Pole-Expansion Approximation of Modal Impedances of a Cavity Resonator Containing a Multilayered Medium

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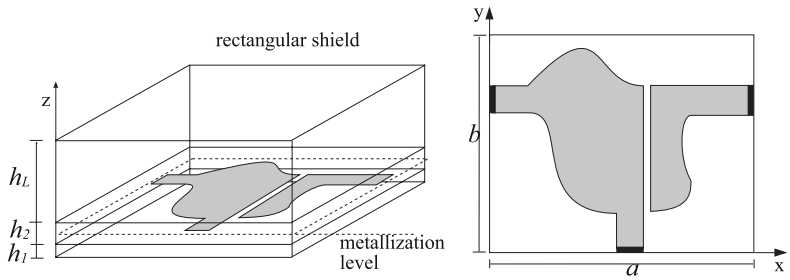
The program POLISTRATA



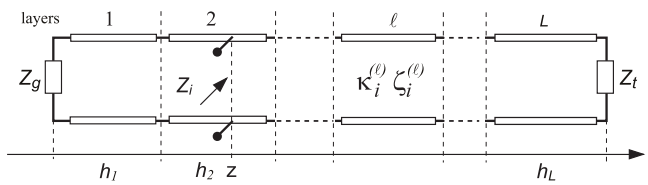
The program POLISTRATA computes all the quantities needed to approximate by a pole-expansion the modal impedances Z_i in a rectangular cavity, containing a layered medium. For each TE and TM mode, POLISTRATA computes all parameters appearing in the following expressions [1,2] valid for representing, in the complex $s = j\omega$ plane, the modal impedance seen at the metallization level:

$$\mathcal{Z}_i^{TE} \approx \mathcal{R}_i + s\mathcal{L}_i + \sum_C \frac{\beta_{i\nu}^2}{s+g_{i\nu}} + \sum_C \left(\frac{(\alpha'_{i\mu}+j\alpha''_{i\mu})^2}{s+r_{i\mu}-j\omega_{i\mu}} + \frac{(\alpha'_{i\mu}-j\alpha''_{i\mu})^2}{s+r_{i\mu}+j\omega_{i\mu}} \right) \quad (1)$$

$$\mathcal{Z}_i^{TM} \approx \mathcal{R}_i + s\mathcal{L}_i + \frac{\mathcal{S}_i}{s} + \sum_C \frac{\beta_{i\nu}^2}{s+g_{i\nu}} + \sum_C \left(\frac{(\alpha'_{i\mu}+j\alpha''_{i\mu})^2}{s+r_{i\mu}-j\omega_{i\mu}} + \frac{(\alpha'_{i\mu}-j\alpha''_{i\mu})^2}{s+r_{i\mu}+j\omega_{i\mu}} \right) \quad (2)$$

In equations above, i denotes the ordering index of the modes and corresponds to a couple of indices $\{p,q\}$ which, as usual, completely specify the structure of the mode (for instance the cut-off wavenumber of the i-th mode is $k_i = \sqrt{(p\pi/a)^2 + (q\pi/b)^2}$), furthermore $\sum_C$ denotes a summation that includes all the poles whose absolute value is smaller than $\zeta\, 2\pi f_{max}$, where f_{max} is the maximum frequency of interest and ζ is an "accuracy factor" sufficiently greater than one.

Equations (1,2) derive from the general theory [3] with the assumption that the metallization level is at an interface between two different layers or inside a lossless layer. For the computation of modal impedances the following equivalent circuit is used



1] G. Conciauro, P. Arcioni, M. Bressan, "Integral Equation and State Variables in the S-Domain Modeling of Passive Multilayered Components", 2003 IEEE MTT-S IMS, Philadelphia, June 8-13, 2003.

2] G. Conciauro, P. Arcioni, M. Bressan, "State Space – Integral Equation Method for the S-Domain Modeling of Planar Multilayered Circuits", submitted to IEEE Trans. on MTT.

3] G. Conciauro, M. Bressan, "Syngularity expansion of Mode Voltages and Currents in a Layered Anisotropic Dispersive Medium Included Between Two Ground Planes", IEEE Trans on MTT, vol. 47, n. 9, Sept. 1999.

The program POLISTRATA is a 32 bit Fortran Console Application running under Windows Operating System.

It reads data relative to the structure from a ASCII file, identified by the ".str" extension and it can work in two different ways: interactive and automatic. In the interactive mode it accepts the values of f_{max} , ζ , p and q from the console and it prints the results relative to Z_i^{TE} and Z_i^{TM} on the screen; of course if p or q is zero, the TM mode does not exist and the relative parameters are missing. In the automatic mode the code uses the values of f_{max} , ζ , p_{max} and q_{max} read from the .str file and it writes the results relative to all TE and TM modes with $p \leq p_{max}$ and $q \leq q_{max}$ in a new ascii file with the same name and the ".abox" extension.

The input file structure

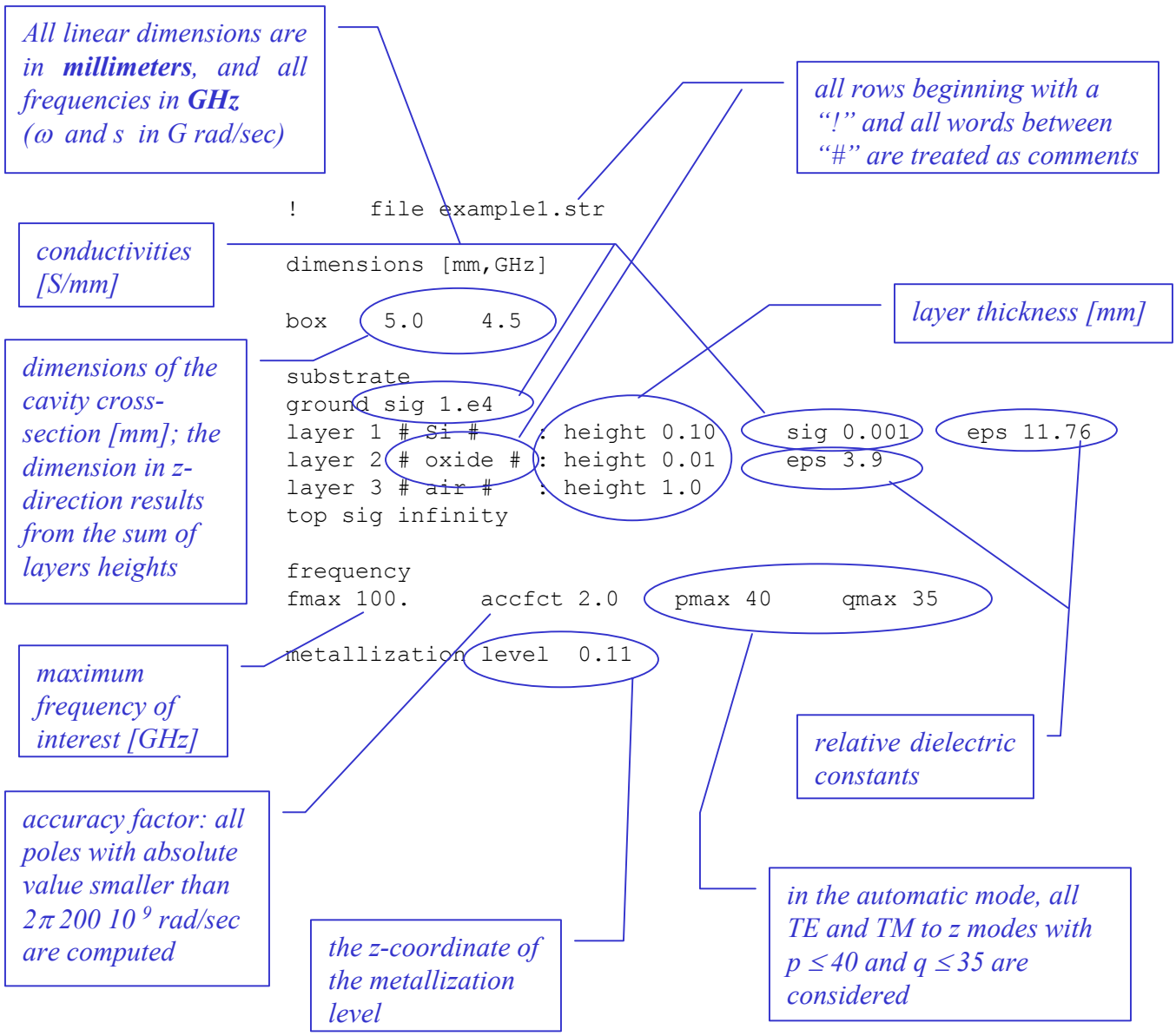
The input file contains the description of the cavity and of the media, together with the specification of the maximum frequency of interest and of the transverse modes to consider. Any numerical data is recognized by a keyword immediately preceding it; other keywords are used to identify other data or to separate different class of data.

Used keywords are:

dimensions	specifies the length and frequency units of all input data; output data units are congruent with the input ones. The recognized units are: **nm** (nanometer), **mu** (micrometer), **mm**, **cm**, **m**, and **Hz**, **kHz**, **MHz**, **GHz**, **THz**; default units are **m** and **Hz**. Note that length unit affects conductivity unit as well: for instance, if you choose **mm** to describe the structure, all numbers following the keyword **sig** are intended as **S/mm**;
box	indicates the dimensions of the cross section of the cavity (*a*,*b*);
substrate	begins the substrate description;
ground sig	specify the conductivity of the ground plane (z = 0), the default value is **sig *infinity***;
layer	begins data relative to a new layer; the order of layers is with increasing z; the maximum number of layers is 10;
height	indicate the thickness of the layer (*h*);
sig	indicate the conductivity of the layer (default: **sig** *0.0*)
eps	indicate the relative permittivity of the layer (default: **eps** *1.0*)
top sig	specify the conductivity of the top plane, (default **sig *infinity***);
frequency	begins data relative to the band of interest and to the modes to consider;

fmax	indicates the maximum frequency of interest:
accfct	indicates the "accuracy factor" ζ ($2\pi f_{max}\zeta$ is the radius of the circle in the complex s-plane where poles are to be found)
pmax	indicates the maximum index of the modes in x direction p_{max};
qmax	indicates the maximum index of the modes in y direction q_{max};
metallization level	indicates the z coordinate of the metallization level.

The example1.str file



Output from POLISTRATA

When POLISTRATA works in the interactive mode, it prints output data on the screen: data are self-explanatory. An example is as follows.

```
 Input file name: []example1
interactive/automatic computation (i/a) : [a]i

 maximum frequency of interest  [GHz] = [100.]
 accuracy factor                      = [2.]
 x-axis index                         = [1]
 y-axis index                         = [0]1
 transverse wavenumber         [1/mm] =   0.9392401E+00

  Z_TE

 R                [Ohm] =  -0.9285638E-01
 L         [ nanoHenry] =   0.2497097E-01

 No. of real poles      =   0

 No. of c.c. pole pairs =   2
  r ,       omega [ gigarad/sec]        alpha', alpha" [1/sqrt( nanoFarad)]
  0.8818665E+00    0.7693607E+03        0.1220597E+03   -0.2671506E+00
  0.2245384E+01    0.1208038E+04        0.1852582E+03    0.2770730E+00

  Z_TM

 R                [Ohm] =  -0.9359316E-01
 L         [ nanoHenry] =   0.2432639E-01
 S       [1/ nanoFarad] =   0.2544567E+03

 No. of real poles      =   1
  g [ gigarad/sec]                    beta**2 [1/ nanoFarad]
  0.9477796E+01                       0.8267358E+03

 No. of c.c. pole pairs =   3
  r ,       omega [ gigarad/sec]        alpha', alpha" [1/sqrt( nanoFarad)]
  0.1120352E+00    0.2597478E+03        0.1995139E+02   -0.9478782E-01
  0.9032564E+00    0.7573442E+03        0.1210586E+03   -0.2566857E+00
  0.2221838E+01    0.1210695E+04        0.1834240E+03    0.2659280E+00

continue/stop                    (c/s) ? [c]
```

When POLISTRATA works in the automatic mode, it writes all the parameters needed to approximate the modal impedances relative to all modes with $p \leq p_{max}$ and $q \leq q_{max}$ in the output file. The output data are grouped in a number of blocks, each reporting the parameters appearing in equation (1,2) relative to TE and TM modes for each considered couple of indices $\{p,q\}$; it is understood that in blocks where p or q is zero, parameters relative to TM mode are missing.

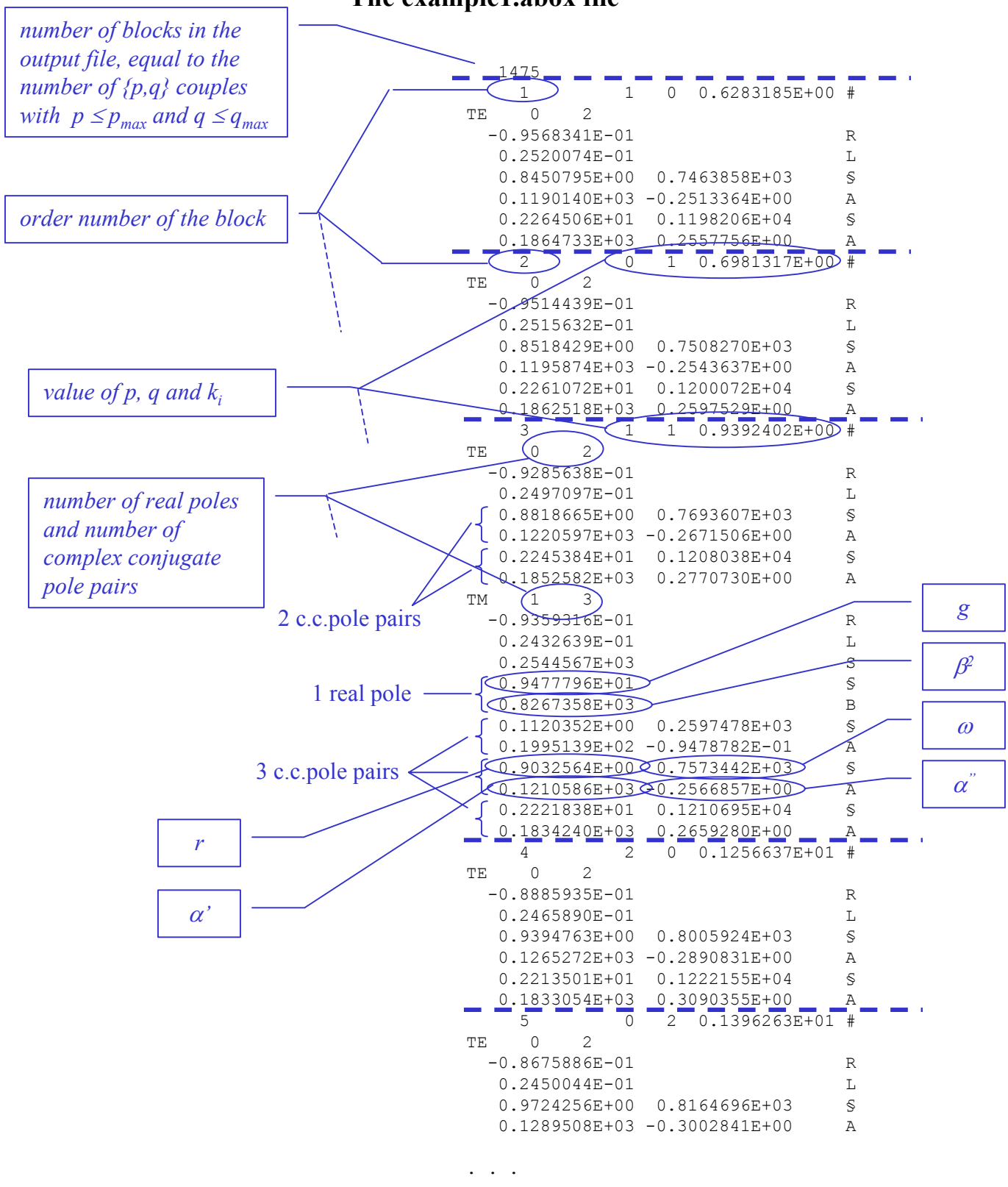
The number in the first line of the output file indicate the number of blocks, corresponding to the number of the $\{p,q\}$ couples with $p \leq p_{max}$ *and* $q \leq q_{max}$.

Each block begins with a row reporting its order number (index i), the values of p and q and the corresponding value of the cut-off wavenumber k_i; the row is market with the symbol #.

Each block, in turn, is divided into two sub-blocks, one reporting data relative to TE mode and one to TM mode. Each sub-block begins with the **TE** or **TM** symbol, followed by the number of the real poles and the number of the complex conjugate pole-pairs used to approximate the modal impedance. Following rows of the sub-block contain the values of R_i, L_i, and, only for TM modes, the value of S_i. These rows are marked by the symbols **R**, **L** and **S**, respectively. These data are followed by a number of couples of rows reporting the real pole-residue parameters $g_{i\nu}$ and $\beta_{i\nu}{}^2$ marked by the symbols **§** and **B**, respectively. Remaining rows of the sub-block report the complex conjugate pair pole-residue parameters $\{r_{i\mu}, \omega_{i\mu}\}$ and $\{\alpha_{i\mu}', \alpha_{i\mu}''\}$ marked by the symbols **§** and **A**, respectively.

An example of the output file structure is given in the following.

The example1.abox file



Limits of the code and known issues

The code is intended to be used for the analysis of boxed planar circuits on semiconducting substrates, for this reason the correct operation of the code and /or the accuracy of its results, when used in very different situations, are not assured. Actually the code uses a static memory management, so that in some cases a matrix bounds exceeding is possible. In particular this can happen when thick layers of very high conductivity are present, in these cases, in fact, the number of real poles can become very high.

The effects of the finite conductivity of the ground and top planes is taken into account by a perturbative approach, so that results may be meaningless if a very low conductivity of the screen planes is specified.

In some particular cases, especially in presence of symmetries, it may happen that two or more poles are so close to be numerically degenerate. This possibility is not controlled and wrong results may be given in this occurrence.

To avoid numerical underflow/overflow during the computation, it is recommended to choose the most appropriate units to describe the structure and to specify the frequency band of interest.