Faculty of Electronic and Computer Engineering

A NOVEL MICROWAVE SENSOR WITH HIGH-Q RESONATOR FOR HIGH SENSITIVITY MATERIAL CHARACTERIZATION

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A NOVEL MICROWAVE SENSOR WITH HIGH-Q RESONATOR FOR HIGH SENSITIVITY MATERIAL CHARACTERIZATION

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DECLARATION

I declare that this thesis entitled "A Novel Microwave Sensor with High-Q Resonator for High Sensitivity Material Characterization" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering

Signature	:	……………...
Supervisor Name	:	Associate Professor Dr. Zahriladha Zakaria
Date	:	……………………..

DEDICATION

To my beloved mother and father

ABSTRACT

The use of novel microwave sensor on material characterization is an attractive idea. There are many applications that could benefit from this such as food industry, quality control and biomedical applications. The potential for highly accurate measurements of characterizing the material properties is offered by microwave resonant techniques at single or discrete set of frequencies. Conventionally, coaxial cavity, waveguide, and dielectric resonators have been used for characterizing the properties of materials. However, there are also challenges that arise from these resonators. One of them is the problem of fabricating the sensors which increase the cost and the other one they require large amount of circuit size and consequently require similar processing capability which restrict their use in many important applications. Thus, planar resonant techniques have gained a considerable interest over the past few years due to their advantages such as low cost, ease of fabrication and compact in circuit size. Conversely, these techniques suffer from low sensitivity and poor Q-factors which constrain their use and limit the range of materials characterizing applications. Therefore, this thesis presents novel structures of planar microwave sensors for detecting and characterizing the dielectric properties in common solids materials which produce high Q-factor with capability to suppress undesired harmonic spurious. These planar resonator structures are based on novel metamaterial symmetrical split ring resonator (SSRR) with and without spurlines filters by employing the perturbation theory, in which the dielectric properties of the resonator affect the Q-factor and resonance frequency. The sensors are designed at operating frequency of 2.2 GHz with resonant frequency ranging from 1 GHz to 10 GHz. As a results, the sensors achieve narrow resonance with low insertion loss and high Q sensitivity which peaked up to 652 at 2.2 GHz operating frequency. The circuit size of symmetrical split ring resonator is minimized about 30 % of total size by introducing spurlines filters. By using a specific experimental methodology, practical materials have been used as standards to validate the sensitivity of the sensors for permitting potentially material characterization and determination. In addition, a detailed sample thickness analysis has been carried out and accordingly the mathematical equation is derived to extract the materials with unknown properties. Experimentally, the measured and theoretical results are found in an excellent agreement with a 2 to 3 % possibility of typical error in the permittivity measurements. The average accuracy percentage of the measured results for all cases of the designed sensors is found within 97 to 98 % compared to those in literatures which has an average accuracy percentage of 91 to 92 % for the same tested standard materials. The most significant of using SSRR sensors with and without spurlines filters are to be used for various industrial applications such as food industry, quality control, bio–sensing medicine and pharmacy applications. It is believed that these techniques would lead for a promising solution of characterizing material particularly in determining material properties and quality.

ABSTRAK

Penggunaan penderia gelombang mikro terbaharu untuk pencirian bahan adalah satu idea yang menarik. Terdapat banyak aplikasi yang boleh mendapat manfaat daripada penderia baharu ini seperti industri makanan, kawalan kualiti dan aplikasi bio-perubatan. Potensi ukuran yang sangat tepat untuk mencirikan sifat-sifat bahan boleh ditawarkan oleh teknik gelombang salunan pada sesuatu atau pelbagai frekuensi. Secara konvensional, rongga sepaksi, pandu gelombang, dan resonator dielektrik telah digunakan untuk mencirikan sifat-sifat bahan. Walaubagaimanapun, terdapat juga cabaran yang timbul daripada penderia resonator ini. Antaranya adalah kekangan proses pembuatan penderia yang memerlukan kos yang tinggi serta saiz litar yang besar dan akibatnya menghadkan penggunaan penderia ini dalam banyak aplikasi penting. Oleh itu, teknik satah salunan telah mendapat minat yang tinggi sejak beberapa tahun kebelakangan ini kerana kelebihan mereka seperti kos rendah, kemudahan fabrikasi dan saiz litar yang padat. Tetapi, teknik ini mempunyai sensitiviti yang rendah dan kecil dari segi Q-faktor yang mengekang dan menghadkan penggunaannya dalam pelbagai aplikasi pencirian bahan. Oleh itu, tesis ini membentangkan struktur penderia gelombang satah untuk mengesan dan mencirikan sifat dielektrik dalam bahan-bahan pepejal yang mempunyai Q-faktor tinggi serta berupaya menyekat harmonik palsu yang tidak diingini. Struktur-struktur satah resonator adalah berdasarkan kepada bahan Symmetrical Split Ring Resonator (SSRR) dengan spurlines penapis dengan menggunakan teori usikan (Perturbation), di mana sifat-sifat dielektrik resonator menjejaskan Q-faktor dan frekuensi resonan. Penderia gelombang mikro direka pada frekuensi operasi 2.2 GHz dengan kadar salunan yang bermula dari 1 GHz hingga 10 GHz. Dengan itu, penderia mencapai lebar jalur resonan yang sempit dengan mempunyai kehilangan sisipan yang rendah serta mempunyai sensitiviti Q tinggi yang sehingga 652 pada frekuensi 2.2 GHz. Saiz litar simetri Split Ring Resonator dikurangkan kira-kira 30% daripada jumlah saiz dengan memperkenalkan penapis spurlines. Dengan, menggunakan kaedah eksperimen tertentu, bahan-bahan praktikal telah digunakan sebagai piawai untuk mengesahkan sensitiviti penderia bagi membenarkan pencirian dan penentuanbahan. Dalam pada itu, analisa terperinci ketebalan sampel telah dikaji dan seterusnya persamaan matematik telah dihasilkan bagi mengeluarkan dan menentukan sifat bahan-bahan yang tidak diketahui. Daripada eksperimen, hasil yang diukur dan teori adalah mempunyai kolerasi sangat baik iaitu hanya sekitar 2 hingga 3% ralat dalam ukuran ketelusan. Purata peratusan ketepatan keputusan diukur untuk semua kes penderia yang dihasilkan adalah sekitar 97 hingga 98%, berbanding dalam kajian sedia ada yang mempunyai purata peratusan ketepatan sekitar 91 hingga 92% bagi bahan untuk piawaian yang sama. Penggunaan penderia SSRR dengan penapis spurlines adalah sangat penting untuk digunakan bagi pelbagai aplikasi industri seperti industri makanan, kawalan kualiti, bio-perubatan dan aplikasi farmasi.

Adalah dipercayai bahawa teknik-teknik ini akan membawa penyelesaian dalam pencirian sesuatu bahan terutamanya dalam menentukan sifat bahan dan kualitinya.

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