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Microwave Subsurface Imaging: Methodologies and Applications

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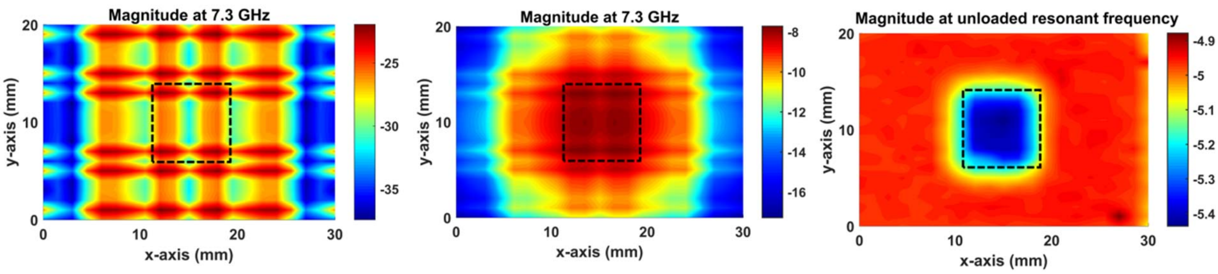
Over the years, microwave subsurface imaging has gained widespread attention in many fields such as concealed weapon detection at security checkpoints, landmine detection, biomedical imaging, structural health monitoring, quality inspection of composite structures etc. The strategy of microwave imaging is to illuminate the object under investigation using a known electromagnetic source, and from the reflection and transmission parameters received in response, information regarding the electromagnetic signature of the target is derived using suitable inverse process. Of the various measurement techniques available, the criteria for selecting a particular scheme for microwave imaging would be primarily based on factors such as the ease of imaging, frequency of operation, imaging accuracy etc. In recent years, real-time imaging of objects has garnered interest where the imaging scheme does not involve complex iterative inverse solutions or time-consuming calibration procedures [1]. Accordingly, the focus has been shifted from theoretical studies to the development of sophisticated practical arrangements where one can acquire information about objects in real time.

This work presents an investigative study of microwave subsurface imaging using two different methodologies; i.e., a general antenna-based free space measurement scheme and a planar resonant technique using a sensor based on complementary split ring resonator (CSRR), with regard to high resolution imaging. The approach utilizes the imaging capability of near-field and far-field electromagnetic waves. The objective would be to demonstrate the advantage of near-field imaging for attaining superior resolution while imaging electrically small structures. As an instance, the imperfections under paint coating are being explored in this paper. A patch antenna and CSRR sensor operating at the same frequency of 7.3 GHz are designed and utilized for imaging the test structure by raster scanning [2]. The magnitude of the reflection parameter in case of patch antenna, and transmission parameter in case of CSRR sensor, are studied for extracting useful information. From the observations shown in Figure 1, far-field imaging could not yield any acceptable information. However, the near-field image obtained using patch antenna could recover an approximate profile of the test structure which rationalizes the idea of using evanescent waves for imaging. Predictably, superior images were retrieved using the CSRR based sensor and thus recommended for high resolution imaging of small structures, defects and cracks in materials.



(a) (b) (c)

Figure 1. Retrieved images of a test structure based on the magnitude of S-parameters at 7.3 GHz. (a) Far-field imaging using patch antenna, (b) near-field imaging using patch antenna and (c) CSRR sensor-based image.

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2. G. Govind, N. K. Tiwari, K. K. Agrawal and M. J. Akhtar, "Microwave Subsurface Imaging of Composite Structures Using Complementary Split Ring Resonators," *IEEE Sensors J.*, **18**, 18, Sept., 2018, pp. 7442-7449.