Student Design Competition

IEEE IMS 2024 Washington, DC

Electromagnetic Detection of Tumors

TC3 – Microwave Measurements Committee

TC28 - Biological Effects and Medical Applications Committee

Introduction:

The goal of this design competition is to design a VNA measurement to detect the presence of tumors in tissue phantoms. Measurement devices can be decided on by the students (for example, antenna, waveguide or coaxial measurements). Tumor detection based on different measurement device types have been demonstrated in the literature. Examples to provide inspiration for different types of measurements can be found below in the references section [1 – 7].

Design Specification and Rules:

1. The measurement device can have a maximum of two coaxial connector outputs in one of the following connector types:
    a. 3.5 mm, 2.92 mm or SMA (female output only).
2. Connections will be calibrated up from 10 MHz to 33 GHz at the mating male connectors output.
3. The measurement device can interface with the tumor phantom directly (contact) or indirectly.
4. The circuit must incorporate passive components only. Use of active devices in the RF path is not allowed.
5. Students must provide a presentation describing the construction of the measurement device and the principles of measurement behind the detection of tumor phantoms.
6. Students must calculate uncertainties on their measurements and present their uncertainty analysis.
7. Students will be allowed to move the sample between sweeps, or to immerse the sample in a non-destructive fluid if they choose to.

The judges shall provide a set of tumor phantoms at IMS to all participants to ensure uniformity in sample. Tumor phantoms shall be cylindrical in shape and in the following sizes:

Height of tumor cylinder	**Diameter of tumor cylinder**
0 (blank)	0
1 mm	1 mm
1.5 mm	1.5 mm
2.5 mm	2.5 mm
5 mm	5 mm
8 mm	8 mm

Tumor phantoms will be prepared using methods described in [8] with summary provided in Appendix A

Evaluation Process

Students will have 15 minutes to setup their measurement device on the provided VNA at the competition followed by an additional 20 minutes to collect s-parameter measurements on the tumor phantoms. An additional 30 minutes will be provided following measurements to complete data processing and uncertainty analysis.

Students will be able to collect either 2-port or 1-port measurements on the samples with up to 50 frequency points. Each sample can be measured three times for a maximum of 18 measurements used for the competition (6 tumor phantoms x 3 measurements each). The measurement s2p or s1p files will can be collected from the VNA to prepare their results on each measured tumor phantom.

Results should be reported in s-parameter form to ensure consistency.

Students shall be awarded points out of 100 for the following:

Element	**Points**
Number of tumors distinguished	25 (5 points per sample)
Smallest tumor detected	20 (4 less points for larger size)
Uncertainty analysis • Description of method for quantifying uncertainties • Uncertainty on each phantom measurement • Description of sources of systematic uncertainty	20
Presentation of methodology • Definition of what the measurement is measuring • Explanation of the impact of the tumor tissue on the measurement • Explanation of device	30
Budget (breakdown of device costs)	5

How to Participate:

Competing teams will be required to register to the IMS Student Design Competition according to the rules posted on the IMS-2024 homepage.

Students may enter as individuals or as a team. There may be no more than four students on a team with a maximum of one entry per competing team.

Contact Information:

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Appendix A: Tumor Preparation [8]

The phantom will consist of two components as described below.

LWCT (Low water content tissue). This will constitute the matrix of the phantom

Ingredients:

- 100 g glycerin
- 8 g de-ionized water
- 52 g ethylene glycol
- 10 g polyethylene powder
- 11.5 g agar

Procedure for glycerin phantom recipes If the total volume of phantom mixture is below 800 mL, the following procedure can be used to make the phantoms.

1. Follow standard laboratory safety regulations.
2. Pour DIW into a glass flask and put on a burner with a low flame or on a digital plate.
3. Pour all liquids needed in the recipe and stir to form a clear solution. Heat the solution to approximately 46 C.
4. Add a few drops of a bactericide, such as Bactine spray
5. Add the powder reagents, as a mixture of PEP and agar in the recipe. The powder mixture is added in tiny amounts to the liquid. The mixture is stirred continuously and gently to form a homogenous solution with minimal bubbles.
6. Once the mixture is homogeneous and thick, pour into a suitable mould. Initially, the temperature is about 68 C to 75 C. Allow the phantom to cool down to room temperature then place it at 5o C for solidification.
7. Use high quality plastic wraps, such as parafilm, to store the phantom after solidification to prevent dehydration. If a phantom batch is above 800 mL, it is recommended to use an automatic blender to mix the solution. Steps 3 and 5 are changed to (a) and (b), relatively. The remaining steps are the same as in the case of a small batch. (a) Heat the solution to 88 C. High temperature is required as there cannot be any heat supply to the blender. (b) Pour the liquid mixture into the blender. Add the powder mixture in tiny amounts and start churning the mixture at slow rotation speed – around 40 rpm to 60 rpm

Malignant tumor. This will constitute the tumor component of the phantom

Ingredients:

- 100 g de-ionized water
- 7 g gelatin OR 18 g alginate powder
- 0.7 g NaCl

The procedure for malignant tissue phantoms requires a saline solution as per the given ratio. For gelatin-based tumor phantoms, gelatin powder is dissolved in hot saline (about 60 C) and set to solidify. For alginate-based tumor phantoms, alginate is dissolved in cooled saline and immediately set in a mold, as alginate powder solidifies rapidly.

Phantoms shall be 1 cm cubes, with the matrix prepared with recipe for LWCT tissue. The tumor will be embedded in the center of the phantom as shown in Figure 1.

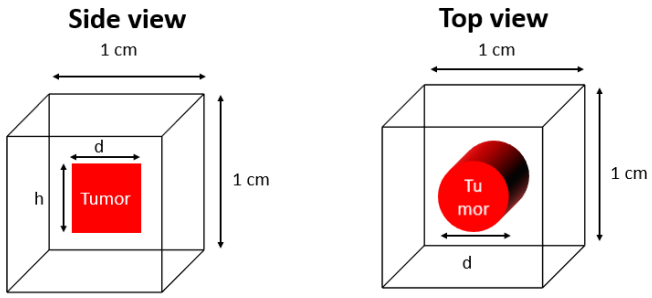

Figure 1. Tumor Phantom

To prepare the tumor phantoms in the matrix:

1. Pour the "malignant tumor" material into a flat mold to the desired thickness and allow to cure
2. Use a biopsy punch (for example https://4mdmedical.com/products/disposable-biopsy-punch-with-optional-plunger) to make a cylindrical tumor volume
3. Pour the LWCT material into a flat mold (at least 1 cm deep) to the corresponding thickness (1 cm – cylinder height)/2. Let cure
4. Place the tumor cylinder on top of the cured LWCT material, then cover with LWCT material until a total height of 1 cm is achieved. Let cure.
5. Remove tumor phantom from mold and trim excess LWCT material to obtain a 1 cm x 1 cm cube.

References:

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2. M. Alibakhshikenari et al., "Metamaterial-Inspired Antenna Array for Application in Microwave Breast Imaging Systems for Tumor Detection," in IEEE Access, vol. 8, pp. 174667-174678, 2020, doi: 10.1109/ACCESS.2020.3025672.

3. Islam, M.T., Mahmud, M.Z., Islam, M.T. et al. A Low Cost and Portable Microwave Imaging System for Breast Tumor Detection Using UWB Directional Antenna array. Sci Rep 9, 15491 (2019). doi: 10.1038/s41598-019-51620-z

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5. O. M. Ramahi and M. H. Kermani, "Transmission line resonators for breast tumor detection," 2005 IEEE Antennas and Propagation Society International Symposium, Washington, DC, USA, 2005, pp. 803-806 vol. 3A, doi: 10.1109/APS.2005.1552379.

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8. Y. Baskharoun, A. Trehan, N. K. Nikolova and M. D. Noseworthy, "Physical phantoms for microwave imaging of the breast," 2012 IEEE Topical Conference on Biomedical Wireless Technologies, Networks, and Sensing Systems (BioWireleSS), Santa Clara, CA, USA, 2012, pp. 73-76, doi: 10.1109/BioWireless.2012.6172736.