شبكة المعلومات الجامعية

التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم

HANAA ALY

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جامعة عين شمس

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قسم

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AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics and Electrical Communications Engineering

Passive Microwave Sensors

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics and Electrical Communications Engineering)

by

Michael Moheb Youssef Rizk Riad

Bachelor of Science in Electrical Engineering

(Communication Systems – Credit Hours Engineering Program)

Faculty of Engineering, Ain Shams University, 2018

Supervised By

Prof. Dr. Amr Mohamed Ezzat Safwat

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Cairo - (2021)

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Statement

This thesis is submitted as partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

This thesis presents novel passive microwave-based sensors measuring the levels of sodium chloride in human sweat for non-invasive dehydration and cystic fibrosis monitoring. First, a new interface technique using cellulose filter papers as a superstrate for sampling Liquid under test (LUT)/Sweat was proposed and tested. Using filter paper had enhanced the sensitivity of the sensors compared to other traditional liquid sampling mechanisms such as capillary and container techniques reported in the literature.

Second, a set of 4 designs using coupled slots (CPW) to coupled microstrip transitions as well as their developed circuit models were used in designing a family of resonator-based sensors. Those models managed to accurately model the behavior of the sensor under various stimuli. Consequently, the parameters of sensors can be optimized using circuit simulations instead of time-consuming EM simulations.

The prototypes were fabricated and verified experimentally using prepared sodium chloride solutions with concentrations in the range of 0.01-2 mol/L.

Finally, a novel low-cost wi-fi-based system had been proposed to complement the proposed sensors in transmission measurements. Preliminary measurements with the proposed system show the potential to bring microwave sensors to an affordable price point for the public consumer market.

The proposed sensors have simpler structures, a simpler sampling mechanism for liquids, excelling performance, enhanced sensitivity as well as lower operating costs. The proposed sensors are not limited to sweat monitoring but could also fit in

many agriculture and industrial applications that require fast response liquid characterization.

The thesis is divided into six chapters as listed below:

Chapter 1:

This chapter introduces the background, motivation, objectives, major contributions, and organization of the thesis.

Chapter 2:

This chapter provides a classification of the different microwave-based material sensors in the literature.

Chapter 3:

This chapter presents a broadband, simple, re-useable, and low-cost approach for noninvasive sweat monitoring using a passive microwave circuit and a cellulose filter paper as a superstrate. The proposed sensor is composed of filter paper with the ability to absorb the sample liquid under test (LUT) placed on top of a coplanar waveguide (CPW) transmission line. Various samples of sodium chloride (NaCl) solutions with concentrations in the range of 0.01-2 mol/L and models of artificial sweat are used to test the proposed sensor. The difference in transmission coefficient (S21) between dry and wet states is used to determine the concentrations of tested solutions in the band of 1-6 GHz. The sensor detects concentrations as low as 0.01 mol/L (0.58 g/L) and quantities as low as 137 μL with a maximum sensitivity of 46.7 dB/g/L. The proposed sensor presents a simple approach to sample and characterize liquids with enhanced sensitivity and consistent performance using microwave signals.

Chapter 4:

This chapter presents dual-layer planar resonant sensors using paper superstrates for liquid characterization. The proposed sensors are composed of coplanar waveguides and microstrips multi-mode transitions. Equivalent circuit models are derived, which enables the understanding of the behaviour of the sensors as lossy transmission lines. A prototype was manufactured, and the measurement results are in very good agreement with the EM simulations around the operating frequency (1.6 GHz). Moreover, the circuit model can predict the changes in the response of the sensor between different concentrations of sodium chloride. Furthermore, the sensor achieved double the sensitivity of the sensor presented in chapter 3 using the same dimensions of the sensing element in the literature.

Chapter 5:

This chapter proposes a simple low-cost Wi-Fi-based sensing system using a passive microwave circuit operating at 2.4 GHz. The system replaces the traditionally used vector network analyzer (VNA) with a Wi-Fi access point with an overall cost of 20 USD. The difference in power levels measured with Material Under Test (MUT) and reference level is found to be equivalent to transmission level (S21). Experiments are conducted with saline solutions with NaCl concentrations in the range of 0.01-0.35 mol/L. Transmission coefficients in different rooms and setups are recorded and compared. Results from VNA are in good agreement with the Wi-Fi-based system and validate the proposed approach.

Chapter 6:

This chapter provides a conclusion to the executed work and suggests future research directions.

Keywords: Microwave Bio-sensing, Paper Superstrate, Hydration Sensor, Cystic Fibrosis (CF) Diagnosis, Liquid Characterization, Re-useable Sensor, Sweat Monitoring, Smart Sensor, Microwave Sensor, Low-cost Material Characterization, Cross-junction, Defected Ground Structures.

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Michael Riad

Cairo, Egypt

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