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Comparison of two analytic approaches for the Prediction of EMP Coupling to Multiconductor Transmission Lines

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***Abstract*—The distributed analytical representation and iterative technique (DARIT) Jacobi iteration (Jacobi-DARIT-field) method has been proposed for the calculation of electromagnetic pulse (EMP) radiated field coupling to multiconductor transmission lines (MTLs). More recently, based on the Jacobi-DARIT-field method, the Seidel-DARIT-field method (the DARIT-field method which adopted the Gauss-Seidel Iteration Algorithm) has been developed as well. This paper compares these two methods from the points of view of the accuracy and convergence speed, etc.**

Keywords-analytical solution; Gauss-Seidel iteration; electromagnetic pulse; iterative method; transient analysis; transmission line modeling; waveform relaxation.

I. INTRODUCTION

To predict the effects of EMP coupling to multiconductor transmission lines (MTLs), many researchers have proposed the method of modeling of EMP coupling to MTLs [1]-[2]. In 2013, Y.-Z. Xie, J. Guo and F. Canavero proposed an approach using the distributed analytical representation and iterative technique (DARIT) method which is based on the Waveform Relaxation and Transverse Partitioning (WR-TP) for the response computation between multiconductor transmission lines illuminated by the incident EMP field [1]. Hereafter, this algorithm is named Jacobi iterative method of DARIT-field (Jacobi-DARIT-field). The algorithm can avoid the need for inversing the matrix when solving MTLs equations and leading to high computational efficiency.

Based on the Jacobi-DARIT-field method, another DARIT-field method employing the Gauss-Seidel Iteration Algorithm (Seidel-DARIT-field) has been developed [2]. This paper provides comparison result between these two methods.

II. OUTLINE OF THE TWO METHODS

By applying waveform relaxation techniques [2] to the Telegrapher's equations, we obtain a recursive set of decoupled differential equations in:

$$\frac{dv_i^{(r+1)}(x,s)}{dx} + z'_{ii}(\omega)i_i^{(r+1)}(x) = -\sum_{j=1,j\neq i}^{N} z'_{ij}i_j^{(r+1)}(x,s) + V'_i(x,s)$$
$$\frac{di_i^{(r+1)}(x,s)}{dx} + y'_{ii}(\omega)v_i^{(r+1)}(x) = -\sum_{j=1,j\neq i}^{N} y'_{ij}v_j^{(r+1)}(x,s) + I'_i(x,s) \quad (1)$$

The algorithm of iteration 1 of the two methods is the same, it only takes the illuminating EMP wave into account. At iteration 2, each line is excited not only by the incoming EMP wave but also by the coupling effects of all the other adjacent lines, this is where the main difference between the two methods happen:

- Jacobi-DARIT-field method handles every line parallelly and updating the state of lines based on the state of lines at the previous iteration.
- Seidel-DARIT-field method handles every line one by one. It update the state of *n*th line based on the state of line 1~n-1 at the present iteration and line n+1~N at the previous iteration.

The details of the two methods are proposed in [1], [2].

III. VALIDATION OF THE PROPOSED ALGORITHM

A validation example is proposed to give a comparison between the two methods. In the example, a symmetrical and lossy three wires with the length of 7.5 cm, height of 2 mm and diameter of 0.2 mm which above the lossy ground is considered. The loads on both sides are 50 Ω. There are three cases in this example with the distance between wires of 6.76 mm, 2.14 mm and 1.50 mm to make the coupling factors (the expression of CF see [1]) equal to 0.05, 0.25 and 0.35, respectively. Fig. 1 shows the frequency response of wire #1 obtained with the two methods and with the conventional one (Chain Parameters Matrix method). The results of the relative errors ε after Iteration 3 and 4 of the two methods are presented in Table I. It can be seen that the results from iteration 3 of Seidel-DARIT-field are more convergent than them from iteration 4 of Jacobi-DARIT-field.

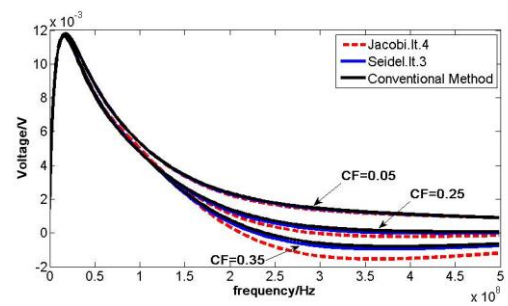

Figure 1. The far-end response of wire 1 with different coupling factors.

TABLE I. RELATIVE ERRORS OF THE EACH METHOD

CF	ε (%)		
	Jacobi.It.3	*Jacobi.It.4*	*Seidel.It.3*
0.05	0.049	0.029	0.012
0.25	0.330	0.198	0.095
0.35	1.000	0.925	0.385

V. CONCLUSION

The validation result shows that Seidel-DARIT-field method has a faster convergence speed than Jacobi-DARIT-field method. However, it is worthy to note that the current Seidel-DARIT-field method is not so convenient for the very large conductors case, which is still an open problem.

REFERENCES

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