Final Project Report: Development of a Standalone Wireless Sensing System for Humanitarian Approaches

Apala Banerjee, ***Graduate Student Member, IEEE*** **and M J Akhtar,** ***Fellow, IEEE***

***Abstract*— It was an overwhelming experience to receive the IEEE MTT-S Graduate Fellowship Award 2023 and I would like to express my thanks and gratitude to the whole MTT-S community for making this huge event successful and support young scientists and researchers to achieve their dreams and goals. The Graduate Fellowship helped me to achieve my research targets of last year through several interesting paths. I also found my way to decide for my future research goals and establishing my career in microwave research field. This report briefly summarizes the outcome of Graduate Fellowship Award of June 2023.**

Index terms*— *Biomedical, industrial, humanitarian, microwave, resonators, sensors, sensing applications, standalone sensing system

I. INTRODUCTION

THE primary aim of my Graduate Fellowship Award was targeted in the development of a number of Split Ring Resonators (SRR) and Complementary Split Ring Resonators (CSRR) based improved RF sensors for industrial, humanitarian approaches etc. and then develop a wireless standalone sensing system without any bulky measuring device. The standalone system should have a flexible sensing block where any sensor for a specific application can be used as and when required, is highly efficient, and should have ease of portability for off-site measurements. Various kinds of sensors are being developed in the lab owing to several different applications for altruistic approaches like flexible printed sensors for simultaneous displacement and rotation tracking, slot radiating sensor for homogeneity check of dielectric materials, improved RF sensors for water quality assessment, sodium -ion imbalance check in human body fluids and a very novel sensor to determine the quality of cooking oils with improved performances.

My research plan for the IEEE MTT-S Graduate Fellowship Award was mainly divided into two parts: a) Development of the RF sensors to meet the application specifications and b) To propose a standalone system for RF sensing without the requirement of any heavy measuring instrument like the VNA which is the most common measuring device for RF sensing systems. The major fulfilment of the project has been summarized in the subsequent sections.

II. DEVELOPEMNT OF IMPROVED RF SENSORS FOR REAL WORLD APPLICATIONS

A. Industrial Applications

Two sensors have been developed and tested using the CSRR concept to determine homogeneity check in dielectric discontinuity [1] and to evaluate the quality assessment of wood using non-destructive RF testing[2].

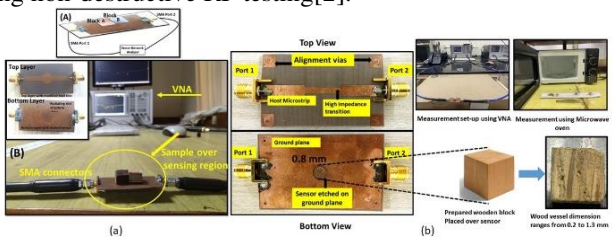

Fig. 1. RF sensors developed for industrial applications in (a) Dielectric homogeneity check and (b) Non-destructive assessment of wood quality

B. Biomedical Applications

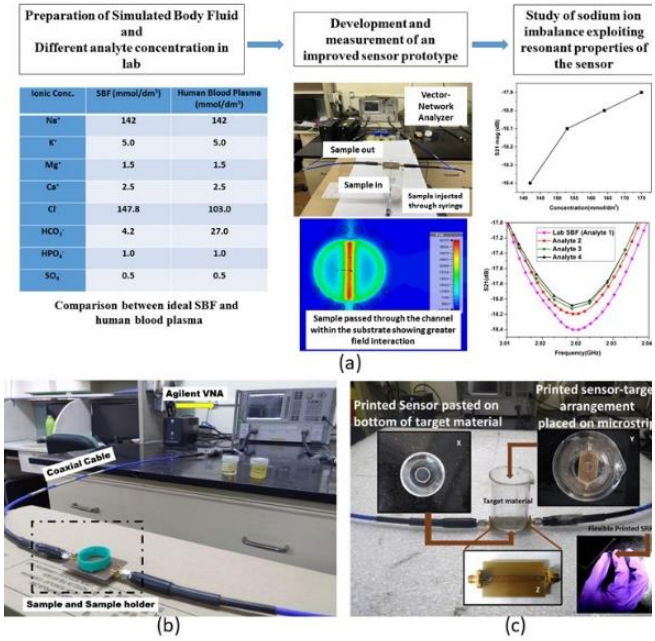

Fig.2. RF sensors to determine (a) sodium imbalance in human body (b) quality of cooking oils and (c) flexible printed sensor for rotation and displacement measurements

A novel RF sensor is designed, developed, and tested to determine sodium ion imbalance in human body fluids[3]. The proposed sensor consists of a CSRR-based structure with the sensing region surrounded by air vias to improve the confinement of the E-field within the sensing region. The proposed sensor confines the field in the sensing area and the test fluid is injected into the sensing region through a specially designed 1.5 mm fluidic channel made across the width of the substrate. This kind of channel embedded in the substrate limits the quantity of fluids interacting with the sensing region thereby facilitating testing of Simulated Body Fluid (SBF) possessing even high-value permittivity in the range of 80-100.

Apala Banerjee and M. Jaleel Akhtar are with the Department of Electrical Engineering, Indian Institute of Technology, Kanpur 208016, India (email: apala@iitk.ac.in, nileshkt@iitk.ac.in, mjakhtar@iitk.ac.in)

C. Humanitarian Applications

An improved planar microwave sensor comprising a resistor-embedded top microstrip line and a ground-etched complementary split-ring resonator (CSRR), designed on a 1.6 mm Taconic substrate (ε_r=2.2), is presented to assess the quality of recycled cooking oils[4]. The proposed resonant sensor exhibits an improved quality factor, and a reasonably larger shift in the resonant parameters under loading conditions, thereby facilitating the detection of even slight variations in electrical and chemical properties of low-loss dielectric samples. Several fresh and recycled cooking oil samples showed their acid values get degraded from 1.5 to even 9.4 indicating the toxic nature of the recycled oils and their adverse effect on human health. Another work is also carried out to determine the solute concentration level in water [5] through the development of a bridge type RF sensor. This sensor was typically found useful for detection of solute elements like sugar, salt, detergents etc.

D. Flexible Printed Sensor for Rotation and Displacement

A planar split ring resonator-based flexible RF sensor is developed for linear and rotational position tracking of a target object [6]. The proposed displacement sensing scheme employs a 100 μm thin flexible printed resonator that facilitates ease of adherence to a target object than that of the conventional RF sensor. The realized printed resonator is excited by a near-field proximity coupling mechanism using a standard 50 Ω microstrip line. A detailed numerical analysis for the linear and rotational displacement of several dummy targets is carried out by recording the change in measured parameters corresponding to the relative change in position of the printed resonator attached to a dummy target under test. Lastly, a fabricated prototype of a printed flexible sensor is developed and tested for the linear and rotational displacement of several target materials under observation and an ANN model is developed to curb the uncertainty.

III. STANDALONE RF SENSING SYSTEM

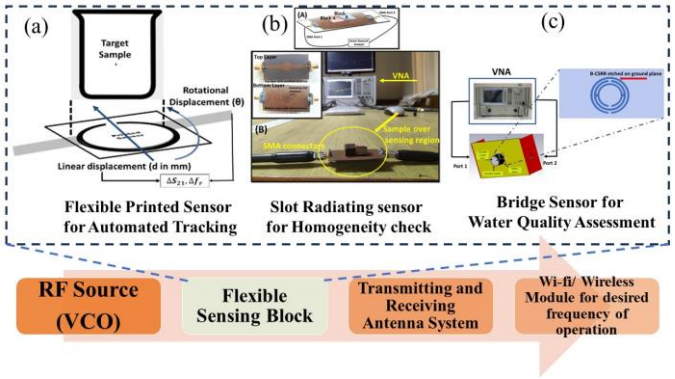

Fig.2. Pictorial representation of the Wireless Sensing system set-up where a few individual sensors (a),(b),(c) can be corroborated within the sensing block for wireless sensing

After the development of the fabricated sensors, the wireless sensing system is proposed as an overall integrated block having a flexible sensing module. In this module, the sensors can be used for testing their respective applications as and when required. A wireless RF source is developed using a a)VCO with a maximum power output of 0 dBm at 2.45 GHz and a tuning range from 2.1 to 2.5 GHz using HMCLP4. b) Development of a CSRR-based planar sensor at 2.45 GHz. c) A standard antenna system to wirelessly transmit the signal to a designated detector (in this case a Spectrum Analyzer). The standalone detector block is in progress to develop into a completely wireless module avoiding any bulky equipment to enhance portability and efficiency. The future scope of the work includes the development of an entire System-on-Chip for the proposed system for the ease of portability for off-site measurements.

IV. IMS 2023 IMPRESSIONS

I extremely enjoyed my time during IMS 2023 held at San Diego, California, being with the amazing community of MTT-S, making new friends and connections, getting an overall view of the state-of-art scenario on a global platform. The most remarkable part of the journey was my chance to interact with some of the renowned microwave personnels of the world and getting an opportunity to finalize my Post doctoral journey. I was previously unsure to decide between research industry and research academia and IMS helped me in my decision to pursue my career for the future. I was overwhelmed on being one of the few female candidates of my country to receive this highly prestigious Award during IMS 2023.

CONCLUSION AND CAREER PLANS

The Graduate Fellowship has helped me immensely with my financial independence and carry out my plans with the aim of research in the academic field for my future. I plan to start my post-doctoral journey soon and eagerly waiting for my final PhD defense to take place. My plan is to stay in the research field of RF and Microwave domain and contribute to the younger microwave community especially to young women who want to pursue their career in this field. I also want to be an active part of IEEE in the days to come and motivate more young people to participate in the MTT-S activities, research grants and awards which will help them to achieve their research dreams in the long run.

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