IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 13, Issue 5, Ver. I (Sep.-Oct. 2018), PP 13-17
www.iosrjournals.org

Determination of Characteristic Impedance of a Stripline

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Abstract:
The characteristic impedance of a stripline was evaluated using conventional methods like finite difference method, and method of moments by solving the Poisson's equation for the capacitance and hence finding Z0. To improve the computational efficiency we tried wavelets.

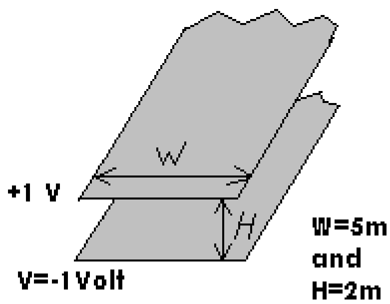
Date of Submission: 28-08-2018 Date of acceptance: 13-09-2018

I. Introduction:

To find the characteristic impedance of a strip transmission line using MATLAB.

PROBLEM STATEMENT:
The characteristic impedance of the infinitely long strip transmission line with the following dimensions has to be evaluated.
Please refer the figure given.

Problem Figure



SOLUTION:
An appropriate solution to the above problem can be found using the methods given below:

(I) FINITE DIFFERENCE METHOD
Although a simple method, it has considerable range of applications.
A finite difference solution to *Poisson's equation* proceeds in 3 steps:

(a) Dividing the solution grid into a grid of nodes.
(b) Approximating the differential equation and boundary condition by a set of linear algebraic equations (called difference equations).
(c) Solving this set of algebraic equations.

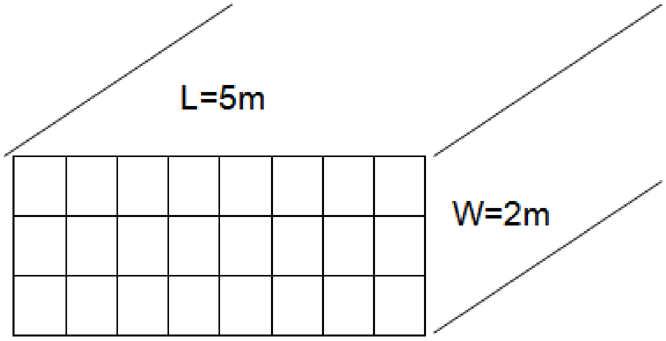
$V_{ij}=1/4(V_{i+1,j}+V_{i-1,j}+V_{i,j+1}+V_{i,j-1}+h^2\rho_s/\varepsilon_0)$ Where, h=mesh size (in m)=0.66 m

$\varepsilon=8.8548 \times 10^{-12}$ Farad/m

ρ_s=surface charge density (C/m^2)

If the solution region is charge free, then the above equation becomes

Laplace Equation.



Divide the solution area horizontally into 8 parts and vertically into 3 parts as shown in the above figure.
The surface charge density between the 2 plates is considered zero, whereas on the plates it is calculated using the equation

$$\boxed{\rho_s=\varepsilon_0[4V_{i,j}-\{V_{i+1,j}+V_{i-l,j}+V_{i,j+1}+V_{i,j-1}\}]/\,h^2}$$

The capacitance of the plates is calculated as follows

$$C = Q/Vd$$

$$= \sum_{i=1}^{N} \frac{\rho_i \Delta l}{Vd}$$

N=8 Δl=0.62m
Vd=difference voltage between strips
=2Volts

After finding C, the characteristic impedance can be calculated as follows:

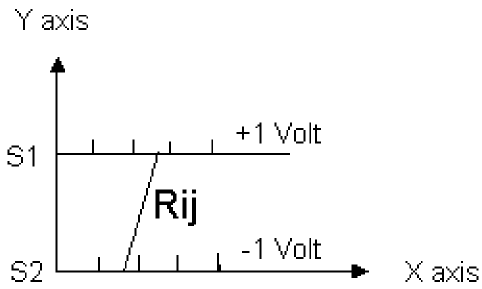
$$\boxed{Z_0=(\mu_0\varepsilon_0)^{½}/\,C} \text{ (ohms)}$$

(II) METHOD OF MOMENTS
The moment method has the advantage of being conceptually simple. Unlike the finite difference method, which is used for solving difference equations, this method is used for solving integral equations.
The solution to the Poisson's equation for the problem is given by:

$$Aij = -\frac{\Delta l \ln Rij}{2\pi Eo} \quad \text{when } i \neq j$$

$$Aij = \frac{-\Delta l}{2\pi Eo} \quad \ln\Delta l \ -1.5\ ;\ i=j$$

Where, Rij = the distance between the i^{th} and the j^{th} sub areas.

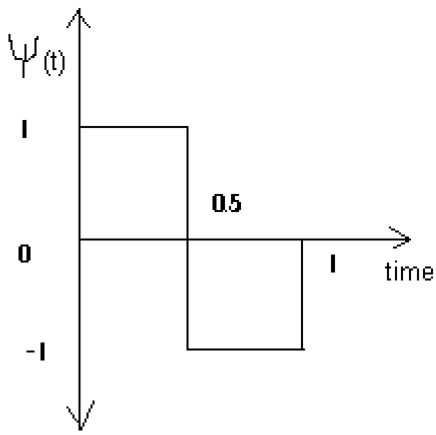


$$V_i = \sum_{j=1}^{2N} A_{ij} \rho_j$$

Representation of the above integral equation in matrix form is,
[V] = [A] [ρ]
So, [ρ] = $[A]^{-1}$ [V]
After calculating the [ρ] array we can calculate the characteristic impedance just like we did in case of finite difference method.
(III) BY WAVELET TRANSFORM Wavelet analysis allows researchers to isolate and manipulate specific types of patterns hidden in the data; in much the same way our eyes pick out trees in a forest, or our ears pick out a flute in the symphony.
In our analysis, we employ Haar wavelets to find out the characteristic impedance of the strip line.

The Haar wavelet function is defined as follows:

$$\psi(t) = \begin{cases} 1 ; 0 <= t <= 0.5 \\ -1; 0.5 <= t <= 1 \\ 0; \text{elsewhere} \end{cases}$$



The wavelet matrices are defined as follows:

$$W_3W_2W_1 = \begin{pmatrix} \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} \\ \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{pmatrix}.$$

Where W1 is the matrix of the Haar wavelet of the first level.

$$W_2 = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

where W2 is the matrix of the Haar wavelet of second level.

Therefore, the compound wavelet matrix is given by
W = W1*W2

$$W_3W_2W_1 = \begin{pmatrix} \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} \\ \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{pmatrix}.$$

As we use higher levels of wavelet matrix, the [A]' will become more sparse. This is the primary advantage of this method. Computations are eased due to the sparseness of [A]'

The governing equations are [V]' = [A]' [ρ]'
where [V]' = [W] [V]
[A]' = [W] [A] [W]' [ρ]' = [W] [ρ]
Therefore, [ρ]' = $[A]^{-1}$ [V]
[ρ] = $[W]^{t}$ [ρ]'

II. Result:

The characteristic impedance of the stripline was found using the above methods. Results are summarized in the table below:

Method used	Value of Capacitance (Farad/m)	Value of Z0 (in ohms)
Finite Difference	2.295×10^{-9}	1.45
Method of Moments	1.3×10^{-10}	23.9
Wavelet transform	1.12×10^{-10}	29.7

III. Conclusion:

The above results were simulated using MATLAB software. In case of wavelet transform method, we have used Haar wavelet. There is scope for work with other wavelets too. Also, using wavelets of higher levels can enhance the result.

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