Study, Design and Fabrication of Microwave Resonant Sensors for Detection of Contamination in Agricultural and Food Products

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***Abstract*— The main objective of this research is to investigate various resonator based improved and advanced techniques to characterize the dielectric, magnetic, and composite samples. A number of planar sensors based on waveguides, surface integrated waveguides and epsilon-near-zero effect are implemented to characterize and detect contamination in solids or liquids. Due to the high accuracy, sensitivity and simple measurement procedure of the resonator based method, it has the potential to be used for various applications such as in the biomedical, food, petroleum, military, pharmaceutical, paper and the pulp industries.**

***Index Terms*— Magneto dielectric material characterization, multiband RF sensors, planar microwave sensors, resonant sensors.**

I. Introduction

THIS report summarizes the outcomes of the project that has been accomplished with the partial help of the IEEE MTT-S Fellowship 2015 awarded to the author during IMS 2015 Student's Luncheon in Phoenix, AZ, USA on Thursday, May 21, 2015.

II. Project Report

A novel planar epsilon-near-zero (ENZ) tunnel sensor has been designed using the surface integrated waveguide (SIW) technology for detection of contamination in various liquid solutions (Fig. 1). The contamination has been detected in terms of the volumetric percentage by measuring the change in the dielectric properties of reference and adulterated solutions. The method is based on the cavity perturbation technique in which the tunneling electric field gets perturbed by the sample inclusion. An accurate sensitivity analysis shows the advantage of the proposed ENZ sensor over the conventional SIW cavity for accurate measurement of liquid contamination. Various types of adulterated liquid solutions have been tested with the help of the specially designed sample holder, and the results are found to in good agreement with the theoretical values [1].

Afterward, a novel planar multilayered epsilon-near-zero (ENZ) tunnel sensor based on fully laminated surface integrated waveguide (SIW) technology has been proposed for the microwave measurement of dispersive materials (Fig. 2). The proposed sensor has been designed and optimized using parametric analysis to obtain the multilayered ENZ tunnel dimensions. The complex permittivity measurement using the proposed ENZ tunnel sensor is possible at multiple frequencies including the 3G and 4G frequency bands with a single set of measurement data (Fig. 3). It is found that the proposed sensor is highly sensitive, and typically demonstrates 6% error under ideal conditions, thus making it a good candidate for the microwave measurement of dispersive materials [2]-[3].

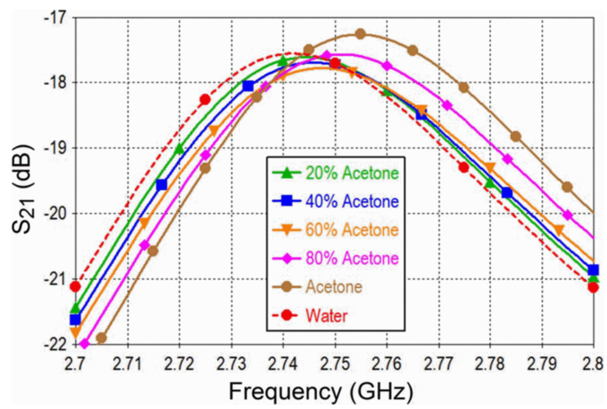

Fig. 1: Measured transmission coefficient of 20–80% water inclusion in acetone.

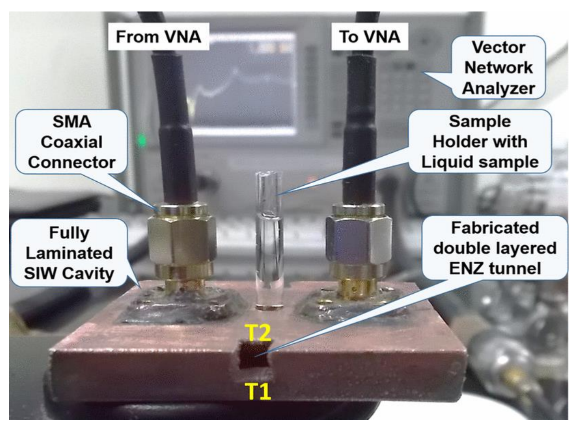

Fig. 2. Measurement setup of fabricated double-layer ENZ SIW cavity sensor for microwave testing of liquids.

A generalized cavity method relaxing the major assumptions of conventional cavity perturbation technique has been presented for characterization of the powdered sample in the microwave frequency range [4]. The unified method, which is based on the inverse optimization technique, eliminates the complexity of measurement caused due to the existence of sample holder and produces an accurate result (Fig. 4). For verification of the proposed technique, the pulverized alumina and polyethylene oxide with various

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packing fractions are measured using the fabricated cavity and the vector network analyzer. The dielectric constant of these samples is extracted using the proposed unified approach which is found to be in good agreement with the theoretical data obtained by Landau-Lifshitz and Looyenga model [4].

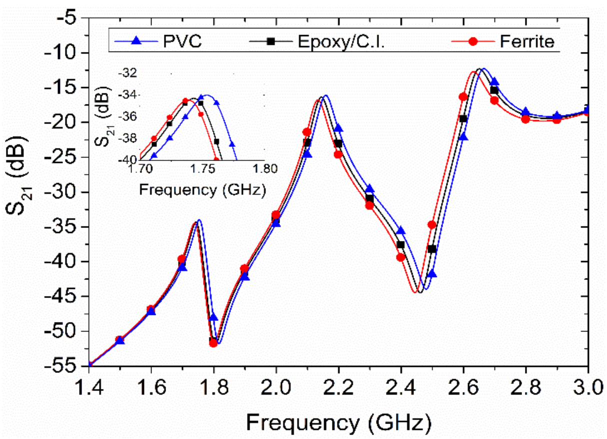

Fig. 3. Measured transmission coefficient of various MUT using proposed tri-band ENZ SIW device obtained by VNA.

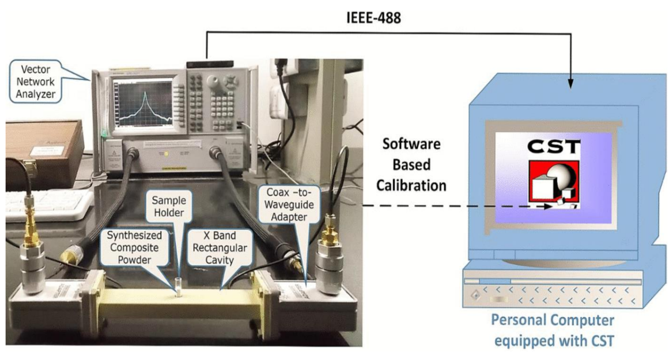

Fig. 4. Proposed generalized cavity perturbation model for automated calculation of complex permittivity.

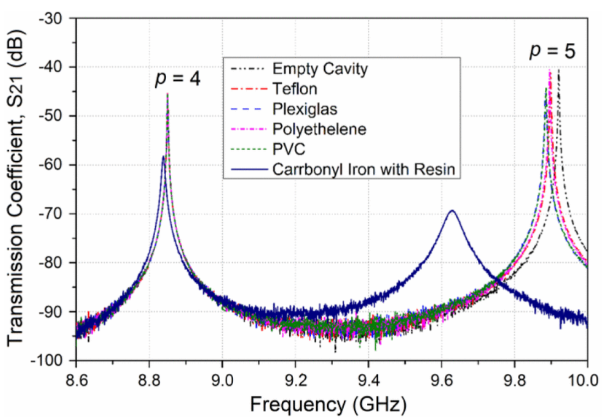

Fig. 5. Measured transmission coefficients of various dielectric and magneto-dielectric test samples.

The applications of magnetic composites in electromagnetic shielding, resonance imaging, and biomedical drug research are growing rapidly. Therefore, a novel rectangular cavity method is proposed to obtain the complex permeability and permittivity of the magneto-dielectric sample placed in the E-plane of the rectangular cavity (Fig. 5). The proposed method eliminates the need for physical relocation of a specimen in the H-plane, which is usually required in the case of presently available methods to characterize the magnetic samples. The closed-form formula for this unified approach is developed from the first principle and is later modified to consider some practical consideration. The significance of the proposed approach can be appreciated from the fact that even for finite-size samples, the permeability and permittivity can be extracted with the typical errors of 5% and 2%, respectively [5].

III. Next Career Plans

My short-term goal is to complete the Ph.D. program, which is expected by the end of this summer. I am open to joining either a company or university where I can continue my research. I would like to join such academia where the grass root research can be harvested with brilliant young minds. In my opinion, academia and industry should play the complementary role for each other, where the industry should promote and escalate growth of the idea originated and incubated in the academia.

IV. IMS Impression

I have been honored to attend the IMS2015. Though it was my first visit at IMS, it helped me a lot to learn more about the society and given a platform to discourse with the like-minded individuals and the experts of microwaves that changed my outlook on research and cement myself more in the microwave community. I am very happy and in the debt of the MTT-S for providing this opportunity to being a part of such a technical, cheerful and cerebral event.

Acknowledgement

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