Resolution Enhancement with UWB Antennas for Microwave Imaging with RAR Algorithm

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Abstract — **The presented paper provides a study with different antenna types selected with a dominant parameter oriented to determine which parameter increase the resolution for microwave imaging algorithms. The used algorithm in this study is a Robust and Artefact Resistance (RAR) based, developed on the last years for breast cancer detection. This study shows that with directivity as dominant parameter the resolution of the image increases.**

1 INTRODUCTION

In recent years UWB (Ultra wideband) Imaging has become popular due to its wide applications, especially for breast cancer detection. This emerging methodology is a valid alternative to existing systems. These systems use electromagnetic waves to investigate under the tissues. The wave propagates through the breast and being shifted and attenuated in amplitude due the different dielectric characteristic between the healthy tissue, and the tumoral tissue. In the last years a system based on RAR algorithm [1] has been developed but its resolution is still not sufficient acceptable for an effective application. For this reason it is needed to test different typology of antennas in order to determine which parameter could improve the resolution of the reconstructed image. The presented paper provides an overview of a study based on 4 different types of antennas and the relative results.

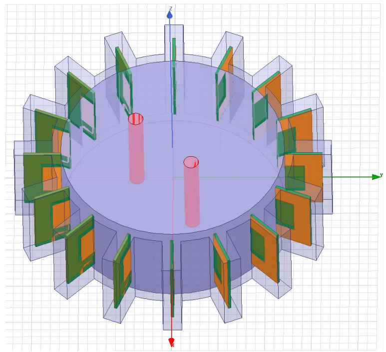

Figure 1: Simulation setup

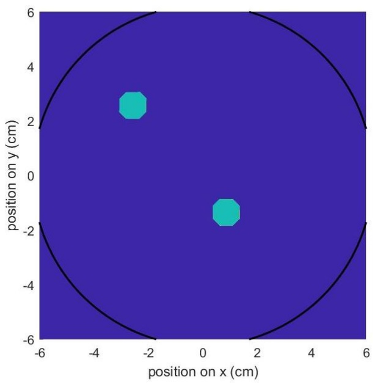

Figure 2: Perfect lesion reconstruction

2 DESIGN APPROACH AND SIMULATION RESULTS

The simulation of the system has been conducted with Ansys HFSS FEM EM simulator. The model used on this study consists of a cylindrical area of analysis surrounded by 16 antennas (Figure 1). A chirp-up signal was used to irradiate the electromagnetic wave from the first antenna and measured by the other 15 antennas. This procedure will occur for all 16 antennas. The reference image is shown in Figure 2. These data will then be used as a reference for the quality comparison of the reconstructed images for each antenna topology tested during the study.

The first analyzed antenna is a microstrip antenna with T-slot [2]. This antenna presents a reduced size, sufficient gain over the operative badwidth and omnidirectionality. In fact this antenna present a size of 25x14.4x0.8 mm^3, a bandwidth form 3.77GHz to 9.43GHz , gain 3 dB. For cross-checking a second antenna with similar properties has been selected [3]. This antenna presents a dimension of 32.3x19x1.6 mm^3 a bandwidth from 3.28GHz to 17.5GHz, a Gain of 5 dB and is ominidirectional. The third antenna selected is a circular patch with reflector [4] which is more directive with bandwidth of 1.52GHz to 15.09GHz and gain of 3 dB with size is 55x40x1 mm^3. The last antenna is a quasi-yagi with reduced size [5] which presents a bandwidth of 2.35GHz to 10.66GHz and gain of

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	Low gain	High gain
Omnidirectional	[2]	[3]
Directional	[5]	[4]

Figure 3: Mapping antenna parameter.

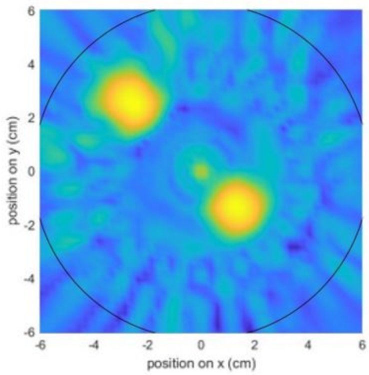

Figure 4: Reconstructed image with antenna circula with reflector

4.5 dB with size 30*34*0.8mm^3. Simulations have been performed with all four type of antennas and all of them can detect the presence of lesion inside the analysis area.

A sweep-up frequency stepped signal has been used with 2048 frequency points.

In order to compare the reconstructed image quality it has been assumed that if the antennas can perfectly detect the lesion no difference will appear on the rebuilded image but if the detection will not be identical the lesion will be oversized.

The reconstructed image is divided by the reference image and calculated in percentage. The equation 1 represents the accuracy percentage (AP) of the calculation.

$$AP = \left(1 - mean\left(\frac{Measured\ image}{Reference\ image}\right)\right) \cdot 100 \quad (1)$$

The results are reported on Figure 7.

As shown in the table the most accurate antenna is the Circular with reflector. A first conclusion is that the directivity is the key parameter for better resolution as shown in Figure 4.

3 EXPERIMENTAL MEASUREMENTS AND RESULTS

In order to evaluate the experimental measurements a setup developed on the last years on our laboratory will be used [6] [7] [8].This system, presents the same antenna configuration as the simulation. The analysis area is bounded by a 3D

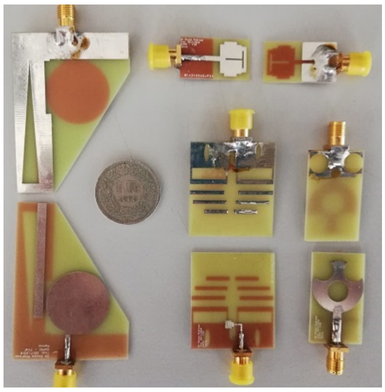

Figure 5: Realized antennas.

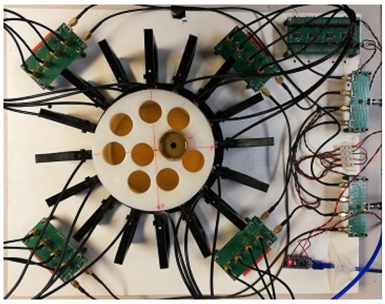

Figure 6: Setup for measurement

printed PLA cylinder with circular cross section of D=12cm and a relative dielectric constant of 3. The area containing a specific oil with same dielectric constant as the PLA and tangent loss of 0.1. For the lesion a mixture of water and salt is used with a dielectric constant approximately of 7.4.

In Figure 5 are shown the produced antennas which are on the left corner the circular with reflector antenna [4], on center the quasi-yagi antenna [5], at the right corner the circular planar monopole [3] and on the upper right corner the T-slot antenna [2].

Moreover Figure 6 shows the experimental measurement setup. An RF switch was used in order to be able to use all 16 antennas as RX or TX having so a total of 240 possible combinations. A chirp-up signal with bandwidth of 1GHz to 8GHz is used with 2048 frequency points setted on the Network analyzer.

Upon completion of the measures, the data are send to a PC running a Matlab algorithm for the image reconstruction.

With the produced antennas it is possible to observe that the most accurate antennas are those with higher directivity as shown in simulation.

On Figure 7 is reported the accuracy of each antenna.

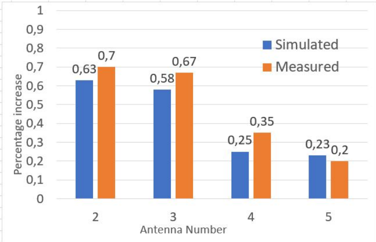

Figure 7: Accuracy percentage of simulated and experimental image reconstruction.

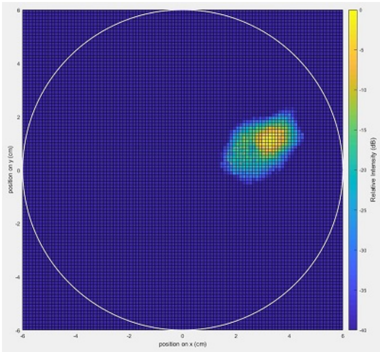

Figure 8: New antennas measurement

For show the increased resolution a comparation between the new antenna on Figure 8 ans the old antenna [7] on Figure 9 can be done.

4 CONCLUSION

A study with 4 antennas which have different parameter is presented. The results shown that an antenna with a good directivity and gain can slightly improve the resolution of the image. On the other hands if the directivity is too high it will not be able to detect lesions on the border of the analysis area.

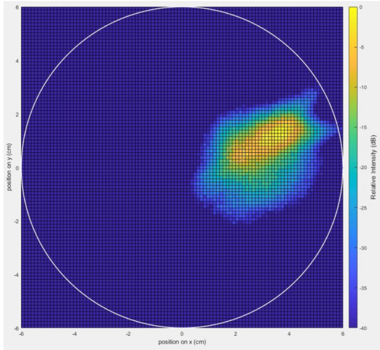

Figure 9: Old antennas measurement

References

[1] Tengfei Yin, Falah H. Ali, Constantino Carlos Reyes-Aldasoro, “A Robust and Artifact Resistant Algorithm of Ultrawideband Imaging System for Breast Cancer Detection“ in: IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 62, NO. 6; 2015.

[2] Radouane Karli, “Miniaturized UWB Microstrip Antenna with T-Slot for Detecting Malignant Tumors by Microwave Imaging“INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,VOL.9, NO.3, MAY 2014.

[3] N. Anveshkumar, Dr. A. S. Gandhi, “Design and Performance Analysis of a Modified Circular Planar Monopole UWB Antenna“in: IEEE - 40222.

[4] N. Anveshkumar, Dr. A. S. Gandhi, “Design and Performance Analysis of a Modified Circular Planar Monopole UWB Antenna“in: IEEE - 40222.

[5] J. Wu, Z. Zhao, Z. Nie and Q.H. Liu, “ Bandwidth Enhancement of a Planar Printed Quasi-Yagi Antenna with Size Reduction“in: IEEE Transactions on Antennas and Propagation, Volume: 62 , Issue: 1 , Jan. 2014.

[6] M. Maffongelli, S. Poretti, A. Salvadè, R. Monleone, C. Pagnamenta, A. Fedeli, M. Pastorino, A. Randazzo, “ Design and Experimental Test of a Microwave System for Quantitative Biomedical Imaging“in: 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), June 2018.

[7] S. Poretti, M. Lanini, A. Salvadè, M. Maffongelli, R. Monleone, “ Antenna design for microwave tomography imaging of high contrast mediums“in: 2017 11th European Confer-

ence on Antennas and Propagation (EUCAP), March 2017.

[8] M. Lanini, S. Poretti, A. Salvadè, R. Monleone, " Design of a slim wideband-antenna to overcome the strong reflection of the air-to-sample interface in microwave imaging"in: 2015 International Conference on Electromagnetics in Advanced Applications (ICEAA), Sept. 2015.