# Effect of Eccentricity in Microwave Imaging of Multiple Composite Pipes

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## ABSTRACT

The use of non-metallic composites is growing fast in various industries such as oil and gas sectors mainly in the form of pipes. Such pipes can be damaged which may cause major production failures or environmental mishaps. Traditional non-destructive testing (NDT) methods are mainly used for metallic pipes. Microwave imaging has been proposed as a promising approach for examination of multi-layer non-metallic pipes. Here, we demonstrate that the effect of undesired eccentricity of the multiple pipes can impose additional imaging errors. For the first time, we study this effect via simulations contaminated with artificial noise.

## BACKGROUND/INTRODUCTION

Non-metallic pipes and composite components are replacing metallic pipes throughout different industries due to advantages such as durability, low cost, lightweight, resistance to corrosion, etc. With the growing demand for these materials, the use of proper NDT techniques is necessary for material integrity inspections.

In general, traditional NDT methods such as ultrasonic testing [1,2], eddy current, and magnetic flux leakage have been widely applied for inspections of metallic components. However, these NDT methods cannot successfully fulfill the demand for testing certain materials and components such as non-metallic composite pipes.

Thus, to fulfill the growing demand for NDT on non-metallic materials, microwave measurement techniques have been proposed [3,4]. The usage of microwave imaging helps detecting defects, cracks, holes, and more in such components.

Near-field holographic imaging has been extended to inspection of multi-layer concentric non-metallic pipes [5,6]. Here, we study the performance of the near-field holographic imaging of double pipes with different eccentricity values, i.e., the centers of the two pipes are not perfectly aligned. We consider this factor for the first time and we use a quantitative measure, called reconstruction error (RE), to evaluate the degradation of the images of the defects on the inner and outer pipes of a double-pipe configuration due to various eccentricity values.

## METHODS

Approximation of the imaging system with a linear system:

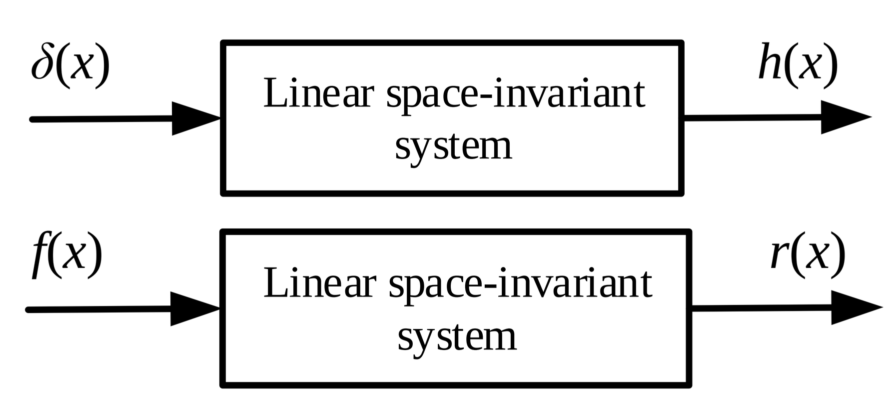


**Fig.1.** Block diagram of linear systems.

response for an unknown: $r(x) \approx f(x) * h(x)$

unknown function: $f(x) = k_s^2(x) - k_b^2(x)$

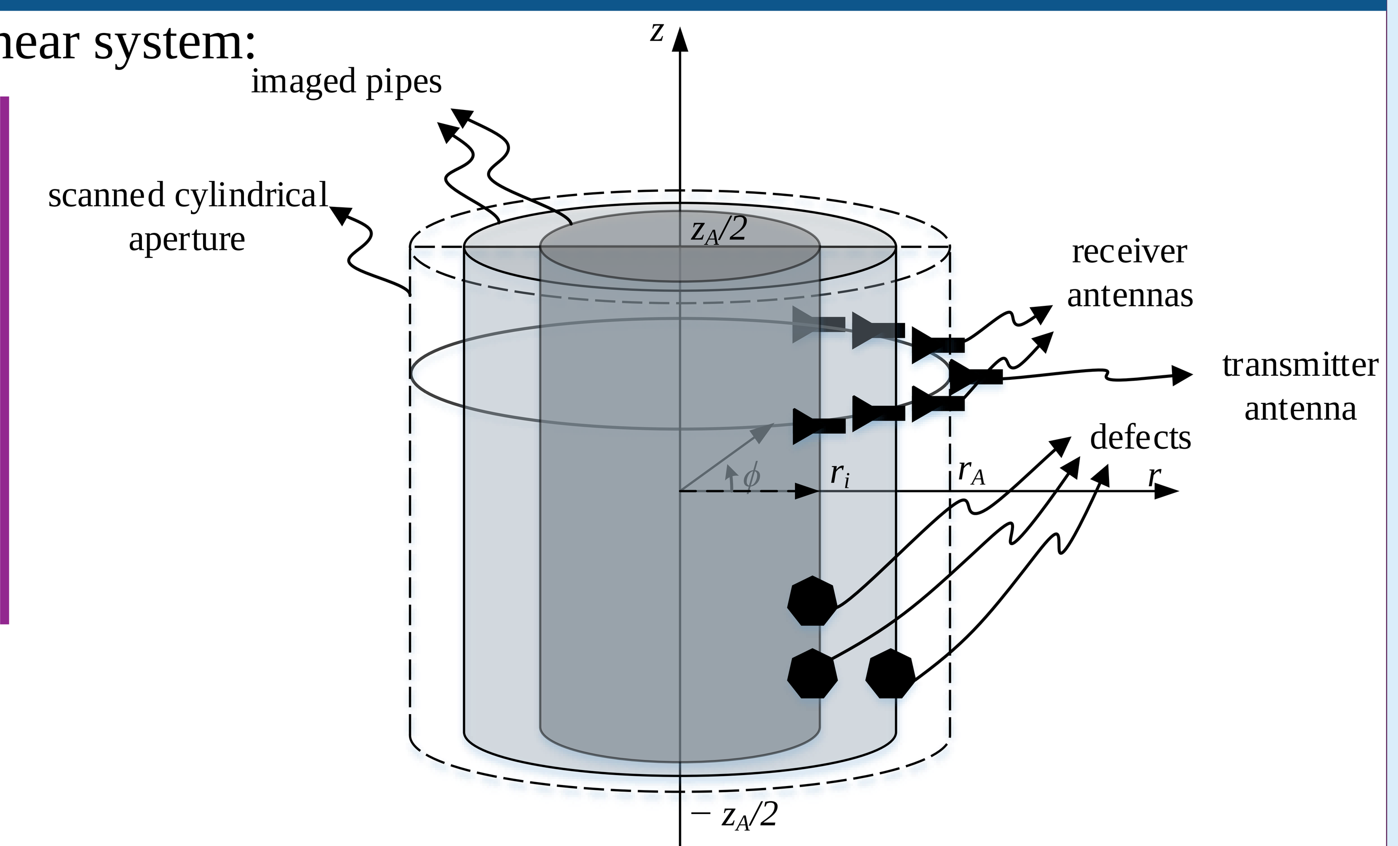


**Fig.2.** Illustration of the microwave imaging setup.

- Assumptions: linear imaging system, using one transmitter antenna and 12 receiver antennas, defects are infinite along the *z* axis
- Measure point-spread functions (PSFs) by putting small defects one at a time at the origin for each pipe
- Measure the responses of the defects over a circular aperture
- Use the theory of convolution and Fourier transform to construct systems of equations to be solved

## RESULTS

- Simulation study is performed using Altair FEKO software.
- Artificial noise of SNR = 20 dB is added for a realistic study.

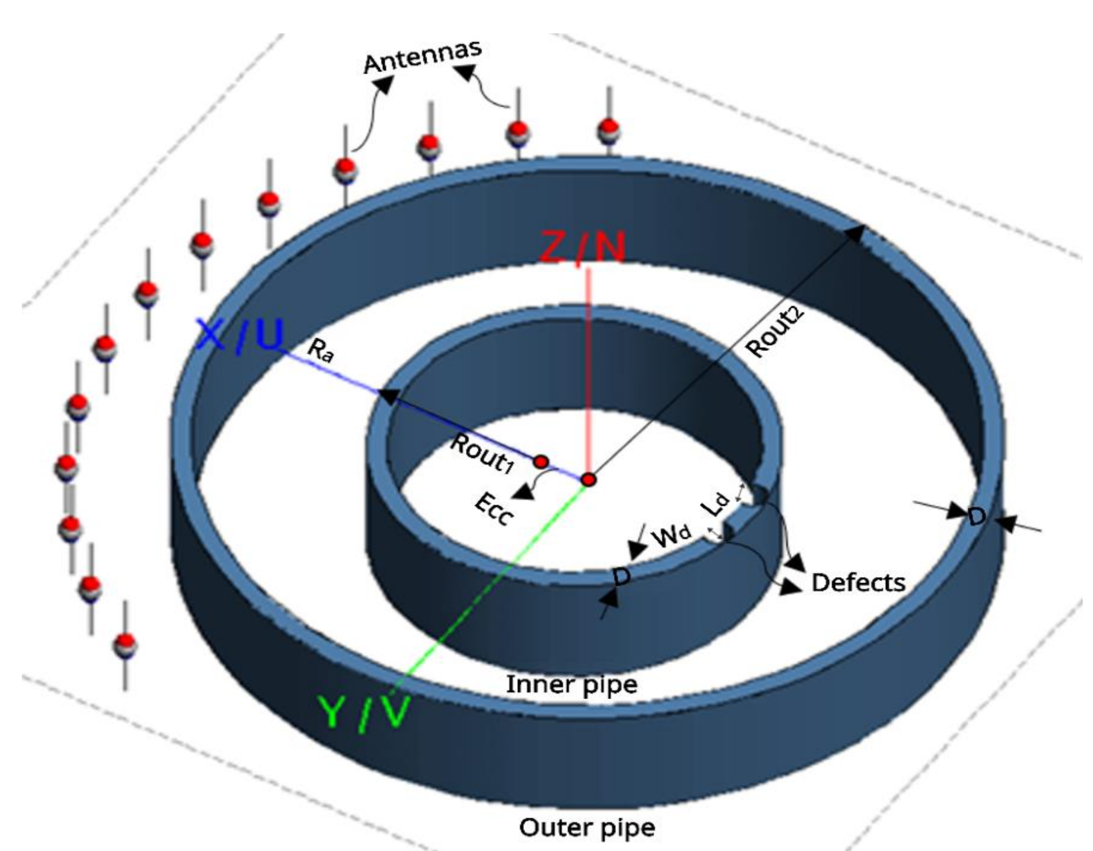


**Fig.3.** Simulation setup.

TABLE I. PARAMETER VALUES FOR THE SETUP

| $\Delta\phi_a$ | $R_a$ | $R_{out1}$ | $R_{out2}$ | $D$ | $L_d$ | $W_d$ | $\Delta\phi_d$ |
|---|---|---|---|---|---|---|---|
| 10° | 50 mm | 20 mm | 40 mm | 2 mm | 1.5*D* | 0.75*D* | 20° |

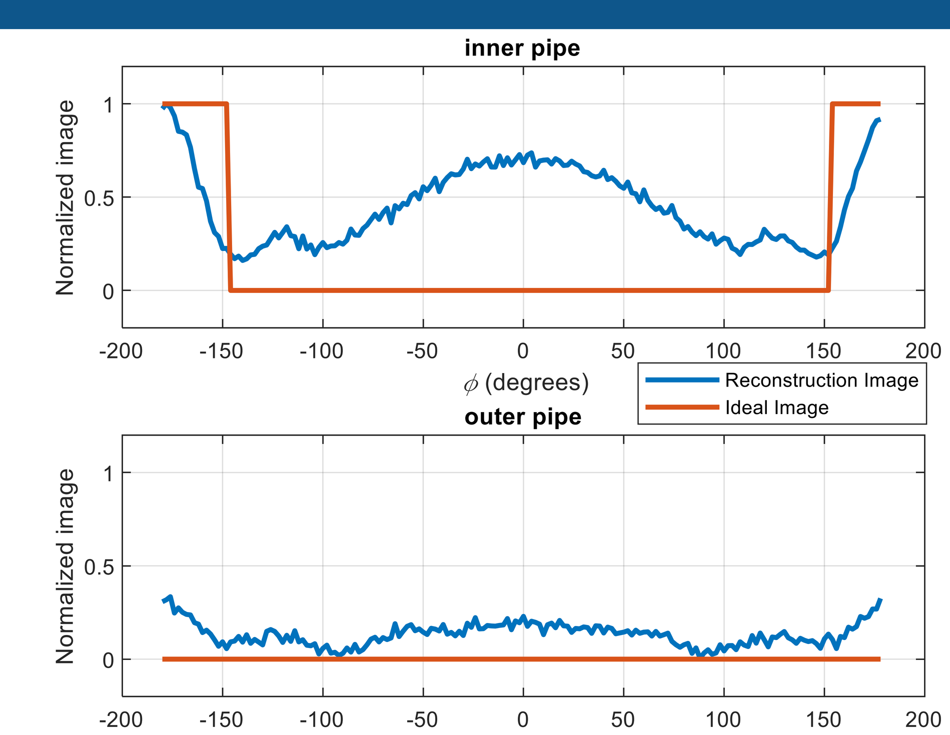


**Fig.4.** Reconstructed 1D image of inner pipe with ecc = 0.5mm.

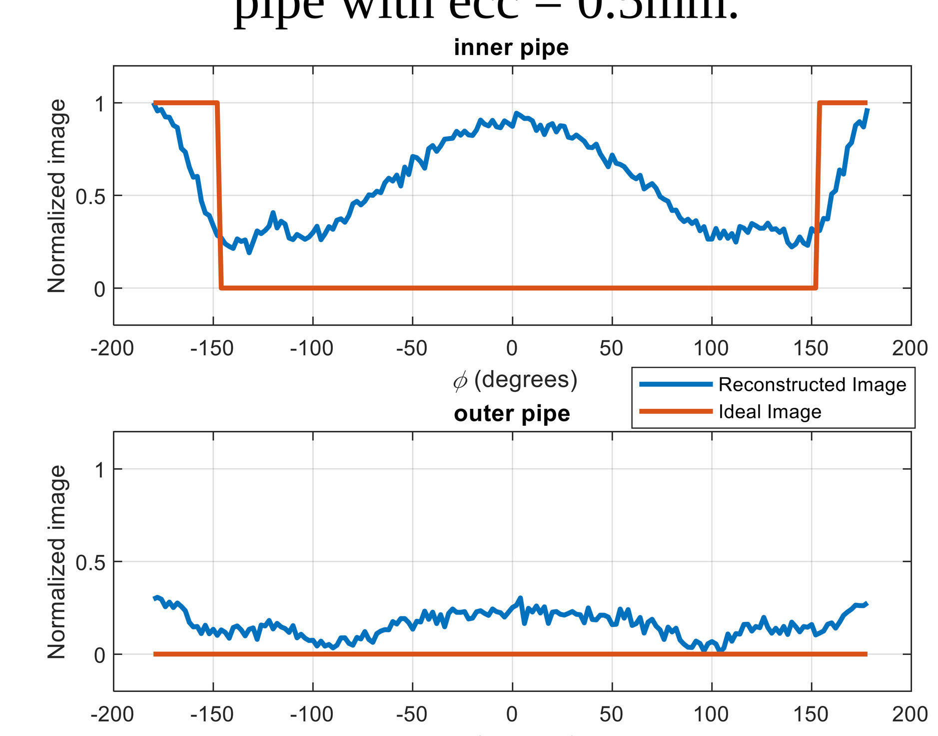


**Fig.5.** Reconstructed 1D image of inner pipe with ecc = 0.9mm.

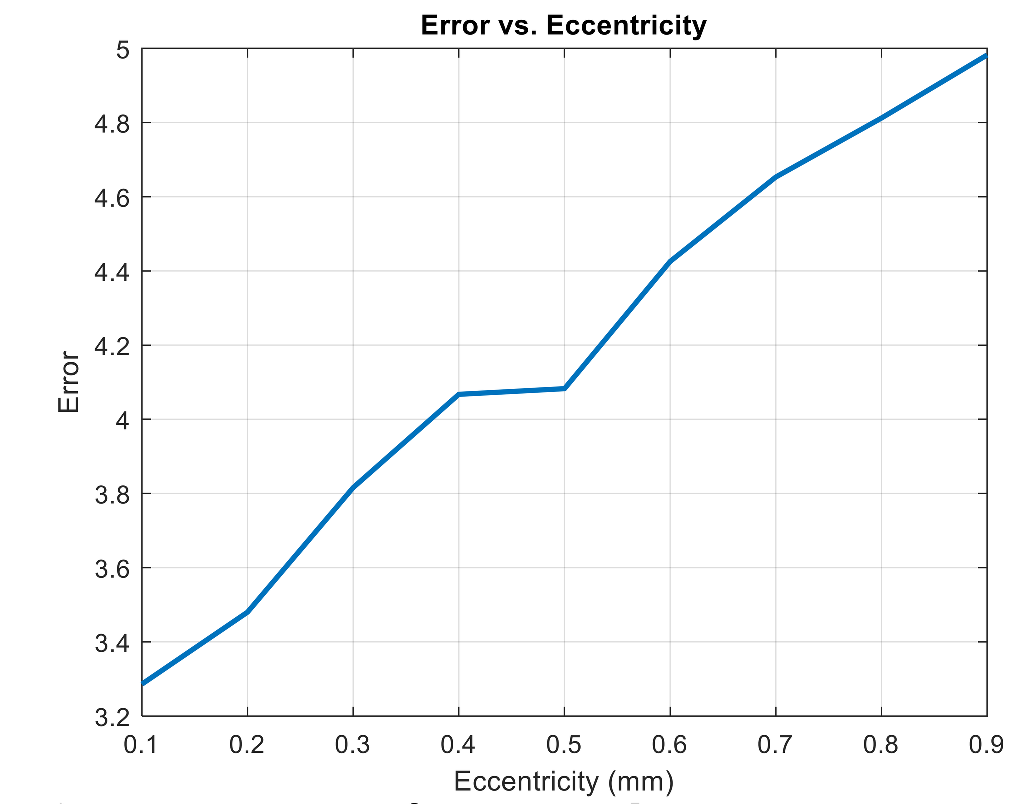


**Fig.6.** Variation of computed RE vs. eccentricity.

The result shows deterioration of reconstructed image as the eccentricity increase.

## CONCLUSION/FUTURE WORK

Overall, the results indicate that the quality of the reconstructed images is highly sensitive to non-zero eccentricity values such that even an eccentricity of 0.5 mm imposes image quality deteriorations. It was also observed that the images of the defects on the inner pipes would be affected more seriously by non-zero eccentricity effects.

Due to the serious adverse effects of eccentricity, we plan to further study and develop a technique to estimate the value of unknown eccentricity parameters and then reduce the effect of that on the reconstructed images.

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