In Vitro Dielectric Properties of Rat Skin Tissue for Microwave Skin Cancer Detection

Cemanur Aydinalp, Sulayman Joof, Tuba Yilmaz
Department of Electronics and Communication Engineering
Istanbul Technical University
Istanbul, Turkey
{aydinalp16,joof,yilmazabdolsahe} @itu.edu.tr

Nural Pastacı Özsobacı
Department of Biophysics, Cerrahpasa Medical Faculty, Istanbul University - Cerrahpasa
Istanbul, Turkey
nuralp@istanbul.edu.tr

Fatma Ateş Alkan
Department of Biophysics, Medical School, Beykent University,
Istanbul, Turkey
fatmaalkan@beykent.edu.tr

Ibrahim Akduman
Department of Electronics and Communication Engineering
Istanbul Technical University
Istanbul, Turkey
akduman@itu.edu.tr

***Abstract*—Dermal tissue characterization based on dielectric properties can be utilized as a non-invasive method for diagnosis of skin cancers. To enable such technology, there is a need to develop techniques that can rapidly and accurately collect the dielectric properties of the skin tissues. Therefore, the current measurement techniques and tools has to be optimized for skin cancer detection. To this end, this study presents dielectric property measurements with open-ended coaxial probes having small apertures customized for detection of skin cancer. Relative permittivity and conductivity of rat skin tissue is characterized with open-ended coaxial probes with outer diameters of 0.9mm and 0.5mm between 0.5GHz-6GHz and the measurement results are compared with the traditional probes having diameter of 2.2mm. The results agree well with the reported literature data.**

Keywords—Dielectric properties, in vitro measurement, open-ended coaxial probe, rat skin tissue, skin cancer.

I. Introduction

Skin cancer, comprising 40% of cancer cases globally, is one of the most common form of cancers in the world [1]. Basal cell carcinoma (BCC), squamous cell carcinoma (SCC), melanoma are main types of skin cancer. BCC and SCC are also called as non-melanoma skin cancer (NMSC) [2]. The number of diagnosed melanoma cases annually has increased by 53% since 2008 [3]. The diagnosis methods for melanoma are dermoscopy, digital dermoscopy, and pathological analysis of skin biopsy [2]. Dermoscope has several drawbacks such as low accuracy and risk of false positive detections that can stem from alteration of melanoma over time and human observation error. Digital dermoscope provides the map of moles in body by photographing and recording dermoscopic images in order to detect the point localization. Thus, it becomes possible to follow-up of high-risk skin cancer patients [2]. Even though pathological analysis of skin biopsy provides highly accurate results, it is not suitable for patients with multiple moles since biopsy process results in undesirable scars.

Recently, it was concluded that the tumors lead to changes in the physiological composition of tissues via changes in water, sodium and protein content of the tissue and such changes can be detected with electromagnetic technology operating at microwave region [3]. One such technology is reported in [4], where the dielectric property discrepancy at microwave frequencies between hepatic malignancies and healthy liver tissues has been identified with open-ended coaxial probes. Open-ended coaxial probes can also be employed to identify the skin cancer. However, there is a need to characterize the dielectric properties of different moles and customize the technique for skin cancer diagnosis. The possibility of using microwave diagnostic technologies for melanoma detection attracted the interest of researchers and dielectric property measurements have been reported in the literature. In [5], dielectric properties of freshly excised normal and malignant human skin is measured via slim-form open-ended coaxial probe in the range of 0.5-50GHz. In another recent study [6], a formula has been derived to calculate the dielectric properties of skin cancer tissues and healthy tissues based on a function of water content in the frequency range of 1GHz to 50GHz. In order to estimate the dielectric properties of malignant and healthy skin tissues, [7] has utilized the effective medium theory in the range of 20-100GHz. Moreover, [7] introduced mm-wave reflectometry as a potential non-invasive tool for skin cancer diagnosis. The dielectric properties of porcine skin tissue have been measured in the frequency range of 300MHz-3GHz because of the possibility that porcine skin tissue may be used as a substitute for human skin in medical research [8]. Knowledge of dielectric characteristics of skin tissue is fundamental to develop new diagnostic methods.

In this paper, the dielectric properties of rat skin tissues have been measured between 500MHz–6GHz frequency range with slim-form open-ended coaxial probes having three different aperture diameters in an attempt to customize the open-ended coaxial probes for skin cancer characterization. The rest of the paper is organized as follows, measurement methods and sample details are given in Section II, dielectric property measurement results are given in Section III, and conclusion is drawn in Section IV.

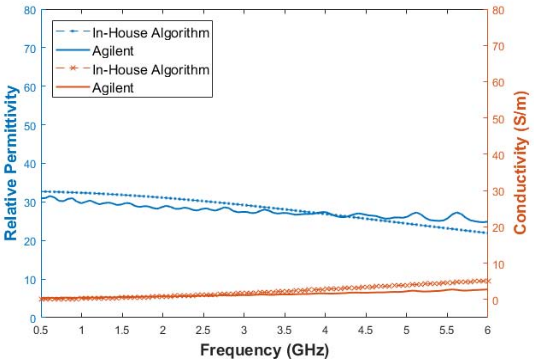
II. Materials And Methods

Measurement samples included skin sample from 3 months old, 180g Sprague-Dawley rat was obtained from Center for Life Sciences and Technologies Department, Bogazici University (BU), Istanbul, Turkey. The experimental protocol was in accordance with the regulations on animal experiments approved by the Animal Experiments Local Ethics Committee of Bogazici University.

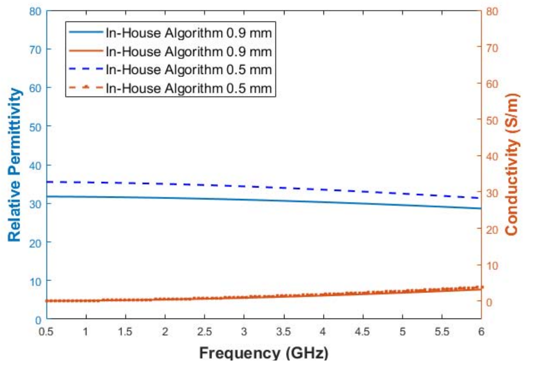
The measurement set-up included Agilent N9923A FieldFox Handheld RF Vector Network Analyzer 6GHz, Agilent 85070E software, slim form open-ended coaxial probes with outer diameters 2.2mm, 0.9mm, and 0.5mm all manufactured by Mitos Medical Technologies.

(a) (b)

Fig. 1. Measurement set-up: (a) probe with the in vitro rat skin sample, and (b) three probes with 0.5mm, 0.9mm and 2.2mm diameters from left to right.



(a)



(b)

Fig. 2. Dielectric property measurements: (a) comparison of Agilent's and in-house algorithm's relative permittivity and conductivity of rat skin tissue samples using 2.2mm probe, and (b) the relative permittivity and conductivity of rat skin tissue samples using 0.9mm and 0.5mm probes with in-house algorithm.

Also, a laptop computer to run the commercial software for dielectric property verification.The measurement set up and the probes are shown in Fig. 1 (a) and Fig. 1 (b), respectively. The dielectric material sandwiched between the inner and outer conductor of the probes is Teflon (ε_r=2.1).

III. Results

The calibration process has been performed with measurement sequence of air, a conductive textile and distilled water. The relative dielectric constant (ε_r) and conductivity (σ) measurements were performed in the range of 0.5GHz–6GHz with 55MHz intervals. The measurements were taken within 1 hour following the excision. To obtain reliable results for each position, five measurements were performed and their medians were used for computation of the relative dielectric constant (ε_r) and the conductivity (σ) of the sample. In order to calculate the relative permittivity and conductivity with the in-house algorithm, S-parameter response of the probes is also collected. The results from in-house software have been validated with Agilent 85070E software by using slim form probe with diameter 2.2mm.

The relative permittivity and conductivity measurements are shown in Fig. 2. The relative permittivity and conductivity computed by in-house software and verified with Agilent 85070E software via 2.2mm aperture probe are shown in Fig. 2 (a). The relative permittivity and conductivity calculated through in-house software from the data collected by the probes with diameters 0.9mm and 0.5mm are shown in Fig. 2 (b). In this study, the relative permittivity conductivity values agree well with the data reported in the literature [9].

IV. Conclusion

Classification of anomalies based on dielectric properties emerges as a new diagnostic and therapeutic method. In this study, dielectric properties of rat skin tissues have been measured via open-ended coaxial probes with outer diameters 2.2mm, 0.9mm and 0.5mm in the frequency range 0.5GHz and 6GHz. Obtained results are in agreement with the literature.

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References

[1] B. Ö. Cakir, P. Adamson, and C. Cingi. "Epidemiology and economic burden of nonmelanoma skin cancer," Facial Plastic Surgery Clinics of North America, 20, pp. 419-22, 2012.

[2] L. Thomas and S. Puig, "Dermoscopy, Digital Dermoscopy and Other Diagnostic Tools in the Early Detection of Melanoma and Follow-up of High-risk Skin Cancer Patients," vol. 97, 2018.

[3] M. Gniadecka, O. F. Nielsen, and H. C. Wulf, "Water content and structure in malignant and benign skin tumours," Journal of Molecular Structure, vol. 661-662, pp. 405-410, 2003.

[4] T. Yilmaz, et al., "Machine learning aided diagnosis of hepatic malignancies through in vivo dielectric measurements with microwaves," Physics in Medicine & Biology, 61.13 (2016): 5089.

[5] A. Mirbeik-Sabzevari, R. Ashinoff, and N. Tavassolian, "Ultra-wideband millimeter-wave dielectric characteristics of freshly excised normal and malignant human skin tissues," in IEEE Transactions on Biomedical Engineering, vol. 65, no. 6, pp. 1320-1329, June 2018.

[6] B. J. Mohammed, S. A. R. Naqvi, M. Manoufali, K. Bialkowski, and A. M. Abbosh, "Changes in epidermal dielectric properties due to skin cancer across the band 1 to 50 GHz," 2018 Australian Microwave Symposium (AMS), Brisbane, QLD, 2018, pp. 77-78.

[7] R. Aminzadeh, M. Saviz, and A. A. Shishegar, "Dielectric properties estimation of normal and malignant skin tissues at millimeter-wave frequencies using effective medium theory," 2014 22nd Iranian Conference on Electrical Engineering (ICEE), Tehran, 2014, pp. 1657-1661.

[8] T. Karacolak, R. Cooper, E. S. Unlu, and E. Topsakal, "Dielectric properties of porcine skin tissue and in vivo testing of implantable antennas using pigs as model animals," IEEE Antennas and Wireless Propagation Lett., vol. 11, pp. 1686-1689, Jan. 2013.

[9] A. Peyman, A. A. Rezazadeh, and C. Gabriel, "Changes in the dielectric properties of rat tissue as a function of age at microwave frequencies," Phys. Med. Biol., vol. 46, no. 6, pp. 1617-1629, June 2001.