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Breaking the Diffraction Limit Manifold Using Specially Designed Metamaterial Split Ring Resonator

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Abstract—A novel and efficient method to overcome the barriers of conventional diffraction limit using a specially designed metamaterial Split Ring Resonator (SRR) structure as an imaging sensor at microwave frequency is proposed. The topology of the proposed sensor is ingeniously designed to identify imaging objects having dimensions much less than the interacting wavelength λ. The split gap field region of the conventional SRR, used as the sensing region of the imaging sensor, is modified for enhancing the resolution capacity, by slightly raising the split region of the outer ring structure perpendicular to the plane of the resonator (Projected Split Ring Resonator — PSRR) which will reduce the area of the sensing region of the SRR probe considerably. The isolation of the structural parts of the SRR other than projected split region helps in using the localized evanescent field at the split region of the PSRR for imaging of minute objects having dimension ranges up to 0.0001λ by precisely choosing the split gap. The required projection height of the split region and the possible resolution limits of the PSRR sensor probe are evaluated by simulation. Experimental 2-dimensional sub-wavelength images obtained for various dielectric objects using a typical PSRR test probe having resolution capability up to 0.01λ are also presented.

1. INTRODUCTION

Microwave based imaging techniques have been used for various sensor applications due to their non-destructive and non-invasive nature. Different types of metamaterial structural units and surfaces have been widely proposed recently for various modes of sensors [1–6]. Near field microwave probes can confine evanescent fields to regions having dimensions much smaller than operating wavelength, and hence they are able to resolve sub-wavelength features and thereby provide a resolution much higher than the classical Abbe limit [7, 8]. Earlier microwave near-field techniques mainly focused on a topology of microstrip line resonator terminated with a sharpened tip or a small loop and were reported to achieve a better resolution in dielectrics [9–11]. With sophisticated experimental setup, they were able to map material non-uniformities by carefully designed conductivity mapping technique [12]. Later, the possibility of making a perfect lens using metamaterial structures and thereby achieving a resolution higher than classical diffraction limit was theoretically proposed in the pioneering work of Pendry [13]. In that work, the concept of a negative refractive index material capable of completely restoring both propagating and evanescent waves in phase and amplitude resulting in the recovery of sub-wavelength features leading to a perfect imaging of the sample was presented. Microwave near-field probe made of single rectangular Split Ring Resonator (SRR), and an electrically small rectangular loop was designed by Ren et al. which provided a resolution of $\lambda/74$ based on sub-surface detection technique [8]. For the purpose of obtaining super resolution imaging using metamaterial structures, specially designed

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