Jurnal Kejuruteraan 35(4) 2023: 901-912
https://doi.org/10.17576/jkukm-2023-35(4)-12

An Efficient of Overlapping Grid Method with Scattering Technique in Time Domain for Numerical Modeling

Bong Siaw Wee[a*], Kismet Hong Ping[b] & Shafrida Sahrani[c]

[a]*Department of Electrical Engineering, Politeknik Mukah, 96400 Mukah, Sarawak, Malaysia*
[b]*Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia, Malaysia*
[c]*Institute of IR4.0, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Malaysia*

**Corresponding author: shaweibong2016@gmail.com*

Received 6 October 2022, Received in revised form 18 January 2022
Accepted 18 February 2023, Available online 30 July 2023

ABSTRACT

An Overlapping Grid Method (OGM) with Biquadratic Spline Interpolation in scattering technique was developed to solve the direct and inverse scattering issues. A two-dimensional (2D) numerical image model was used to analyze the accuracy of the proposed method in a direct scattering process. It was discovered that when the sub-grid, Δ_{x_s} increased, the absolute error for the electric field amplitude will also increase. The results also discovered that as the grid size ratio increased, the absolute error of the amplitude E_Z will also increase. The findings show that smaller grid spacing and a finer grid size can produce more accurate results. The Overlapping Grid Method (OGM) with Biquadratic Spline Interpolation was expanded by incorporating with Forward-Backward Time Stepping (FBTS) technique to solve inverse scattering issues. Homogenous embedded objects with a square and circular shape are used to validate the efficiency of the proposed method. The findings showed that the proposed numerical method could detect and reconstruct embedded objects in different shapes. The efficiency of the proposed method was examined by Mean Square Error (MSE) and normalizing the functional error. The findings revealed that the MSE of dielectric profiles for the proposed method were lower than the FDTD method in FBTS. The relative permittivity and conductivity profile differed by 27.06% and 20%, respectively. Hence, it was proven that the proposed method successfully solved a known drawback to the FDTD method and produced more accurate and efficient results.

Keywords: Overlapping Grid Method; Spline Interpolation; scattering technique; object reconstruction

INTRODUCTION

Microwave imaging attracted significant interest among researchers due to its unique features as an excellent diagnostic tool or as a practical resource in several areas. For example, the microwave is primarily used for ground-penetrating radar (Catapano, Gennarelli, Ludeno & Soldovieri 2019; Zhou, Chen, Lyu, & Chen 2022), geophysical exploration (Rosa, Bergmann, & Teixeira, 2020), buried object detection (Wee 2020), and medical diagnostic (Dachena et al. 2020; Stancliff 2017; Salleh et al. 2020).

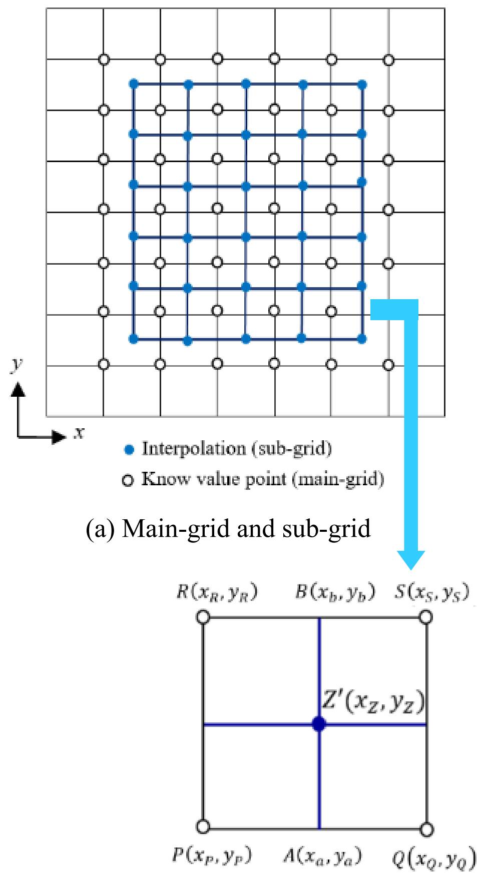
Active microwave imaging is a wave-based non-invasive imaging method involving two principles; tomographic and confocal radar. Microwave tomography is divided into two categories: qualitative and quantitative imaging. The qualitative microwave imaging method generates a qualitative profile, such as a reflectivity feature or a qualitative picture representing a hidden item. The quantitative imaging approach is used to obtain the electrical and magnetic properties distribution to obtain the geometrical parameters of an imaged object. The spatial distribution of the complex permittivity is calculated using the transmitted (incident) and received (scattered) fields (Nikolova 2011).

The FDTD algorithm is a simple and effective way of addressing Electromagnetic (EM) interaction problems (Baek, Kim, & Jung 2018; Rahman & Rather 2020). Moreover, it can analyse a wide range of frequencies without using additional computer resources. Therefore, the time-domain inversion method is suitable for improving the detection and reconstruction of embedded objects (Narayan 2017; Okada 2014; Schneide 2016). However, this algorithm is limited to intrinsic orthogonal grids due to it is based on a Cartesian coordinate system. Hence, it is challenging to build the meshes for modelling curved borders and microscopic structures (E. Jiménez-Mejía, & Herrera-Murcia, J. 2015; Nilavalan 2002). Several approaches for improving the efficiency of the FDTD method have been published in the literature, including non-uniform (E. Jiménez-Mejía & Herrera-Murcia 2015), sub-gridding (Cabello et al. 2017), and sub-cell algorithm (Navarro et al. 2021). Nevertheless, those approaches still have some disadvantages, such as requiring a long calculation time and additional memory, as well as the Courant-Friedrichs-Lewy (CFL) stability requirement restricting time step or cell size (De Moura & Kubrusly 2013).

Therefore, an Overlapping Grid Method (OGM) with Biquadratic Spline Interpolation in Forward-Backward Time Stepping (FBTS) Technique was proposed and developed in this paper. In order to calculate the dispersed fields for an embedded object, two-dimensional (2D) numerical simulations for electromagnetic (EM) field analysis in various ratios for the sub-grid were carried out. Then, the proposed method incorporated the FBTS inverse scattering technique for detecting and reconstructing embedded objects with different shapes. Finally, the efficiency of the proposed method was examined by Mean Square Error (MSE) and by normalizing the functional error.

METHOD

Overlapping Grid Method (OGM) with Biquadratic Spline Interpolation



(a) Main-grid and sub-grid

(b) 4-point Biquadratic Spline interpolation

FIGURE 1. Overlapping Grid Method