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A FRACTAL MINKOWSKI DESIGN FOR MICROWAVE SENSING APPLICATIONS

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Abstract: This work describes a low-cost, extremely sensitive microwave sensor that may be used to distinguish between different liquid samples by measuring the variation in S_{21} magnitude. An interdigital capacitor (IDC) in series with a circular spiral inductor (CSI) and linked directly to a light dependent resistor (LDR) is used to do this and been installed minkowski farctal on end both stub. The suggested sensor operates at a frequency of 1.47 GHz. Using Computer Simulation Technology (CST) Microwave studio, the impacts of modifying the proposed LDR's value are evaluated parametrically. However, When the LDR value changes in relation to the light of incidence, a considerable change in the resonance band is observed. Many recent wireless technologies that use optical-based interface systems have found that such technology is an excellent candidate. The same model is developed for validation using a High-Frequency Simulator Structure (HFSS). The suggested sensor is built on an FR4 substrate with a 40×60 mm^2 surface area. As a ground plane, a copper layer is applied to the rear panel. The results obtained by the two software systems are in perfect agreement.

Keywords: *IDC, CSI, Sensor, Minkowski, LDR.*

1. Introduction

Characterization and quantification of liquids have been more important in recent years in a variety of sectors, including diagnostics, pharmaceutical operations, biomedical engineering, manufacturing, agriculture, and food safety [1–6]. The majority of liquids are polar in nature and have electrical properties that provide vital information about their properties. The performance of microwave devices is greatly influenced by such electrical qualities. Varying electrical properties allow polar liquid materials to exhibit different polarization and thus different orientation of the constituent molecules when electromagnetic waves interact with them. Microwave sensors use this interaction to characterize liquids by utilizing their dielectric characteristics.

Electromagnetic sensors have a number of advantages, including quick response time, non-invasiveness, and ease of use. It must obviate the usage of costly markers like fluorescent molecules and gold particles [7], which make the sensing strategy more invasive and costly. Measurements [8]. The transmission/reflection method and the resonant cavity method are two types of microwave techniques for liquid characterisation [9]. Because of its superior sensitivity and accuracy over the short bandwidth of operation, the resonant technique is given priority [10].

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The first commercial sensors for food processing, as well as for monitoring fruit ripeness and moisture content, were developed in the early 1970s [4]. Due to its inherent qualities of self-similarity, unlimited complexity, and small dimensions with space-filling properties, fractal geometry reduces sensor dimensions while improving sensitivity. The term fractal refers to objects whose pieces are identical or very similar to the total structure. As the viewing scale increases or lowers, the shape of the object does not change, remaining identical or very similar to the original structure. Fractal structures are currently being used in a variety of microwave applications, including the development of compact interferometers based on fractal geometry [10,11], fractal phase shifters [12], and resonators for filter miniaturization [13,14]. Minkowski fractal antennas are becoming increasingly important for transferring data with other devices. These gadgets are extremely useful for determining material qualities. Minkowski fractal technology [15,16] concatenates different fractal or non-fractal shapes to create new designs with unique properties. B.B Mandelbrot coined the term 'fractal', which means "uneven or non-uniform fragments, to characterize a class of complicated structures that share fundamental geometrical traits [17, 18]. Self-similarity and space-filling are two interesting aspects of fractals that make them attractive and research-oriented [19,20]. Several researchers have been drawn to fractal curves such as Minkowski, Koch, and Giuseppe Peano to develop antennas that are tiny, low-cost, and miniaturized [21,22].

A microwave resonator is proposed in this paper for liquid monitoring utilizing a CSI. To operate at 1.47 GHz, the resonator is conjugated with IDC and minkowski fracta and is simple to integrate with various platforms. To study the design technique, CST microwave studio and a verified High-Frequency Simulator Structure were used to simulate it numerically (HFSS).

2. Geometrical Details

Figure 1 shows the proposed sensor, which consists of a transmission line connected to an RLC branch network. The designed RLC network is mainly made up of an interdigital capacitor (Cint) in series with a circular spiral inductor (Lse) and directly coupled to a photo-resistor (light dependant resistor) (RLDR). The RLDR is positioned in the centre of the sensor, between two LC branches, where the sample under test (SUT) would reside. To eliminate the impacts of field fringing from the inductor toward the proposed capacitor, two stubs are imposed from the digital capacitors [13]. Furthermore, the proposed stub was put minkowski fractal on the end of the stub to minimize the impacts of distortion while, to maximize accuracy and resonance. As mentioned in section 2, the proposed sensor was mounted on a FR4 substrate with a relative dielectric constant of r =4.3 and a thickness of t =1.6 mm with a full ground plane.

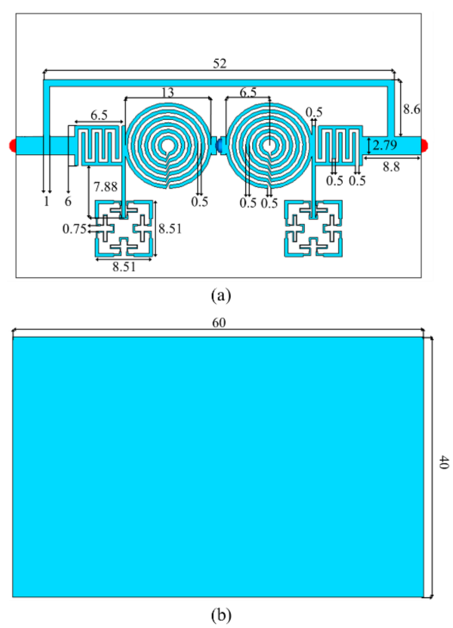

Figure 1. The suggested sensor geometrical details: (a) front and (b) back views

3. Numerical Simulation Results

CST is used to replicate the sensor's performance. The simulated outcome of the proposed sensor with a pan at two resonant frequencies of 1.47 GHz is shown in Figure 2. This resonance frequency is taken into account since it is the first resonance where maximal energy flow is simple. To imitate practical measurements, the suggested sensor is positioned beneath a pan of the material under test. As a result, a numerical assessment is shown in Figure 2 for two examples with and without a pan to explore the effects of the pan introduction on the suggested sensor performance in terms of S_{21}.

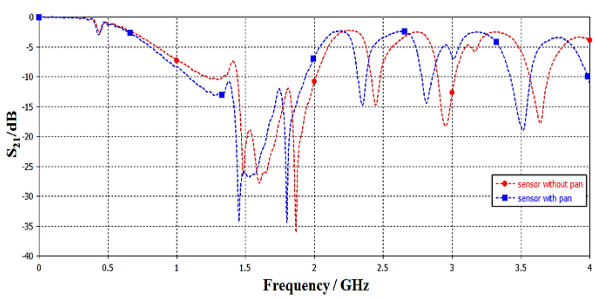

Figure 2. In terms of S_{21}, spectral variations of the proposed sensor with and without a pan.

The electric field distribution over the sensor surface is now examined to determine the maximum fringing spots. We discovered that field is largely dispersed on the CSI, as shown in Figure 3. The majority of the electric field is spread on the CSI outer rings and across the IDC at resonance. To avoid interaction with CSI and IDC, pan is set above the LDR, as shown in Figure 4.

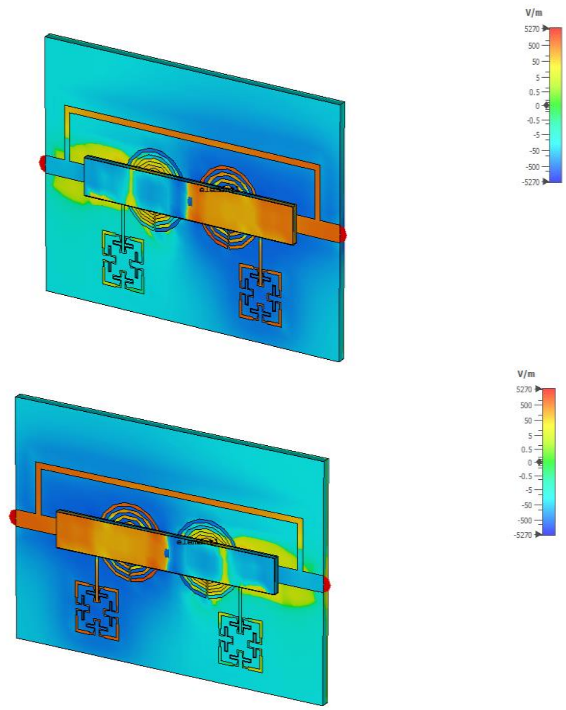

Figure 3. At 1.47 GHz, the electrical field from ports 1 and 2

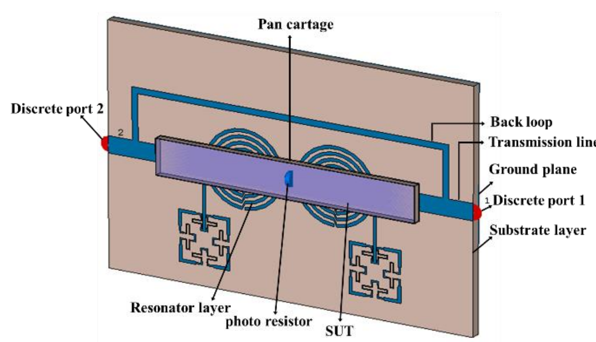

Figure 4. Structure of the sensor

After that, a numerical analysis is carried out by using distilled water as the material under test in the pan, while be height of the distilled water in pan is 1.2. The frequency resonance in the first mode is found to be unaffected after loading the pan with the material under test, as illustrated in Figure 5. This ensured that the first mode was the best option, as well as motivating us to use the 1.47 GHz detection procedure.

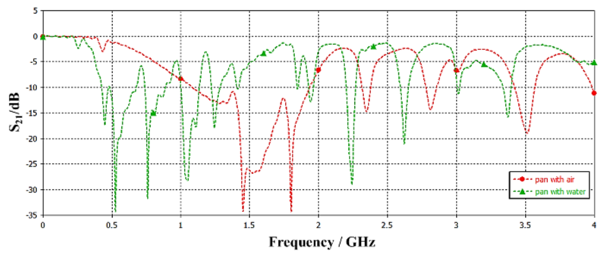

Figure 5. Variation in S_{21} spectra with different types of water.

Any change in water content with respect to a relative change in liquid height can be seen in Figure 6. As a result, a parametric analysis is conducted for three different pan heights: 1.2 mm, 1.4 mm, and 1.6 mm, in order to determine the impacts on the frequency shift. It's chosen at 1.2 mm.

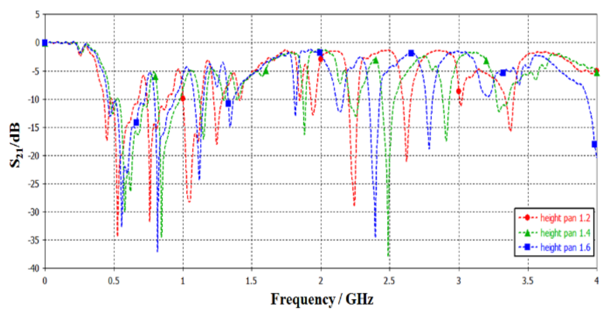

Figure 6. Variations in S_{21} spectra with respect to pan height.

4. Validation

Finally, as shown in Figure 7, the proposed design findings in terms of S_{21} are numerically valid using HFSS. There is a high level of agreement between the acquired results in relation to each other.

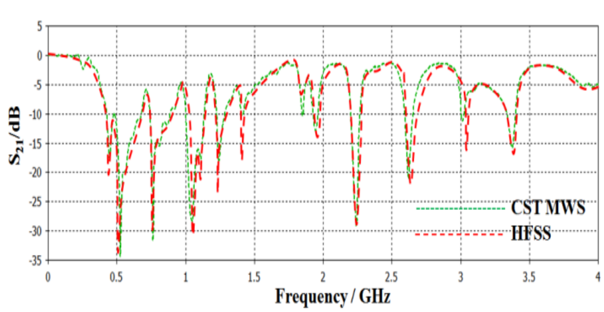

Figure 7. Validation of S_{21} spectra.

Table 1 compares the proposed sensor in this paper to a microwave resonator previously reported in the literature.

Table 1. Comparsion between microwave resonator

Ref	Area of Sub/mm^2	Fr (GHz)	Res.type
[11]	35×50	9-10	Oval Wing Res.
[12]	20×35	2.5	CSRRs
[13]	30×40	2.4	Copm. Circular Spiral Res.
This work	40×60	1.47	OS-CRLH

5. Conclusions

Transmission line technology was used to create the proposed sensor. It comprises of a transmission line connected to an RLC network, which is essentially structured as an IDC in series with a CSI and connected directly to an LDR, with minkowski fractals on both sides of the CSI. The liquid samples are placed in a pan made of the same substrate material as the substrate. The suggested sensor operates at a frequency of 1.47 GHz. The sensor is a device that detects the presence this part successfully detects water input by directly modifying the S_{21} magnitude. The resonance frequency of the material under test shifted insignificantly, according to the data.

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Conflict of interest

The authors state that there is no conflict of interest in the publishing of this work.

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