Compact Microstrip Antenna Design for Microwave Imaging

S.Adnan[1], R.A.Abd-Alhameed[2], H.I.Hraga[3] I.T.E.Elfergani[4] and M.B.Child[5].

Mobile & Satellite Communications Research Centre, School of Engineering, University of Bradford, Bradford, West Yorkshire, United Kingdom, BD7 1DP.

[1]s.adnan@bradford.ac.uk, [2]r.a.a.abd@bradford.ac.uk, [3]h.i.hraga@bradford.ac.uk,

[4]i.t.e.elfergani@bradford.ac.uk, [5]m.b.child@bradford.ac.uk,

***Abstract-* An ultra–wideband microstrip antenna design is considered with respect to applications in breast cancer detection. The underlying design concept is based on ground penetrating radar (GPR). Simulated and measured prototype performance show excellent performance in the input impedance and radiation pattern over the target range from 4 GHz to 8 GHz. The 4 GHz to 8GHz frequency band for microwave imaging perform better in comparison with other microwave frequencies. The antenna also shows a reasonable uniform radiation performance in the broadside direction which contributes to the reduction of clutter levels, thus aiding the re-construction quality of the final image**

Index-term- Breast cancer, Ground Penetrating Radar (GPR), Ultra-wide Band (UWB)

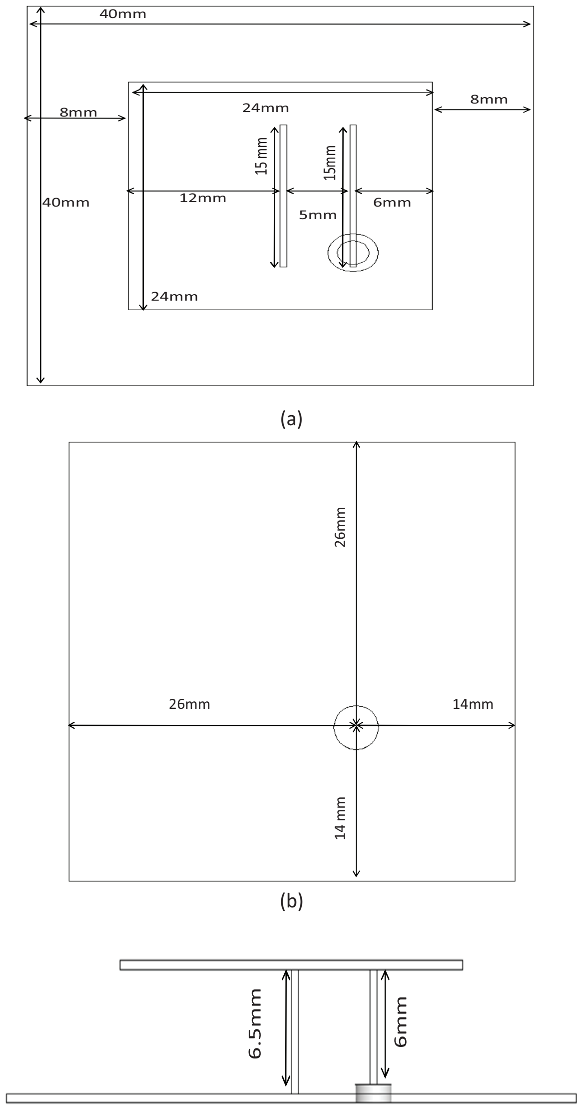
I. INTRODUCTION

The use of microwave imaging in non destructive testing is well established in a wide range of industrial and military applications, this methodology has potential for several medical procedures, such as breast cancer screening [1–2]. Breast cancer is a major cause of death among women, and its early detection through screening programmes increases the rate of successful outcomes, and promotes prevention. X–ray mammography is thought to be the most effective detection tool, with a very high success ratio compared with other imaging modalities. X–ray imaging does have some limitations, including occasional false positive/negative findings; also the electron beams used for X–ray scanning are highly ionising, and subject to a tough safety regime. Microwave imaging offers an interesting alternative, is non invasive, and non ionizing, and in principle can reconstruct a detailed three dimensional image. Normal tissue is transparent to microwaves, but the higher water content clustered within cancerous cell colonies act as strong scattering centres, the resulting differential response is used to detect the tumour [3–4]. These back–scattered signals may be used to reconstruct a high contrast three dimensional image of the region. Microwave imaging has other attractive features, e.g. it does not require compression of the breast.

This method is closely related to the form of ground penetrating radar used in aerial targeting and landmine detection. For radar base microwave imaging short-pulsed signal is transmitted from a single UWB antenna into the breast and receives any back-scattered wave from the same antenna. This process will be repeated for different location around the breast. Much energy is reflected back with the presence of tumor and this may significantly affect the response to predict the location of tumor. The travel time of the signals at various locations are recorded and computed. This system does not require complex image reconstruction algorithms similar to any radar-based system and hence offer detailed information than the tomography microwave imaging method. To produce a high level of resolution an ultra–wideband pulse must be used, which limits the class of antenna which may be used at both the receive and transmit front end. The basic antenna requirements will include large fractional bandwidth, low side lobes levels and, and low levels of mutual coupling between the radiators. Fat dipoles (bowties), monopoles, horns and Vivaldi antennas are all candidates for ultra-wideband responses, however some of these constructions are expensive and relatively bulky, and some are not suitable for imaging applications. The radiator element needs to be light, planar, or possibly conformal, and low cost. Microstrip antennas meet several of these criteria, but have fundamentally constrained bandwidth performance. Nevertheless, there are several proven methods for bandwidth expansion in microstrip antennas. This paper presents a design of microstrip antenna which is mounted on two vertical rectangular plates. The modelling was mostly carried out using a frequency domain finite element analysis (HFSS), the optimised model was cross validated, and used as a template for construction.

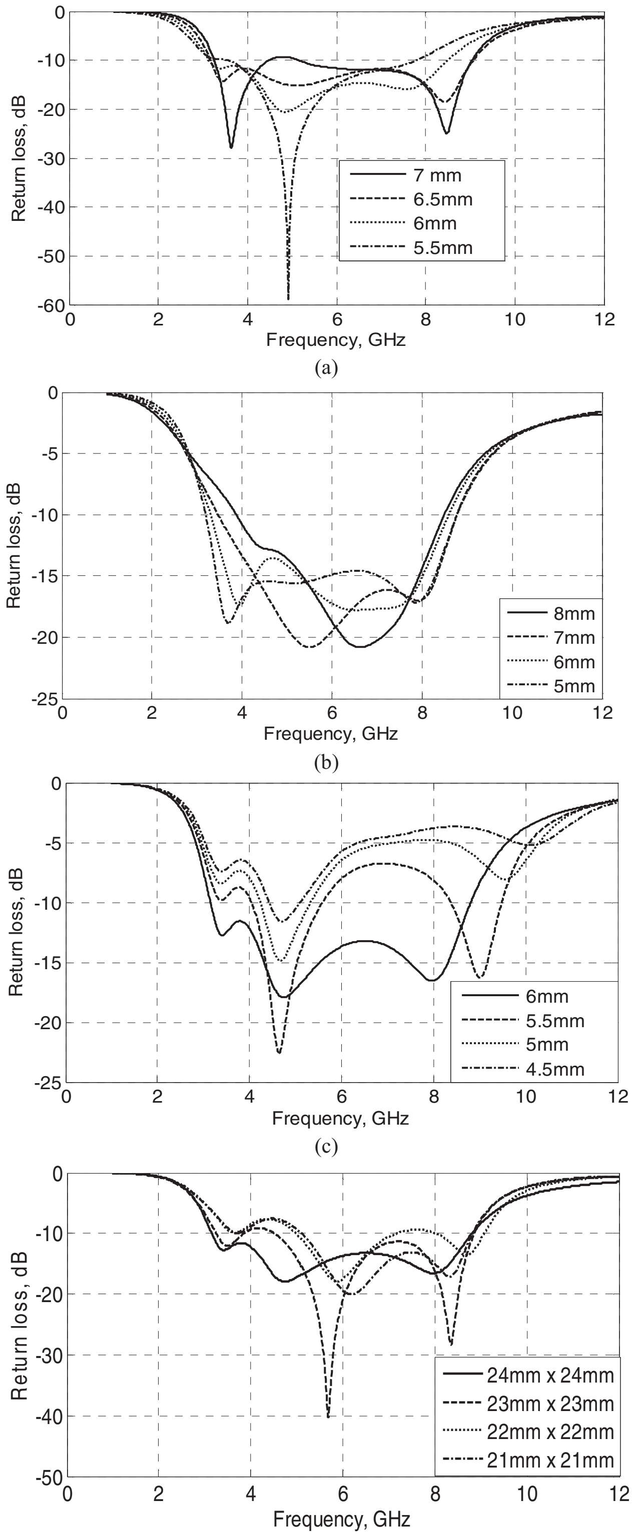
II. ANTENNA DESIGN

The proposed antenna geometry is shown in Figure 1, the antenna is mounted on two vertical 15mm plates over a finite ground plane (40 mm × 40 mm), the metal thickness is 0.5mm. A rectangular plate of height 6 mm is used to feed the antenna by connecting the vertical plate to the feeding probe through the slot of diameter 4 mm in the ground plane (refer to Fig. 1). Parametric reduced order models for this structure were generated and analysed using Ansoft HFSS. The parameter sweeps were used to guide the optimisation of the target antenna performance. Four parameters are considered in this analysis: the height of the antenna over the ground plane, the size of the rectangular patch, the separation, and height of the vertical plates.



(c)

Figure 1: Geometry of the Antenna. (a) Top view, (b) Ground plane (c) Side view.



(d)

Figure 2: Parametric study. (a)Height of Antenna, (b) Gap between the vertical plates, (c) Height of the feeding plate (d) Size of the radiating patch.

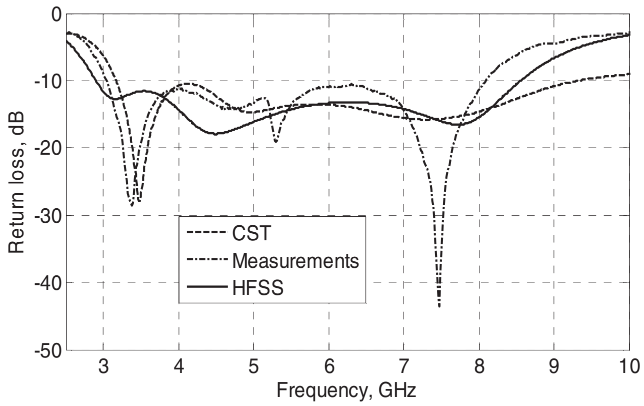


Figure 3: The input return loss of the proposed antenna

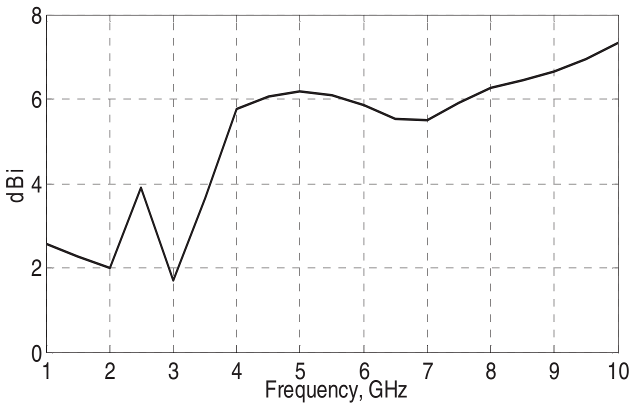


Figure 4: The power gain of the proposed antenna.

III. RESULT AND DISCUSSION

Return losses are compared for the simulated model and the measured prototype are given in Figure 3, it can be seen that these results are in close agreement over the proposed operating bandwidth (i.e. 4 GHz to 8 GHz). Variations of antenna power gain vs. frequency are given in Figure 4, these results clearly show that the gain was mostly 6 dB over the operating bandwidth. However, the minimum gain is 1.9 dBi at 3 GHz. The simulated E_θ and E_ϕ far field characteristics in the xz and yz planes are given for four selected frequencies are given in Figure 6. The radiation patterns show an approximately 10 dB front–to–back ratio. The operating frequencies under consideration display a beam width of ±40°, which is acceptable for our purposes. In addition, the antenna presents a strong linear polarisation in the vertical sense

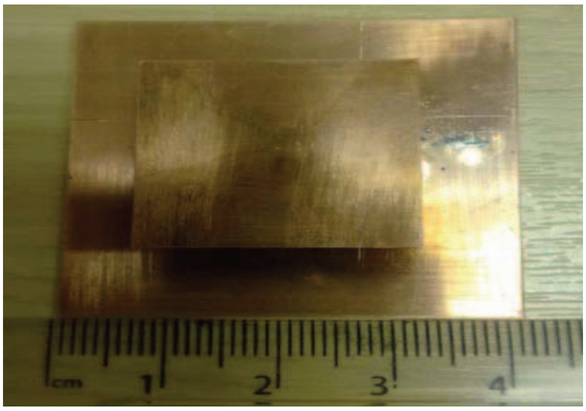


Figure 5: Prototype of the Antenna.

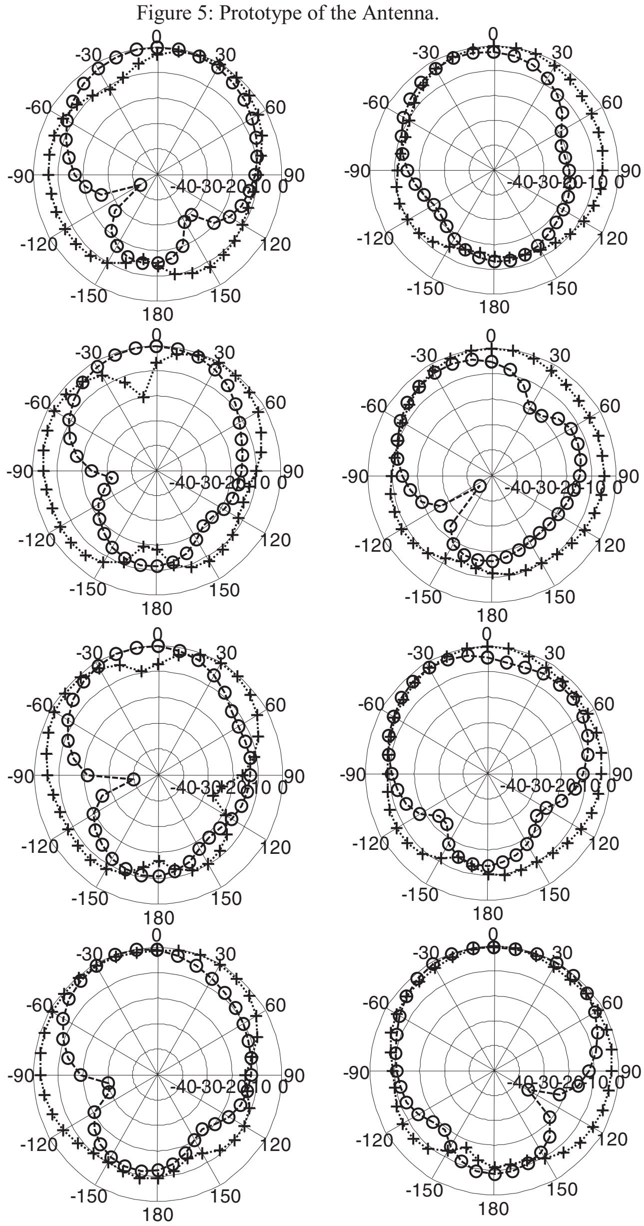


Figure 6: Radiation pattern for the proposed antenna at (starting from the top) 5GHz, 6GHz, 7GHz and 8GHz at z-x plane(left) and z-y plane (right) ('++++' E_θ and o-o-o E_φ).

IV. CONCLUSION.

An ultra–wideband antenna mounted on two vertical planes has been designed for microwave imaging arrays, the selected application being breast cancer detection. The antenna has shown good impedance matching over the whole required bandwidth. The antenna has achieved 6 dBi in the broadside direction, with an acceptable front–to–back ratio of 10 dB which promotes good image reconstruction through reducing the clutter levels

ACKNOWLEDGMENT

The authors wish to acknowledge the help of Mr Dhirajlal Chavda (Workshop Manager, School of Engineering, University of Bradford) for his help in the fabrication and construction of the antenna prototypes.

REFERENCES

[1] C Yeh, R Zoughi "A novel microwave method for detection of long surface cracks in metals," *IEEE Trans Instrum Meas*, pp. 719-25, 1994.

[2] N Qaddoumi , S Ganchev , GW Carriveau , R Zoughi "Microwave imaging of thick composites with defects," *Mater Eval*, 1995.

[3] E. C. Fear, X. Li, S. C. Hagness, and M. A. Stuchly, "Confocal microwave imaging for breast cancer detection: Localization of tumors in three dimensions," *IEEE Trans. Biomed. Eng*, vol. 49, pp. 812-822, Aug. 2002.

[4] E. C. Fear, P. M. Meaney, and M. A. Stuchly, "Microwaves for breast cancer detection," pp. 12-18, February/March 2003.

[5] X. Yun, E. C. Fear, and R. H. Johnston, "Compact antenna for radar-based breast cancer detection," *IEEE Trans. Antenna Propagat*, vol. 53, pp. 2374-2380, Aug. 2005.

[6] C. J. Shannon, "A dielectric filled slotline bowtie antenna for breast cancer detection," *M. Sc. Thesis, The University of Calgary, Alberta, Canada*, Sep. 2004.

[7] M Chiappe, G. L. Gragnani,, "Vivaldi antennas as detectors for microwave imaging: Further steps in its radiation feature analysis," *IEEE International Workshop on Imaging Systems and Techniques*, 2005.

[8] X. Yun, E. C. Fear, and R. Johnston, "Broadband cross-polarized bowtie antenna for breast cancer detection," *IEEE Proc. Antennas Propagat*, pp. 1091-1094, 2003.

[9] S.D Targonski, R. B.Waterhouse, "Design of wide-band aperture stacked patch microstrip antennas," *IEEE Transaction on Antennas and Propagation*, vol. 46, 1998.

[10] R.Nilavalan, I. J. Craddock, A. Preece, J. Leendertz, and R. Benjamin,, "Wideband microstrip patch antenna design for breast cancer tumour detection," *IET Microwave Antenna Propagation*, vol. 1, pp. 277 - 281, 2007.

[11] "Ansoft High Frequency Structure Simulator corporation, 11, 2007."