Microwave Flexible Antennas for Breast Cancer Imaging

M. Liaqat*, LG. Costa*, TC. Vasconcelos*, PS. Lessa*, EC. Lins* and FD. Nunes*,

* Universidade Federal de Pernambuco, Recife, Brasil

e-mail: maryamag698@gmail.com

Abstract – *Microwave Imaging is an emergent and low-cost modality of medical imaging that is suitable for use in tissue diagnostics, in special, cancer in breast tissue. Because of that, the design and substrate of antenna plays an important rule on the system performance. This article presents the development of compact, cost-effective and wearable microwave flexible antennas, specially designed for female breast imaging. The results of simulations of two different shapes of like Rectangular patch and Bow-Tie antennas ranging between 1.9GHz and 2.7GHz are shown here. Pyralux Polyimide (ϵ=3.2 and thickness= 0.0508mm), cotton (ϵ=1.6 and thickness= 0.48mm) and polyester (ϵ=3.2 and thickness=0.36mm) are the substrate material of the flexible antennas to evaluated to find the best performance of Return Loss and Gain as well as Electromagnetic Field Distribution. Simulations were done using HFSS software. Results revealed that bow-tie antenna is more efficient and smaller than patch antenna. The pyralux polyimide antenna is highly omnidirectional.*

Keywords: *Microwave Imaging, Compact and flexible antenna, Cost-effective antenna, wearable technology, Breast Cancer*

Introduction

Breast cancer is one of the principal cause of global mortality and morbidity in the 21st century and almost 12% of all kinds of cancer worldwide [1]. Early detection is the key to control the death rate (which is 80%) due to breast cancer [1], which is hard with x-ray mammography. Therefore, Microwave Imaging (MI) of breast emerges as a novel modality of imaging to be complimentary to x-ray mammography. MI is based on detection of non-ionizing microwave radiation diffused inside and transmitted throughout the whole female breast [2][3]. The working principle of microwave imaging technique is based on the contrast of dielectric properties between tumors and healthy tissues. The scattered signals of microwave antennas are collected. The size and location of tumor is estimated by difference of electric and magnetic fields strengths of scattered waves [4]. The shape of antenna plays very important role along with the type of antenna substrate [4]. Specifically, for the present case the substrate material is of great importance due to the flexibility to make a wearable diagnostic device. This article presents the initial results of flexible patch antennas for development of a cost-effective and user friendly for breast cancer diagnosis.

Microstrip patch antennas of Rectangular and Bow-Tie shape ranging between 1.9GHz and 2.6GHz were simulated using High Frequency Simulator Structure (HFSS) software. The performance parameters like Return Loss, Gain and directivity of three different flexible substrates materials (pyralux polyimide, cotton and polyester) were evaluated.

Materials and Methods

Microstrip antennas are selected for current research because of its characteristics like low profile, low weight, ease of fabrication, flexibility and low cost. Microstrip antenna has small bandwidth and highly directive. Patch antenna also known as resonant antenna [5]. Microstrip patch designed on metal surface are feed by either, feed line or coaxial cables. Patch antenna consist of at least 3 layers, ground (metal), dielectric substrate and upper layer of conducting material. The length of the patch (L) is almost half of the wavelength [6]. Electric field is perpendicular to the patch whereas the magnetic field is parallel. [6]. The resonant frequency of patch antennas can be tuned by changing the geometric parameters (like width, length etc) [4]. Different characteristics parameters like radiation gain, resonant frequency return loss and directivity of antenna are of great importance. The matching impedance of antennas are set to be 50ohms which can be found using the following mathematical relations in table 1. Geometry parameters and substrate material affects the properties of antenna.

The antennas in this article were theoretically designed for 2GHz, but resonance frequency can be shifted 2-4%. According to antenna theory for half-wavelength patch antennas, this shift is due to fringing field effect. Fringing effect is also affected by thickness of substrate of antenna.

Table 1: Effective Permittivity, Parameters and Impedance [7][8]

Effective Parameters
For Patch antenna when w/h≥1 $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[[1 + 12h/w]^{-\frac{1}{2}} + 0.4(1 - w/h)^2\right]$ $Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} ln\left[\frac{8h}{w} + \frac{w}{h}\right]$
For Patch Antenna when w/h<1 $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[[1 + 12h/w]^{-1/2}]$ $Z_0 = \frac{1}{\sqrt{\varepsilon_{eff}}} \frac{120\pi}{\left[\frac{w}{h} + 1.393 + \frac{2}{3}\, ln\left[\frac{w}{h} + 1.444\right]\right]}$
For Bow-Tie $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[[1 + 12h/a]^{-1/2}]$ $Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} ln\left[\frac{8h}{a} + \frac{a}{h}\right]$

In present study, Bow-Tie patch and Rectangular patch as design (Figure 1) were chosen because of their symmetry, ease of draw and manufacturing.

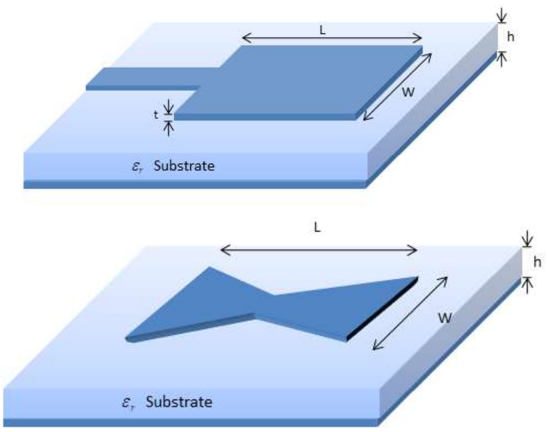


Figure 1: Schematics of both for Rectangular Patch and Bow-Tie Antenna

Different substrate materials were studied for two types of antennas operating between 1.9-2.6GHz. For flexible antennas Cotton, Polyester and Pyralux Polyimide were used as substrate.

Results and Discussion

Two types of antennas were simulated and analyzed for different types of flexible substrates like Pyralux Polyimide, Polyester and Cotton. Polyester and Cotton are fabric materials which may be used for wearable antennas in the future. The rectangular patch antennas are feed by microstrip feedline whereas bow tie antenna is feed by coaxial feedline.The antennas were simulated to optimize the charateristics properties of antenna like return loss (S11), gain and directivity of antenna. Several factors influence the frequency shift between measurements and simulated as manufacturing tolerance, errors, and limitations in measurement. Moreover, in the simulation the material is perfect with no variations in thickness and often the dielectric constant of the material is little different from that commercially available.

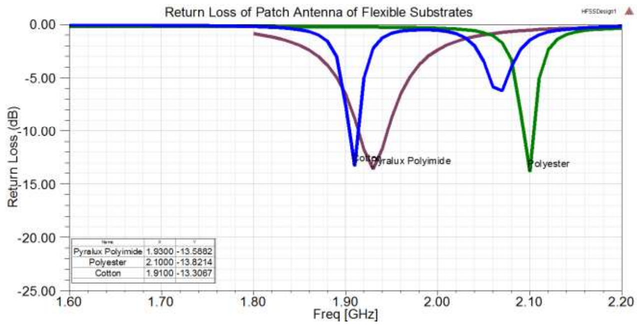


Figure 2: Return Loss of different Substrate for single Rectangular Patch Antenna

Return Loss of patch antennas is less than -10dB as shown in figure 2. For radiating frequency of all different substrates, at the center (phi=0), figure 3, shows that the Patch antennas are omni-directional. Directivity and gain are directly related parameters of antenna. The gain of all three types of substrates is shown in figure 4.

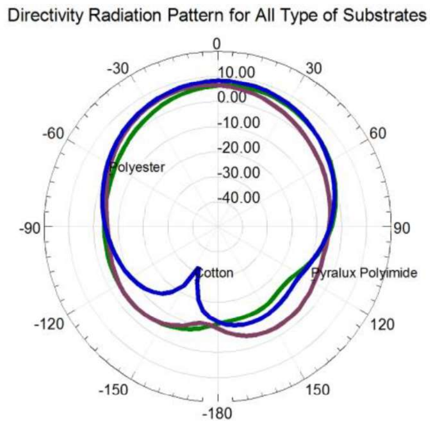
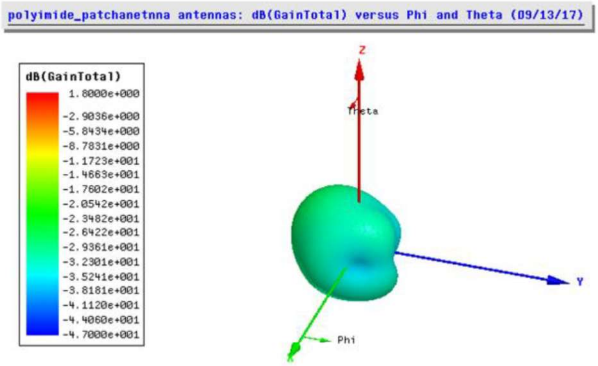
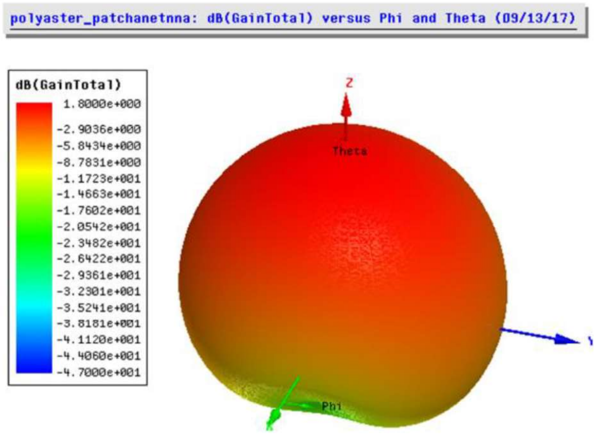


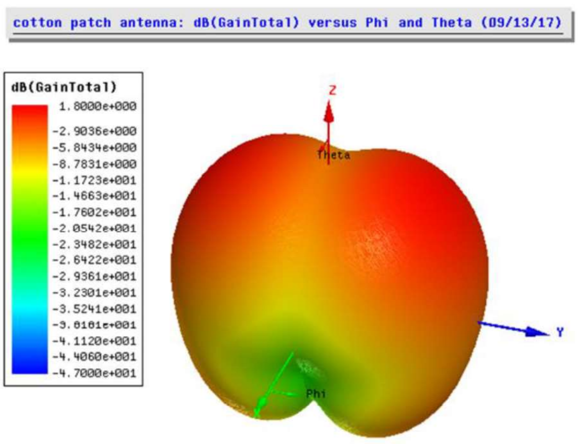
Figure 3: The directivity of Patch Antennas for all substrates



(a)



(b)



(c)

Figure 4: The gain and directivity of Patch Antennas for all substrates a) Gain of Pyralux Gain of Polyimide b) Gain of Polyester c) Gain of Cotton

The gain of Pyralux polyimide material is very low as shown in figure 4, which makes this material very suitable for making wearable devices using antennas of pyralux polyimide for MWI.

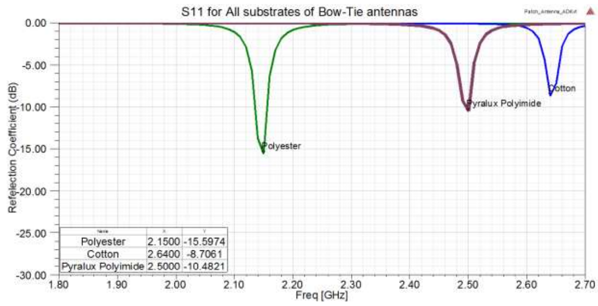
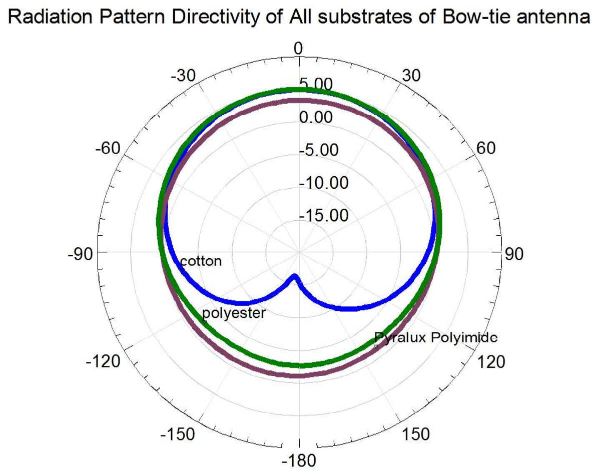
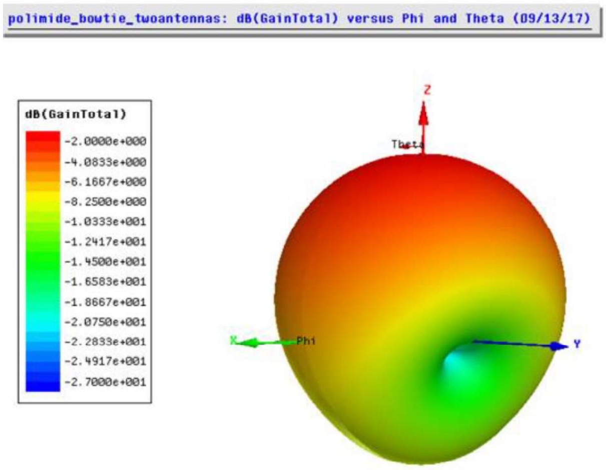


Figure 5: Return Loss of Bow-Tie antennas



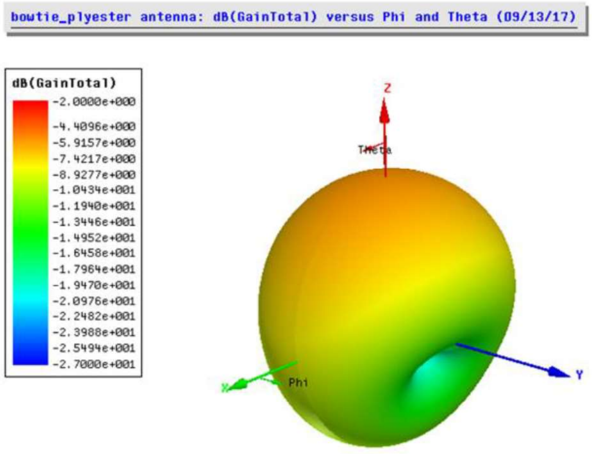
(a)



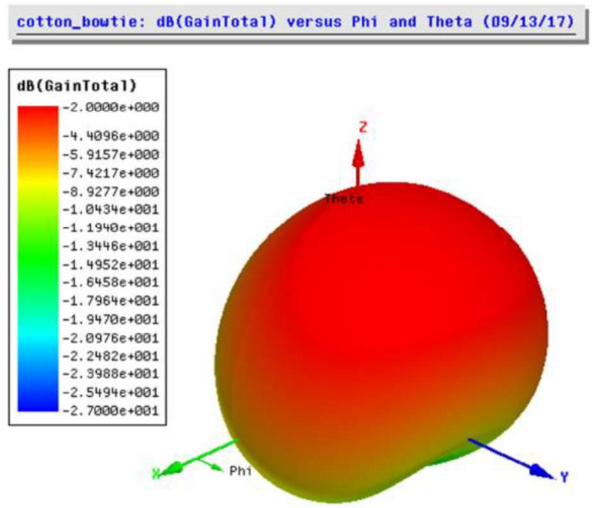
(b)

Figure 6: The gain and directivity of Bow-Tie Antennas for all substrates a) Directivity and b) Gain of Pyralux Polyimide

Figure 5-7 shows the characteristics behavior of bow-tie antennas which shows that the bow-tie antennas are high in gain and omni-directional as well.



(a)



(b)

Figure 7: The gain and directivity of Bow-Tie Antennas for all substrates a) Gain of Polyester b) Gain of Cotton

The values of gain with respect to resonance frequency for all antennas is given in table 2.

Table 2: The Resonance Frequency and Gain of Antennas

Antenna Type	Substrate	Freq(GHz)	Gain (dB)
Rectangular Patch	PP	1.93	7.2299
	Polyester	2.1	6.7049
	Cotton	1.91	5.3845
Bow-Tie Patch	PP	2.15	4.9979
	Polyester	2.6	6.7049
	Cotton	2.5	5.3845

Conclusion

In this article, our research group had presented initial results in the development of a cost-effective flexible MI system. Simulations of Bow-Tie patch and Rectangular patch resulted in Input Return Loss lower than -10dB at around 2 GHz. Both types of antennas are high in gain, compact and omnidirectional. Bow-Tie patch is preferable design as the gain of Bow-Tie antenna is greater than Rectangular patch antennas.

Regarding substrate materials, Polyester and Pyralux Polyimide reveled to be a better option for cost-effective antennas with higher flexibility. Polyester has best performance in gain and directivity while Pyralux Polyimide revealed lower Reflection coefficient than Polyester.

Next steps are focused to improve the design to an array of multiple antennas and characterize it. Beyond, the development of electronic circuitry to acquire first images and apply it on in vitro experiments in phantoms.

Acknowledgment

The Project is funded by CAPES, Brazil.

References

[1] Ferlay J, Soerjomataram I, Ervik M, Dikshit R, Eser S, Mathers C et al. GLOBOCAN 2012 v1.0, Cancer Incidence and Mortality Worldwide: IARC CancerBase No. 11 Lyon, France: International Agency for Research on Cancer; 2013. World Heath Organization [internet]. 2017; Available from: http://www.who.int/mediacentre/factsheets/fs297/en/ Accessed: 07/10/2017.

[2] Yu, C Et al. Review Article: The potential of terahertz imaging for cancer diagnosis: A review of investigations to date: Quant Imaging Med Surg, 2012;2: 33-45.

[3] Bertram, MJ et al. Antenna design for microwave hepatic ablation using an axisymmetric electromagnetic model: Biomedical Engineering OnLine,2006; 5:15.

[4] Caliskan, R et al. A microstrip Patch Antenna Design for Breast Cancer Detection: Procedia Social and Behavioural Sciences, 2015;195:2905-2911.

[5] Stutzman, WL and Thiele, G.A. Antenna Theory and Design: Wiely,2013;3rd Edition.

[6] Saunders, SR and Aragon-Zavala, A, Antennas and Propagation for Wireless Communication Systems: John Willey & Sons, Ltd., London, 2007.

[7] Singh, PK et al. Design and simulation of Microstrip Antenna for Cancer Diagnosis: IJSER, 2013;4(11): 1821-1815.

[8] Rahim MKA et al. Bow-tie microstrip antenna design: IEEE, 2005; doi: 10.1109/ICON.2005.163542