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Reading Ansoft's Output Matrices

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Novice users of Ansoft EM modeling software may have difficulty determining how to read the matrix results provided by Ansoft's software. This paper provides helpful hints, by example, outlining the author's understanding concerning this matter.

The presented methods for reading the matrix are correct. However, peculiarities in the simulation process itself can lead to erroneous results. Particular problems have been observed when calculating even-mode inductance. When even-mode inductance is wrong, even-mode impedance and propagation delay will also be wrong.

For structures that concern the author, ways have usually been found to eliminate the even-mode problem. These solutions are beyond the scope of this tutorial.

Comments are solicited.

MATRIX CONVENTION

$$\begin{bmatrix} A_{1,1} & A_{1,2} & A_{1,3} \\ A_{2,1} & A_{2,2} & A_{2,3} \\ A_{3,1} & A_{3,2} & A_{3,3} \end{bmatrix}$$

ODD-MODE & EVEN MODE

For simplicity, consider the 2 x 2 matrix:

$$\begin{pmatrix} Z_{1,1} & Z_{1,2} \\ Z_{2,1} & Z_{2,2} \end{pmatrix}$$

Symmetrical Matrix

($Z_{1,1} = Z_{2,2}$ and $Z_{2,1} = Z_{1,2}$)

$$Z_{ODD} = Z_{1,1} - Z_{2,1}$$

$$Z_{EVEN} = Z_{1,1} + Z_{2,1}$$

Non-Symmetrical Matrix

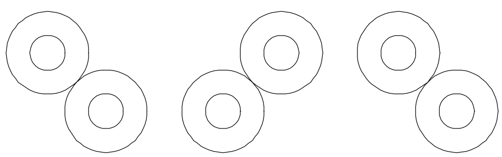
($Z_{1,1} \neq Z_{2,2}$ or $Z_{2,1} \neq Z_{1,2}$)

$$Z_{ODD} = \frac{Z_{1,1} + Z_{2,2}}{2} - \frac{Z_{2,1} + Z_{1,2}}{2}$$

$$Z_{EVEN} = \frac{Z_{1,1} + Z_{2,2}}{2} + \frac{Z_{2,1} + Z_{1,2}}{2}$$

EXAMPLE STRUCTURE

This structure is representative of twisted pair flat-cable (i.e.: Twist 'N' Flat®). Details have been changed to eliminate proprietary information. All calculations are based on this structure.



Wire diameter	10 mils
Dielectric diameter	23.5 mils
Rotation	± 45°
Permittivity	2.5
Boundary	± 2000 mil box

CALCULATE L, C, and Z (center two wires are set as "Signal", others are "Floating")
Floating some of the wires results in a simple 2 x 2 L and C matrices:

Inductance Matrix (Distributed H/m)

	wire3	wire4
wire3	1.2039E-006	9.0362E-007
wire4	9.0362E-007	1.2039E-006

Capacitance Matrix (Distributed F/m)

	wire3	wire4
wire3	3.6602E-011	-3.0833E-011
wire4	-3.0833E-011	3.6602E-011

Now we calculate L and C, using the simpler equations because we have symmetry:

$$\text{Lodd} := L_{3,3} - L_{4,3} \qquad \text{Codd} := C_{3,3} - C_{4,3}$$

$$\text{Lodd} = 3.003 \cdot 10^{-7} \qquad \text{Codd} = 67.435 \cdot 10^{-12}$$

We know that $Z_{odd} = \sqrt{\frac{L_{odd}}{C_{odd}}}$ $\qquad \sqrt{\frac{\text{Lodd}}{\text{Codd}}} = 66.73$

CALCULATE Z (all six wires are "Signal", yielding more complicated matrix)
This time, we will look at Ansoft's "Characteristic Impedance Matrix". We will calculate the impedance of each pair.

	wire1		wire2	wire3		wire4	wire5		wire6
wire1	337.25	Left	269.29	223.15		210.39	186.79		178.73
wire2	269.29	Pair	334.99	243.16		222.46	195.11		186.79
wire3	223.15		243.16	333.83	Center	267.23	222.46		210.39
wire4	210.39		222.46	267.23	Pair	333.83	243.16		223.15
wire5	186.79		195.11	222.46		243.16	334.99	Right	269.29
wire6	178.73		186.79	210.39		223.15	269.29	Pair	337.25

The 6 x 6 matrix is non-symmetrical, therefore we use the somewhat more complicated equation:

$Z_{1,1} := 337.25$ $Z_{2,1} := 269.29$
$Z_{1,2} := 269.29$ $Z_{2,2} := 334.99$

$$Z\_left\_pair := \left(\frac{Z_{1,1} + Z_{2,2}}{2}\right) - \left(\frac{Z_{2,1} + Z_{1,2}}{2}\right)$$

$Z_{3,3} := 333.83$ $Z_{4,3} := 267.23$
$Z_{3,4} := 267.23$ $Z_{4,4} := 333.83$

$$Z\_center := \left(\frac{Z_{3,3} + Z_{4,4}}{2}\right) - \left(\frac{Z_{4,3} + Z_{3,4}}{2}\right)$$

$Z_{5,5} := 334.99$ $Z_{6,5} := 269.29$
$Z_{5,6} := 269.29$ $Z_{6,6} := 337.25$

$$Z\_right\_pair := \left(\frac{Z_{5,5} + Z_{6,6}}{2}\right) - \left(\frac{Z_{6,5} + Z_{5,6}}{2}\right)$$

$Z\_left\_pair = 66.83$ $Z\_center = 66.6$ $Z\_right\_pair = 66.83$

Observe the center pair impedance here closely matches the first calculated impedance. Furthermore, the impedances of the two edge pairs are a bit higher than the center pair, as might be expected.