Rigorous and Fast Computation of Modal Johns Responses

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A technique has been introduced for the analytical computation of impulse responses (Johns streams) of dispersive structures from frequency domain expressions. The procedure has been applied to generate modal Absorbing Boundary Conditions for a rectangular waveguide.

The procedure leads to a saving of one order of magnitude if compared to the generation of modal Johns matrices via simulation of a long section of waveguide.

Let us consider a parallel plate waveguide where only a TEM mode is present. We can discretize this structure with a mesh of TLM lines as shown in Fig. 1a.

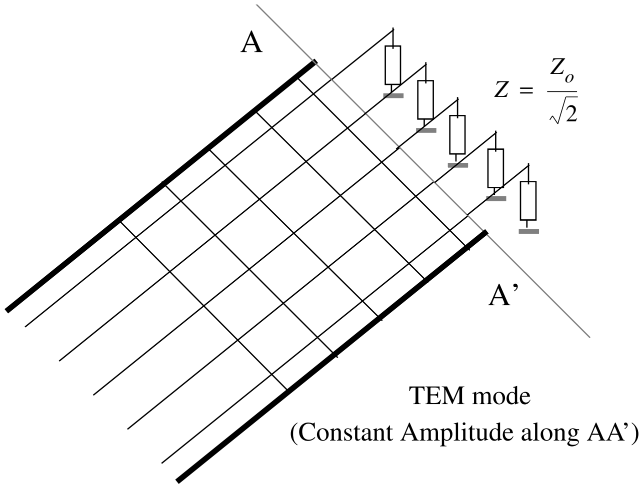

Fig. 1 a TLM Description of a parallel-plate waveguide using a 2-D mesh terminated at the reference plane AA'

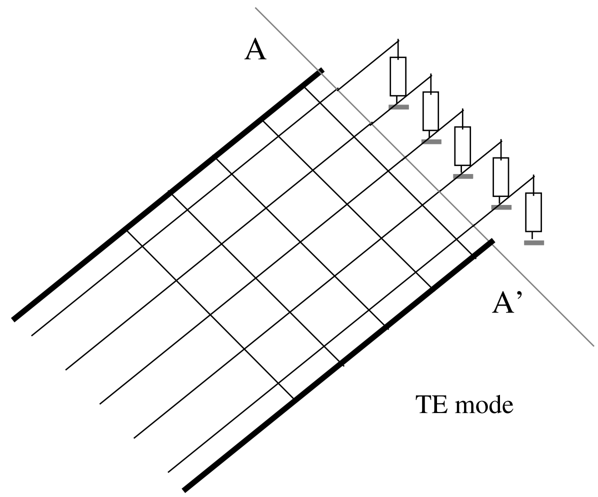

Fig. 1 b 2D-mesh with single mode propagation terminated with Z_{TE}

In order to provide matched conditions for the TEM wave propagating toward the reference plane AA', it is well know that it is necessary to terminate each TLM line with an impedance $Z_o/\sqrt{2}$, therefore obtaining an impulse reflection coefficient given by:

$$\Gamma_i = \frac{\frac{Z_o}{\sqrt{2}} - Z_o}{\frac{Z_o}{\sqrt{2}} + Z_o} = -0.17157$$

If we now consider a parallel plate waveguide with just a mode TE present as shown in Fig. 1b, we must terminate each TLM line with the impedance $Z_{TE}/\sqrt{2}$ in order to provide a match for the TE mode. This leads to the following impulse reflection coefficient in the frequency domain:

$$\Gamma_i(\omega) = \frac{\frac{Z_{TE}(\omega)}{\sqrt{2}} - Z_o}{\frac{Z_{TE}(\omega)}{\sqrt{2}} + Z_o}$$

To obtain the time domain impulse response $\Gamma_i(t)$ it is necessary to perform an inverse discrete Fourier transform (IDFT) of $\Gamma_i(\omega)$ after including the causality conditions.

It is interesting to note that the time domain impulse reflection coefficient can be separated into two components:

- an early response, responsible for the matching of the high frequency content of the impulse excitation. Such high frequencies travel in the waveguide like a plane wave and therefore are matched by nearly plane wave conditions.
- a late term response responsible for the matching of the frequency content of the impulse excitation just above cutoff. Such low frequencies travel in fact very slowly in the waveguide, giving raise to a long tail in the time domain.

The early and late terms of the modal Johns matrix for the fundamental mode of a waveguide are shown in Fig. 2 and compared with the corresponding Johns stream computed via TLM simulation of a long section of waveguide.

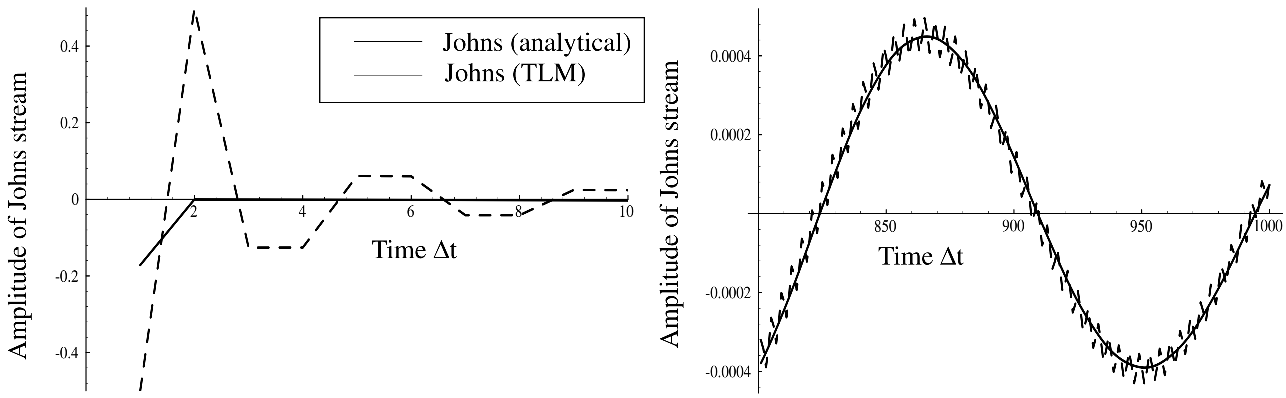

Fig. 2 Comparison of the early and late terms of the Johns matrix computed via TLM and via analytical formulation

Details of this project can be found in the following paper:

M. Mongiardo, M. Righi, R. Sorrentino, W.J.R. Hoefer, "Rigorous and fast computation of modal Johns responses" in Proceedings of the 2nd International Workshop, Berlin 1993