



Faculty of Electronic and Computer Engineering

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

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Master of Science in Electronic Engineering

2016

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

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of
Science in Electronic Engineering**

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

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.

Signature :

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Date :

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 penentuan bahan. 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.

ACKNOWLEDGMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. I am deeply indebted to my main supervisor Associate Professor Dr. Zahriladha Zakaria from Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), whose help, stimulating suggestions and encouragement helped me in all the time of research and writing of this thesis.

Another great debt is to my co-supervisor Pn. Eliyana Ruslan from Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for her advice and suggestions towards the completion of this thesis.

I would also like to express my debt to my fellow Ph.D. students in Makmal Pasca Siswazah laboratory, Ahmed, Mohtade, Sam, Ariffin. Thanks for the helps, talks, laughs and friendship.

I appreciate all the care and support from my beloved mother, father, brothers and sisters.

Special thanks to all my colleagues and friends, Ammar, Sharif, Toh, Zaimah and Amyrul for their moral support in completing this degree. Lastly, thank you to everyone who had been associated to the crucial parts of realization of this research project.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	xi
LIST OF ABBREVIATION	xxi
LIST OF SYMBOLS	xxii
LIST OF APPENDICES	xxiv
LIST OF PUBLICATIONS	xxv
AWARDS	xxvii
PATENT	xxviii
COPYRIGHT	xxix
CHAPTER	1
1. INTRODUCTION	1
1.1 Background	1
1.2 The Importance of Material Characterization	3
1.3 Problem Statement	5
1.4 Objectives of This Thesis	6
1.5 Scope of Work	7
1.6 Contribution of the Thesis	7
1.7 Review of Thesis Organization	9
2. LITERATURE REVIEW	11
2.1 Introduction to Material Characterization	11
2.2 Fundamental Concepts of Electromagnetic Material Characterization	14
2.2.1 Dielectric Properties of Materials	14
2.2.2 Electromagnetic Resonant Modes	16
2.2.3 Resonant Perturbation Theory	20
2.3 Non-Resonator Methods	23
2.3.1 Coaxial Transmission Line and Waveguide Techniques	24
2.3.2 Open Reflection Method	26
2.3.3 Shorted Reflection Method	27
2.3.4 Free Space Techniques	27
2.4 Resonator Methods	28
2.4.1 Dielectric Resonator Methods	29
2.4.2 Resonator Perturbation Methods	29
2.5 Recent Development on Microwave Resonators	30
2.6 Comparative Analysis Summary for Material Characterization	33
2.7 Microwave Planar Resonator Techniques	36

2.8	Summary of the Planar Techniques	45
2.9	Concluding Remarks	48
3.	METHODOLOGY	50
3.1	Introduction	50
3.2	Flow Chart of the Project	51
3.3	Conventional Microstrip Planar Ring Resonator	56
3.3.1	Microwave Network and Scattering Parameters	56
3.3.2	Design Structure	57
3.3.3	The Quality Factor	61
3.3.4	Regular Resonant Modes	62
3.3.5	Location of Material under Test (MUT) on Ring Resonator	63
3.4	Gap and Slit Perturbations on Ring Resonator	65
3.4.1	One-port Ring Resonator	65
3.4.2	Two-port Network system	67
3.4.3	Ring Resonator with one Slit	69
3.4.4	Ring Resonator with Two-slits	70
3.5	Coupling Gap Enhancement	71
3.5.1	Stub-Matched Loose Coupling Ring Resonator	72
3.5.2	Quasi-Linear Periphery Coupling Ring Resonator	72
3.5.3	V-shaped Coupling Ring Resonator	73
3.5.4	Enhanced Coupling Ring Resonator	74
3.6	Symmetrical Split Ring Resonator (SSRR)	75
3.6.1	Design Structure	75
3.6.2	Equivalent Circuit of SSRR	77
3.7	SSRR with Spurlines	85
3.7.1	Design Structure	85
3.7.2	Equivalent Circuit	90
3.8	SSRR Sensors with/without Spurlines for Permittivity Measurements	94
3.8.1	Electric Field Distributions	94
3.8.2	Location of Material Under Test (MUT)	96
3.8.3	Fabrication and Measurement Process	99
3.9	Concluding Remarks	101
4.	RESULTS AND DISCUSSIONS	102
4.1	Introduction	102
4.2	Results of Conventional Ring Resonator Design	103
4.2.1	Simulation Results	103
4.2.2	Gap Perturbation (Slit)	104
4.2.3	Enhanced Coupling	107
4.3	Results of Symmetrical Split Ring Resonator (SSRR)	110
4.3.1	Simulation Results of SSRR Design Structure	110
4.3.2	Optimization Process of SSRR Coupling Gaps	111
4.3.3	Simulated Result with/without Material Under Test (MUT)	115
4.3.4	Numerical Modeling of Real Part Permittivity	119
4.3.5	Resonant Frequency Analysis	122
4.3.6	The Quality Factor Analysis	123
4.3.7	Measurements and Results Verifications	123

4.3.8	Experimental Validation with Material under Test (MUT)	126
4.4	Results of Compact SSRR with Single Spurline Filter	132
4.4.1	Optimization of SSRR Sensor with Single Spurline	132
4.4.2	Resonant Frequency Analysis	134
4.4.3	The Q-factor Analysis	135
4.4.4	Measurements and Results Verification	137
4.4.5	Experimental Validation with MUT	138
4.5	Results of SSRR with Double Spurlines Filter	141
4.5.1	Optimization of SSRR Sensor with Double Spurlines	141
4.5.2	Resonant Frequency Analysis	144
4.5.3	The Q-factor Sensitivity	145
4.5.4	Measurements and Results Verifications	147
4.5.5	Experimental Validation with MUT	149
4.6	Comparison Between the SSRR with and without Spurlines Filters	152
4.7	Summary of Proposed Sensors with Commercialized and Existing Sensors	156
4.7.1	Validation with Existing Sensors	157
4.7.2	Validation with Commercialized Coaxial Probe Kit Sensor in Laboratory	160
4.8	Concluding Remarks	163
5.	CONCLUSION AND SUGGESTION FOR FUTURE WORK	165
5.1	Conclusion	165
5.2	Suggestion for Future Work	168
	REFERENCES	171
	APPENDIX A	188
	APPENDIX B	190
	APPENDIX C	192
	APPENDIX D	194

LIST OF TABLES

TABLE	TITLE	PAGE
1.1	Classification of resonator methods for the study of low loss dielectric properties of samples.	2
2.1	The 50 Ω Coaxial Line for the Working Frequency Ranges with Different Outer Diameters (<i>mm</i>).	26
2.2	Microwave Resonator Designs for Several Researchers.	31
2.3	Extracting the Dielectric Properties of Different Materials at Various Measurement Methods.	34
2.4	Comparisons between the Most Popular Techniques and Their Advantages and Disadvantages	35
2.5	Comparative analysis of aligned-gap and centered-gap devices in terms of transmission coefficients and Q-factor	45
2.6	Comparison between different planar techniques in terms of quality factor, resonant frequency and insertion loss.	47
2.7	Measurement error of the existing microwave planar sensors.	48
3.1	Design specifications of planar ring resonator	53
3.2	Symmetrical split-ring resonator (SSRR) design specification.	76
3.3	Symmetrical split-ring resonator (SSRR) with spurlines design specification.	90

3.4	Standards material under test (MUT) with known permittivity	100
4.1	Comparison between the simulated and theoretical results for the first four modes in terms of resonant frequency and insertion loss.	104
4.2	Theoretical and simulated result at different modes for conventional ring resonator with one slit.	105
4.3	Theoretical and simulated frequency at different modes for conventional ring resonator with two slits.	107
4.4	Comparison of resonance frequencies and insertion losses of the first four modes with different excitation designs.	109
4.5	Comparison of resonance frequencies and return loss of the first four modes with different excitation designs.	109
4.6	Comparison before and after optimization for SSRR in terms of resonant frequency, Q-factor, transmission coefficients.	114
4.7	Comparison between simulation and measurement result in terms of resonant frequency, Q-factor and transmission coefficients (S_{21} dB).	126
4.8	Summary of experimental results for the proposed SSRR sensor in comparison to the standard materials permittivity.	128
4.9	Comparison between the normal SSRR and SSRR with single spurline in terms of resonant frequency, Q-factor and transmission coefficients.	136
4.10	Summary of experimental results for the SSRR sensor with single spurline in comparison to standard materials permittivity.	141

4.11	Comparison between the normal SSRR design and compact SSRR design with double spurlines in terms of resonant frequency, Q-factor and transmission coefficient.	146
4.12	Summary of experimental results for the SSRR sensor with double spurlines in comparison with standard materials permittivity.	151
4.13	Comparison between Normal SSRR, Single and Double Spurlines Filters.	154
4.14	Overall summary of experimental results for the SSRR sensors with/without spurlines filters.	156
4.15	Accuracy summary of comparison between the sensors of previous researchers and this work based on permittivity of tested material	159
4.16	Comparison between different techniques with the proposed SSRR technique in terms of resonant frequency, quality factor and insertion loss.	160
4.17	Summary of experimental results for the SSRR sensors and commercialized coaxial probe kit sensor.	162
4.18	Comparison between the SSRR Sensor and Commercialized Coaxial Probe Kit sensor.	163

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	The important of materials characterization.	4
2.1	The transmission system of microstrip (a) Microstrip geometry (b) Magnetic and electric field lines.	17
2.2	The equivalent geometry of Quasi-TEM microstrip (a) Original geometry of a material with permittivity (ϵ_r) (b) Equivalent geometry of effective permittivity (ϵ_{eff}) of homogeneous medium when it is replaced by the air and dielectric regions.	18
2.3	The concept of effective permittivity. (a) Microstrip filled completely with air, (b) Microstrip filled completely with ϵ_r , (c) Microstrip filled partially with ϵ_r , and (d) Microstrip filled completely with ϵ_{eff} .	19
2.4	The circulating current generates a magnetic field and behaves as an inductance while the capacitance is represented by the gap on the ring and the separation between rings.	22
2.5	Design structures for the concept of quasi-static resonator (a) Split-ring resonator (SRR) (b) Complementary split-ring resonator (CSRR) (c) Hilbert curves (d) Spiral ring resonator. They are electrically small structures at their resonance frequencies.	23

2.6	Incident, transmitted and reflected electromagnetic waves in a filled transmission line	25
2.7	Transmission line methods (a) Sample inside the waveguide line, (b) Sample inside the coaxial line	25
2.8	Coaxial open-circuit reflection	26
2.9	Coaxial short circuit reflection	27
2.10	Free space measurement setup using VNA	28
2.11	A cylindrical dielectric sandwiched between two conducting plates	29
2.12	Measurement for the surface resistance of conductor using cavity perturbation method	30
2.13	(a) Complementary split ring resonator (CSRR) sensor (b) Side view and location of material under test (MUT)	38
2.14	Fabrication of CSRR sensor. (a) Top view. (b) Bottom view. (c) Close-up picture of the CSRR	38
2.15	CSRR planar sensor (a) The top view of CSRR with transparent substrate, (b) Model of material under test (MUT) simulation which placed over ground plane, (c) Side view showing substrate, ground and MUT	39
2.16	Fabricated CSRR sensor (a) Setup for measurement, (b) Top view, (c) Bottom view of etched CSRR sensor	40
2.17	(a) The schematic of the symmetric SRR, (b) The schematic of the asymmetric SRR	41
2.18	The design structure of VSRR sensor with the distributions of electric field	41

2.19	Demonstration of the CSRR sensor with MUT and equivalent circuit of RLC resonance model	42
2.20	Split-ring microstrip sensor schematic view connected to network analyzer and controlled by a LabVIEW	43
2.21	Fabricated sensor with the location of quartz capillary	43
2.22	Design structure view of the aligned-gap MSRR and its dimensions	44
2.23	Design structure view of the centered-gap MSRR and its dimensions	44
2.24	Fabricated sensors: (a) aligned-gap; (b) centered-gap	45
3.1	Flow chart of the Project.	52
3.2	Experimental setup: The resonator sensor is connected to VNA.	55
3.3	A two-port microwave network.	57
3.4	Microstrip ring resonator shows the two-layer board with one dielectric material.	58
3.5	Planar ring resonator network circuit with gap and modeled ring.	59
3.6	Design structure of microstrip ring.	60
3.7	Measurement of quality factor from S21.	62
3.8	Distribution of electric field at the first four frequency modes for two-port ring resonator. (a) 1 st order mode. (b) 2 nd order mode. (c) 3 rd order mode. (d) 4 th order mode.	63
3.9	Location of MUT on ring resonator (a) the MUT perturbs the electric field (b) Location of MUT at the maximum electric fields point.	64
3.10	One-port ring circuit (a) configuration and (b) equivalent circuit.	66
3.11	Two-port ring circuit (a) configuration and (b) equivalent circuit.	67

3.12	Simulated results for two different coupling gap size $g = 0.15 \text{ mm}$ and 0.65 mm .	68
3.13	Absolute values of maximum field point of a): port 1, b): port 2.	69
3.14	Loose coupling scheme with one slits at 90° .	70
3.15	Maximum electric field points for mode $n = 1.5$ for MRR with one slit (a) port 1, (b) port 2.	70
3.16	Loose coupling with two slits at 90° and 270° .	71
3.17	Maximum field point of MRR with two slits at $n = 2$ (a): port 1, (b): port 2.	71
3.18	Design structure for stub matched loose coupling.	72
3.19	Design structure of enhance coupling ring resonator.	73
3.20	Design structure for V-shaped coupling enhancement.	74
3.21	Design structure for enhanced coupling periphery.	74
3.22	Design structure for symmetrical split ring resonator (SSRR).	75
3.23	3D model of symmetrical split ring resonator structure in HFSS.	77
3.24	The impedance circuit for (a) low-pass prototype at impedance 1Ω (b) low-pass prototype at impedance 50Ω .	78
3.25	Low-pass prototype to bandpass prototype transformation.	79
3.26	Inductance transformation from low-pass to bandpass prototype.	80
3.27	Capacitance transformation from low-pass to bandpass prototype.	80
3.28	Single-mode circuit of ring resonator (a) Bandpass prototype using K inverter (b) Bandpass prototype of fundamental frequency (1^{st} resonance frequency).	81

3.29	Equivalent circuit of analogically first four modes for the SSRR resonator at different harmonics frequencies.	82
3.30	Simulated response of a capacitively coupled bandpass filter (a) single-mode (b) First four harmonic modes.	84
3.31	The schematic diagram for spurlines filters (a) single spurline (b) Double spurline.	85
3.32	Schematic view of 3D model of (a) single spurline filter (b) double spurlines filter.	86
3.33	Comparison of simulated transmission coefficients (S_{21} in dB) for both single and double spurline filter.	87
3.34	Design structure of (a) SSRR with single spurline (b) SSRR with double spurline.	88
3.35	Schematic view of 3D model in HFSS for (a) SSRR with single spurline (b) SSRR with double spurline.	89
3.36	Low-pass prototype to band-stop prototype transformation.	91
3.37	LC connection of band-stop prototype.	92
3.38	Single-mode circuit of band-stop spurlines filters (a) Band-stop prototype using K inverter (b) Band-stop prototype of fundamental frequency.	93
3.39	Simulated response of a capacitively coupled band-stop filter.	94
3.40	Simulated electric field distribution on symmetrical split ring resonator (SSRR) for first four modes.	95
3.41	Simulated electric field on symmetrical split ring resonator (SSRR) with both single and double spurlines.	96

3.42	The possible location of material under test (MUT) (a) above the copper track (b) inside the substrate.	97
3.43	The 3D model of the MUT for symmetrical split ring resonator (SSRR).	98
3.44	3D model of the MUT for SSRR with single and double spurlines.	98
3.45	Connection of DUT and VNA for measurement process.	99
3.46	Fabricated SSRR sensor with the measurement of the unknown material under test (MUT).	100
4.1	S21 parameters behavior of Two-Port Ring Resonator with unloaded material.	104
4.2	S21 parameters behavior of MRR with one slit.	105
4.3	S21 parameters behavior for MRR with two-slit.	106
4.4	Comparison of resonance frequencies for insertion loss at different excitation designs.	108
4.5	Comparison of resonance frequencies for return loss at different excitation designs.	108
4.6	Simulation results of symmetrical split ring resonator (SSRR) before and after optimization.	111
4.7	The effect of the coupling-gaps on resonant frequency (a) measured transmission coefficients (S21) (b) shifted frequencies.	112
4.8	The effect of coupling gap in Q-factor.	114
4.9	Comparison between the simulation result of unloaded and loaded with an overlay sample.	115
4.10	Resonance frequency as a function of multiple overlay thickness.	116

4.11	The amount of shift frequency over the range of overlay thickness.	117
4.12	The effect of overlay thickness on: (a) resonance frequency, (b) Insertion loss S21 in <i>dB</i> .	118
4.13	MUT permittivity as a function of resonance frequency for the proposed SSRR sensor.	119
4.14	Effects of the change in MUT thickness with respect to various value of permittivity and resonant frequency.	121
4.15	Effects of the change in MUT thickness with respect to various value of permittivity and resonant frequency	121
4.16	Sensitivity response of SSRR in terms of relative shift and resonance frequency corresponding to various MUT permittivity.	122
4.17	Sensitivity response of SSRR in terms of quality factor and transmission coefficients with respect to the change of loss tangent.	123
4.18	Fabricated SSRR sensor without material under test (MUT).	125
4.19	Measured S21 parameter: comparison between simulation and measurement results.	125
4.20	Fabricated SSRR sensor with testing the standards MUT.	127
4.21	Changes in resonance frequency when known permittivity of MUT is tested.	128
4.22	Comparison between the reference and measured MUT permittivity using SSRR sensor with the fitted mathematical model.	129
4.23	Fabricated SSRR sensor with overlay meat sample.	130
4.24	Simulated S21 parameter: behavior response of resonance frequency with/out overlay fresh meat sample ($\epsilon_r = 56.5$).	130

4.25	Shifted frequency with and without MUT (a) Comparison between the simulated and the measured result with and without MUT, (b) Shifted frequency when placing MUT (Beef with thickness 1 <i>mm</i>).	131
4.26	Comparison of normal SSRR design and single spurline filter before optimization in terms of transmission coefficients.	133
4.27	The transmission coefficients of SSRR with single spurline before and after optimization.	134
4.28	Sensitivity response of SSRR sensor with single spurline in terms of relative shift and resonance frequency corresponding to various MUT permittivity.	135
4.29	The change of quality factor and transmission when changing the MUT loss tangent.	136
4.30	Fabrication of compact SSRR sensor with single spurline.	137
4.31	Simulated and measured result of compact SSRR with single spurline.	138
4.32	The MUT experimental validation for the SSRR sensor with single spurline.	139
4.33	Changes in resonance frequency when known permittivity of MUT is tested.	139
4.34	Comparison between the reference and measured MUT permittivity using SSRR sensor with the fitted mathematical model.	140
4.35	Simulated transmission results of the normal SSRR sensor and SSRR sensor with double spurlines.	143

4.36	Comparison results before and after optimization of the compact SSRR design double spurlines filter in terms of transmission coefficients and resonant frequency.	143
4.37	The change of resonant frequency and relative shift when changing the MUT permittivity.	145
4.38	The change of the quality factor and transmission coefficients when changing the MUT loss tangent.	147
4.39	Fabrication of compact SSRR sensor with double spurlines.	148
4.40	The comparison of the simulation and measurement results for SSRR with double spurlines.	148
4.41	Fabricated SSRR sensor with double spurlines during measuring the standard materials with known permittivity.	149
4.42	The response behavior of SSRR sensor with double spurlines when loaded with various MUT.	150
4.43	Comparison between the standards and measured MUT permittivity using SSRR with double spurline with the fitted mathematical model	151
4.44	Comparison results of the normal SSRR sensor with/without single and double spurlines filter for simulated transmission coefficients (S ₂₁) (a) before optimization (b) after optimization.	153
4.45	Comparison results of the normal SSRR sensor with/without the single and double spurlines filter for measured transmission coefficients (S ₂₁).	154
4.46	The measured permittivity of the proposed sensors in comparing with the standards permittivity of material under test (MUT).	155