Arbitrary Shaped Objects Detection and Reconstruction through Overset Grid Generation Method with B_2-spline Interpolation in Forward-Backward Time-Stepping Inverse Scattering

Bong S. Wee [1, 2], Kismet A. H. Ping [1], Shafrida Sahrani [1], and Toshifumi Moriyama [3]

[1] Applied Electromagnetic Research Group, Department of Electrical and Electronic Engineering
Faculty of Engineering, Universiti Malaysia Sarawak, Kota Samarahan, 94300, Malaysia
bongsw@pmu.edu.my, hpkismet@unimas.my, sshafrida@unimas.my

[2] Department of Electrical Engineering
Politeknik Mukah, Mukah, 96400, Malaysia
bongsw@pmu.edu.my

[3] Department of Electrical and Electronic Engineering, Graduate School of Engineering
Nagasaki University 1-14 Bunkyo-machi, Nagasaki, 852-8521, Japan
t-moriya@nagasaki-u.ac.jp

Abstract ─ Finite-Difference Time-Domain (FDTD) method is a simple and powerful tool used to solve electromagnetic (EM) problems. However, the drawbacks of FDTD method are difficult to model the curved boundaries and small features due to its restriction to inherent orthogonal grids. We have previously proposed that the B_2-spline or biquadratic spline interpolation technique for Overset Grid Generation and Finite-Difference Time-Domain (OGG-FDTD) method be utilised to overcome the limitations of FDTD method. This proposed method has the ability to accurately measure a scattered field around an unknown object. In this paper, the OGG-FDTD method with B_2-spline interpolation in Forward-Backward Time-Stepping (FBTS) inverse scattering technique was proposed for the detection and reconstruction of arbitrary shaped objects in Case A and malignant breast tumour detection in Case B. The results showed that the Mean Square Error (MSE) of reconstructed dielectric profiles by using the proposed method has achieved significantly lower values than the FDTD method in FBTS. In Case A, the accuracy difference between the two methods was 26.67% for relative permittivity and 27.63% for conductivity, respectively. In Case B, it was found that the implementation of the proposed method increased the accuracy of reconstructed the relative permittivity image by 50.54%, and conductivity by 74.42% as compared to the FDTD method in FBTS technique. Furthermore, the values of normalised error function for the proposed method were also lower than the FDTD method in FBTS. Hence, it is proven that this numerical method can provide clearer and better reconstructed images to improve the quality of retrieve the dielectric profiles of the investigation area.

Index Terms ─ B_2-spline interpolation, buried object detection, inverse scattering problem, overset grid generation method.

I. INTRODUCTION

Microwave tomography is the new technology which evaluates buried or embedded objects in a medium by using EM waves. The main applications of microwave tomography are ground-penetrating radar [1-3], buried object detection applications in remote sensing [4-6], non-destructive evaluation [7-9], and medical diagnostic for biomedical engineering [10-13]. Microwave imaging technique (MWT) for non-destructive evaluation utilises frequency-domain [14] or time-domain [15] to solve the electromagnetic (EM) scattering problems. The EM scattering problems can be classified into two, which are direct and inverse scattering problems, respectively. The inverse scattering problem is the problem of determining characteristics of an unknown objects from the measurement data of a scattered field based on the actual objects detected [16].

Several methods have been reported in literature for solving the inverse scattering problem such as Bojarski-Lewis method [17], Linear Sampling method [18], and Lagrange Multipliers method [19]. However, those methods have some limitations such as instability, fails to estimate the target support for certain frequencies, and needed a large number of data for images reconstruction. Therefore, the Forward-Backward Time-Stepping (FBTS)

Submitted On: February 7, 2019
Accepted On: October 23, 2019