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# Microwave Imaging with Open-Ended Coaxial Probes

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**Abstract**— This work proposes an innovative approach to microwave imaging by combining robotics with open-ended coaxial probes. Traditionally, open-ended coaxial probes have been employed for precise dielectric measurements. However, their integration with robotics introduces a novel dimension, enabling dynamic movement and positioning during imaging processes. This synergy between robotics and open-ended coaxial probes promises enhanced imaging capabilities, allowing for detailed characterization of materials and structures at microwave frequencies. In this work, we explore the potential of this combined approach and its applications in fields such as non-destructive testing on relatively large scale dimension.

## I. INTRODUCTION

Open-ended coaxial probes have become valuable tools for microwave dielectric measurements, providing a non-destructive and highly sensitive method for assessing the electrical properties of materials [1]-[2]. In particular, it is much more practical to measure the signal reflected by an object rather than the transmitted signal [3]-[5]. This is especially the case when only one face of the material is accessible. The method of dielectric characterization by coaxial probe (or line) relies on determining the reflection coefficient of the discontinuity between an open coaxial probe and the material under investigation over a wide range of frequencies. This method is one of the most widespread because it does not require prior conditioning of the test material. The technique involves placing the probe in direct contact with the solid material or immersing the probe in the case of liquid measurements.

We propose to extend the capabilities of open coaxial probe techniques by combining them with a 3-axis positioner capable of centimeter-scale displacement with nanometer-level resolution. The entire system is automated within the LabVIEW environment to achieve a microwave imager. The system can accommodate conventional coaxial probes as well as evanescent probes, depending on the lateral and depth resolution required. The measurement system comprises a compact 1-port VNA from Anritsu, operating up to 6 GHz.

## II. EXPERIMENTAL MICROWAVE SYSTEM

The experimental setup is illustrated in Figure 1. utilizes a compact one-port VNA [Anritsu® MS46121B] in conjunction with an open-ended coaxial probe. The coaxial probe features a center conductor diameter of 0.92 mm, has an outer conductor diameter of 3.58 mm, is constructed with PTFE (Polytetrafluoroethylene) dielectric material, and spans a total

length of 205 mm. The probe is connected to the VNA through a flexible coaxial cable. The XYZ positioning stages from SmarAct® utilize the linear SMARSLIDE stages of the SLC series, which are constructed on linear slides with crossed roller bearings. These stages offer compactness, high rigidity, and straightness, making them well-suited for applications requiring stability and high accuracy in positioning systems. Two series of SLC linear stages are used: the SLC-17 (for X and Y – travel = 16 mm) and the SLC-24 (for Z – travel = 21 mm), differing primarily in width and height. Both series are equipped with position sensors for closed-loop operations.

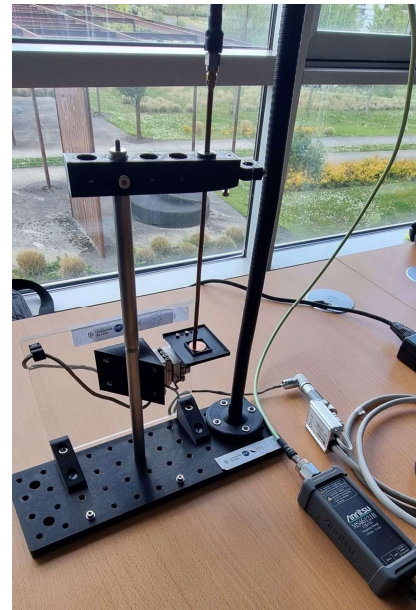


Fig. 1. Experimental setup with a compact one-port VNA [Anritsu® MS46121B] and an open-ended coaxial probe. The probe, connected to the VNA via a flexible coaxial cable, measures materials mounted on XYZ positioning stages from SmarAct®.

During the scanning operation, all microwave components remain fixed to ensure high measurement stability. Only the material under test, mounted on the positioning stages, is moved beneath the probe.

## III. SYSTEM AUTOMATION & PRELIMINARY RESULTS

SmarAct® offers Software Development Kits (SDKs) for seamless integration of their positioning systems, facilitating rapid implementation in the workplace. These SDKs provide

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comprehensive documentation of all functions and procedures, enabling smooth integration. They support programming languages such as C/C++, Python®, and LabVIEW®. In this study, we use LabVIEW® programming for centralized automation. It enables the automation of the entire process,

including movement of positioners considering different imaging modes, and configuration of VNA settings, as well as acquisition of measurement data.

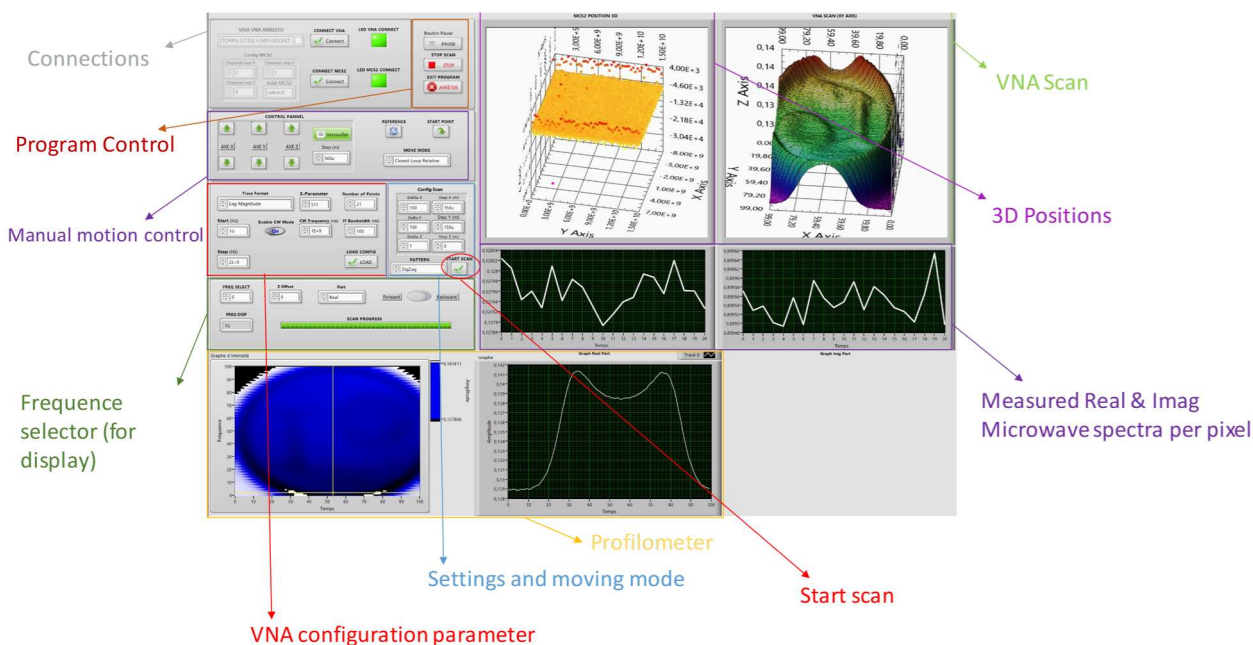


Fig. 2. Graphical User Interface for Open-Ended Coaxial Probe Microwave Imaging Software.

Qualitatively and preliminarily, we imaged a 1euro cent coin (diameter = 16.25 mm ; material = copper) at a probe-to-sample distance of 0.5 mm at a frequency of 1 GHz (Fig. 3).

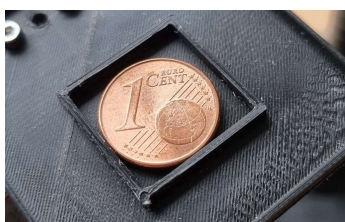


Fig. 3. 1 Euro Cent Coin in 3D-Printed Chuck: Preliminary Imaging Study.

As seen in the top-right section of Figure 2, which depicts the 2D imaging of the real part of the reflection coefficient, details with dimensions on the order of the probe's central conductor diameter become apparent.

This preliminary study paves the way for microwave dielectric imaging in different measurement configurations / different forms of probes, which has been limited thus far to point measurements.

#### IV. CONCLUSION

The open-ended coaxial probe measurement technique has been enhanced with nanorobotics tools, paving the way for new applications in dielectric scanning. The technique is straightforward to implement and can be adapted to higher frequencies without particular constraints.

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