UNIVERSITAS TRISAKTI

Assoc. Prof. Syah Alam S Pd, MT, PhD <syah.alam@trisakti.ac.id>

New MS SENSL-23-11-RL-1000

1 message

IEEE Sensors Letters <onbehalfof@manuscriptcentral.com> Tue, Nov 7, 2023 at 5:21 PM
Reply-To: sensl-admin@ieee.org
To: syah.alam@trisakti.ac.id
Cc: syah.alam@trisakti.ac.id, zahriladha@utem.edu.my, indra@trisakti.ac.id, noorazwan@utem.edu.my, mudrikalaydrus@mercubuana.ac.id, teguhfirmansyah@untirta.ac.id, yuli_kn@trisakti.ac.id, lydia_sari@trisakti.ac.id

07-Nov-2023

Dear Dr. Alam:

Your manuscript entitled "Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" has been successfully submitted online and is presently being given full consideration for publication in the IEEE Sensors Letters.

Your manuscript ID is SENSL-23-11-RL-1000.

Please mention the above Manuscript ID in all future correspondence. If there are any changes to your personal information, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/sensors-letters and edit your account as appropriate.

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While your manuscript is undergoing review, you may also submit it in its current form to IEEE's preprint server, TechRxiv at https://www.techrxiv.org/. By uploading your manuscript to TechRxiv you can quickly disseminate your work to a wide audience and gain community feedback. Any comments you receive on the TechRxiv submission have no bearing on the peer review process.

Thank you for submitting your manuscript to the IEEE Sensors Letters.

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ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi • Reject (28-Nov-2024) view decision letter	SENSL-24-10-RL-1332	Single-Port IDC using Asymmetry Branch Feed Line with Shielded Structure for Dual Band Frequency Microwave Sensor View Submission	14-Oct-2024	28-Nov-2024
Copyright transferred on 13-Jun-2024	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi • Accept (12-Jun-2024)	SENSL-24-03-RL-0183.R1	Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity	04-Jun-2024	12-Jun-2024

ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
	view decision letter		Sensor using T-Shaped Resonator Embedded with IDC View Final Submission		
a revision has been submitted (SENSL-24-03-RL-0183.R1)	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi • Minor Revision (28-May-2024) • a revision has been submitted view decision letter	SENSL-24-03-RL-0183	Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC View Submission	04-Mar-2024	28-May-2024
a resubmission has been submitted (SENSL-24-03-RL-0183)	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi • Reject & Resubmit (25-Feb-2024) • a resubmission has been submitted view decision letter	SENSL-23-12-RL-1121	Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC View Submission	25-Dec-2023	25-Feb-2024
a resubmission has been submitted	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi	SENSL-23-11-RL-1000	Collaboratively Far-Field and Near-Field Regions for	07-Nov-2023	21-Dec-2023

ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
(SENSL-23-12-RL-1121)	• Reject & Resubmit (21-Dec-2023) • a resubmission has been submitted view decision letter		Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC View Submission		
	Contact Journal AEIC: Uttamchandani, Deepak ADM: Kukreti, Mansi • Reject (06-Nov-2023) view decision letter	SENSL-23-10-RL-0921	Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC View Submission	11-Oct-2023	06-Nov-2023

IEEE Sensors Letters

Decision Letter (SENSL-23-11-RL-1000)

From: d.uttamchandani@strath.ac.uk

To: syah.alam@trisakti.ac.id

CC: ccchang@ieee.org, d.uttamchandani@strath.ac.uk

Subject: IEEE Sensors Letters: SENSL-23-11-RL-1000

Body: 21-Dec-2023

Dear Dr. Alam:

"Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" (Manuscript ID SENSL-23-11-RL-1000), which you submitted to IEEE Sensors Letters, has been reviewed. The comments from the reviewers appear below and in separate files which may be read by going into the "Manuscripts with Decisions" queue in your Author Center and clicking the "view decision letter" link for this paper.

Unfortunately, we must decline the manuscript for publication at this time. However, because we believe the work has merit, we invite you to consider submitting a revised manuscript that takes the reviewers' comments into consideration. It would be given a new Manuscript ID and reviewed again.

After you have revised your manuscript, please submit it by going to the "Manuscripts with Decisions" queue of your Author Center on our Manuscript Central Web site, https://mc.manuscriptcentral.com/sensors-letters. Then click "create a resubmission."

In Step 1, you will be asked to respond to this decision letter. Here you may include confidential information to the editor, not intended for the reviewers.

In Step 5 of the re-submission process, please indicate that the manuscript has been submitted previously, and enter the original article number, SENSL-23-11-RL-1000.

In Step 6 you should delete any obsolete, original submission files (e.g., MAIN DOCUMENT) and upload your new MAIN DOCUMENT. You should also upload a SUPPLEMENTARY FILE in which you have responded to the reviewers' remarks. Please state how you satisfied (or why you declined to satisfy) each suggestion from the reviewers. Then click Save and Continue, and complete the other steps for re-submission.

Once we receive your revised version, it may be sent again to reviewers (who will see your responses in your SUPPLEMENTARY FILE). They may recommend further changes before a final decision on publication is reached.

Thank you for sending your manuscript to us for consideration. We look forward to further contributions from you in the future.

Sincerely,

Prof. Deepak Uttamchandani
AEIC, IEEE Sensors Letters

Manuscript Title: Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
ID: SENSL-23-11-RL-1000

Reviewers' comments to author, if any (please also check your Author Center for other files):
Reviewer: 1

Comments to the Author
This article needs a major revision.
1- All topics have been reviewed superficially.
The authors have to make significant changes to this version.
Also, its similarity percentage with the previous works is very high.
Please specify the novelty of the work.
Also, the sensitivity and Q-factor of this work are not high compared to similar articles.
What is the invention of this article?
2- Some sentences of the article need to be corrected grammatically.
3- The introduction section is not well-organized.
Studies in this sector are limited.

I suggest writing it from scratch.
Authors can get help from the following references: "10.1016/j.measurement.2023.113232"
"10.1080/03772063.2023.2231875"
" 10.1109/TIM.2021.3052011" "10.1016/j.measurement.2020.107805"
"10.1109/JSEN.2018.2873544"
"10.1002/dac.5417"
4- Before building the sensor, in the simulation environment, how did the authors realize that the designed sensor could be a microwave sensor? Please provide
5- How did the authors achieve the dimensions of the sensor? Please specify a design flowchart.
Authors can use the following articles.
"10.1016/j.aeue.2023.154563"
"10.1002/mop.33453"
6- Please suggest an equivalent circuit for the sensor. Authors can get help from the following references: "10.1017/S1759078723000703"
"10.1017/S1759078723000053"
7- How much is the FDR parameter for this sensor?
Please check it.
Authors can get help from the following references: "10.1080/03772063.2023.2231875"
"10.1002/dac.5417"

Reviewer: 2

Comments to the Author
The paper presents a solution for permittivity analysis of material using an MS structure. I suggest that the following comments better to be addressed:
- Please take a look at the writing as there were a few typos.
- Although the general idea sounds interesting as presented in the title, it is not clear to me how this far-field analysis helps near-field analysis in determining the dielectric permittivity of the material under the test. Please clarify.
- If I understood correctly, there will be two measurements associated with each characterization. How could you make sure that the location of MUT is constant during all the experiments?
- In Fig 7, it is observed that the permittivity of the materials is dropping from ~6 to ~1 in a quite small frequency span. Would you please mention the materials with such permittivity changes? Please make sure that you clarify this point.
-

Date Sent: n/a

Close Window

Professor Andrei Shkel
Editor in Chief – *IEEE Sensors Letters.*
Prof. Deepak Uttamchandani
Associate Editor In Chief - IEEE Sensors Letters

December 25, 2023

Dear Professor,

I hope this email finds you well and healthy. First of all, thank you for evaluating our manuscript and we apologize for disturbing your valuable time.

For your information, this paper has been submitted to IEEE Sensor Letter with:

Title	:	Collaboratively Near-Field and Far-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
Paper ID	:	SENSL-23-10-RL-1000
Author	:	Syah Alam, Zahriladha Zakaria, Indra Surjati, Noor Azwan Shairi, Mudrik Alaydrus, Teguh Firmansyah, Yuli Kurnia Ningsih, Lydia Sari
Date of submitted	:	October 11, 2023
Date of decision	:	December 21, 2023 (Reject & Resubmit)

After reading the fruitful comment and construction discussions from editor and reviewer, we believe that we should make the letter to make clearer explanations and improve our manuscripts based on reviewer and editor comment. Here, we give responses from reviewer comments and revised manuscript. All revisions in the revised manuscript are marked in red.

Again, we apologize for disturbing your valuable time. Please don't hesitate to contact us if there are any questions.

Please find the response letter below for the revision information.

Yours sincerely,

Syah Alam
Department of Electrical Engineering, Universitas Trisakti, DKI Jakarta, 11440
*Corresponding author e-mail: syah.alam@trisakti.ac.id

REVIEWERS' COMMENTS

REVIEWER #1:

Comments to the Author:
This article needs a major revision.

1. ***All topics have been reviewed superficially. The authors have to make significant changes to this version. Also, its similarity percentage with the previous works is very high. Please specify the novelty of the work. Also, the sensitivity and Q-factor of this work are not high compared to similar articles. What is the invention of this article?***

Response:

- We thank the reviewer for this very thoughtful comment. We agree to the reviewer comment. Therefore, to show the significant differences and benefits of this work compared with previous work, we have added clear information in the introduction section and proposed a comparison table to show the performance of the proposed sensor. Furthermore, this letter introduces a collaboration between **near-field and far-field regions** for microwave permittivity sensors with **two independent sensing hotspots** operating at two resonant frequencies. In detail, the main contribution of this research such as **proposed long distance detection MS** with **two independent sensing hotspots** enabling **contact and contactless characterization of solid materials**. To obtain a **clear location between E-field and H-field** with **high sensitivity performance**, T-shaped resonator embedded with **interdigital capacitors (IDC)** was proposed. We also proposed comparison table to show **the contribution and novelty** of the proposed paper.
- This proposed novel has the sensitivity **of 5.13%** and it showed the highest sensitivity compared with previous work in **Table 2**. We also added **the value Q-factor which is 121 and the value is equivalent with other previous works. Moreover, the main contribution of this works in the previous paragraph above and not focused in the high Q-factor.**
- The invention of this works is focussing proposed on long distance detection MS with two independent sensing hotspots enabling contact and contactless characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, T-shaped resonator embedded with interdigital capacitors (IDC) was proposed.

Kindly refer Section: Introduction, page 1 and Table 2, page 4

*In contrast, previous work proposed by [7] introduces a dual T-shaped resonator featuring a single port for characterizing solid materials with contact and non-contact. **However, this work has disadvantages such as a very limited distance of 0.5 - 1.5 mm for non-contact detection, poor sensitivity and the locations of the E-field and H-field are ambiguous.** Another work, presented by [8], suggests a multifunctional dual-band MS with an antenna for communication purposes. **However, the MUT's characterization is only performed directly by placing it on the sensing hotspot.** Additionally, [9] and [10] employs an antenna as a permittivity sensor for contactless detection at a distance of 20 mm and 30 mm using Artificial Magnetic Conductor (AMC) . **However, the proposed sensor features only one sensing hotspot and therefore cannot facilitate contact and***

contactless characterization independently. *Therefore, several requirements are needed to obtain high performance MS with long distance detection, high sensitivity, clear location between E-field and H-field and dual hotspot location for contact and contactless.*

To fulfill this requirement, this letter introduces a collaboration between near-field and far-field regions for microwave permittivity sensors with two independent sensing hotspots operating at two resonant frequencies. ***In detail, the main contribution of this research such as proposed long distance detection MS with two independent sensing hotspots enabling contact and contactless characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, T-shaped resonator embedded with interdigital capacitors (IDC) was proposed.*** *The 1st resonator operating at f_{r1} = 2.43 GHz for contactless detection, and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection. Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators.*

Furthermore, to demonstrate the novelty of this paper, a fair comparison with previous work is shown in ***Table 2.***

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Num. of sensing hotspot	d (mm)	Separated E & H field	S (%) / Q-factor	Contact / contactless detection
[7]	1.81 2.34	1 – 6.15	2	1.5	No	2.30 /117	Yes / No
[8]	1.50 2.00 2.45	1 – 6.15	2	0.0	No	2.71 /120	Yes / No
[9]	6.90	1 – 15	1	20	No	3.80 /69	No / Yes
[10]	4.04	2 – 4	1	30	No	1.89 /268	No / Yes
This work	1.64 2.43	1 – 6.15	2	100	Yes	5.13 /121	Yes / Yes

Table 2 *shows that the proposed sensor has novel dual modalities for contact and contactless detection by utilizing the near -field and far-field region with a* ***high sensitivity of 5.13%, long-distance detection with d = 100 mm and maximum Q-factor of 121*** *for solid materials with a permittivity range of 1 - 6.15 and two different sensing hotspots compared with previous work which only supports contact or contactless detection and limited distance for contactless detection.*

Reference:
[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.
[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.
[9] Q. Shi, X. W. Xuan, H. K. Nie, Z. Y. Wang, and W. Wang, "Antenna Sensor Based on AMC Array for Contactless Detection of Water and Ethanol in Oil," IEEE Sens. J., vol. 21, no. 19, pp. 21503–21510, 2021, doi: 10.1109/JSEN.2021.3102294.
[10] W. J. Wu and G. Wang, "A modified AMC-based antenna sensor for contactless measurement of complex permittivity," Meas. J. Int. Meas. Confed., vol. 206, no. June 2022, p. 112261, 2023, doi: 10.1016/j.measurement.2022.112261.

2. Some sentences of the article need to be corrected grammatically.

Response:

We thank the reviewer for this very thoughtful comment. We have revised writing and sentences in the revised manuscript.

3. ***The introduction section is not well-organized. Studies in this sector are limited. I suggest writing it from scratch. Authors can get help from the following references:***
   "10.1016/j.measurement.2023.113232"
   "10.1080/03772063.2023.2231875"
   "10.1109/TIM.2021.3052011"
   "10.1016/j.measurement.2020.107805"
   "10.1109/JSEN.2018.2873544"
   "10.1002/dac.5417"

Response:

We thank the reviewer for this very thoughtful comment. Furthermore, in the introduction section we have explained the **main issues** of previous research, including **limited distance for non-contact detection [7][9][10]**, **poor sensitivity [7], ambiguous E-field and H-field locations [7][8] and limitations in the number of sensing hotspots from previously proposed sensors [9][10]**. Therefore, several requirements are needed to obtain high performance MS with long distance detection, high sensitivity, clear location between E-field and H-field and dual hotspot location for contact and contactless. In this paper, we proposed a **collaboration between near-field and far-field regions** for microwave permittivity sensors operating at two resonant frequencies. The proposed sensor has a capability to detect for long distance with two independent sensing hotspots enabling contact and contactless characterization of solid materials. Moreover, to obtain a **clear location between E-field and H-field** with high sensitivity performance, a T-shaped resonator embedded with **interdigital capacitors (IDC) was proposed**. We have also included **suggestion previous work** in our revised manuscript **represented by [3] and [6]**.

Kindly refer Section: Introduction, page 1

*Microwave sensors (MS) have gained widespread development for assessing both solids and liquids due to their benefits, including high precision, a high Q-Factor, affordability, and compact size[1]. One of the properties they can detect is permittivity, which refers to a material's capacity to retain an electric field. Moreover, permittivity of the MUT can be ascertained through perturbation theory, assuming the MUT acts as a capacitive load [2]. Previous studies have put forth various microwave sensors employing resonators such as **Split Ring Resonator (SRR)[3],** Complementary Split Ring Resonator (CSRR) [4], Substrate Integrated Waveguide (SIW) [5], and **Interdigital Capacitor (IDC)** [6] for assessing solid substances. **In contrast, previous work proposed by [7] introduces a dual T-shaped resonator featuring a single port for characterizing solid materials with contact and non-contact. However, this work has disadvantages such as a very limited distance of 0.5 - 1.5 mm for non-contact detection, poor sensitivity and the locations of the E-field and H-field are ambiguous. Another work, presented by [8], suggests a multifunctional dual-band MS with an antenna for communication purposes. However, the MUT's characterization is only performed directly by placing it on the sensing hotspot. Additionally, [9] and [10] employs an antenna as a permittivity sensor for contactless detection at a distance of 20 mm and 30 mm using Artificial Magnetic Conductor (AMC) . However, the proposed sensor features only one sensing hotspot and therefore cannot facilitate contact and contactless characterization independently.** Therefore, several requirements are needed to obtain high performance MS with long distance detection, high sensitivity, clear location between E-field and H-field and dual hotspot location for contact and contactless.*

*To fulfill this requirement, **this letter introduces a collaboration between near-field and far-field regions for microwave permittivity sensors operating at two resonant frequencies. In detail, the main contribution of this research such as proposed long distance detection MS with two independent sensing hotspots enabling contact and contactless characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for contactless detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection.** Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11].*

Reference:

[1] K. S. L. Parvathi and S. R. Gupta, "Ultrahigh-Sensitivity and Compact EBG-Based Microwave Sensor for Liquid Characterization," IEEE Sensors Lett., vol. 6, no. 4, pp. 19–22, 2022, doi: 10.1109/LSENS.2022.3159800.

[2] A. Aquino, C. G. Juan, B. Potelon, and C. Quendo, "Dielectric Permittivity Sensor Based on Planar Open-Loop Resonator," IEEE Sensors Lett., vol. 5, no. 3, pp. 2021–2024, 2021, doi: 10.1109/LSENS.2021.3055544.

[3] S. Kiani, P. Rezaei, and M. Navaei, "Dual-sensing and dual-frequency microwave SRR sensor for liquid samples permittivity detection," Meas. J. Int. Meas. Confed., vol. 160, p. 107805, 2020, doi: 10.1016/j.measurement.2020.107805.

[4] H. Xiao, S. Yan, C. Guo, and J. Chen, "Microwave / millimeter wave sensors A Dual-Scale CSRRs-Based Sensor for Dielectric Characterization," vol. 6, no. 12, pp. 10–13, 2022.

[5] W. Liu, J. Zhang, and K. Huang, "Wideband microwave interferometry sensor with improved sensitivity for measuring minute variations in dielectric properties of chemical liquids in microfluidic channels," Meas. J. Int. Meas. Confed., vol. 189, no. September 2021, p. 110474, 2022, doi: 10.1016/j.measurement.2021.110474.

[6] S. Kiani, P. Rezaei, M. Navaei, and M. S. Abrishamian, "Microwave Sensor for Detection of Solid Material Permittivity in Single/Multilayer Samples With High Quality Factor," IEEE Sens. J., vol. 18, no. 24, pp. 9971–9977, 2018, doi: 10.1109/JSEN.2018.2873544.

[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.

[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.

[9] Q. Shi, X. W. Xuan, H. K. Nie, Z. Y. Wang, and W. Wang, "Antenna Sensor Based on AMC Array for Contactless Detection of Water and Ethanol in Oil," IEEE Sens. J., vol. 21, no. 19, pp. 21503–21510, 2021, doi: 10.1109/JSEN.2021.3102294.

[10] W. J. Wu and G. Wang, "A modified AMC-based antenna sensor for contactless measurement of complex permittivity," Meas. J. Int. Meas. Confed., vol. 206, no. June 2022, p. 112261, 2023, doi: 10.1016/j.measurement.2022.112261.

[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

[12] A. Armghan, T. M. Alanazi, A. Altaf, and T. Haq, "Characterization of Dielectric Substrates Using Dual Band Microwave Sensor," IEEE Access, vol. 9, pp. 62779–62787, 2021, doi: 10.1109/ACCESS.2021.3075246.

[13] R. A. Alahnomi, Z. Zakaria, E. Ruslan, S. R. Ab Rashid, and A. A. Mohd Bahar, "High-Q sensor based on symmetrical split ring resonator with spurlines for solids material detection," IEEE Sens. J., vol. 17, no. 9, pp. 2766–2775, 2017, doi: 10.1109/JSEN.2017.2682266.

[14] S. Kiani, P. Rezaei, and M. Fakhr, "Real-Time Measurement of Liquid Permittivity Through Label-Free Meandered Microwave Sensor," IETE J. Res., 2023, doi: 10.1080/03772063.2023.2231875.

4. *Before building the sensor, in the simulation environment, how did the authors realize that the designed sensor could be a microwave sensor? Please provide.*

Response:

We thank the reviewer for this very thoughtful comment. Furthermore, we already described in our paper that the proposed sensor is realized based on the **resonance frequency (f_{r1} = 2.32 GHz and f_{r2}= 1.52 GHz), reflection coefficient (S_{11}) and concentration of the electric field used as a sensing hotspot location**. The location of the sensing hotspot is determined based on the concentration of the E-field and H-field of the proposed resonator. The surface of the resonator with **high E-field** can be used **to detect the permittivity of MUT**. Moreover, **the resonators having S_{11} ≤ -10 dB and high radiation are proposed for contactless** detection while **resonators with S_{11} ≥ -10 dB and low radiation** are proposed **for contact detection**.

Kindly refer Section: Sensor Design, page 2

*In this letter, two scenarios are proposed for far-field and near-field region for characterization of solid materials using the proposed sensor as shown in **Fig. 1(a)** and **Fig. 1(b)** with the following explanation:*

1) ***Furthermore, scenario (1) proposes contactless detection using interrogator antennas operating at the same resonance frequency as the 1st resonator at f_{r1}= 2.32 GHz with S_{11} ≤ -10 dB** and separated by distance (d) of 10 cm. Contactless permittivity detection is carried out by observing changes in the resonant frequency based on S_{21} as shown*

in ***Fig. 1(a)***.

2) ***For scenario (2), near-field region for contact detection is proposed by placing the MUT on the IDC of the 2nd resonator operating at f_{r2}= 1.52 GHz with $S_{11} \geq$ -10 dB*** *by observing changes in the resonant frequency based on S_{11} as shown in* ***Fig. 1(b).***

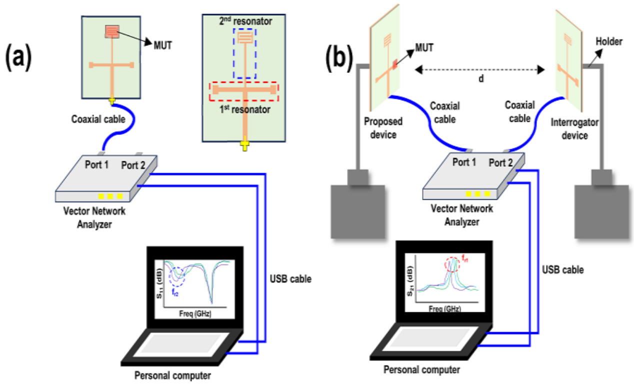

Fig. 1. *Scenario of permittivity detection using proposed sensor; (a) scenario (1) for contactless detection using an interrogator antenna, (b) scenario (2) for contact detection*

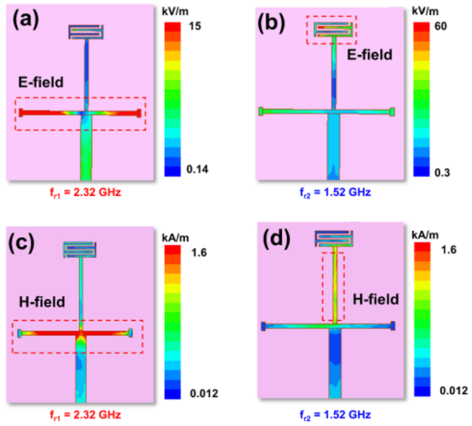

Fig.2 *E-field and H-field concentration; (a) E-field at f_{r1} = 2.32 GHz, (b) E-field at f_{r2} = 1.52 GHz, (c) H-field at f_{r1} =2.32GHz, (d) H-field at f_{r2} = 1.52 GHz.*

The location of the sensing hotspot is determined based on the concentration of the E-field and H-field of the proposed resonator. The surface of the resonator with high E-field can be used to detect the permittivity of MUT. The E-field and H-field concentrations of the resonator are shown in ***Fig. 2(a)***, ***Fig. 2(b)***, ***Fig. 2(c)*** *and* ***Fig. 2(d).***

Fig. 2(a) *and* ***Fig. 2(c)*** *show that the high E-field and H-field concentrations at f_{r1} = 2.32 GHz are at the same location on the arms of the 1st resonator. Other findings,* ***Fig. 2(b)*** *and* ***Fig. 2(d)*** *show that the highest E-field is in the gap of the IDC while the H-field is in the arm of the 2nd resonator. Furthermore, simulations of the radiation patterns at f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz are shown in* ***Fig.3 (a)***, ***Fig.3 (b)*** *and* ***Fig. 3 (c)***

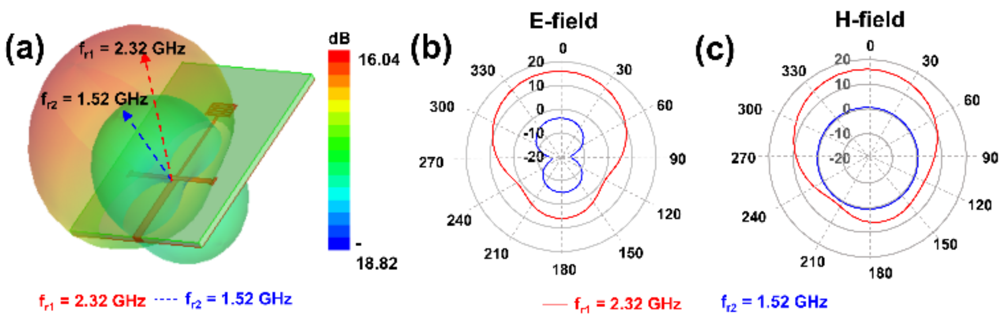

Fig.3 *(a) Radiation pattern of proposed resonator at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz, (b) E-field at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz, (c) H-field at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz.*

Fig.3 (a) shows that the radiation pattern at f_{r1} = 2.32 GHz is higher than f_{r2} = 1.52 GHz. This finding is also in line with

the simulations of E-field and H-field radiation shown in Fig. 3 (b) and Fig. 3 (c). This shows that resonators with high radiation can be used for contactless detection by utilizing the far-field region, while low radiation can be used for contact detection by utilizing the near-field region.

5. How did the authors achieve the dimensions of the sensor? Please specify a design flowchart. Authors can use the following articles.
"10.1016/j.aeue.2023.154563"
"10.1002/mop.33453"

Response:

We thank the reviewer for this very thoughtful comment. The dimensions of the sensor are determined based on equation (1) and (2) [11]:

$$\varepsilon_{eff} = \left(\frac{nc}{2(l+l_c)f}\right)^2 \quad (1)$$

$$f = \left(\frac{nc}{2(l+l_c)\sqrt{\varepsilon_{eff}}}\right) \quad (2)$$

where *l* is the stub length can be approximately modelled with the fundamental equation for a resonator of quarter-wave, l_c is the contribution of the capacitance of the two open ends and ε_{eff} represented the effective dielectric constant of the microstrip.

Furthermore, the development model of the resonator is shown in Fig. 4 (a) and Fig. 4 (b) where the resonator is developed in two steps.

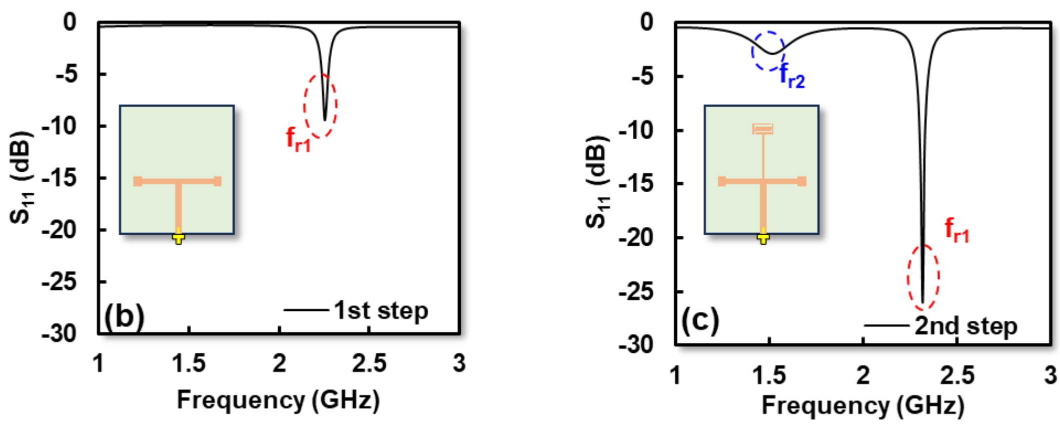

Fig. 4. (a) 1st stages model (b) 2nd stages model

Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. Moreover, the schematic representation of the proposed dual T-shaped resonator is presented in **Fig. 4(a)** and **Fig. 4 (b)**. In the initial phase, the resonator functions at f_{r1} = 2.32 GHz, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz, respectively. We also proposed a flowchart of design process inf Fig 4 in the revised manuscript.

Kindly refer Section: Sensor Design, page 2, Fig 4.

The dual modalities sensor is constructed utilizing of FR-4 substrate with specific properties: a dielectric constant (ε_r) of

4.3, a loss tangent (tan δ) of 0.0265, and a thickness (h) of 1.6 mm. This substrate encompasses a T-shaped resonator embedded with interdigital capacitor (IDC) linked to a microstrip line and connector possessing an impedance of 50 Ω.

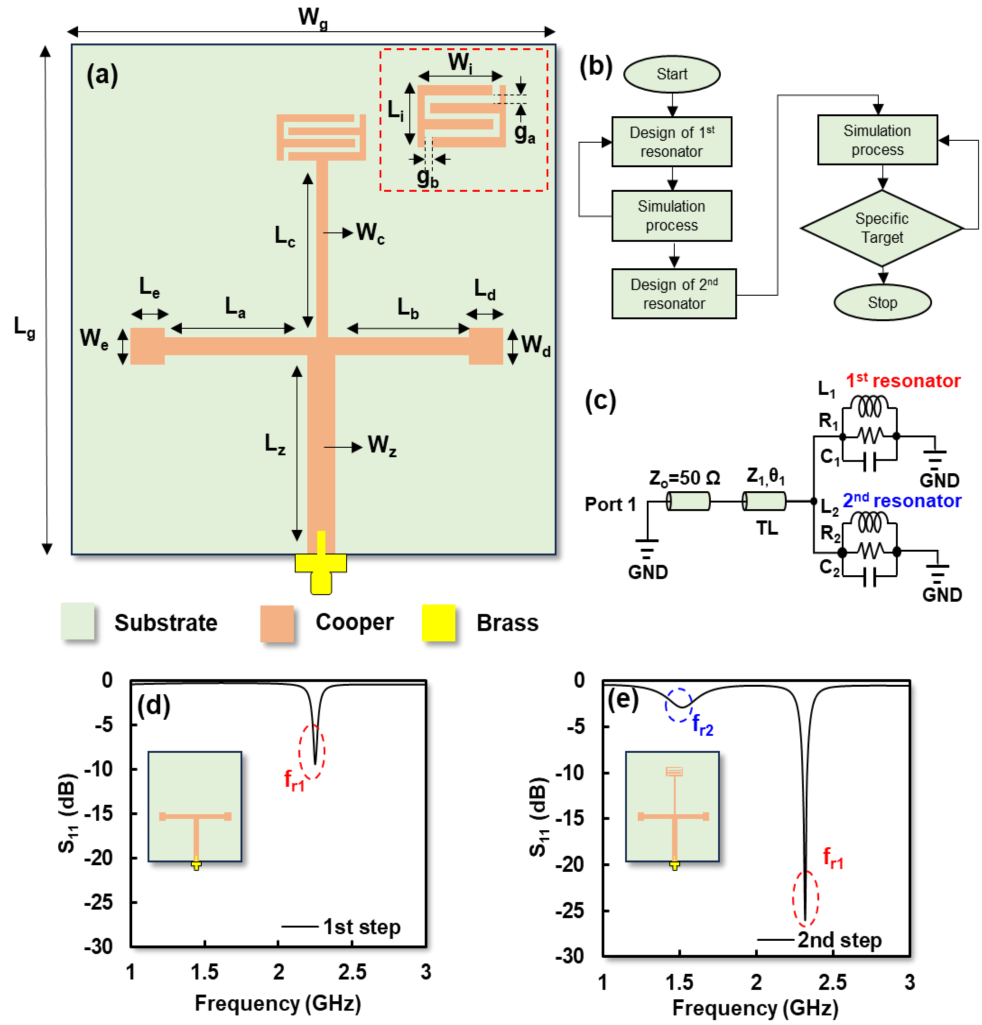

Fig. 4. (a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step, (e) 2nd step.

The configuration of T-shaped resonator and IDC can be observed in **Fig.4 (a).** Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. Moreover, the flowchart of design process dual T-shaped resonator is presented in **Fig. 4 (b)** while for equivalent circuit shown in **Fig 4 (c)**. In the initial phase, the resonator functions at f_{r1} = 2.32 GHz as shown in **Fig.4 (d)**, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz as shown in **Fig.4 (e)**, respectively.

Reference:

[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

6. ***Please suggest an equivalent circuit for the sensor. Authors can get help from the following references:***
   "10.1017/S1759078723000703"
   "10.1017/S1759078723000053"

Response:

We thank the reviewer for this very thoughtful comment. Therefore, we have added equivalent circuit model of the sensor as shown in Fig.4.

Kindly refer Section: Sensor Design, page 2, Fig. 4

The dual modalities sensor is constructed utilizing of FR-4 substrate with specific properties: a dielectric constant (ε_r) of 4.3, a loss tangent (tan δ) of 0.0265, and a thickness (h) of 1.6 mm.

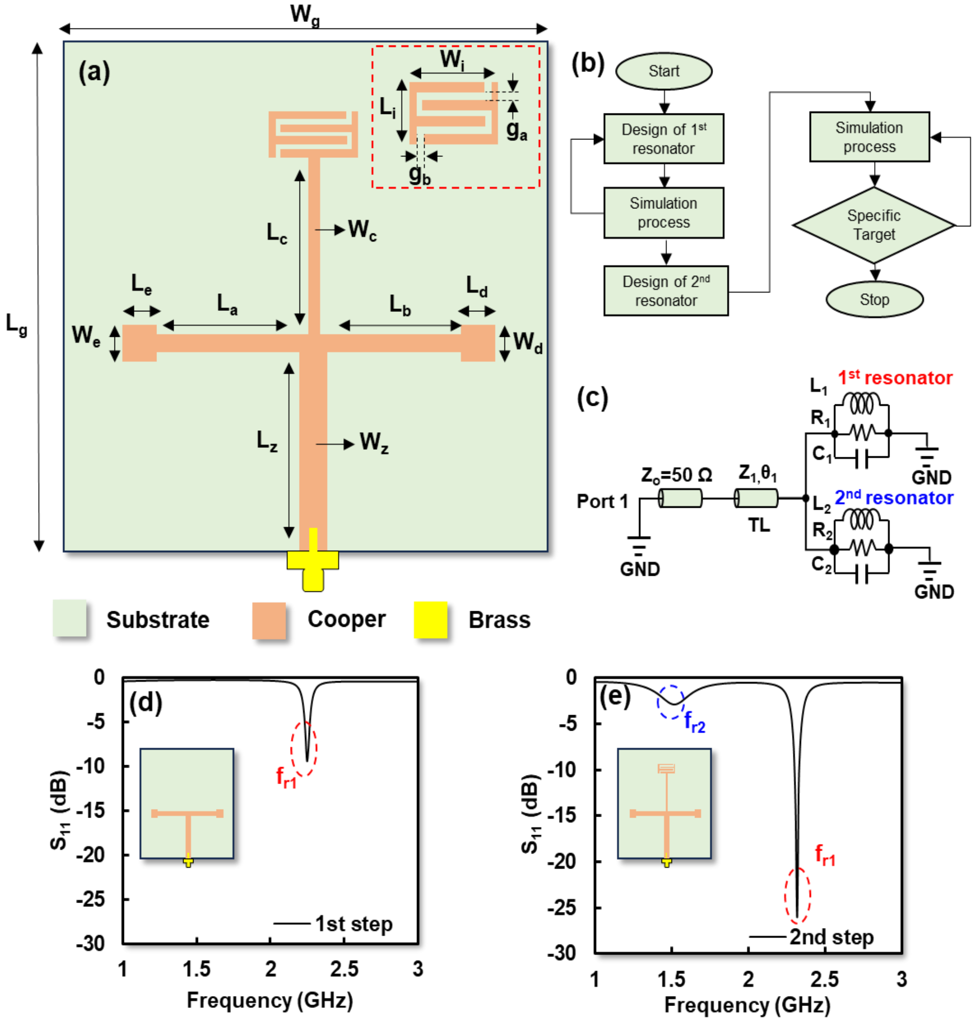

Fig. 4. (a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step, (e) 2nd step.

The configuration of T-shaped resonator and IDC can be observed in **Fig.4 (a).** Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. **Moreover, the flowchart of design process dual T-shaped resonator is presented in Fig. 4 (b) while for equivalent circuit shown in Fig 4 (c).** In the initial phase, the resonator functions at f_{r1} = 2.32 GHz as shown in **Fig.4 (d)**, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz as shown in **Fig.4 (e)**, respectively.

7. ***How much is the FDR parameter for this sensor?***
   Please check it.
   Authors can get help from the following references:
   "10.1080/03772063.2023.2231875"
   "10.1002/dac.5417"

Response:

We thank the reviewer for this very thoughtful comment. Therefore, we have added the value of FDR parameter based on equation (1) from *10.1080/03772063.2023.2231875* and *10.1002/dac.5417*.

$$FDR = \frac{\Delta F}{\Delta \varepsilon_r}\ (GHz) \tag{1}$$

Based on measurement result maximum ΔF for f_{r1} and f_{r2} are 0.08 GHz while for $\Delta\varepsilon_r$ is 5.15. Therefore, FDR of f_{r1} and f_{r2} are 0.016 GHz, respectively. We have added the value of FDR in revised manuscript.

Kindly refer Section: Measurement and Validation, page 4

The sensitivity of the microwave sensor is determined from the shift in the resonant frequency when the MUT is placed on the sensing hotspot. The frequency shift is represented as Δf which shows the difference between the loaded and unloaded frequencies of the resonator. The frequency shift (Δf), sensitivity (S) and Frequency Detection Resolution (FDR) of the microwave sensor can be determined using the following ***Eq. (1), Eq. (2) and Eq. (3)[13][14]:***

$$\Delta f = (f_{unloaded} - f_{loaded})\ GHz \tag{1}$$

$$S = \left(\frac{f_{unloaded} - f_{loaded}}{f_{unloaded}}\right)\% \tag{2}$$

$$\boldsymbol{FDR = \frac{\Delta F}{\Delta \varepsilon_r}} \tag{3}$$

where Δf represents frequency shift in GHz, S represents the sensitivity of the sensor in percentage, $f_{unloaded}$ represent the resonance frequency of the resonator before being loaded by the MUT and f_{loaded} the frequency of the resonator when it is loaded with an MUT. In this letter, the $f_{unloaded}$ used is when the resonator with permittivity of vacuum $\varepsilon_r = 1$. Based on calculations using **Eq. (1)** and **Eq. (2)** shows that the maximum Δf of the 1st resonator and 2nd resonator has the same value of 0.08 GHz /$\Delta\varepsilon_r$ while the average sensitivities are 1.43% and 2.53%, respectively. The permittivity of the MUT is extracted using a polynomial equation obtained from the shift in the resonant frequency of the resonator during the measurement process as shown in **Fig.7(b)** and **Fig.7 (d)**. Therefore, the permittivity of the MUT for contactless and contact detection can be determined using **Eq. (4)** and **Eq. (5)** as follows:

$$\varepsilon_{r1} = 22941 f_{r1}^{\ 3} - 165026\, f_{r1}^{\ 2} + 395600 f_{r1} - 316023 \tag{4}$$

$$\varepsilon_{r2} = -9895.8 f_{r2}^{\ 3} + 47589\, f_{r2}^{\ 2} - 76334 f_{r2} + 40843 \tag{5}$$

where f_{r1} is the resonant frequency of the 1st resonator and ε_{r1} is the permittivity of the MUT used for contactless detection while f_{r2} is the resonant frequency of the 2nd resonator and ε_{r2} is the permittivity of the MUT used for contact detection. The overall performance of the proposed sensors both for contactless and contact detection are shown in **Table 1**.

TABLE 1. Performance of proposed sensor

MUT	ε_r ref	Δf (GHz / $\Delta\varepsilon_r$)		Sensitivity (%)		Accuracy (%)	
		f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}
Vacuum	1.00	0	0	-	-	97.91	95.64
RO5880	2.20	0.02	0.02	0.83	1.23	92.38	92.08
RO4003	3.65	0.03	0.04	1.25	2.50	92.65	92.84
FR4	4.30	0.04	0.06	1.67	3.80	97.08	95.95
RO3006	6.15	0.08	0.08	3.40	5.13	99.93	99.29

Moreover, FDR of the proposed sensor based on Eq. (3) for f_{r1} and f_{r2} are 0.016 GHz. In order to demonstrate the novelty of this paper, a fair comparison with previous work is shown in Table 2.

Reference:

[13] R. A. Alahnomi, Z. Zakaria, E. Ruslan, S. R. Ab Rashid, and A. A. Mohd Bahar, "High-Q sensor based on symmetrical split ring resonator with spurlines for solids material detection," IEEE Sens. J., vol. 17, no. 9, pp.

2766–2775, 2017, doi: 10.1109/JSEN.2017.2682266.

[14] S. Kiani, P. Rezaei, and M. Fakhr, “Real-Time Measurement of Liquid Permittivity Through Label-Free Meandered Microwave Sensor,” IETE J. Res., 2023, doi: 10.1080/03772063.2023.2231875

#REVIEWER 2

Comments to the Author:
The paper presents a solution for permittivity analysis of material using an MS structure. I suggest that the following comments better to be addressed:

1. ***Please take a look at the writing as there were a few typos.***

Response:

We thank the reviewer for this very thoughtful comment. We have revised writing and sentences in the revised manuscript.

2. ***Although the general idea sounds interesting as presented in the title, it is not clear to me how this far-field analysis helps near-field analysis in determining the dielectric permittivity of the material under the test. Please clarify.***

Response:

We thank the reviewer for this very thoughtful comment. In this letter, we propose collaboration of near field and far field region for contact and contactless permittivity detection using microwave sensors that have independent characteristics. It should be noted, contact detection uses the near field region, while contactless detection uses the far field region. The location of the sensing hotspot is determined based on the concentration of the E-field and H-field of the proposed resonator. The surface of the resonator with high E-field can be used to detect the permittivity of MUT. Moreover, the resonators having S_{11} ≤ -10 dB and high radiation are proposed for contactless detection while resonators with S_{11} ≥ -10 dB and low radiation are proposed for contact detection [7][8]. Both have independent characteristics and do not affect each other to detect the permittivity of the MUT so they can work separately for contact and contactless detection purposes. Therefore, we have clarified this suggestion in the revised manuscript.

Kindly refer Section: Introduction, page 1

To fulfill this requirement, this letter introduces a collaboration between near-field and far-field regions for microwave permittivity sensors operating at two resonant frequencies. ***In detail, the main contribution of this research such as proposed long distance detection MS with two independent sensing hotspots enabling contact and contactless characterization of solid materials.*** *To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for contactless detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection.* ***Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11].***

Reference:
[7] *S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.*
[8] *S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.*

[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

3. If I understood correctly, there will be two measurements associated with each characterization. How could you make sure that the location of MUT is constant during all the experiments?

Response:

We thank the reviewer for this very thoughtful comment. We agree with the reviewer's comments. Therefore, to ensure the location of the MUT is constant we carefully place the MUT at the location of the sensing hotspot which is for contact detection on the surface of the IDC while for contactless detection on the surface of the T-shaped resonator. Next, to ensure that the MUT touches directly on the sensor surface, we use plastic clamps as shown in Fig.1 (a) and Fig 1 (b). Therefore, we have explain this suggestion in the revised manuscript.

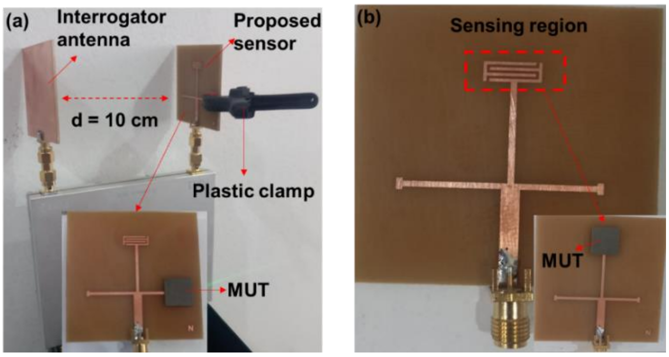

Fig 1. Placement of MUT; (a) for contactless detection, (b) for contact detection

Kindly refer Section: Measurement and Validation, page 3, Fig.6

The experimental validation was conducted utilizing a Vector Network Analyzer (VNA) spanning a frequency range of 1 - 3 GHz, with a frequency sweep increment of 0.01 GHz. The ambient temperature during the measurements was maintained at 25°C. Additionally, four distinct materials with known permittivity were employed as Material Under Test (MUT): RO5880 possessing a permittivity of 2.20, RO4003 of 3.65, FR-4 of 4.30, and RO3006 of 6.15 with the dimension of MUT is 10 x 10 x 1.6 mm^3. ***Moreover, to ensure the location of the MUT is constant we carefully place the MUT at the location of the sensing hotspot using plastic clamp which is for contact detection on the surface of the IDC and for contactless detection on the surface of the T-shaped resonator as shown in Fig 6 (a) and Fig 6(b).***

Furthermore, **Fig.7 (a)** shows that f_{r1} shifts to low frequency in line with the increased permittivity of the MUT placed at the sensing hotspot of the 1st resonator for contactless detection with d = 10 cm while f_{r2} is fixed. The resonant frequency of the 1st resonator shifted from 2.43 GHz to 2.35 GHz with a permittivity range of 1 - 6.15 as shown in **Fig.7 (c)**.

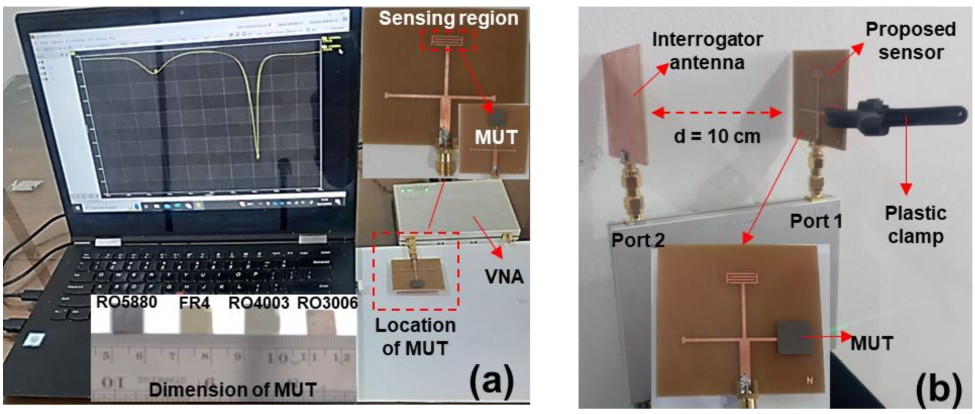

Fig. 6. Measurement setup; (a) contactless detection using scenario (1), (b) contact detection using scenario (2).

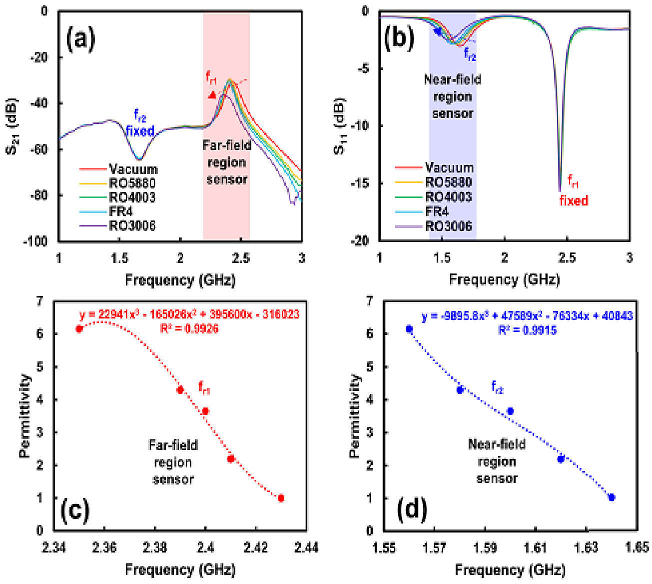

Fig. 7. Permittivity detection using proposed sensor, (a) contactless detection with d = 10 cm, (b) contact detection, (c) polynomial equation for contactless detection, (d) polynomial equation for contact detection.

In the other hand, **Fig. 7 (b)** shows the performance of the proposed sensor for contact detection. It is evident that f_{r2} experiences a downward shift in resonant frequency, corresponding to the increased permittivity of the MUT positioned on the sensing hotspot of the 2nd resonator, whereas f_{r1} remains constant. Moreover, **Fig. 7 (d**) shows that f_{r1} shifted to the lower frequency from 1.64 GHz to 1.56 GHz in line with the increased permittivity of the MUT placed on the 1st resonator while f_{r2} was fixed for permittivity range of 1 – 6.15.

4. ***In Fig 7, it is observed that the permittivity of the materials is dropping from ~6 to ~1 in a quite small frequency span. Would you please mention the materials with such permittivity changes? Please make sure that you clarify this point.***

Response:

We thank the reviewer for this very thoughtful comment. Based on perturbation theory, the addition of MUT will perturbate the E-field of the resonator. This causes the resonant frequency of the resonator to shift in line with increasing permittivity [13][14]. In this letter, four distinct materials with known permittivity were employed as Material Under Test (MUT): RO5880 possessing a permittivity of 2.20, RO4003 with a permittivity of 3.65, FR-4 exhibiting a permittivity of 4.30, and RO3006 with permittivity of 6.15 with dimension of MUT is 10 x 10 x 1.6 mm^3 and vacuum of 1. Therefore, the range of permittivity is 1 – 6.15 and we used the range in Y axis in the Fig.7 (c) and Fig 7(d).

Kindly refer Section: Measurement and Validation, page 3

The experimental validation was conducted utilizing a Vector Network Analyzer (VNA) spanning a frequency range of 1 - 3 GHz, with a frequency sweep increment of 0.01 GHz, depicted in **Fig 6 (a)** and **Fig.6 (b)**. The ambient temperature during the measurements was maintained at 25°C. **Additionally, four distinct materials with known permittivity were employed as Material Under Test (MUT): RO5880 possessing a permittivity of 2.20, RO4003 with a permittivity of 3.65, FR-4 exhibiting a permittivity of 4.30, and RO3006 with permittivity of 6.15. The measurement setup for both contact and contactless by utilizing the near-field and far-field region using proposed sensors refer to scenario (1) and scenario (2) are illustrated in Fig. 6(a) and Fig.6 (b) while the dimension of MUT is 10 x 10 x 1.6 mm^3.**

Furthermore, **Fig.7 (a)** shows that f_{r1} shifts to low frequency in line with the increased permittivity of the MUT placed at the sensing hotspot of the 1st resonator for contactless detection with d = 10 mm while f_{r2} is fixed. The resonant frequency of the 1st resonator shifted from 2.43 GHz to 2.35 GHz with a permittivity range of 1 - 6.15 as shown in **Fig.7 (c)**.

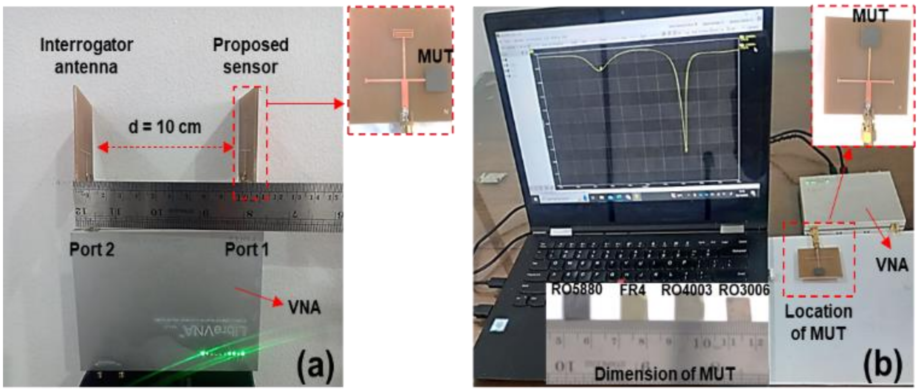

Fig. 6. Measurement setup; (a) contactless detection using scenario (1), (b) contact detection using scenario (2).

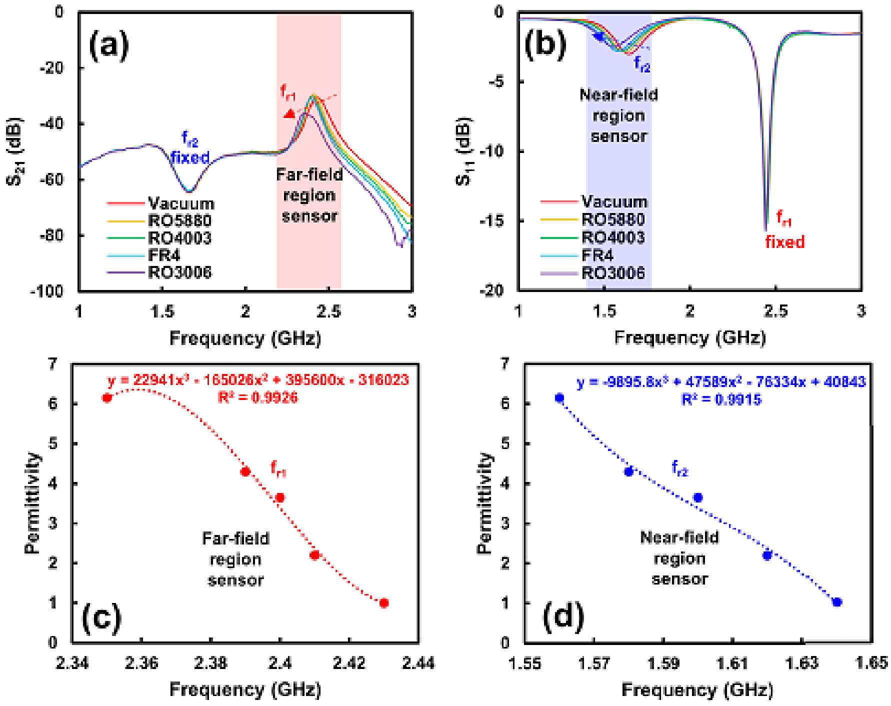

Fig. 7. Permittivity detection using proposed sensor, (a) contactless detection with d = 10 cm, (b) contact detection, (c) polynomial equation for contactless detection, (d) polynomial equation for contact detection.

In the other hand, **Fig. 7 (b)** shows the performance of the proposed sensor for contact detection. It is evident that f_{r2} experiences a downward shift in resonant frequency, corresponding to the increased permittivity of the MUT positioned on the sensing hotspot of the 2nd resonator, whereas f_{r1} remains constant. Moreover, **Fig. 7 (d)** shows that f_{r1} shifted to the lower frequency from 1.64 GHz to 1.56 GHz in line with the increased permittivity of the MUT placed on the 1st resonator while f_{r2} was fixed for permittivity range of 1 – 6.15.

Reference:

[13] R. A. Alahnomi, Z. Zakaria, E. Ruslan, S. R. Ab Rashid, and A. A. Mohd Bahar, "High-Q sensor based on symmetrical split ring resonator with spurlines for solids material detection," IEEE Sens. J., vol. 17, no. 9, pp. 2766–2775, 2017, doi: 10.1109/JSEN.2017.2682266.

[14] S. Kiani, P. Rezaei, and M. Fakhr, "Real-Time Measurement of Liquid Permittivity Through Label-Free Meandered Microwave Sensor," IETE J. Res., 2023, doi: 10.1080/03772063.2023.2231875

IEEE Sensors Letters

Decision Letter (SENSL-23-12-RL-1121)

From: d.uttamchandani@strath.ac.uk

To: syah.alam@trisakti.ac.id

CC: ccchang@ieee.org, d.uttamchandani@strath.ac.uk

Subject: IEEE Sensors Letters: SENSL-23-12-RL-1121

Body: 25-Feb-2024

Dear Dr. Alam:

"Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" (Manuscript ID SENSL-23-12-RL-1121), which you submitted to IEEE Sensors Letters, has been reviewed. The comments from the reviewers appear below and in separate files which may be read by going into the "Manuscripts with Decisions" queue in your Author Center and clicking the "view decision letter" link for this paper.

Unfortunately, we must decline the manuscript for publication at this time. However, because we believe the work has merit, we invite you to consider submitting a revised manuscript that takes the reviewers' comments into consideration. It would be given a new Manuscript ID and reviewed again.

After you have revised your manuscript, please submit it by going to the "Manuscripts with Decisions" queue of your Author Center on our Manuscript Central Web site, https://mc.manuscriptcentral.com/sensors-letters. Then click "create a resubmission."

In Step 1, you will be asked to respond to this decision letter. Here you may include confidential information to the editor, not intended for the reviewers.

In Step 5 of the re-submission process, please indicate that the manuscript has been submitted previously, and enter the original article number, SENSL-23-12-RL-1121.

In Step 6 you should delete any obsolete, original submission files (e.g., MAIN DOCUMENT) and upload your new MAIN DOCUMENT. You should also upload a SUPPLEMENTARY FILE in which you have responded to the reviewers' remarks. Please state how you satisfied (or why you declined to satisfy) each suggestion from the reviewers. Then click Save and Continue, and complete the other steps for re-submission.

Once we receive your revised version, it may be sent again to reviewers (who will see your responses in your SUPPLEMENTARY FILE). They may recommend further changes before a final decision on publication is reached.

Thank you for sending your manuscript to us for consideration. We look forward to further contributions from you in the future.

Sincerely,

Prof. Deepak Uttamchandani
AEIC, IEEE Sensors Letters

Manuscript Title: Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
ID: SENSL-23-12-RL-1121

Reviewers' comments to author, if any (please also check your Author Center for other files):
Reviewer: 1

Comments to the Author
The manuscript has been improved. I think it could be accepted.

Reviewer: 3

Comments to the Author
1. The equivalent circuit for the T-shaped resonator shown in Fig. 4 is obviously not right. Both resonances are modeled by the parallel resonators which behave as short circuit at DC. However, according to the resonator layout, the structure obviously does not show short circuit phenomenon. The equivalent circuit violates the physical nature.
2. “Copper” is incorrectly spelt in Fig. 4.

3. In Fig. 1 and Fig. 6, it is described: Scenario (1) is adopted for contactless detection using an interrogator antenna and Scenario (2) is adopted for contact detection. Now that only one antenna is used in Scenario (1), how is the 2-port S21 obtained through VNA?
4. In both scenarios, the MUT needs to be attached to the surface of the resonator. Why do the authors consider scenario (1) to be contactless while scenario (2) is contact? According to the measurement procedure, both scenarios should be considered as contact type.
5. A couple of materials (actually 5) with “known dielectric constant” are utilized in the detection and the corresponding f_loaded is obtained to get the fitting polynomial equation. However, since the paper aims at proposing permittivity sensor. It is essential to adopt a material with unknown dielectric constant not included in the 5 materials to detect its dielectric constant. For example, since the fitting curve shown in Fig. 7(a) is not so linear, it is wondering how much the detection accuracy a material with dielectric constant around 5 will be.

Date Sent: n/a

Close Window

Professor Andrei Shkel
Editor in Chief – *IEEE Sensors Letters.*
Prof. Deepak Uttamchandani
Associate Editor In Chief - IEEE Sensors Letters

February 29, 2024

Dear Professor,

I hope this email finds you well and healthy. First of all, thank you for evaluating our manuscript and we apologize for disturbing your valuable time.

For your information, this paper has been submitted to IEEE Sensor Letter with:

Title	:	Collaboratively Near-Field and Far-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
Paper ID	:	SENSL-23-12-RL-1121
Author	:	Syah Alam, Zahriladha Zakaria, Indra Surjati, Noor Azwan Shairi, Mudrik Alaydrus, Teguh Firmansyah, Yuli Kurnia Ningsih, Lydia Sari
Date of submitted	:	December 25, 2023
Date of decision	:	February 25, 2024 (Reject & Resubmit)

After reading the fruitful comment and construction discussions from editor and reviewer, we believe that we should make the letter to make clearer explanations and improve our manuscripts based on reviewer and editor comment. Here, we give responses from reviewer comments and revised manuscript. All revisions in the revised manuscript are marked in red.

Again, we apologize for disturbing your valuable time. Please don't hesitate to contact us if there are any questions.

Please find the response letter below for the revision information.

Yours sincerely,

Syah Alam
Department of Electrical Engineering, Universitas Trisakti, DKI Jakarta, 11440
*Corresponding author e-mail: syah.alam@trisakti.ac.id

Reviewer# 1

Comments to the Author

The manuscript has been improved. I think it could be accepted.

Response:

We thank the reviewers for their constructive comments.

Reviewer# 3

Comments to the Author

1. ***The equivalent circuit for the T-shaped resonator shown in Fig. 4 is obviously not right. Both resonances are modelled by the parallel resonators which behave as short circuit at DC. However, according to the resonator layout, the structure obviously does not show short circuit phenomenon. The equivalent circuit violates the physical nature.***

Response:

We thank the reviewers for their constructive comments. Therefore, we have revised the equivalent circuit of the resonator according to the reviewer's comments. Furthermore, to prevent short circuit between parallel resonators, C_g is proposed in the equivalent circuit shown in Fig.1 (c).

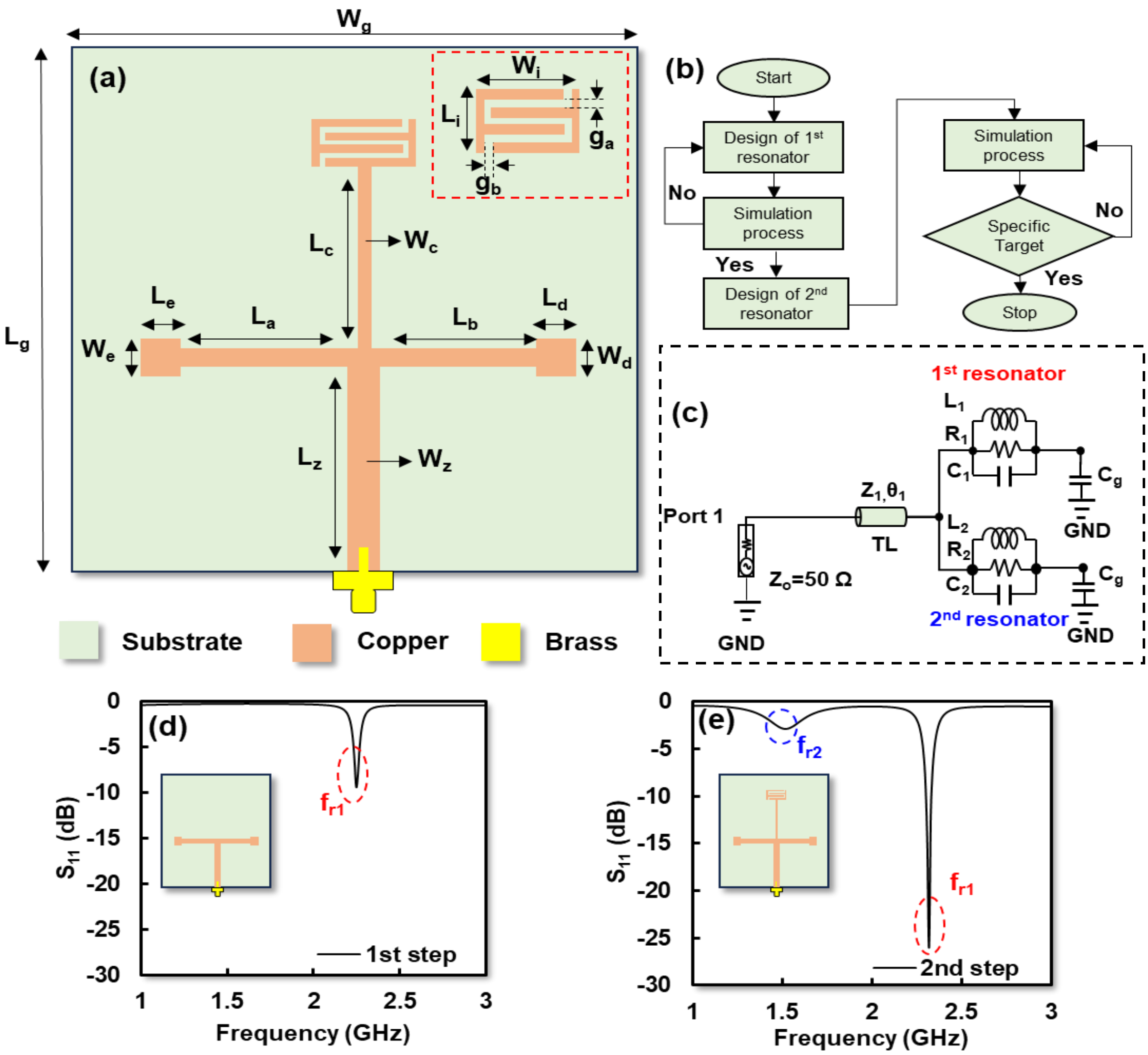

Fig. 1. (a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step model, (e) 2nd step model.

Kindly refer Section: II. Sensor Design, Sub-section B.Structure of proposed sensor, Fig. 4, page 2

The dual modalities sensor is constructed utilizing of FR-4 substrate with specific properties: a dielectric constant (ε_r) of 4.3, a loss tangent (tan δ) of 0.0265, and a thickness (h) of 1.6 mm.

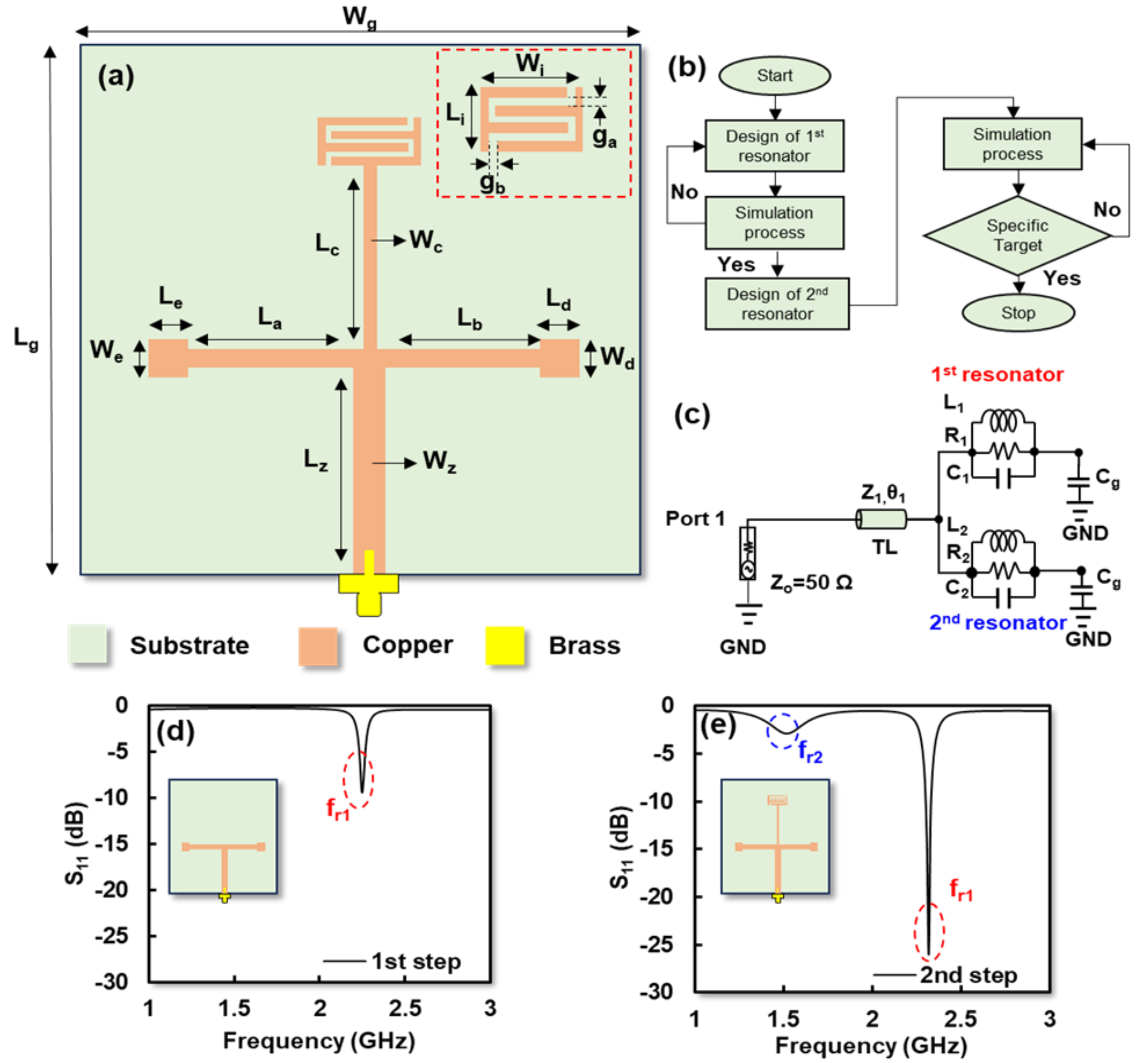

Fig. 4. *(a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step model, (e) 2nd step model.*

*The configuration of T-shaped resonator and IDC can be observed in **Fig.4 (a).** Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. Moreover, the flowchart of design process dual T-shaped resonator is presented in **Fig. 4 (b)** while for equivalent circuit shown in **Fig 4 (c)**. In the initial phase, the resonator functions at f_{r1} = 2.32 GHz as shown in **Fig.4 (d)**, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz as shown in **Fig.4 (e)**, respectively.*

2. “Copper” is incorrectly spelt in Fig. 4.

Response:

We thank the reviewers for their constructive comments. Therefore, we have revised the spelt cooper with copper in Fig.4.

Kindly refer Section: II. Sensor Design, Sub-section B.Structure of proposed sensor, Fig. 4, page 2

The dual modalities sensor is constructed utilizing of FR-4 substrate with specific properties: a dielectric constant (ε_r) of 4.3, a loss tangent (tan δ) of 0.0265, and a thickness (h) of 1.6 mm.

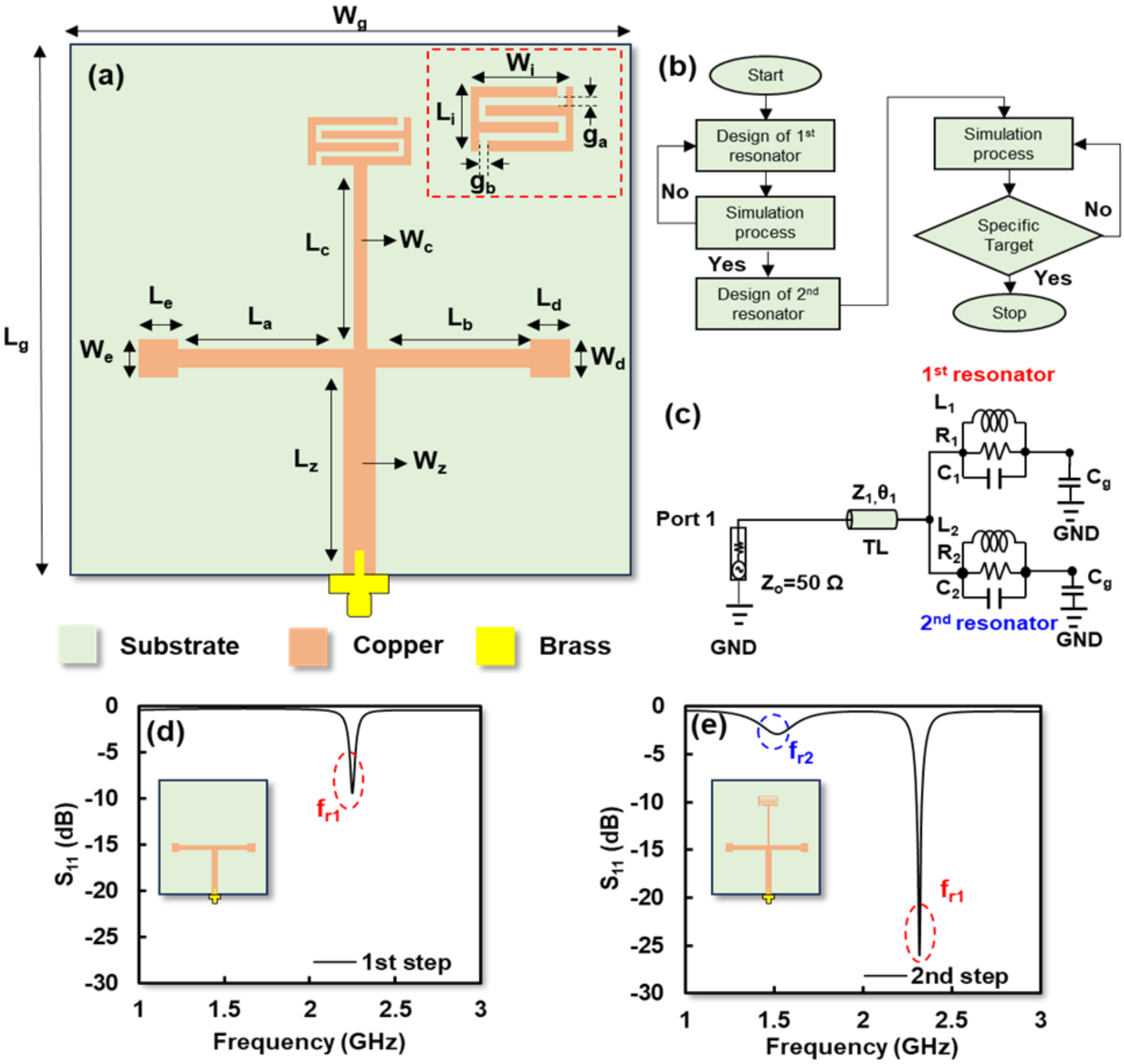

Fig. 4. *(a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step model, (e) 2nd step model.*

*The configuration of T-shaped resonator and IDC can be observed in **Fig.4 (a).** Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. Moreover, the flowchart of design process dual T-*

*shaped resonator is presented in **Fig. 4 (b)** while for equivalent circuit shown in **Fig 4 (c)**. In the initial phase, the resonator functions at f_{r1} = 2.32 GHz as shown in **Fig.4 (d)**, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz as shown in **Fig.4 (e)**, respectively.*

3. ***In Fig. 1 and Fig. 6, it is described: Scenario (1) is adopted for long-distance detection using an interrogator antenna and Scenario (2) is adopted for contact detection. Now that only one antenna is used in Scenario (1), how is the 2-port S21 obtained through VNA?***

Response:

We thank the reviewers for their constructive comments. We have mistakenly placed the wrong figure for scenario (1) and scenario (2) in Fig.1 and Fig. 6. We agree with the reviewer's comments, we have revised Fig.1 and Fig. 6 according to scenarios (1) for long-distance detection using interrogator antenna and scenario (2) for contact detection with IDC. In this case, scenario (1) has two ports for S21 measurement using interrogator antenna.

Kindly refer Section: II. Sensor Design and III. Measurement and Validation, (Sub-section II.B. Structure of proposed sensor, Fig. 1, page 2), (Sub-section III.B. Experimental Validation, Fig. 6, page 3)

1) *Furthermore, scenario (1) proposes long-distance detection using interrogator antennas operating at the same resonance frequency as the 1st resonator at f_{r1}= 2.32 GHz with S_{11} ≤ -10 dB and separated by distance (d) of 10 cm. Long-distance permittivity detection is carried out by observing changes in the resonant frequency based on S_{21} as shown in **Fig. 1(a)**.*
2) *For scenario (2), near-field region for contact detection is proposed by placing the MUT on the IDC of the 2nd resonator operating at f_{r2}= 1.52 GHz with S_{11} ≥ -10 dB by observing changes in the resonant frequency based on S_{11} as shown in **Fig. 1(b).***

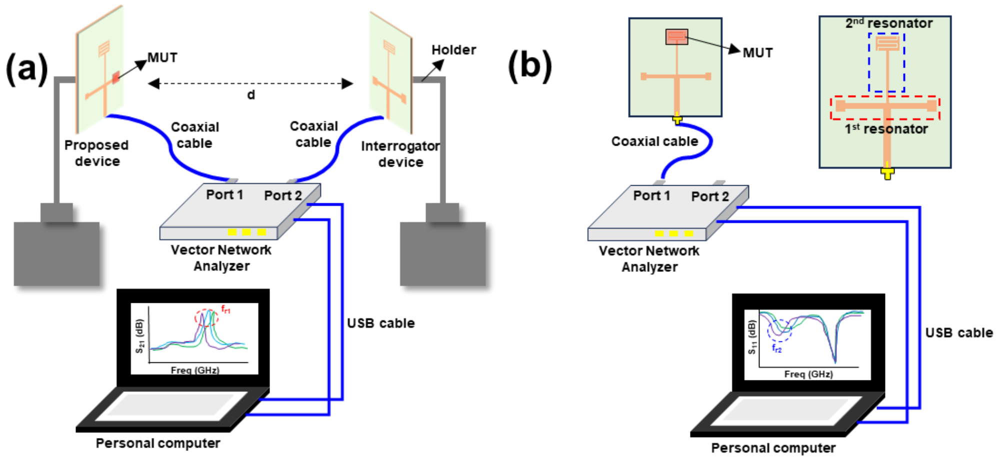

***Fig. 1.** Scenario of permittivity detection using proposed sensor; (a) scenario (1) for long-distance detection using an interrogator antenna, (b) scenario (2) for contact detection*

The experimental validation was conducted utilizing a Vector Network Analyzer (VNA) spanning a frequency range of 1 - 3 GHz, with a frequency sweep increment of 0.01 GHz. The ambient temperature during the measurements was maintained at 25°C. Additionally, four distinct materials with known *permittivity were employed as Material Under Test (MUT): RO5880 possessing a permittivity of 2.20, RO4003 of 3.65, FR-4 of 4.30, and RO3006 of 6.15 with the dimension of MUT is 10 x 10 x 1.6 mm^3. Moreover, to ensure the location of the MUT is constant we carefully place the MUT at the location of the sensing hotspot using plastic clamp which is for contact detection on the surface of the IDC and for long-distance detection on the surface of the T-shaped resonator as shown in **Fig 6 (b)** and **Fig 6(a)**. Furthermore, **Fig.7 (a)** shows that f_{r1} shifts to low frequency in line with the increased permittivity of the MUT placed at the sensing hotspot of the 1st resonator for long-distance detection with d = 10 cm while f_{r2} is fixed. The resonant frequency of the 1st resonator shifted from 2.43 GHz to 2.35 GHz with a permittivity range of 1 - 6.15 as shown in **Fig.7 (c)**.*

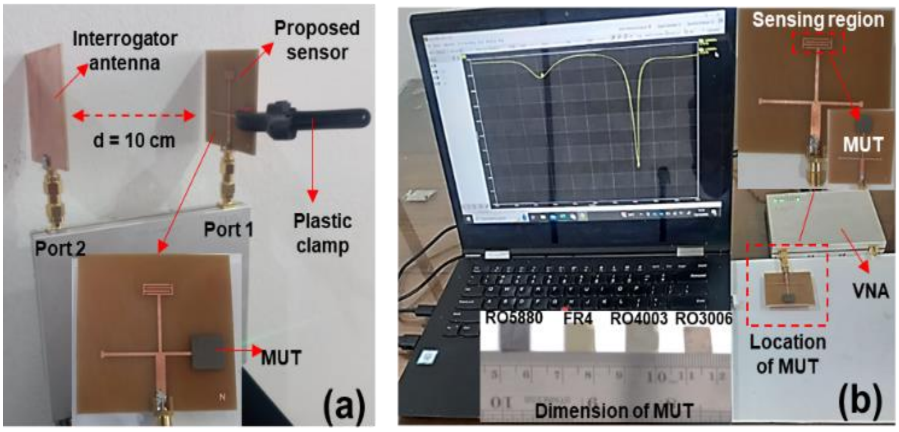

***Fig. 6.** Measurement setup; (a) long-distance detection using scenario (1), (b) contact detection using scenario (2).*

4. ***In both scenarios, the MUT needs to be attached to the surface of the resonator. Why do the authors consider scenario (1) to be long-distance while scenario (2) is contact? According to the measurement procedure, both scenarios should be considered as contact type.***

Response:

1. We thank the reviewers for their constructive comments. We consider scenario (1) to be long-distance detection because using interrogator antennas operating at the same resonance frequency as the 1st resonator at f_{r1}= 2.32 GHz with $S_{11} \leq$ -10 dB and separated by distance (d) of 10 cm. Long-distance permittivity detection is carried out by observing changes in the resonant frequency based on S_{21}. We consider as long distance because we are applying far-field based on the radiation pattern of the two resonators for distance of *(d)* refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11].
2. We thank the reviewers for their constructive comments. We agree with the reviewer's comments that the MUT is in direct contact with the sensing area of the sensor for scenario (1) and scenario (2). In this paper, we used the term contactless detection to refer to the far-field radiation pattern of the two resonators as shown in Fig.1 (a) and Fig 1. (b) where the location of microwave sensor in the left side and the interrogator antenna in the right side. Therefore, to avoid any confusion and to make it clear about term of contact and contactless detection, we have changed the term contactless detection to long-distance detection refer to the scenario (1).

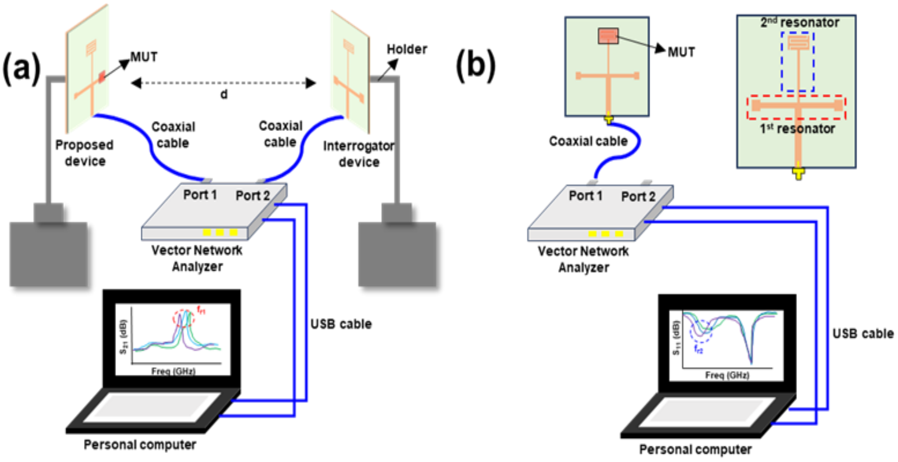

Fig. 1. Scenario of permittivity detection using proposed sensor; (a) scenario (1) for long-distance detection using an interrogator antenna, (b) scenario (2) for contact detection

Kindly refer Section: Introduction, page 1

Microwave sensors (MS) have gained widespread development for assessing both solids and liquids due to their benefits, including high precision, a high Q-Factor, affordability, and compact size[1]. One of the properties they can detect is permittivity, which refers to a material's capacity to retain an electric field. Moreover, permittivity of the MUT can be ascertained through perturbation theory, assuming the MUT acts as a capacitive load [2]. Previous studies have put forth various microwave sensors employing resonators such as Split Ring Resonator (SRR)[3], Complementary Split Ring Resonator (CSRR) [4], Substrate Integrated Waveguide (SIW) [5], and Interdigital Capacitor (IDC) [6] for assessing solid substances. In contrast, previous work proposed by [7] introduces a dual T-shaped resonator featuring a single port for characterizing solid materials with contact and non-contact. However, this work has disadvantages such as a very limited distance of 0.5 - 1.5 mm for non-contact detection, poor sensitivity and the locations of the E-field and H-field are ambiguous. Another work, presented by [8], suggests a multifunctional dual-band MS with an antenna for communication purposes. However, the MUT's characterization is only performed directly by placing it on the sensing hotspot. Additionally, [9] and [10] employs an antenna as a permittivity sensor for contactless detection at a distance of 20 mm and 30 mm using Artificial Magnetic Conductor (AMC) . However, the proposed sensor features only one sensing hotspot and therefore cannot facilitate contact and long-distance characterization independently. Therefore, several requirements are needed to obtain high performance MS with long-distance detection, high sensitivity, clear location between E-field and H-field and dual hotspot location for contact and long-distance.

To fulfill this requirement, this letter introduces a collaboration between near-field and far-field regions for microwave permittivity sensors operating at two resonant frequencies. In detail, the main contribution of this research such as proposed long-distance detection MS with two independent sensing hotspots enabling contact and long-distance characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for long-distance detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection. Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11].

Reference
[1] K. S. L. Parvathi and S. R. Gupta, “Ultrahigh-Sensitivity and Compact EBG-Based Microwave Sensor for Liquid

Characterization," IEEE Sensors Lett., vol. 6, no. 4, pp. 19–22, 2022, doi: 10.1109/LSENS.2022.3159800.
[2] A. Aquino, C. G. Juan, B. Potelon, and C. Quendo, "Dielectric Permittivity Sensor Based on Planar Open-Loop Resonator," IEEE Sensors Lett., vol. 5, no. 3, pp. 2021–2024, 2021, doi: 10.1109/LSENS.2021.3055544.
[3] S. Kiani, P. Rezaei, and M. Navaei, "Dual-sensing and dual-frequency microwave SRR sensor for liquid samples permittivity detection," Meas. J. Int. Meas. Confed., vol. 160, p. 107805, 2020, doi: 10.1016/j.measurement.2020.107805.
[4] H. Xiao, S. Yan, C. Guo, and J. Chen, "Microwave / millimeter wave sensors A Dual-Scale CSRRs-Based Sensor for Dielectric Characterization," vol. 6, no. 12, pp. 10–13, 2022.
[5] W. Liu, J. Zhang, and K. Huang, "Wideband microwave interferometry sensor with improved sensitivity for measuring minute variations in dielectric properties of chemical liquids in microfluidic channels," Meas. J. Int. Meas. Confed., vol. 189, no. September 2021, p. 110474, 2022, doi: 10.1016/j.measurement.2021.110474.
[6] S. Kiani, P. Rezaei, M. Navaei, and M. S. Abrishamian, "Microwave Sensor for Detection of Solid Material Permittivity in Single/Multilayer Samples With High Quality Factor," IEEE Sens. J., vol. 18, no. 24, pp. 9971–9977, 2018, doi: 10.1109/JSEN.2018.2873544.
[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.
[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.
[9] Q. Shi, X. W. Xuan, H. K. Nie, Z. Y. Wang, and W. Wang, "Antenna Sensor Based on AMC Array for Long-distance Detection of Water and Ethanol in Oil," IEEE Sens. J., vol. 21, no. 19, pp. 21503–21510, 2021, doi: 10.1109/JSEN.2021.3102294.
[10] W. J. Wu and G. Wang, "A modified AMC-based antenna sensor for long-distance measurement of complex permittivity," Meas. J. Int. Meas. Confed., vol. 206, no. June 2022, p. 112261, 2023, doi: 10.1016/j.measurement.2022.112261.
[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

5. ***A couple of materials (actually 5) with "known dielectric constant" are utilized in the detection and the corresponding f_loaded is obtained to get the fitting polynomial equation. However, since the paper aims at proposing permittivity sensor. It is essential to adopt a material with unknown dielectric constant not included in the 5 materials to detect its dielectric constant. For example, since the fitting curve shown in Fig. 7(a) is not so linear, it is wondering how much the detection accuracy a material with dielectric constant around 5 will be.***

Response:

We thank the reviewers for their constructive comments. We agree with the reviewer comment. Therefore, we have added 3 types of MUTs with unknown permittivity that are characterized using the proposed sensors as shown in Fig. 1 (a) and Fig.1 (b).

Based on Fig.1(a), the resonant frequencies of the resonator using contact detection for the three types of MUT with unknown permittivity are 1.60 GHz, 1.58 GHz and 1.56 GHz, respectively. Furthermore, for long range detection as shown in Fig.1 (b), the resonant frequencies of the resonator are 2.40 GHz, 2.38 GHz and 2.36 GHz, respectively. The permittivity of the three types of material with unknown permittivity is extracted using a polynomial curve fitting obtained from detection using MUT with known permittivity as shown in Eq.1 and Eq.2 .

$$\varepsilon_{r1} = 22941{f_{r1}}^3 - 165026\,{f_{r1}}^2 + 395600 f_{r1} - 316023 \quad (1)$$

$$\varepsilon_{r2} = -9895.8{f_{r2}}^3 + 47589\,{f_{r2}}^2 - 76334 f_{r2} + 40843 \quad (2)$$

where f_{r1} is the resonant frequency of the 1st resonator and ε_{r1} is the permittivity of the MUT used for long-distance detection while f_{r2} is the resonant frequency of the 2nd resonator and ε_{r2} is the permittivity of the MUT used for contact detection. Based on Eq. (1) and Eq. (2), the permittivity of the three materials for contact and long-distance detection can be determined as shown in Table 1.

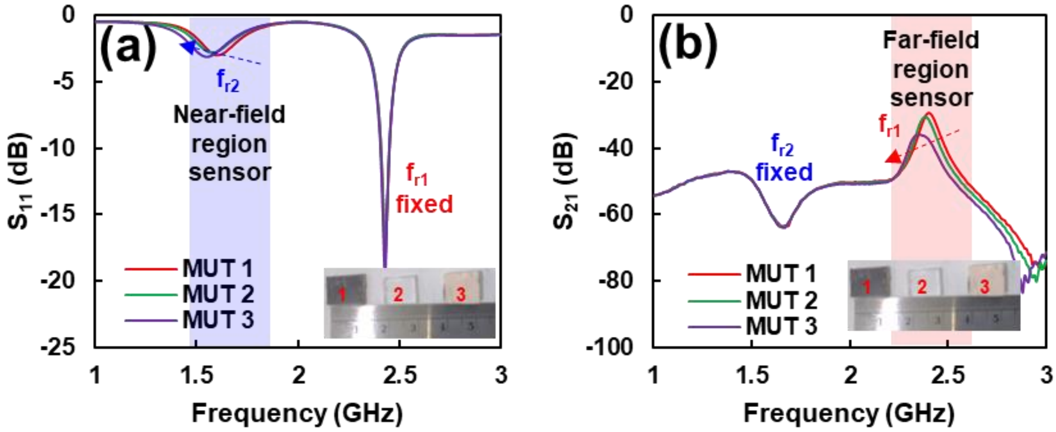

Fig 1. (a) Contact detection for unknown MUT, (b) long-range detection for unknown MUT

Table 1. Permittivity for unknown MUT based on contact detection.

Unknown MUT	Frequency (GHz)		*ε_{r1} calculated. (long-distance detection)*	*ε_{r2} calculated. (contact detection)*
	f_{r1}	*f_{r2}*		
MUT 1	1.60	2.40	3.38	3.39
MUT 2	1.58	2.38	4.36	4.47
MUT 3	1.56	2.36	6.15	6.11

Based on table 1, the permittivity of the unknown MUT shows consistent results for long range and contact detection using the proposed sensor. These findings indicate that the proposed sensor has good accuracy for long range and contact detection in the range permittivity of 1 - 6. We also compared calculated permittivity from the proposed sensor with probe sensor N1501A Dielectric Probe Kit as shown in Table 2.

Table 2. Comparison permittivity based on calculation and measurement.

Unknown MUT	ε_{r1} calculated (long-distance detection)	ε_{r2} calculated (contact detection)	ε_r measured using probe sensor	*Accuracy (%)*	
				ε_{r1}	*ε_{r2}*
MUT 1	3.38	3.39	3.32	94.00%	98.19%
MUT 2	4.36	4.47	4.46	90.00%	97.76%
MUT 3	6.15	6.11	6.09	94.00%	99.01%

Table 2 shows that the proposed permittivity sensor has a good accuracy for long-range and contact detection compared with the measurement using probe sensor with accuracy ≥ 90% for three different MUT with unknown permittivity in the range of 3 – 6 .

Unfortunately, we did not include this data in the revised paper due to the limited number of pages for letters, which is a maximum of 4 pages. Therefore, we include this information in supplementary files of proposed paper.

Kindly refer Section: Supplementary files, Fig. 8 (a), Fig. 8 (b), Table 1 and Table 2, page 8

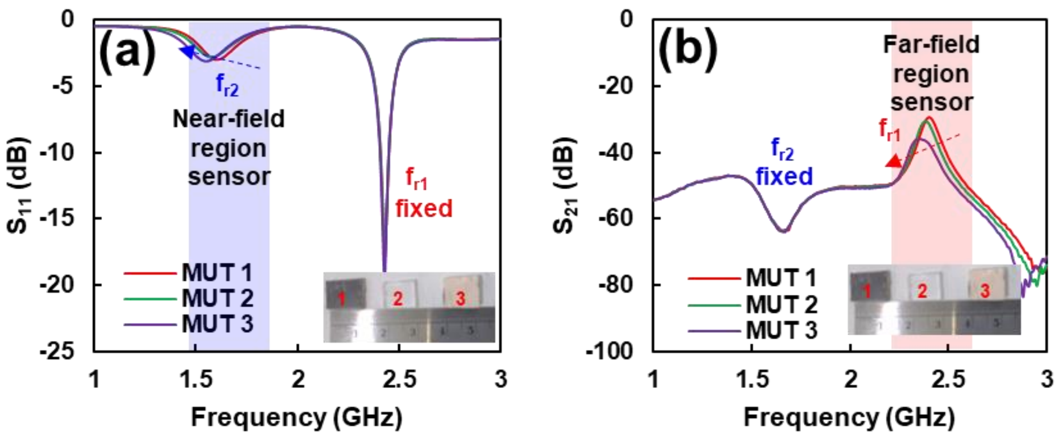

Fig 8. (a) Contact detection for unknown MUT, (b) long-range detection for unknown MUT

Table 1. Permittivity for unknown MUT based on contact detection.

Unknown MUT	Frequency (GHz)		ε_{r1} *calculated (long-distance detection)*	ε_{r2} *calculated (contact detection)*
	f_{r1}	f_{r2}		
MUT 1	1.60	2.40	3.38	3.39
MUT 2	1.58	2.38	5.36	4.47
MUT 3	1.56	2.36	6.15	6.11

Table 2. Comparison permittivity based on calculation and measurement.

Unknown MUT	ε_{r1} calculated (long-distance detection)	ε_{r2} calculated (contact detection)	ε_{r} measured using probe sensor	*Accuracy (%)*	
				ε_{r1}	ε_{r2}
MUT 1	3.38	3.39	3.32	94.00%	98.19%
MUT 2	4.36	4.47	4.46	90.00%	97.76%
MUT 3	6.15	6.11	6.09	94.00%	99.01%

IEEE Sensors Letters

Decision Letter (SENSL-24-03-RL-0183)

From: d.uttamchandani@strath.ac.uk

To: syah.alam@trisakti.ac.id

CC: jmcorres@unavarra.es, d.uttamchandani@strath.ac.uk

Subject: IEEE Sensors Letters: SENSL-24-03-RL-0183

Body: 28-May-2024

Dear Dr. Alam:

"Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" (Manuscript ID SENSL-24-03-RL-0183), which you submitted to IEEE Sensors Letters, has been reviewed. The comments from the reviewers appear below and in separate files which may be read by going into the "Manuscripts with Decisions" queue in your Author Center and clicking the "view decision letter" link for this paper.

We are willing to accept your manuscript for publication after your successful completion of the revisions that our reviewers feel the work requires. When undertaking revisions to the manuscript, authors are reminded that the overall length of the revised manuscript must still adhere to the page limit and formatting requirements of Sensors Letters.

After you have revised your manuscript, please submit it by going to the "Manuscripts with Decisions" queue of your Author Center on our Manuscript Central Web site, https://mc.manuscriptcentral.com/sensors-letters. Then "Click here to submit a revision."

In Step 1, you will be asked to respond to this decision letter. Here you may include confidential information to the editor, not intended for the reviewers.

In Step 6 you should delete any obsolete, original submission files (e.g., MAIN DOCUMENT) and upload your new MAIN DOCUMENT. You should also upload a SUPPLEMENTARY FILE in which you have responded to the reviewers' remarks. Please state how you satisfied (or why you declined to satisfy) each suggestion from the reviewers. Then click Save and Continue, and complete the other steps for re-submission.

Once we receive your revised version, it may be sent again to reviewers (who will see your responses in your SUPPLEMENTARY FILE). They may recommend further changes before a final decision on publication is reached.

Please submit your revision by 11-Jun-2024. If you cannot complete the re-submission by then, please e-mail me in advance to request an extension. If we do not hear from you we will assume that you have decided to withdraw your paper.

Please feel free to get in touch with me if you have any questions about the revision or how to submit your edited version. We will look forward to receiving your completed work.

Sincerely,

Prof. Deepak Uttamchandani
AEIC, IEEE Sensors Letters

Manuscript Title: Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
ID: SENSL-24-03-RL-0183

Reviewers' comments to author, if any (please also check your Author Center for other files):
Reviewer: 1

Comments to the Author
Thanks to the authors for the corrections made.

Reviewer: 4

Comments to the Author
The authors have tried to improve the manuscript, but the following concerns remain in the paper.
1- Do the answers change with changes in the sample size?
Please review these changes and provide the results.

2. The results of the reproducibility of the tests and the uniformity of the results need to be added to the article.

3- I believe this system is complicated to diagnose.
and it is better to check the microwave sensors in the introduction section.
I suggest writing it from scratch.
Authors can get help from the following references:
"A Microwave Sensor System Based on Oscillating Technique for Characterizing Complex Permittivity of Liquid Samples"
"Microwave Substrate Integrated Waveguide Resonator Sensor for Non-Invasive Monitoring of Blood Glucose Concentration: Low Cost and Painless Tool for Diabetics"
"A CSRR-based sensor for full characterization of magneto-dielectric materials"
"Dual-frequency microwave resonant sensor to detect noninvasive glucose-level changes through the fingertip"

4- What is the performance error of this sensor?
What factors caused this amount of error?
What environmental and human conditions affect the results of this proposed analysis?
Provide a solution to reduce each of these errors.

5- Add the following parameters to the comparison table:
FDR, Measurement Error, Sensor Size, Sample Size, ...

6- Why was the sensor designed with these frequencies?
What are the benefits of having multiple frequencies?
Calculate sensitivity, error, quality, and FDR factors for each frequency individually.
Update these values in Table 2.
Authors can get help from the following references:
"Dual-frequency microwave resonant sensor to detect noninvasive glucose-level changes through the fingertip"
"Dual-sensing and dual-frequency microwave SRR sensor for liquid samples permittivity detection"

7-Before building the sensor, how did the authors realize that the designed sensor could be a sensor in the simulation environment? Add this topic in full detail in the article.

Date Sent: 28-May-2024

Close Window

Prof. Deepak Uttamchandani
Associate Editor-in-chief of IEEE Sensors Letters June 4, 2024

SUBMISSION OF REVISED MANUSCRIPT

Dear Professor,
Thank you for giving the opportunity to submit a revised draft of manuscript "Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" (Manuscript ID: SENSL-24-03-RL-0183.R1).

We appreciate the time and effort that you and the reviewers have dedicated to providing your valuable feedback on my manuscript to be published as a research paper in the IEEE Sensors Letters.

We are grateful to the associate editor and reviewers for their insightful comments on my paper. We have been able to incorporate changes to reflect most of the suggestions provided by the associate editor and reviewers. We have highlighted (red marker) the changes within the manuscript.

We look forward to receiving your communication.

Yours sincerely,

Syah Alam*

Please address all correspondence to:

Syah Alam

Department of Electrical Engineering, Universitas Trisakti, DKI Jakarta, 11440
*Corresponding author e-mail: syah.alam@trisakti.ac.id

Reviewer 1

Comments to the Author:
Thanks to the authors for the corrections made.

Response:

We thank the reviewers for their constructive comments.

Reviewer 4

The authors have tried to improve the manuscript, but the following concerns remain in the paper.

1. ***Do the answers change with changes in the sample size? Please review these changes and provide the results.***

Response:

We thank the reviewers for their constructive comments. In this paper, we use four samples with a permittivity range of 1 – 6.15 with a fixed shape and dimensions of 10 mm x 10 mm x 1.6 mm. The dimensions of the sample are adjusted to the size of the sensing area of the proposed sensor. Furthermore, to answer the reviewer's question, we have added simulation results to show the effect of changing the sample dimensions on the performance of the proposed sensor in **Fig. 1** and **Fig. 2**.

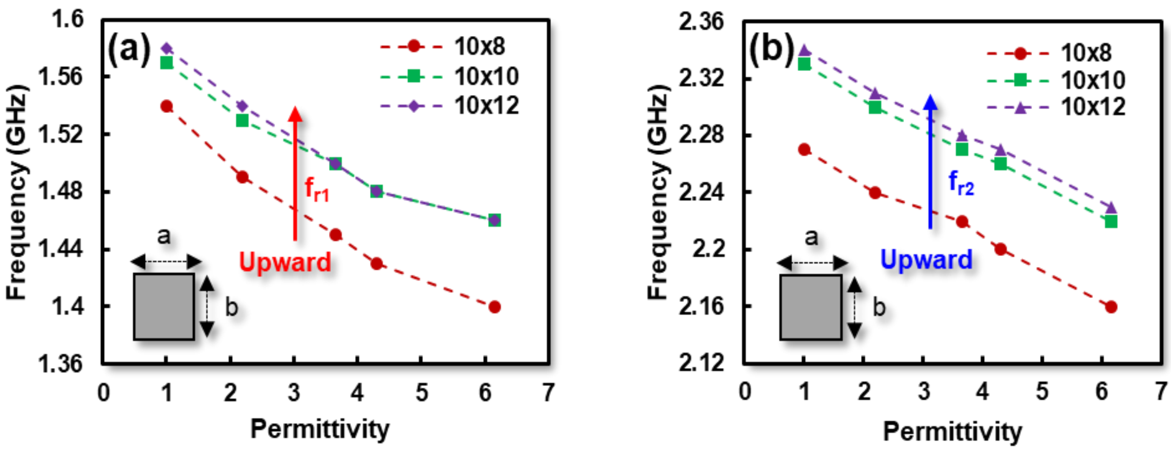

Fig.1 Response of resonance frequency based on different sample dimensions; (a) long-range detection, (b) contact detection

Fig. 1 (a) and **Fig. 1 (b)** show the response of the proposed sensor based on the resonance frequency for long range and contact detection which changes in line with changes in the dimensions of the sample. In this experiment, the dimensions of the sample are represented by *a* and *b* as length and width where the dimensions of the sample used are 8 mm x 10 mm, 10 mm x 10 mm and 12 x 10 mm.

The permittivity range used in this experiment refers to the datasheet for vacuum (ε_r = 1), RO5880 (ε_r = 2.2), RO4003 (ε_r = 3.65), FR4 (ε_r = 4.3) and RO3006 (ε_r = 6.15). Furthermore, the frequency shift of the sensor based on changes in the dimensions of the sample for the permittivity range 1 - 6.15 is shown in **Fig.2 (a)** and **Fig 2 (b)**.

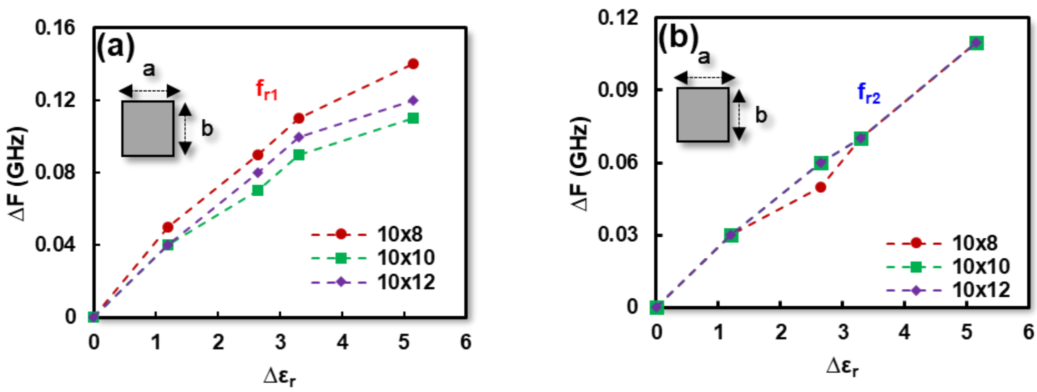

Fig.2 ΔF based on different sample dimensions; (a) long-range detection, (b) contact detection

Based on **Fig. 2(a)** it shows that the frequency shift of the sensor (ΔF) for long-range detection is influenced by changes in the dimensions of the sample. Furthermore, the frequency shift of the sensor (ΔF) for contact detection does not change significantly with the dimensions of the sample as shown in **Fig.2 (b)**. Based on the simulation results, ΔF for long range detection is in the range 0.11 GHz - 0.14 GHz, while for constant contact detection it is 0.11 GHz for three different sample dimensions.

These findings indicate that changing the dimensions of the sample influences the frequency shift but is not significant on the performance of the proposed sensor. For this reason, the dimensions of the sample used must be adjusted to the size of the sensing surface area to obtain optimal performance. Unfortunately, we did not include this data in the revised paper due to the limited number of pages for letters, which is a maximum of 4 pages. Therefore, we include this information in supplementary files of proposed paper.

Kindly refer Section: Supplementary files, Fig. 10 (a) and Fig. 10 (b), page 10.

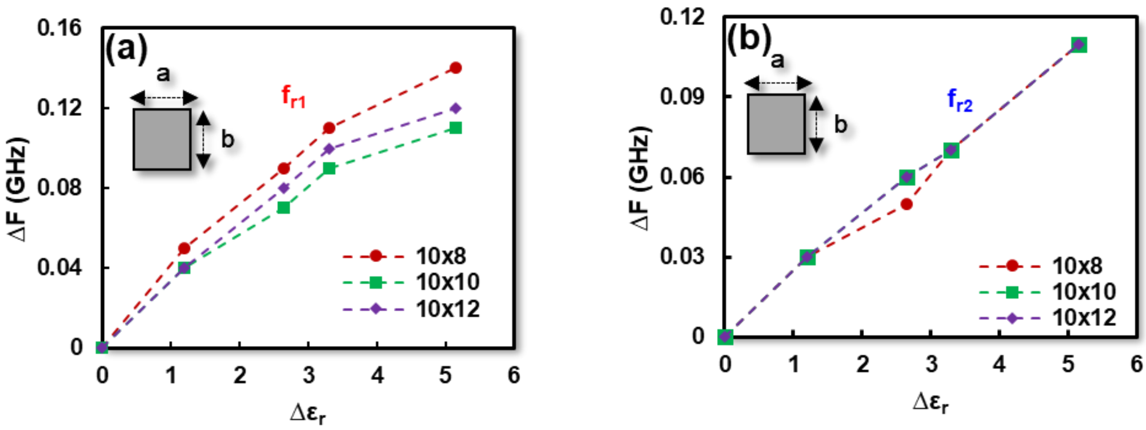

***Fig.10** ΔF based on different sample dimensions; (a) long-range detection, (b) contact detection*

2. ***The results of the reproducibility of the tests and the uniformity of the results need to be added to the article.***

Response:

We thank the reviewers for their constructive comments. To ensure the the reproducibility and the uniformity of the results of the proposed sensor, we propose to repeat the measurement 3 times represented by M1, M2 and M3 to observe the error of the measurement process. **Fig. 3 (a)** and **Fig. 3 (b)** show the repetition data from permittivity detection using the proposed sensor for long-range and contact detection.

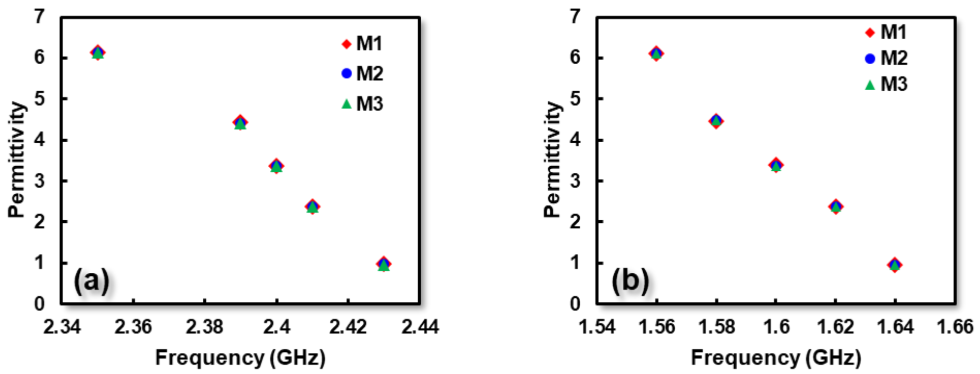

Fig.3 Repeatability of measurement using proposed sensor; (a) long-range detection, (b) contact detection

Fig 3 (a) and **Fig 3 (b)** show that the permittivity detection from the repetition process obtains almost the same value. **Table 2** and **Table 3** show the permittivity values obtained from the measurement process compared to the reference permittivity from the datasheet.

Table 2. Average error and accuracy for long-range detection

Reference Permittivity	M1	M2	M3	Average Permittivity	Average Error	Average Accuracy
1	0.98	0.99	0.97	0.98	2.09%	97.91%
2.2	2.37	2.38	2.38	2.37	7.92%	92.08%
3.65	3.38	3.38	3.38	3.38	7.35%	92.65%
4.3	4.43	4.42	4.42	4.42	2.77%	97.23%
6.15	6.15	6.15	6.15	6.15	0.07%	99.93%

Table 3. Average error and accuracy for contact detection

Reference Permittivity	M1	M2	M3	Average Permittivity	Average Error	Average Accuracy
1	0.96	0.97	0.97	0.96	3.69%	96.31%
2.2	2.37	2.38	2.37	2.38	8.07%	91.93%
3.65	3.39	3.38	3.37	3.38	7.44%	92.56%
4.3	4.47	4.48	4.48	4.48	4.21%	95.79%
6.15	6.11	6.12	6.12	6.11	0.60%	99.40%

Table 2 and **Table 3** show that the proposed sensor has a low error for the three times of the measurement process. For this reason, it can be concluded that the proposed sensor has high accuracy when detecting the permittivity of the MUT both for long range and contact detection. Unfortunately, we did not include this data in the revised paper due to the limited number of pages for letters, which is a maximum of 4 pages. Therefore, we include this information in supplementary files of proposed paper.

Kindly refer Section: Supplementary files, Fig. 11 (a) and Fig. 11 (b), page 11.

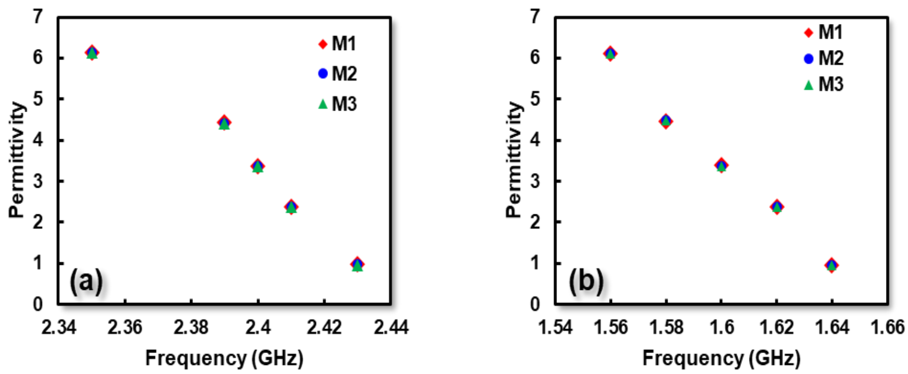

***Fig.3** Repeatability of measurement using proposed sensor; (a) long-range detection, (b) contact detection*

3. ***I believe this system is complicated to diagnose and it is better to check the microwave sensors in the introduction section. I suggest writing it from scratch. Authors can get help from the following references:***
   - ***"A Microwave Sensor System Based on Oscillating Technique for Characterizing Complex Permittivity of Liquid Samples"***
   - ***"Microwave Substrate Integrated Waveguide Resonator Sensor for Non-Invasive Monitoring of Blood Glucose Concentration: Low Cost and Painless Tool for Diabetics"***
   - ***"A CSRR-based sensor for full characterization of magneto-dielectric materials" "Dual-frequency microwave resonant sensor to detect non-invasive glucose-level changes through the fingertip".***

Response:

We thank the reviewers for their constructive comments. We have explained in detail in the paper the working principle of the proposed sensor in the introduction section. This paper proposes a solution for contact and long-distance detection based on T resonator embedded with IDC. In detail, the main contribution of this research as proposed long-distance detection MS with two independent sensing hotspots enabling contact and long-distance characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for long-distance detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection. Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11].

Kindly refer Section: Introduction, page 1

"Microwave sensors (MS) have gained widespread development for assessing both solids and liquids due to their benefits, including high precision, a high Q-Factor, affordability, and compact size[1]. One of the properties they can detect is permittivity, which refers to a material's capacity to retain an electric field. Moreover, permittivity of the MUT can be ascertained through perturbation theory, assuming the MUT acts as a capacitive load [2]. Previous studies have put forth various microwave sensors employing resonators such as Split Ring Resonator (SRR)[3], Complementary Split Ring Resonator (CSRR) [4], Substrate Integrated Waveguide (SIW) [5], and Interdigital Capacitor (IDC) [6] for assessing solid substances. In contrast, previous work proposed by [7] introduces a dual T-shaped resonator featuring a single port for characterizing solid materials with contact and non-contact. However, this work has disadvantages such as a very limited distance of 0.5 - 1.5 mm for non-contact detection, poor sensitivity and the locations of the E-field and H-field are ambiguous. Another work, presented by [8], suggests a multifunctional dual-band MS with an antenna for communication purposes. However, the MUT's characterization is only performed directly by placing it on the sensing hotspot. Additionally, [9] and [10] employs an antenna as a permittivity sensor for contactless detection at a distance of 20 mm and 30 mm using Artificial Magnetic Conductor (AMC) . However, the proposed sensor features only one sensing hotspot and therefore cannot facilitate contact and long-distance characterization independently. Therefore, several requirements are needed to obtain high performance MS with long-distance detection, high sensitivity, clear location between E-field and H-field and dual hotspot location for contact and long-distance.

To fulfill this requirement, this letter introduces a collaboration between near-field and far-field regions for microwave permittivity sensors operating at two resonant frequencies. In detail, the main contribution of this research such as proposed long-distance detection MS with two independent sensing hotspots enabling contact and long-distance characterization of solid materials. To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for long-distance detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection. Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11]".

Reference:

[1] K. S. L. Parvathi and S. R. Gupta, "Ultrahigh-Sensitivity and Compact EBG-Based Microwave Sensor for Liquid Characterization," IEEE Sensors Lett., vol. 6, no. 4, pp. 19–22, 2022, doi: 10.1109/LSENS.2022.3159800.

[2] A. Aquino, C. G. Juan, B. Potelon, and C. Quendo, "Dielectric Permittivity Sensor Based on Planar Open-Loop Resonator," IEEE Sensors Lett., vol. 5, no. 3, pp. 2021–2024, 2021, doi: 10.1109/LSENS.2021.3055544.

[3] S. Kiani, P. Rezaei, and M. Navaei, "Dual-sensing and dual-frequency microwave SRR sensor for liquid samples permittivity detection," Meas. J. Int. Meas. Confed., vol. 160, p. 107805, 2020, doi: 10.1016/j.measurement.2020.107805.

[4] H. Xiao, S. Yan, C. Guo, and J. Chen, "Microwave / millimeter wave sensors A Dual-Scale CSRRs-Based Sensor for Dielectric Characterization," vol. 6, no. 12, pp. 10–13, 2022.

[5] W. Liu, J. Zhang, and K. Huang, "Wideband microwave interferometry sensor with improved sensitivity for measuring minute variations in dielectric properties of chemical liquids in microfluidic channels," Meas. J. Int. Meas. Confed., vol. 189, no. September 2021, p. 110474, 2022, doi: 10.1016/j.measurement.2021.110474.

[6] S. Kiani, P. Rezaei, M. Navaei, and M. S. Abrishamian, "Microwave Sensor for Detection of Solid Material Permittivity in Single/Multilayer Samples With High Quality Factor," IEEE Sens. J., vol. 18, no. 24, pp. 9971–9977, 2018, doi: 10.1109/JSEN.2018.2873544.

[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.

[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.

[9] Q. Shi, X. W. Xuan, H. K. Nie, Z. Y. Wang, and W. Wang, "Antenna Sensor Based on AMC Array for Contactless Detection of Water and Ethanol in Oil," IEEE Sens. J., vol. 21, no. 19, pp. 21503–21510, 2021, doi: 10.1109/JSEN.2021.3102294.

[10] W. J. Wu and G. Wang, "A modified AMC-based antenna sensor for long-distance measurement of complex permittivity," Meas. J. Int. Meas. Confed., vol. 206, no. June 2022, p. 112261, 2023, doi: 10.1016/j.measurement.2022.112261.

[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

4. **What is the performance error of this sensor?**
   What factors caused this amount of error?
   What environmental and human conditions affect the results of this proposed analysis?
   Provide a solution to reduce each of these errors.

Response:

- We have explained the performance of the sensor including accuracy, sensitivity and ∆F for contact and long-distance detection as shown in Table 1.

TABLE 1. Performance of proposed sensor

MUT	ε_r ref	∆f (GHz / $\Delta\varepsilon_r$)		Sensitivity (%)		Accuracy (%)	
		f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}
Vacuum	1.00	0	0	-	-	97.91	95.64
RO5880	2.20	0.02	0.02	0.83	1.23	92.38	92.08
RO4003	3.65	0.03	0.04	1.25	2.50	92.65	92.84
FR4	4.30	0.04	0.06	1.67	3.80	97.08	95.95
RO3006	6.15	0.08	0.08	3.40	5.13	99.93	99.29

  Based on **Table 1**, the average accuracy of the sensor is 95.91 % and 95.16% for long range detection and contact detection, respectively. Therefore, the performance error of the sensor is in the range of 0.07% - 7.35%.
- The small amount of errors due to the permittivity variation of the material under test. For example, the tolerance permittivity and thickness for RO5880 is about 1% and 0.062" refer to datasheet. https://rogerscorp.com/-/media/project/rogerscorp/documents/advanced-electronics-solutions/english/data-sheets/rt-duroid-5870---5880-data-sheet.pdf
- For your information, we have tried our best to minimize environmental and human conditions affect where we try to maintain the temperature of 25̊ and we ensure that there are no other objects close to the sensor during the measurement process in the laboratory. However, for commercial sensor application it is recommended to validate the parameters (permittivity, thickness, etc) of the actual substrate for material under test.
- Our suggestion to reduce the error is maintaining the environmental and human conditions as we did in this research (we have explained in Section III. Measurement and Validation, sub-section B. Experimental Validation, page 3). In addition, we suggest measuring the parameters (permittivity, thickness, etc) of the actual substrate for material under test.

Kindly refer Section: Section III. Measurement and Validation, sub-section B. Experimental Validation, page 3.

"The experimental validation was conducted utilizing a Vector Network Analyzer (VNA) spanning a frequency range of 1 - 3 GHz, with a frequency sweep increment of 0.01 GHz. The ambient temperature during the measurements was maintained at 25°C. Additionally, four distinct materials with known permittivity were employed as Material Under Test (MUT): RO5880 possessing a permittivity of 2.20, RO4003 of 3.65, FR-4 of 4.30, and RO3006 of 6.15 with the dimension of MUT is 10 x 10 x 1.6 mm^3. Moreover, to ensure the location of the MUT is constant we carefully place the MUT at the location of the sensing hotspot using plastic clamp which is for contact detection on the surface of the IDC and for long-distance detection on the surface of the T-shaped resonator as shown in Fig 6 (b) and Fig 6(a). Furthermore, Fig.7 (a) shows that f_{r1} shifts to low frequency in line with the increased permittivity of the MUT placed at the sensing hotspot of the 1st resonator for long-distance detection with d = 10 cm while f_{r2} is fixed. The resonant frequency of the 1st resonator shifted from 2.43 GHz to 2.35 GHz with a permittivity range of 1 - 6.15 as shown in Fig.7 (c)".

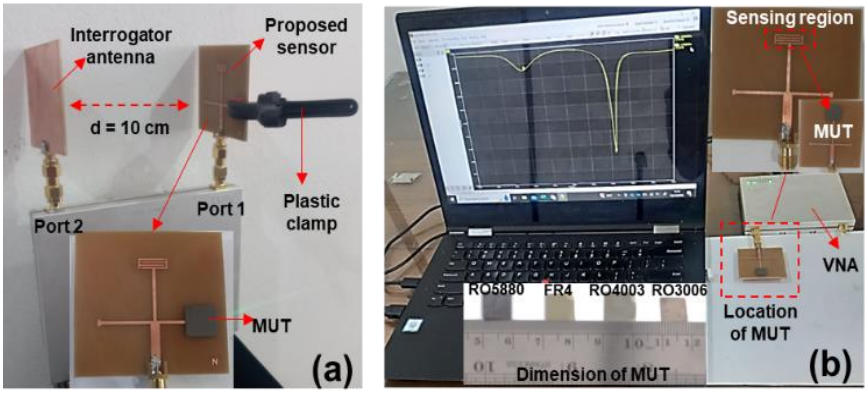

Fig. 6. Measurement setup; (a) long-distance detection using scenario (1), (b) contact detection using scenario (2).

5. Add the following parameters to the comparison table: FDR, Measurement Error, Sensor Size, Sample Size, ...

Response:

We thank the reviewers for their constructive comments. We have added recommended parameters in table II including sensitivity, FDR, sample dimensions, sensor dimensions and Q-factor.

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Dimension (mm)		Num. of sensing hotspot	d (mm)	FDR (GHz)	S (%) / Q-factor	Separated E & H field	Contact / long-distance detection
			Sensor	Sample						
[7]	1.81/2.34	1 – 6.15	50 x 50	10 x 10 x 1.6	2	1.5	0.023/0.003	2.30 /117	No	Yes / No
[8]	1.50/2.00/2.45	1 – 6.15	50 x 50	10 x 10 x 1.6	2	0.0	0.013/0.027	2.71 /120	No	Yes / No
[9]	6.90	1 – 15	40 x 40	10 x 10 x 4	1	20	0.038	3.80 /69	No	No / Yes
[10]	4.04	2 – 4	30 x 30	25 x 25 x 2.1	1	30	NA	1.89 /268	No	No / Yes
T.W.	1.64/2.43	1 – 6.15	50 x 50	10 x 10 x 1.6	2	100	0.016/0.016	5.13 /121	Yes	Yes / Yes

Kindly refer Section: Section IV. Measurement and Validation, sub-section C. Sensitivity and accuracy of proposed sensor, Table II, page 4.

Table 2 *shows that the MS has novel dual modalities for contact and long-distance detection by utilizing the near-field and far-field region with a high sensitivity of 5.13%, long-distance detection with d = 100 mm and maximum Q-factor of 121 for solid materials with a permittivity range of 1 - 6.15 and two different sensing hotspots compared with previous work which only supports contact or long-distance detection and limited distance for long-distance detection.*

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Dimension (mm)		Num. of sensing hotspot	d (mm)	FDR (GHz)	S (%) / Q-factor	Separated E & H field	Contact / long-distance detection
			Sensor	Sample						
[7]	1.81/2.34	1 – 6.15	50 x 50	10 x 10 x 1.6	2	1.5	0.023/0.003	2.30 /117	No	Yes / No
[8]	1.50/2.00/2.45	1 – 6.15	50 x 50	10 x 10 x 1.6	2	0.0	0.013/0.027	2.71 /120	No	Yes / No
[9]	6.90	1 – 15	40 x 40	10 x 10 x 4	1	20	0.038	3.80 /69	No	No / Yes
[10]	4.04	2 – 4	30 x 30	25 x 25 x 2.1	1	30	NA	1.89 /268	No	No / Yes
T.W.	1.64/2.43	1 – 6.15	50 x 50	10 x 10 x 1.6	2	100	0.016/0.016	5.13 /121	Yes	Yes / Yes

Reference:

[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, “Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material,” IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.

[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, “Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities,” Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi:

10.1016/j.measurement.2023.113078.

[9] Q. Shi, X. W. Xuan, H. K. Nie, Z. Y. Wang, and W. Wang, "Antenna Sensor Based on AMC Array for Contactless Detection of Water and Ethanol in Oil," IEEE Sens. J., vol. 21, no. 19, pp. 21503–21510, 2021, doi: 10.1109/JSEN.2021.3102294.

[10] W. J. Wu and G. Wang, "A modified AMC-based antenna sensor for long-distance measurement of complex permittivity," Meas. J. Int. Meas. Confed., vol. 206, no. June 2022, p. 112261, 2023, doi: 10.1016/j.measurement.2022.112261.

[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

6. ***Why was the sensor designed with these frequencies?***
What are the benefits of having multiple frequencies?
Calculate sensitivity, error, quality, and FDR factors for each frequency individually. Update these values in Table 2.
Authors can get help from the following references:
    - ***"Dual-frequency microwave resonant sensor to detect noninvasive glucose-level changes through the fingertip."***
    - ***"Dual-sensing and dual-frequency microwave SRR sensor for liquid samples permittivity detection"***

Response:

We thank the reviewers for their constructive comments. For this reason, we added some new information to answer reviewer questions as follows:

- This sensor is designed in the frequency range from 1 - 3 GHz. This frequency is determined based on previous work where the commonly used resonance frequency is in the range 1 - 6 GHz as shown in **Table 2.**

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Dimension (mm)		Num. of sensing hotspot	d (mm)	FDR (GHz)	S (%) / Q-factor	Separated E & H field	Contact / long-distance detection
			Sensor	Sample						
[7]	1.81/2.34	1 – 6.15	50 x 50	10 x 10 x 1.6	2	1.5	0.023/0.003	2.30 /117	No	Yes / No
[8]	1.50/2.00/2.45	1 – 6.15	50 x 50	10 x 10 x 1.6	2	0.0	0.013/0.027	2.71 /120	No	Yes / No
[9]	6.90	1 – 15	40 x 40	10 x 10 x 4	1	20	0.038	3.80 /69	No	No / Yes
[10]	4.04	2 – 4	30 x 30	25 x 25 x 2.1	1	30	NA	1.89 /268	No	No / Yes
T.W.	1.64/2.43	1 – 6.15	50 x 50	10 x 10 x 1.6	2	100	0.016/0.016	5.13 /121	Yes	Yes / Yes

- The advantage of using multiple frequencies is that one of the resonant frequencies can be used for another functions, including antennas for data transfer capability [8] and antenna sensor for non-contact detection [7].
- We have added calculations of the FDR, sensitivity and Q-factor of the sensor as shown in Table II. Furthermore, we have added the error performance of the sensor in Table I.

TABLE 1. *Performance of proposed sensor*

MUT	ε_r ref	Δf ($GHz / \Delta\varepsilon_r$)		Sensitivity (%)		Accuracy (%)	
		f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}
Vacuum	1.00	0	0	-	-	97.91	95.64
RO5880	2.20	0.02	0.02	0.83	1.23	92.38	92.08
RO4003	3.65	0.03	0.04	1.25	2.50	92.65	92.84
FR4	4.30	0.04	0.06	1.67	3.80	97.08	95.95
RO3006	6.15	0.08	0.08	3.40	5.13	99.93	99.29

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Dimension (mm)		Num. of sensing hotspot	d (mm)	FDR (GHz)	S (%) / Q-factor	Separated E & H field	Contact / long-distance detection
			Sensor	Sample						
[7]	1.81/2.34	1 – 6.15	50 x 50	10 x 10 x 1.6	2	1.5	0.023/0.003	2.30 /117	No	Yes / No
[8]	1.50/2.00/2.45	1 – 6.15	50 x 50	10 x 10 x 1.6	2	0.0	0.013/0.027	2.71 /120	No	Yes / No
[9]	6.90	1 – 15	40 x 40	10 x 10 x 4	1	20	0.038	3.80 /69	No	No / Yes
[10]	4.04	2 – 4	30 x 30	25 x 25 x 2.1	1	30	NA	1.89 /268	No	No / Yes
T.W.	1.64/2.43	1 – 6.15	50 x 50	10 x 10 x 1.6	2	100	0.016/0.016	5.13 /121	Yes	Yes / Yes

Kindly refer Section: Section IV. Measurement and Validation, sub-section C. Sensitivity and accuracy of proposed sensor, Table I and Table II, page 4.

*The overall performance of the proposed sensors both for long-distance and contact detection are shown in **Table 1**.*

TABLE 1. *Performance of proposed sensor*

MUT	ε_r ref	Δf (GHz / Δε_r)		Sensitivity (%)		Accuracy (%)	
		f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}
Vacuum	1.00	0	0	-	-	97.91	95.64
RO5880	2.20	0.02	0.02	0.83	1.23	92.38	92.08
RO4003	3.65	0.03	0.04	1.25	2.50	92.65	92.84
FR4	4.30	0.04	0.06	1.67	3.80	97.08	95.95
RO3006	6.15	0.08	0.08	3.40	5.13	99.93	99.29

*Moreover, FDR of the proposed sensor based on **Eq. (3)** for f_{r1} and f_{r2} are 0.016 GHz. **Table 2** shows that the MS has novel dual modalities for contact and long-distance detection by utilizing the near-field and far-field region with a high sensitivity of 5.13%, long-distance detection with d = 100 mm and maximum Q-factor of 121 for solid materials with a permittivity range of 1 - 6.15 and two different sensing hotspots compared with previous work which only supports contact or long-distance detection and limited distance for long-distance detection.*

TABLE 2. *Comparison with previous work*

Ref	f_r (GHz)	Range of ε_r	Dimension (mm)		Num. of sensing hotspot	d (mm)	FDR (GHz)	S (%) / Q-factor	Separated E & H field	Contact / long-distance detection
			Sensor	Sample						
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[8]	1.50/2.00/2.45	1 – 6.15	50 x 50	10 x 10 x 1.6	2	0.0	0.013/0.027	2.71 /120	No	Yes / No
[9]	6.90	1 – 15	40 x 40	10 x 10 x 4	1	20	0.038	3.80 /69	No	No / Yes
[10]	4.04	2 – 4	30 x 30	25 x 25 x 2.1	1	30	NA	1.89 /268	No	No / Yes
T.W.	1.64/2.43	1 – 6.15	50 x 50	10 x 10 x 1.6	2	100	0.016/0.016	5.13 /121	Yes	Yes / Yes

Reference:

[7] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Integrated Microwave Sensor and Antenna Sensor Based on Dual T-Shaped Resonator Structures for Contact and Noncontact Characterization of Solid Material," IEEE Sens. J., vol. 23, no. 12, pp. 13010–13018, 2023, doi: 10.1109/JSEN.2023.3273008.

[8] S. Alam, Z. Zakaria, I. Surjati, N. A. Shairi, M. Alaydrus, and T. Firmansyah, "Multifunctional of dual-band permittivity sensors with antenna using multicascode T-shaped resonators for simultaneous measurement of solid materials and data transfer capabilities," Meas. J. Int. Meas. Confed., vol. 217, no. November 2022, p. 113078, 2023, doi: 10.1016/j.measurement.2023.113078.

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[11] Pozar DM. Microwave Engineering. Fourth Edi. John Wiley & Sons, Inc; 2012

7. ***Before building the sensor, how did the authors realize that the designed sensor could be a sensor in the simulation environment? Add this topic in full detail in the article.***

Response:

We thank the reviewers for their constructive comments. We have clearly explained the stages in building the proposed sensor in Section II - Sensor Design, page 2. In this paper, a sensor is developed based on a single port resonator operating at two different frequencies. To obtain a clear location between E-field and H-field with high sensitivity performance, a T-shaped resonator embedded with interdigital capacitors (IDC) was proposed. The 1st resonator operating at f_{r1} = 2.43 GHz for long-distance detection and the 2nd resonator operating at f_{r2} = 1.64 GHz for contact detection. Furthermore, near-field and far-field regions for permittivity detection are determined based on S_{11} and the radiation pattern of the two resonators while for distance of (d) refer to Fresnel region with $d \geq \frac{2D^2}{\lambda}$ [11]. We have also presented the simulation results of the E-field and H-Field concentrations in Figure 6 as a reference in determining the sensing area of the sensor. Moreover, we have also shown the structure, model development and equivalent circuit of the resonator in Figure 8.

Kindly refer Section: Section II. Sensor Design, sub-section A. Scenario of near field and far field region for characterization of solid materials, sub-section B. structure of proposed sensor, page 2

*In this letter, two scenarios are proposed for far-field and near-field region for characterization of solid materials using the proposed sensor as shown in **Fig. 1(a)** and **Fig. 1(b)** with the following explanation:*

1) *Furthermore, scenario (1) proposes long-distance detection using interrogator antennas operating at the same resonance frequency as the 1st resonator at f_{r1}= 2.32 GHz with $S_{11} \leq$ -10 dB and separated by distance (d) of 10 cm. Long-distance permittivity detection is carried out by observing changes in the resonant frequency based on S_{21} as shown in **Fig. 1(a)**.*
2) *For scenario (2), near-field region for contact detection is proposed by placing the MUT on the IDC of the 2nd resonator operating at f_{r2}= 1.52 GHz with $S_{11} \geq$ -10 dB by observing changes in the resonant frequency based on S_{11} as shown in **Fig. 1(b).***

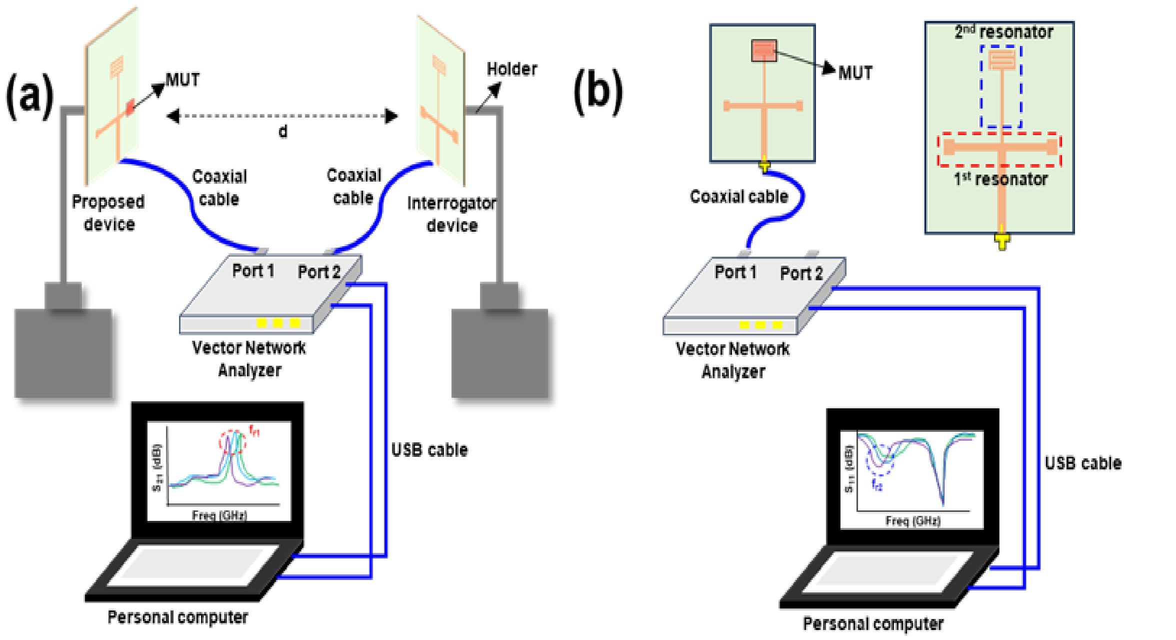

Fig. 1. *Scenario of permittivity detection using proposed sensor; (a) scenario (1) for long-distance detection using an interrogator antenna, (b) scenario (2) for contact detection*

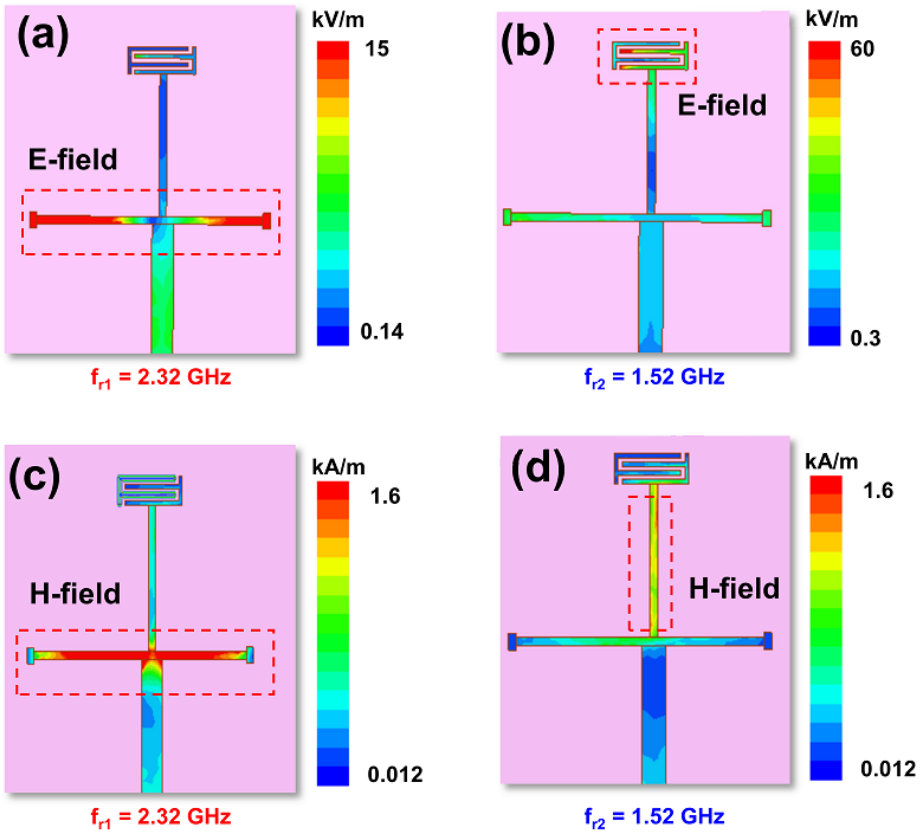

Fig.2 *(a) E-field at f_{r1}, (b) E-field at f_{r2}, (c) H-field at f_{r1} (d) H-field at f_{r2}*

*The location of the sensing hotspot is determined based on the concentration of the E-field and H-field of the proposed resonator. The surface of the resonator with high E-field can be used to detect the permittivity of MUT. The E-field and H-field concentrations of the resonator are shown in **Fig. 2(a)**, **Fig. 2(b)**, **Fig. 2(c)** and **Fig. 2(d).***

Fig. 2(a)** and **Fig. 2(c)** show that the high E-field and H-field concentrations at f_{r1} = 2.32 GHz are at the same location on the arms of the 1st resonator. Other findings, **Fig. 2(b)** and **Fig. 2(d)** show that the highest E-field is in the gap of the IDC while the H-field is in the arm of the 2nd resonator. Furthermore, simulations of the radiation patterns at f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz are shown in **Fig.3 (a)**, **Fig.3 (b)** and **Fig. 3 (c)

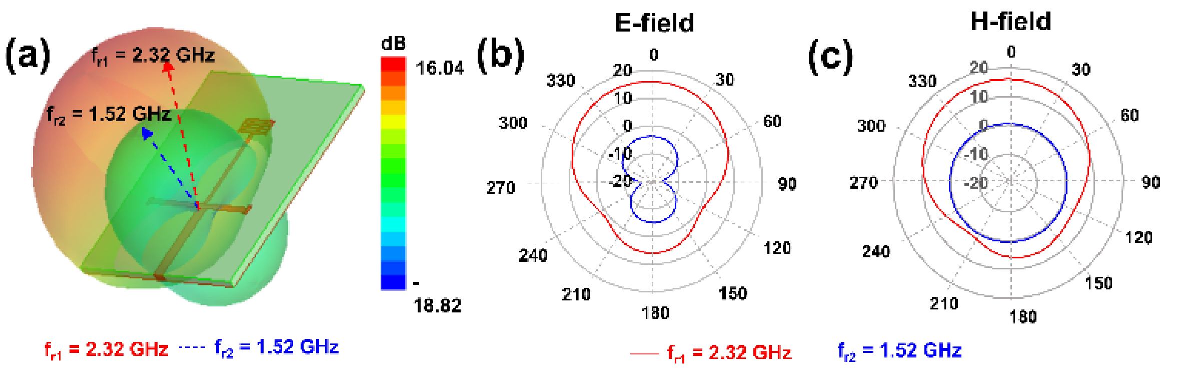

Fig.3 *(a) Radiation pattern of proposed resonator at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz, (b) E-field at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz, (c) H-field at f_{r1} = 2.32 GHz and f_{r2} =1.52 GHz.*

***Fig.3 (a)** shows that the radiation pattern at f_{r1} = 2.32 GHz is higher than f_{r2} = 1.52 GHz. This finding is also in line with the simulations of E-field and H-field radiation shown in **Fig. 3 (b)** and **Fig. 3 (c)**. This shows that resonators with high radiation can be used for long-distance detection by utilizing the far-field region, while low radiation can be used for contact detection by utilizing the near-field region.*

The dual modalities sensor is constructed utilizing of FR-4 substrate with specific properties: a dielectric constant (ε_r) of 4.3, a loss tangent (tan δ) of 0.0265, and a thickness (h) of 1.6 mm.

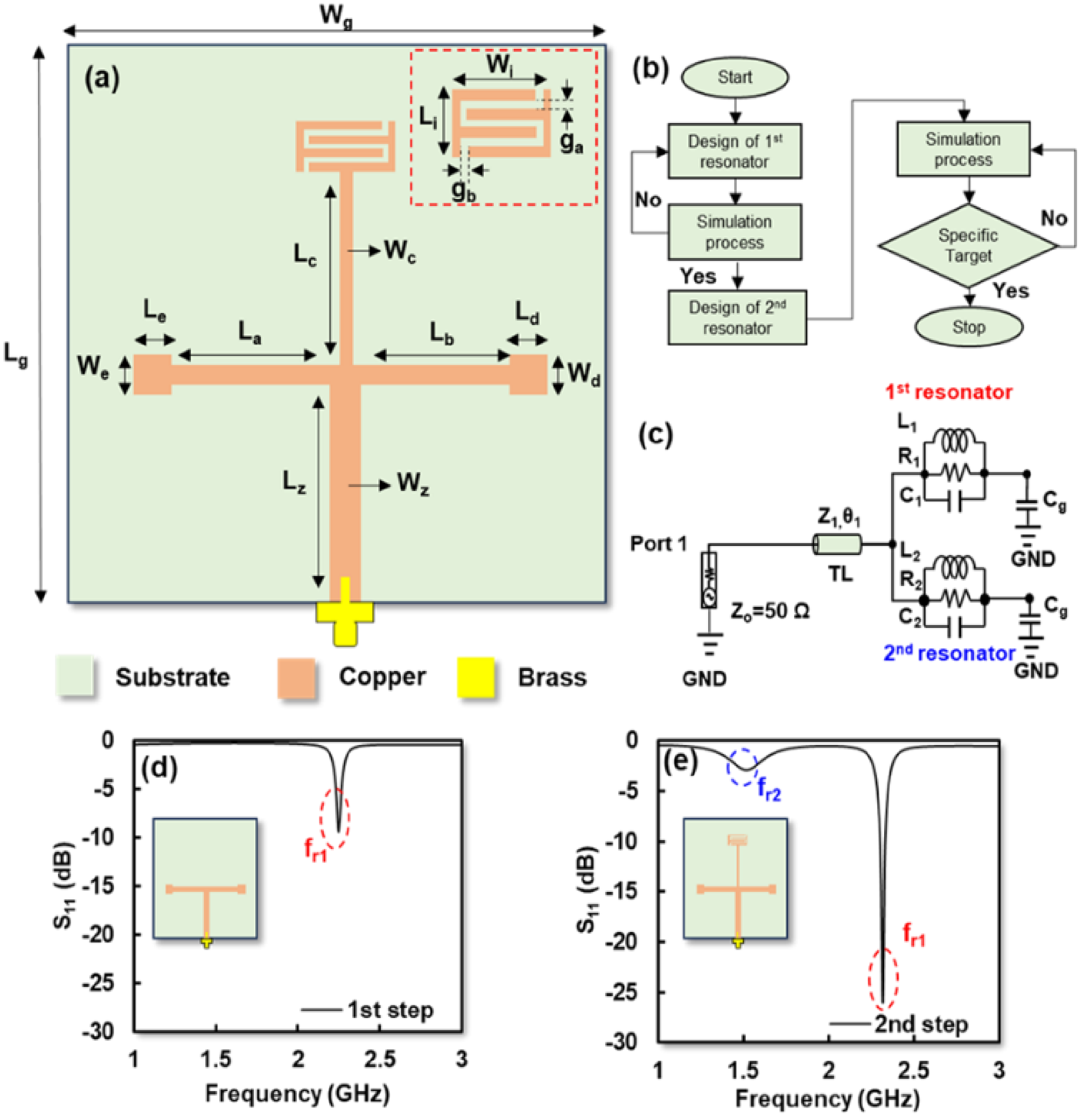

Fig. 4. *(a) Structure of T-shaped resonator, (b) flowchart of design process, (c) equivalent circuit, (d) 1st step model, (e) 2nd step model.*

The configuration of T-shaped resonator and IDC can be observed in ***Fig.4 (a).*** *Detailed dimensions of the proposed T-shaped resonator can be described as follows W_z = 3 mm, L_z = 17 mm, L_a = 16 mm, L_b = 12.5 mm, L_c = 18 mm, L_d = L_e = 1 mm, W_d = W_e = 2 mm, W_g = L_g 50 mm while for IDC represented by W_i = 9.5 mm, L_i = 3.5 mm and g_a = g_b = 1 mm. Moreover, the flowchart of design process dual T-shaped resonator is presented in* ***Fig. 4 (b)*** *while for equivalent circuit shown in* ***Fig 4 (c)****. In the initial phase, the resonator functions at f_{r1} = 2.32 GHz as shown in* ***Fig.4 (d)****, while in the subsequent phase, it operates at a dual-band resonant frequency, with f_{r1} = 2.32 GHz and f_{r2} = 1.52 GHz as shown in* ***Fig.4 (e)****, respectively.*

IEEE Sensors Letters

Decision Letter (SENSL-24-03-RL-0183.R1)

From: d.uttamchandani@strath.ac.uk

To: syah.alam@trisakti.ac.id

CC: jmcorres@unavarra.es, d.uttamchandani@strath.ac.uk

Subject: SENSL-24-03-RL-0183.R1: Accepted for publication pending final submission

Body: DearDr. Alam

It is my pleasure to inform you that your manuscript, "Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC" (Manuscript ID SENSL-24-03-RL-0183.R1), which you submitted to IEEE Sensors Letters, is accepted for publication. At this time you must send all final versions of your files through the “Awaiting Final Files” queue in your Author Center on ScholarOne Manuscripts. Please submit all files no later than 26-Jun-2024.

In order for us to proceed, you need to do the following:

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Thank you for submitting your manuscript to IEEE Sensors Letters. We look forward to further contributions from you in the future.

Sincerely,

Prof. Deepak Uttamchandani
AEIC, IEEE Sensors Letters

Manuscript Title: Collaboratively Far-Field and Near-Field Regions for Dual-Modalities Microwave Permittivity Sensor using T-Shaped Resonator Embedded with IDC
ID: SENSL-24-03-RL-0183.R1

Reviewers' Comments (other than attachments):
Reviewer: 4

Comments to the Author
Thanks to the respected authors who have answered all the concerns. The article is ready for publication.

Reviewer: 1

Comments to the Author
All my concerns have been addressed completely and the quality of the manuscript has improved significantly. It is recommended to publish the revised manuscript.

Date Sent: 12-Jun-2024

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