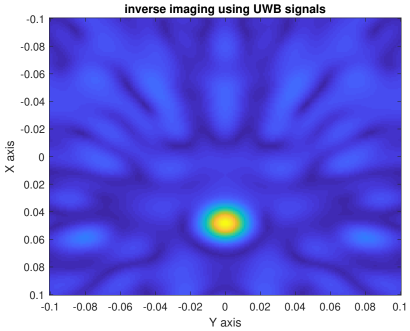

Figure 4: Target at $x = 50mm$.

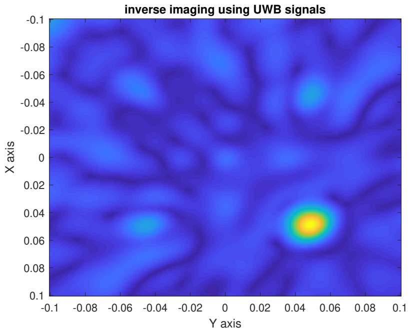

Figure 5: Target at $x = 50mm$ and $y = 50mm$.

4. Conclusions

In this work a microwave imaging System based on the Multi-Frequency Bi-Focusing technique is presented to be used for medical application such as brain and breast cancer detection using EGRH antennas.

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