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[tlnomiva] : Transmission Line Nominal Values without Tolerance - from Cable Specifications and Technical Data Sheets : FLOSS for MS Windows

N.I. Yannopoulou, P.E. Zimourtopoulos *

Antennas Research Group, Austria

Abstract

[[tlnomiva] is a visual software application developed by the authors for a transmission line characterization from the user's point of view. The numerical computations are based on the precise formulation within the distributed circuit coefficients model of a transmission line, which was theoretically developed by the authors and published in a previous paper. The use of [tlnomiva] is fully demonstrated by an example for the popular RG 214 coaxial cable. This application is Free Libre Open Source Software and provides an option for more detailed figures by calling the executable of the freely distributed source [wgnuplot].

Keywords

transmission line, nominal value, propagation characteristics, circuit coefficients, floss

Introduction

A lot has been published for transmission lines in general, as well as, specifically for their use at high frequencies. The software application [tlnomiva], that is under development and illustrated here, is an intermediate step in the authors' recent effort to clarify a number of obscure or confusing points on this subject. It is intended to reveal the limits in the coexistence of precise formulas of transmission line theory with the available nominal values, usually without tolerance, which are given as cable specifications by established authorities or as data sheets from manufacturers.

The main formulas of [tlnomiva] were presented in [1], while the basic theory is cited in [2], thus only a small part of them is repeated here and just for the sake of completeness. The cut-off frequency has not been taken into account. The data for the presented examples are publicly available through internet.

[tlnomiva] is provided both as Free Libre Open Source Software and ready to install and use executable. It is developed in MS Visual Basic 6 in MS Windows XP 32 and in order to support a more sophisticated way of plotting data and functions it optionally uses the [wgnuplot] software, version 5.0 patchlevel 3 [3]. It is tested for compatibility with various MS Windows operating systems, up to W10-64.

To the best of the authors' knowledge, there is no available FLOSS for transmission lines, especially with a precise formulation one.

[tlnomiva]

Fig. 1 shows the main window of [tlnomiva] with the window of [About] open, while Fig. 2 contains all the menu items along with their submenu options numbered from 1 to 6. The application features can be divided according to their functionality in three groups:

(1) R, L, G, C intervals computation from the nominal values of: the attenuation factor α or accurately A in [dB/100m], the velocity factor vf and the characteristic impedance Z_0 and plotting with respect to frequency f [MHz], using working formulas from [1], [2],

(2) a new estimation of A, vf and Z_0 using the numerical results from the previous window for the R, L, G, C, intervals either directly or reading them from a previously saved file and plotting them and

(3) α, β, R_0, X_0 computation as functions of frequency considering R, L, G, C constant in a range of frequency and plotting them.

In these three groups the plot of all the involved quantities with respect to frequency is possible. Except of R, L, G, C distributed circuit coefficients and α, β, R_0, X_0 propagation characteristics there are included: the A attenuation factor, the vf velocity factor, the E, and H terms, the mαβ angles as the upper and lower limit of the $\dot{Z}_0$ phase angle and finally the ωL, ωC and f/vf. The used units are remain to all forms the same: R [mΩ/m], L [nH/m], G [μS/m], C [pF/m], f [MHz], α [Np/m], A [dB/100m], β [rad /m], R_0, X_0, Z_0 [Ω], mαβ [deg], ωL [mΩ/ m], ωC [μS/m], f/vf [MHz]. The [feet] option is disabled.

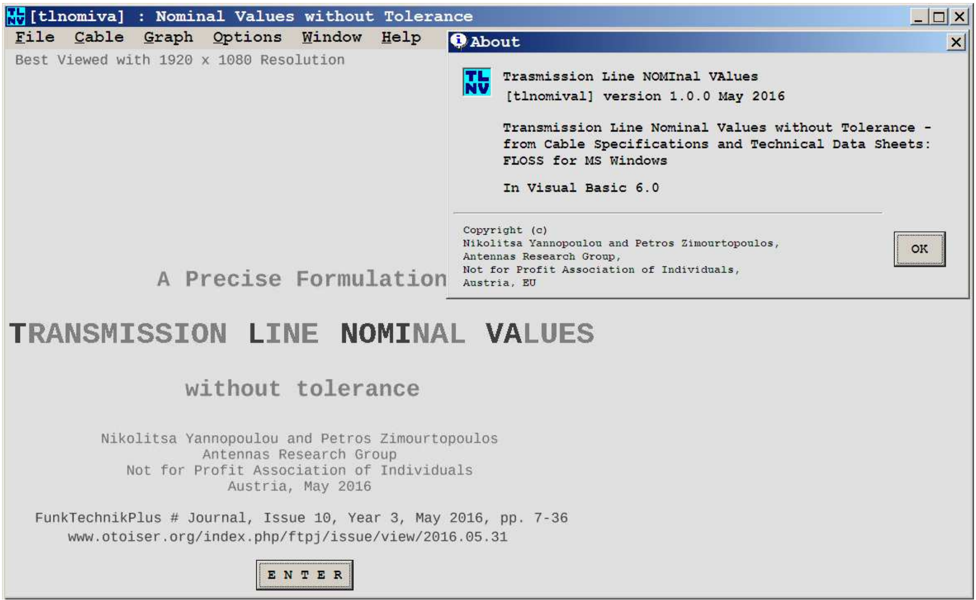


Fig. 1: [tlnomiva] : The main window

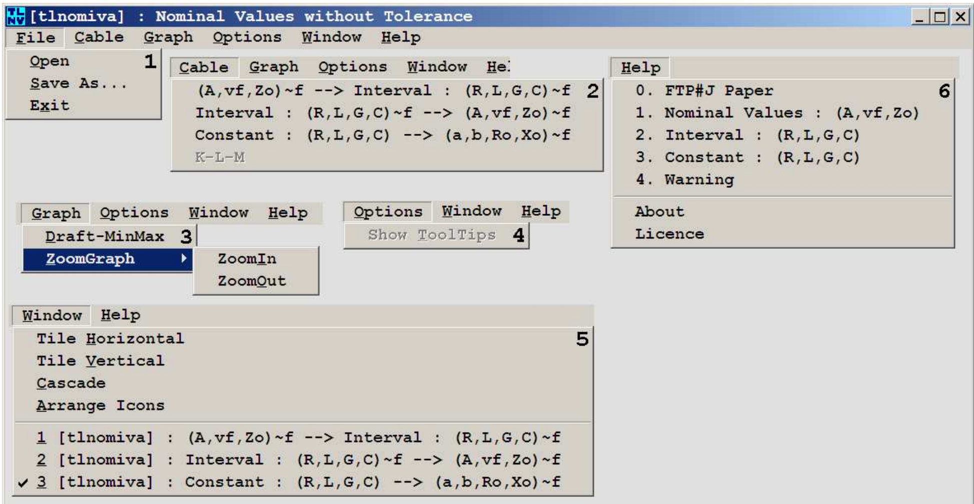


Fig. 2: Main window: The unfolded menu items

Working Formulas

The basic expressions between the nominal values of A, vf and Z_0 and the R, L, G, C distributed circuit coefficients of a line are given in [1] and repeated here as:

$$R = \alpha R_0 - \beta X_0 \qquad (1)$$

$$L = (\alpha X_0 + \beta R_0)/\omega \qquad (2)$$

$$G = (\alpha R_0 + \beta X_0)/Z_0^2 \qquad (3)$$

$$C = (-\alpha X_0 + \beta R_0)/(\omega\, Z_0^2) \qquad (4)$$

It is obvious that if the nominal value of Z_0 is substituted with R_0, then X_0 will be zero and the above expressions will be actually independent of frequency, a case that will be examined last. Thus, we have to consider Z_0, as it is usually given in data sheets of cables, as the amplitude of $\dot{Z}_0$. Then by using the standard relation

$$Z_0^2 = R_0^2 + X_0^2 \qquad (5)$$

where

$$R_0 = Z_0 \cos(z_0) \qquad (6)$$

$$X_0 = \pm Z_0 |\sin(z_0)| \qquad (7)$$

the above (1)-(4) become functions of the z_0 phase angle. Since:

i. the interval of z_0 is the open interval (π/4, π/4),

ii. the four quantities R, L, G, C do not have an extreme inside this interval. This results from the fact that the phase angle of $\dot{Z}_0$, which is the angle (z – y)/2, and of $\dot{\gamma}$, which is the angle (z + y)/2 [1], can not be equal inside this interval but only for the case of $y = 0$ which is impossible since $y \neq 0$ always,

we have to look for the two extreme values only at the ends of the open interval. Furthermore, since the four functions (1)-(4) are continuous with respect to z_0 in the above closed interval, the mentioned extremes will be the values of the continuous extension of these functions at the closed interval, at its ends. Three separated cases are distinguished:

$$\alpha < \beta : -\alpha/\beta < X_0/R_0 < \alpha/\beta \qquad (8)$$

$$\beta < \alpha : -\beta/\alpha < X_0/R_0 < \beta/\alpha \qquad (9)$$

$$\alpha = \beta : -1 < X_0/R_0 < 1 \qquad (10)$$

Tab. 1 contains the two extreme values for the four coefficients and for the H term if we consider that

$$H = \omega L\, G - \omega C\, R\ . \qquad (11)$$

Tab. 1: RLGC and H Open Intervals

	$\alpha < \beta$	$\alpha > \beta$	$\alpha = \beta$
R	$(0,\ \frac{2\alpha\beta}{\gamma}Z_0)$	$(\frac{\alpha^2-\beta^2}{\gamma}Z_0,\ \gamma Z_0)$	$(0,\ \gamma Z_0)$
L	$(\frac{\beta^2-\alpha^2}{\omega\gamma}Z_0,\ \frac{1}{\omega}\gamma Z_0)$	$(0,\ \frac{2\alpha\beta}{\omega\gamma}Z_0)$	$(0,\ \frac{1}{\omega}\gamma Z_0)$
G	$(0,\ \frac{2\alpha\beta}{\gamma Z_0})$	$(\frac{\alpha^2-\beta^2}{\gamma Z_0},\ \frac{\gamma}{Z_0})$	$(0,\ \frac{\gamma}{Z_0})$
C	$(\frac{\beta^2-\alpha^2}{\omega\gamma Z_0},\ \frac{\gamma}{\omega Z_0})$	$(0,\ \frac{2\alpha\beta}{\omega\gamma Z_0})$	$(0,\ \frac{\gamma}{\omega Z_0})$
H	$(-2\alpha\beta,\ +2\alpha\beta)$	$(-2\alpha\beta,\ +2\alpha\beta)$	$(-\gamma^2,\ +\gamma^2)$

The reverse relations of α, β, R_0 and X_0 from the RLGC values are also presented in [1] and repeated here as

$$\alpha = \frac{\sqrt{ZY + RG - X_L X_C}}{\sqrt{2}} \tag{12}$$

$$\beta = \frac{\sqrt{ZY - RG + X_L X_C}}{\sqrt{2}} \tag{13}$$

$$R_0 = \frac{\sqrt{ZY + RG + X_L X_C}}{\sqrt{2}\,Y} \tag{14}$$

$$X_0 = \operatorname{sgn}(LG - RC)\frac{\sqrt{ZY - RG - X_L X_C}}{\sqrt{2}\,Y} \tag{15}$$

where $X_L = \omega L$ and $X_C = \omega C$, or directly for Z_0 from its definition as

$$Z_0 = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{R^2 + X_L^2}{G^2 + X_C^2}} \tag{16}$$

RLGC Intervals from A, vf, Z_0 Nominal Values

The most usual case of available cable data concerns the attenuation factor per some length of cable, i.e. 100 [m] or 1000 [ft], denoted here as A, the velocity factor vf as a number between 0 and 1, and the characteristic impedance $\dot{Z}_0$ [Ω], or more accurately its amplitude Z_0, of the cable. Fig. 3 shows the first window of [tlnomiva] where it is possible from these data to calculate an interval for R_0, X_0, and R, L, G, C coefficients in a [Single] frequency. The user must first type the frequency in [MHz] and then the three data A, vf, Z_0. The application will evaluate all the other quantities through (1)-(11), and display them at the corresponding text boxes using the indicated units. The letter m stands for the minimum and the letter M for maximum for all the quantities.

The mαβ [°] is significant since it results the boundary angle inside which $\dot{Z}_0$ will be. This angle is defined by both –mαβ and +mαβ and depends on the relation between α and β as it is described in (8)-(10) above. Fig. 4 shows the three cases with the grayed horizontal and vertical thick lines to represent the values range of R_0, X_0.

When the option [Multiple] is selected a grid opens where the values for each frequency will be written and two more buttons appear at the right part of the window: [Add Values to Grid] and [Estimation]. The user must give the first and last frequency. Then type each frequency at the text box above and the corresponding A, vf,Z_0 as in [Single] option. By pressing the [Add Values to Grid] button all the calculated values are transferred to a grid line, as it is shown in Fig. 5. In any time it is possible to select from the [File] menu the [Save As] item and save these data to a text file for later use.

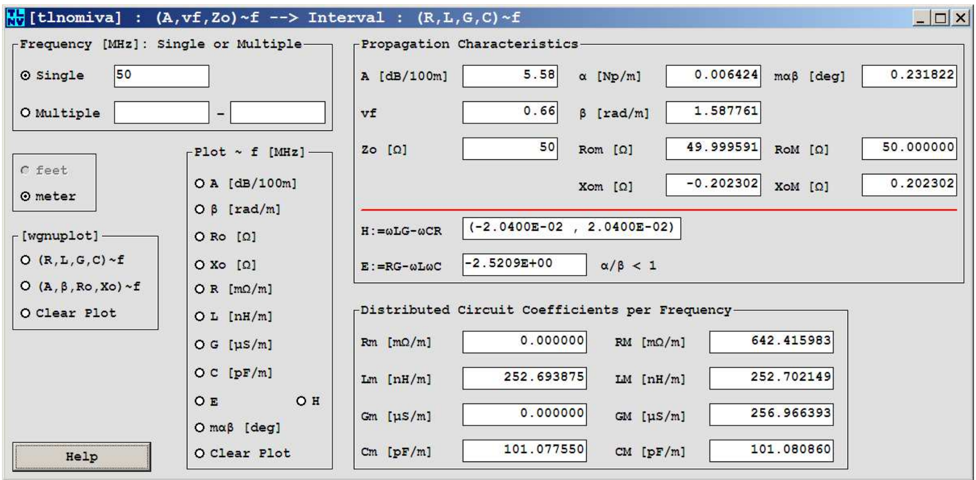


Fig. 3: [(A,vf,Z_0)~f --> Interval : (R,L,G,C)] – [Single]

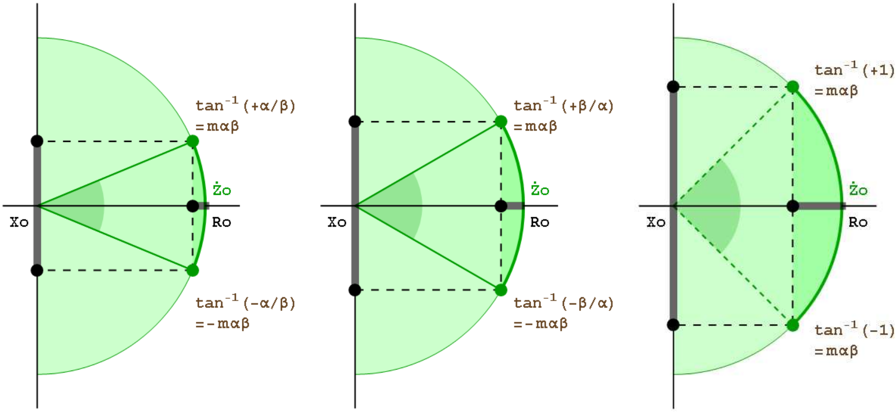


Fig. 4: ±mαβ angle: Intervals for R_0 , X_0

The [Multiple] option enables simultaneously all the buttons in frames [Plot ~ f [Mhz]] and [wgnuplot], but if there is no data available a message will appear to the screen to guide the user. It is possible to enter as many frequency data as it is desired but not for frequencies below or above the first and last frequency respectively.

The user may either plot all the quantities versus f [MHz], directly in the application, as for example is illustrated in Fig. 6 where A [dB/100m] is selected or to use [wgnuplot] and take one of the two possible quadruples as shown in Figs. 7 and 8. Only the points are plotted in wgnuplot application while inside [tlnomiva] it is possible to plot either points with lines, the default state, or only points if the user uncheck the box [Show Lines] at the right of the picture. The lines used here between points are only straight segments of lines.

The chart inside [tlnomiva] is movable with the left mouse button. Two very useful features have been added under the [Graph] menu: [Draft-MinMax] and [ZoomGraph] with two items [Zoom In] and [ZoomOut] as it is shown in Fig. 2 (3). The first produces a plot exactly with min and max values for both vertical and horizontal axis, and with the second a much bigger chart appears for the plot, centered at the screen. The access to both features is also possible through their shortcut keys Alt+G+D and Alt+G+ Z+I or Alt+G+Z+O and in addition through the (+) and (-) from the keyboard's numerical pad.

Fig. 9 shows an example for the L coefficient, where it is obvious that the points of different color and shape for its interval ends reveals the existing too small difference between them.

The user may not enter one by one the frequencies and the corresponding nominal values of A, vf and Z_0 but just to read them from an already existing text file using the [File][Open] menu item. An example of such a file is given in Fig. 10, where the first line is a text line. The second contains the number of frequencies (10 in this example) and the common characteristics of the cable as 0.66 for vf, 50. for Z_0, separated by spaces. Then a list of f in MHz and A in dB/100m couples follows. The grid will be filled in automatically after reading the file. The width of the grid columns is adjustable to ensure the visibility of all the produced values.

Another way is to open an already existing file with previously saved data from this application, as in Fig. 11. Then, again the grid contains the read values while all the text boxes for all the quantities are remain blank except the vf, Z_0, and the first and last frequency as it shown in Fig. 6.

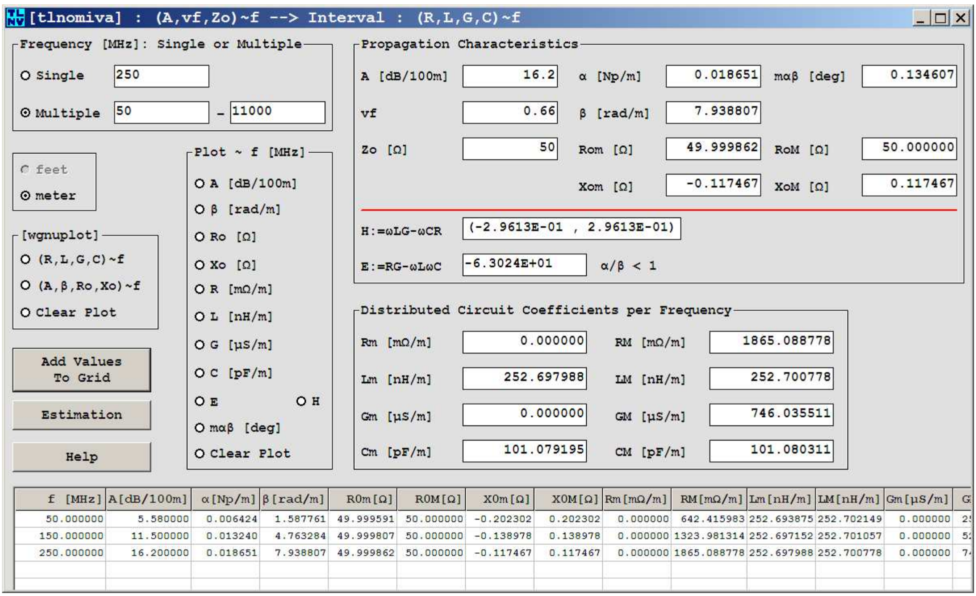


Fig. 5: [(A,vf,Z_0)~f --> Interval : (R,L,G,C)~f] – [Multiple]

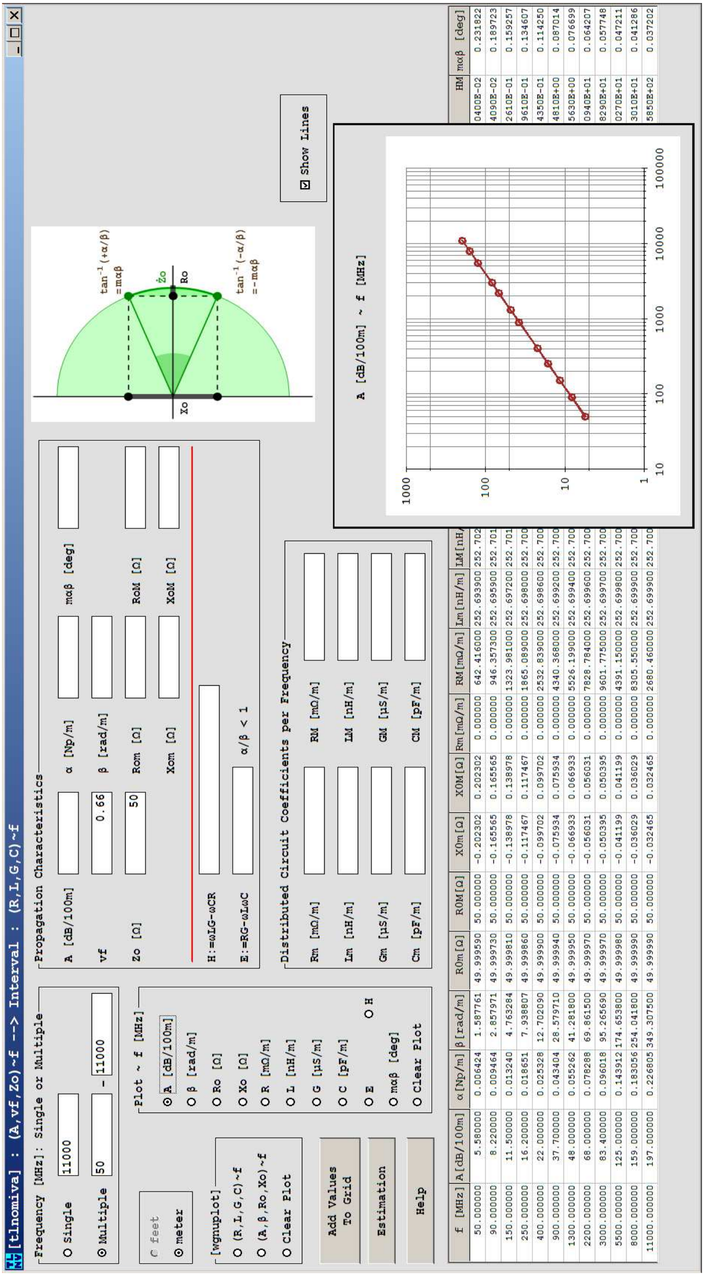


Fig. 6: [(A, vf, Z_0)~f --> Interval : (R,L,G,C)~f] – Plot

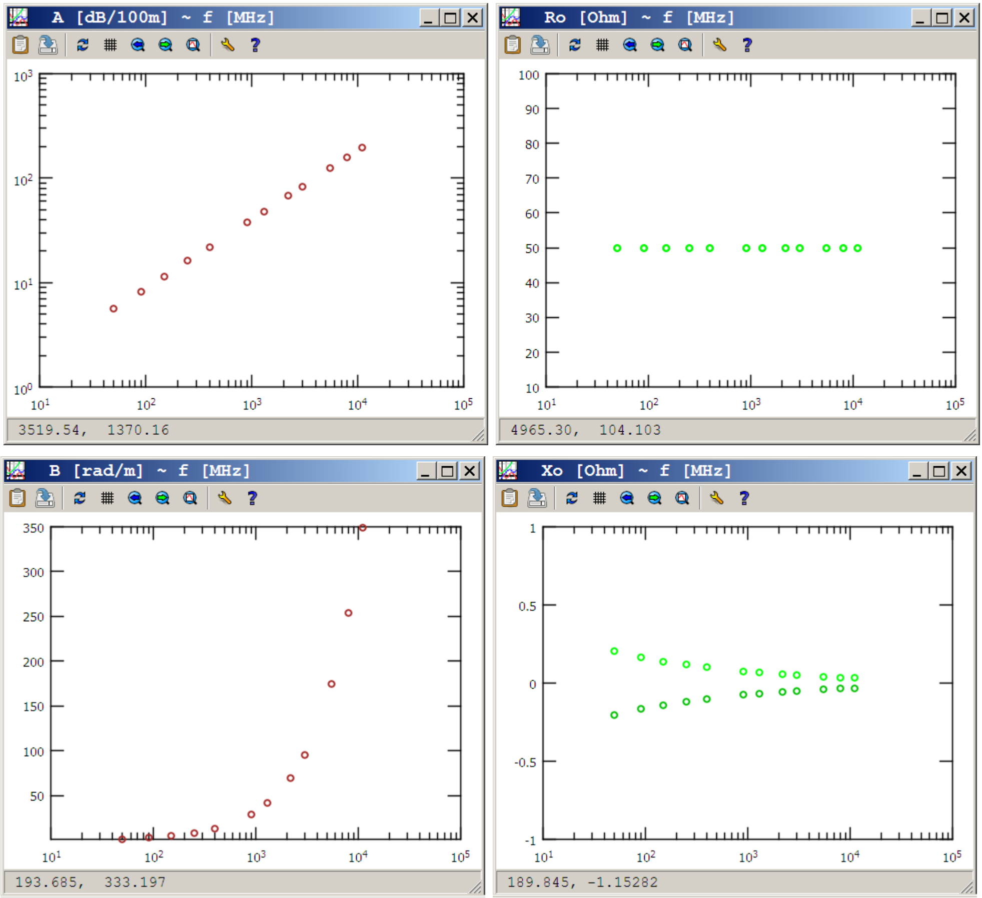
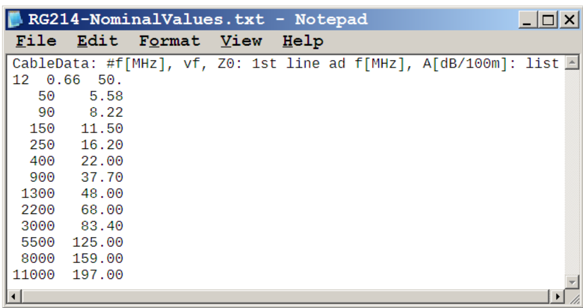


Fig. 7: A, β, R_0 , X_0 versus frequency from [wgnuplot]


RG214-NominalValues.txt - Notepad

File Edit Format View Help

```
CableData: #f[MHz], vf, Z0: 1st line ad f[MHz], A[dB/100m]: list
12  0.66   50.
   50      5.58
   90      8.22
  150     11.50
  250     16.20
  400     22.00
  900     37.70
 1300     48.00
 2200     68.00
 3000     83.40
 5500    125.00
 8000    159.00
11000    197.00
```

Fig. 10: Nominal data values in a text file

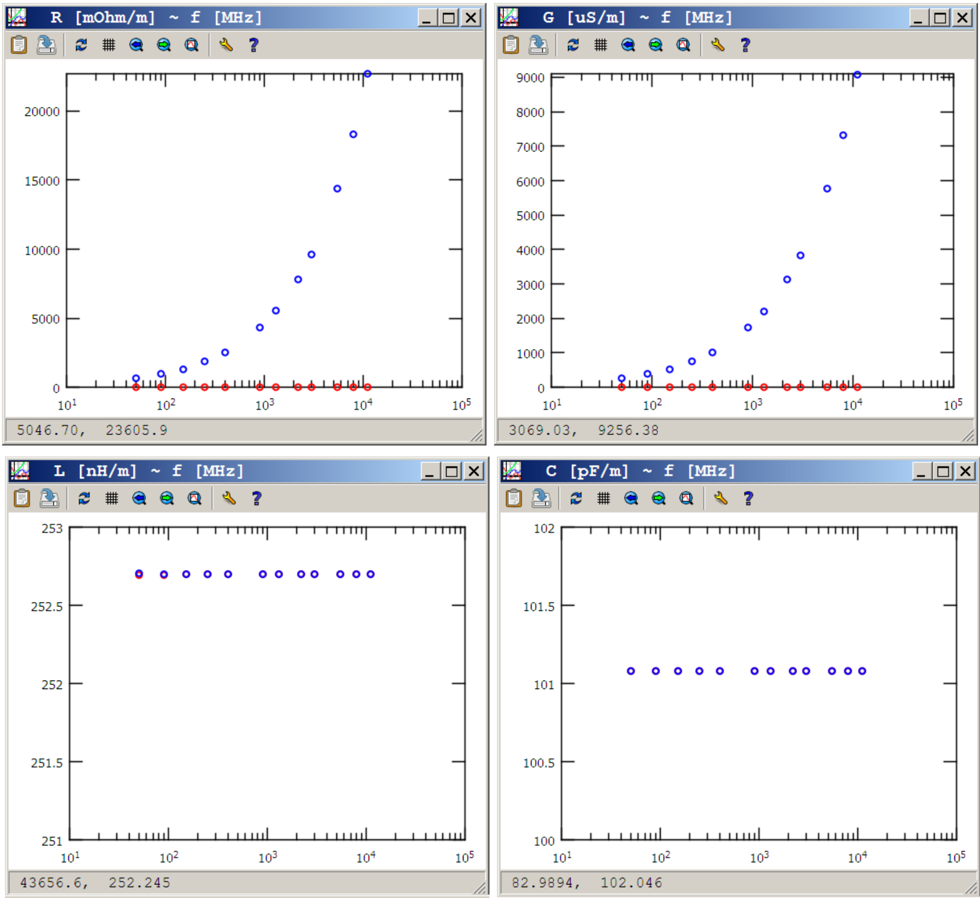
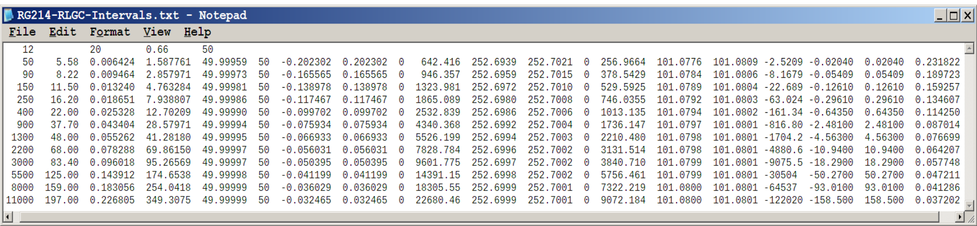


Fig. 8: R, L, G, C, coefficients versus frequency from [wgnuplot]



12		20	0.66	50																
50	5.58	0.006424	1.587761	49.99959	50	-0.202302	0.202302	0	642.416	252.6939	252.7021	0	256.9664	101.0776	101.0809	-2.5209	-0.02040	0.02040	0.231822
90	8.22	0.009464	2.857971	49.99973	50	-0.165565	0.165565	0	946.357	252.6959	252.7015	0	378.5429	101.0784	101.0806	-8.1679	-0.05409	0.05409	0.189723
150	11.50	0.013240	4.763284	49.99981	50	-0.138978	0.138978	0	1323.981	252.6972	252.7010	0	529.5925	101.0789	101.0804	-22.689	-0.12610	0.12610	0.159257
250	16.20	0.018651	7.938807	49.99986	50	-0.117467	0.117467	0	1865.089	252.6980	252.7008	0	746.0355	101.0792	101.0803	-63.024	-0.29610	0.29610	0.134607
400	22.00	0.025328	12.70209	49.99990	50	-0.099702	0.099702	0	2532.839	252.6986	252.7006	0	1013.135	101.0794	101.0802	-161.34	-0.64350	0.64350	0.114250
900	37.70	0.043404	28.57971	49.99994	50	-0.075934	0.075934	0	4340.368	252.6992	252.7004	0	1736.147	101.0797	101.0801	-816.80	-2.48100	2.48100	0.087014
1300	48.00	0.055262	41.28180	49.99995	50	-0.066933	0.066933	0	5526.199	252.6994	252.7003	0	2210.480	101.0798	101.0801	-1704.2	-4.56300	4.56300	0.076699
2200	68.00	0.078288	69.86150	49.99997	50	-0.056031	0.056031	0	7828.784	252.6996	252.7002	0	3131.514	101.0798	101.0801	-4880.6	-10.9400	10.9400	0.064207
3000	83.40	0.096018	95.26569	49.99997	50	-0.050395	0.050395	0	9601.775	252.6997	252.7002	0	3840.710	101.0799	101.0801	-9075.5	-18.2900	18.2900	0.057748
5500	125.00	0.143912	174.6538	49.99998	50	-0.041199	0.041199	0	14391.15	252.6998	252.7002	0	5756.461	101.0799	101.0801	-30504	-50.2700	50.2700	0.047211
8000	159.00	0.183056	254.0418	49.99999	50	-0.036029	0.036029	0	18305.55	252.6999	252.7001	0	7322.219	101.0800	101.0801	-64537	-93.0100	93.0100	0.041286
11000	197.00	0.226805	349.3075	49.99999	50	-0.032465	0.032465	0	22680.46	252.6999	252.7001	0	9072.184	101.0800	101.0801	-122020	-158.500	158.500	0.037202

Fig. 11: Previously saved Data in a text file

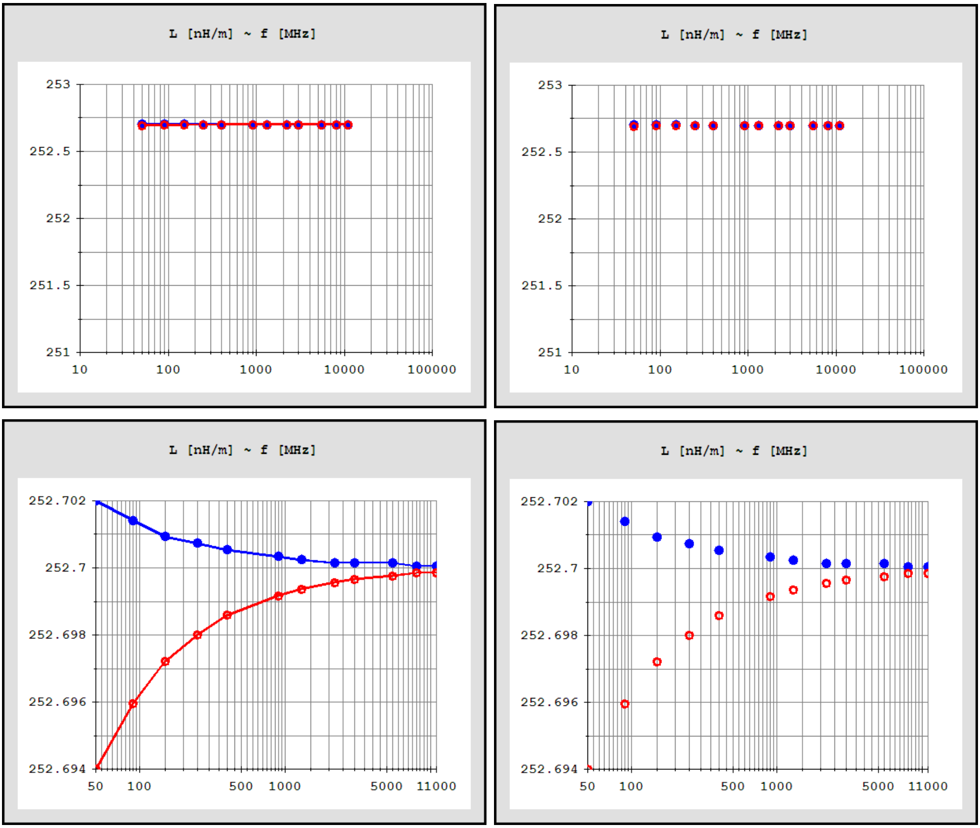


Fig. 9: L with-without lines and [Draft-MinMax]

The first line of this file contains four (4) numbers: two (2) integers, the number of lines and columns, and two (2) reals, vf and Z_0. The following lines are exactly the same as the grid lines of the window.

Fig. 12 shows R_0 , X_0 , mαβ and H with the [Draft-MinMax] enabled. The difference of R_0 from 50 [Ω] is small enough and the values of mαβ permit a small imaginary part X_0 , since they are less than a quarter of 1° in both sides of the horizontal line of real Z_0. It is also evident that for lower frequencies the H intervals are, initially, closer to zero (0) which means closer to the Heaviside condition while more data are needed to characterize the line as capacitive or inductive.

This window generates eight (8) files in the directory of [tlnomiva] which are used from the [wgnuplot.exe], with specific filenames of obvious meaning:

R-points	L-points
G-points	C-points
A-points	B-points
Ro-points	Xo-points

Finally, the [Clear Plot] button in the [wgnuplot] frame just closes all occurrences of the wgnuplot application [4] while the same button in the [Plot ~ f [MHz]] frame clears the displayed plot, leaving the chart empty. A short help is available by pressing the [Help] button. The [Estimation] button opens the next window of [tlnomiva] that uses the intervals of RL GC circuit coefficients for a new estimation of A, vf, Z_0.

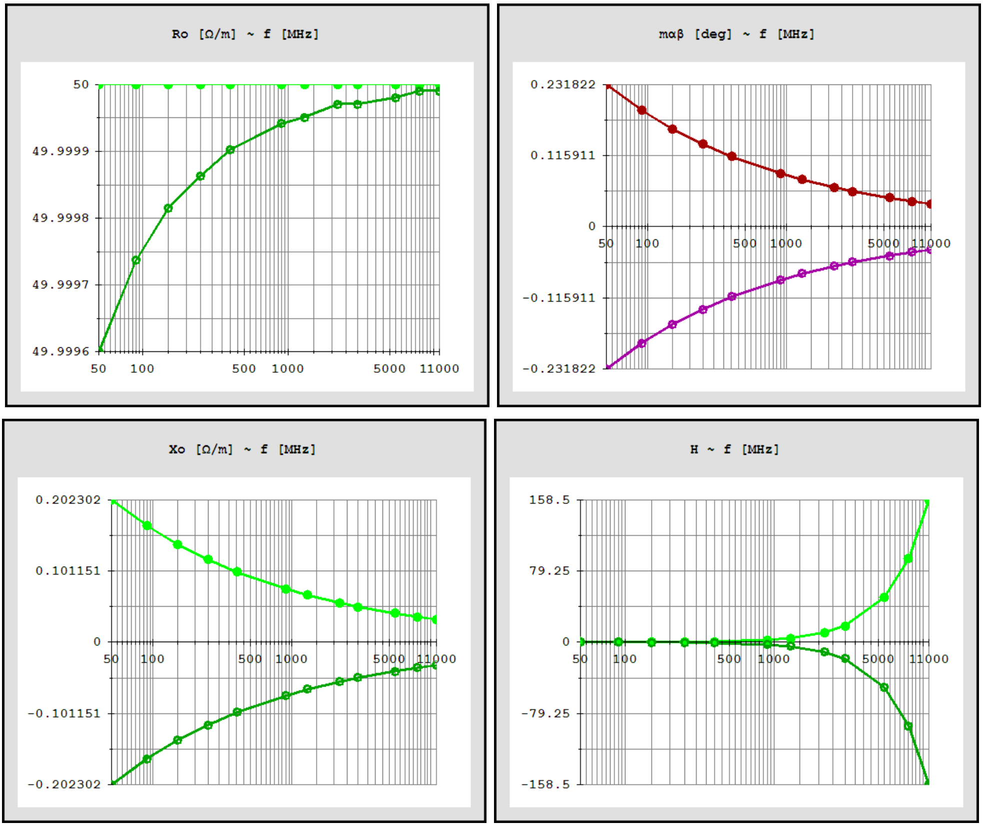


Fig. 12: R_0 , X_0 , mαβ and H with [Draft-MinMax]

A, vf, Z_0 estimation from RLGC Intervals

Relations (12)-(16) are actually result directly from the definition of $\dot{Z}_0$ and $\dot{\gamma}$. The problem is that R, L, G and C are not easily determined. They are closely related to the geometrical characteristics of the line and as distributed quantities not measured directly. Here, an attempt is presented to determine some values for A, vf, Z_0 and thereafter for α, β, H, E, mαβ using the RLGC intervals from the previous widow of [tlnomiva]. Additionally, the ωL, ωC and f/vf are also given.

In particular three values are evaluated: the one that corresponds to the lower end of the RLGC intervals, the mean value and the one from the upper end of the intervals. The nominal values are given, respectively, where they are available. The main purpose of this effort is to estimate A, vf, and Z_0 and to achieve a closer approach of RLGC by means of the known nominal values.

Fig 13 shows the second window of [tlnomiva], when it is opened from the [Cable] [Interval : (R,L,G,C)~f-->(A, v,f,Z_0)~f] menu. The table contains the values at the frequency selected from the drop down list box, 400 [MHz] here. Initially, the table has no values and the message of Fig. 14 is at the top of the window. After pressing the [Load Data] the well known in windows users [Open] dialog box appears to select a file to read. The first line in Fig. 13 shows the path of this data file. If the window is accessed through the [Estimation] button of the previous window [(A,vf,Z_0)~f-->Interval : (R, L,G,C)~f] then there is no message at the top and the table is filled automatically with the values corresponding to the first frequency.

The first four (4) lines of the table shows the values of RLGC as described above. The next eight (8) lines in the red frame contain the new estimated values. Their corresponding nominal values are shown at the right. To plot one of these quantities versus frequency, its option button under the label [Plot] must be selected. The colored little squares beside its data column (Red for minimum, Green for mean value, Blue for maximum) and the Black larger square above the nominal values correspond to the used color for the plot and they are buttons. Their default state is on. Pressing one of them or all, changes the state to off and the corresponding data are removed from the plot for each line.

Fig. 15 shows the full window with the plot of A [db/100m] in the chart. The light blue open circles in the plot indicate the current frequency which is selected from the drop down list box, 1300 [MHz] in this example. Since all the colored buttons are on, all the values are plotted. The menu item [Draft -MinMax] is active for a closer view of the plot as described in the previous section and it is selected here.

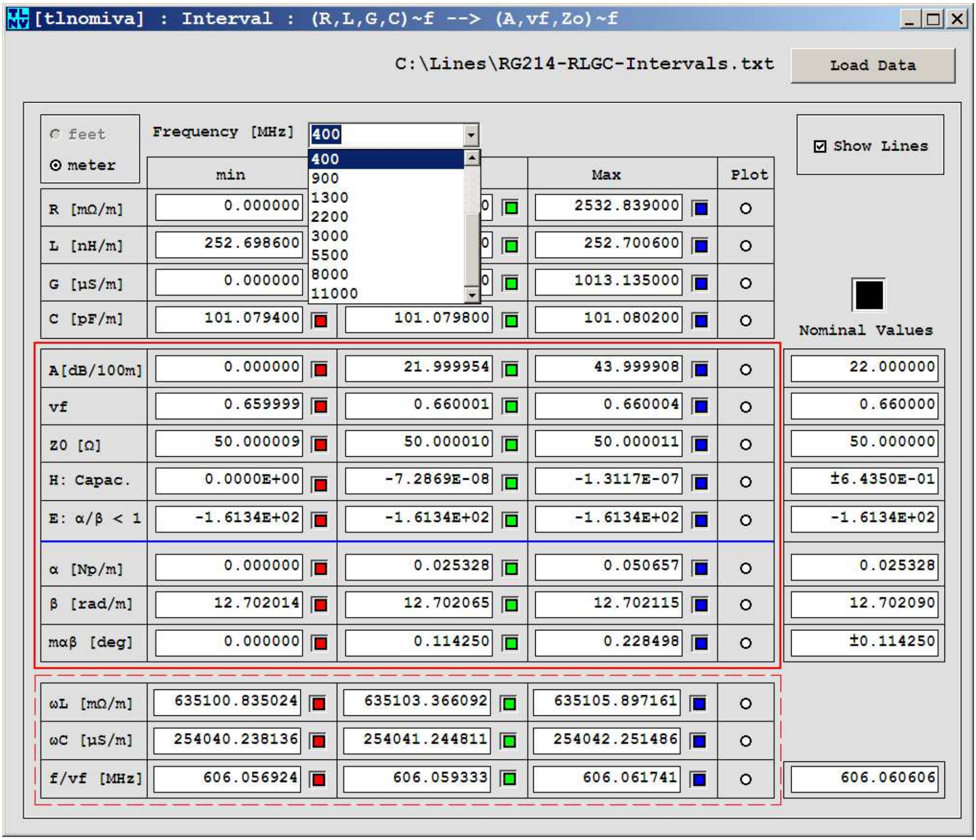


Fig. 13: [Interval : (R,L,G,C,)~f --> (A,vf,Z_0)~f] – Table

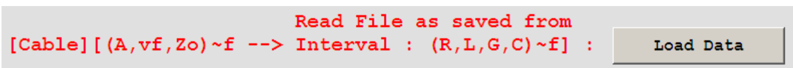


Fig. 14: Initial message: Load Data

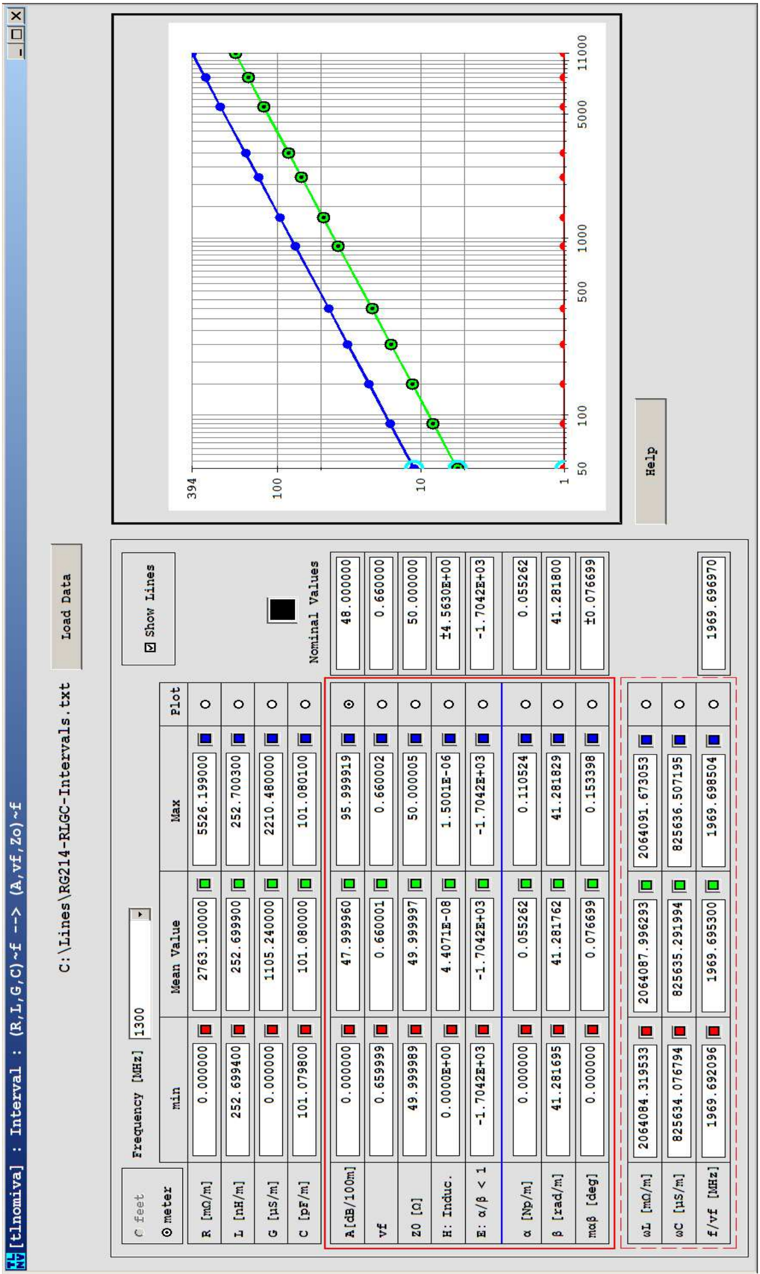


Fig. 15: [Interval : (R,L,G,C,)~f --> (A,vf,Z_0)~f] – Plot

The minimum value results from (12) to be zero since the lower limits for R and G are equal to zero and the same is true for mαβ and H, for this cable. It is obvious that the nominal value of A is achieved for the mean value as shown in Fig. 16 where the green and black colored points are plotted. The light blue point corresponds to the values shown above the chart. Velocity factor is illustrated in Fig. 17 and in Fig. 18 mαβ is given. Both of them are shown with [Draft-MinMax] enabled. For mαβ only the positive number is written at the table, while at the plot both plus and minus mαβ is shown. Fig. 19 contains Z_0 in both scales, where it is obvious that the difference from nominal value can not be denoted and Fig. 20 shows the H term, almost zero, similarly. If it is positive/ negative in both mean and maximum value then a Capacitive/Inductive label is added. For completeness Figs. 21-22 shows α and β respectively.

The [feet] option is again disabled, the [Show Lines] acts the same as in the previous window, while the [Zoom Graph] item with its sub-items is disabled in the current [tlnomiva] version.

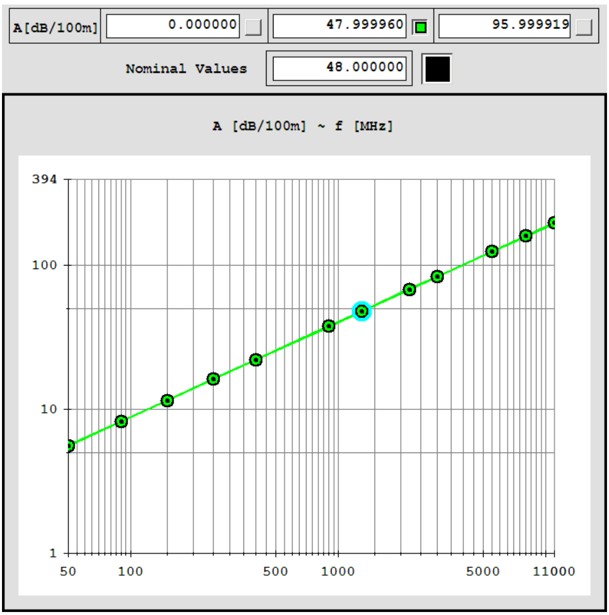


Fig. 16: Attenuation factor estimation and nominal value

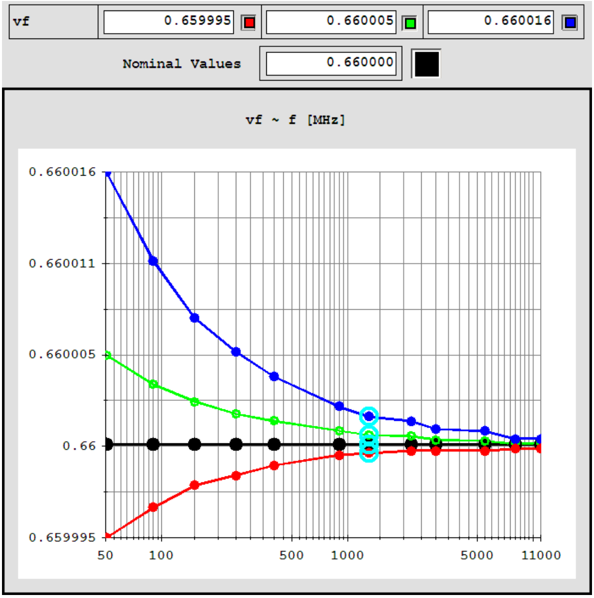


Fig. 17: Velocity factor estimation and nominal value

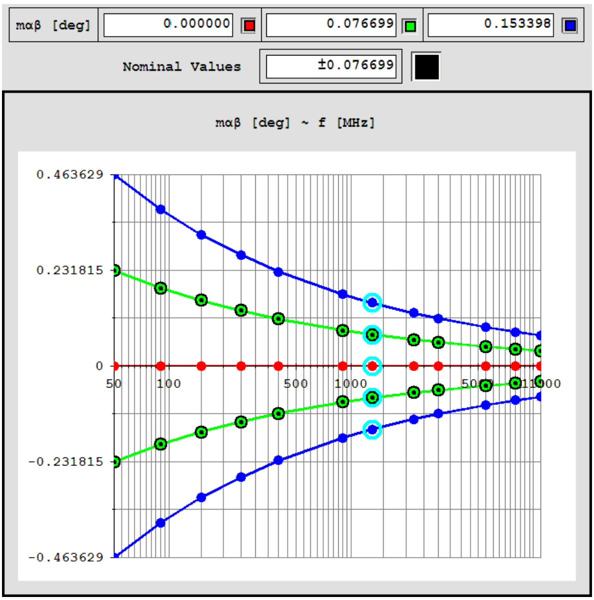
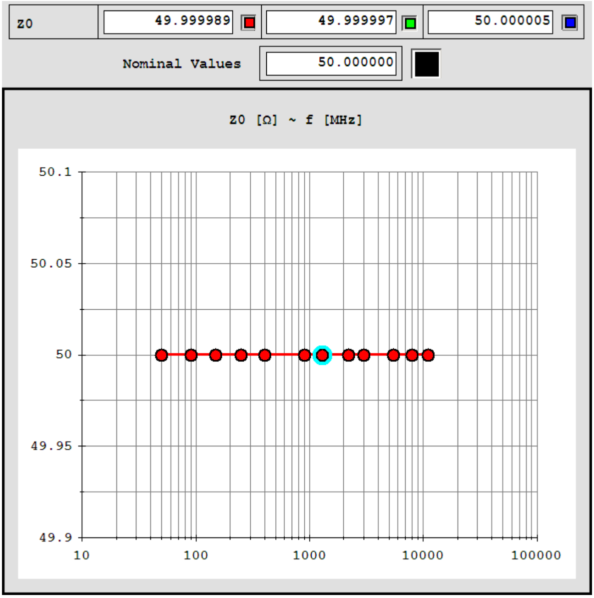


Fig. 18: mαβ estimation and nominal values



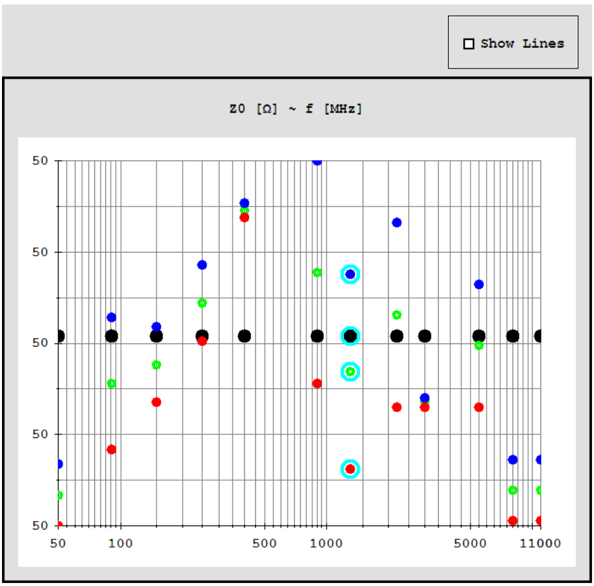
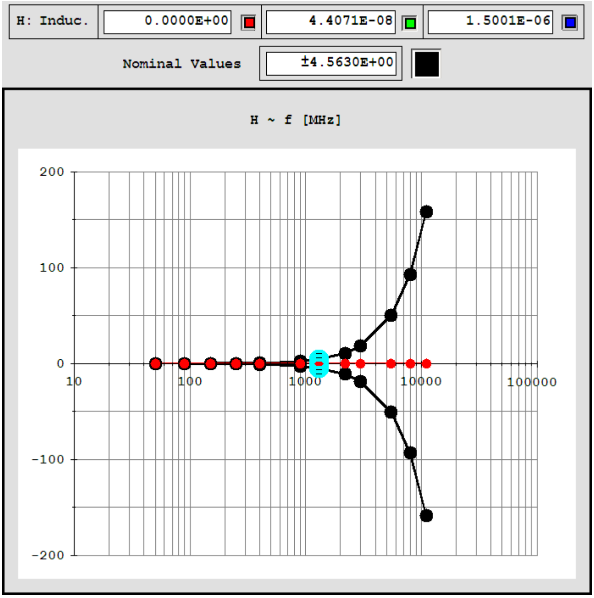


Fig. 19: Z_0 estimation and nominal values



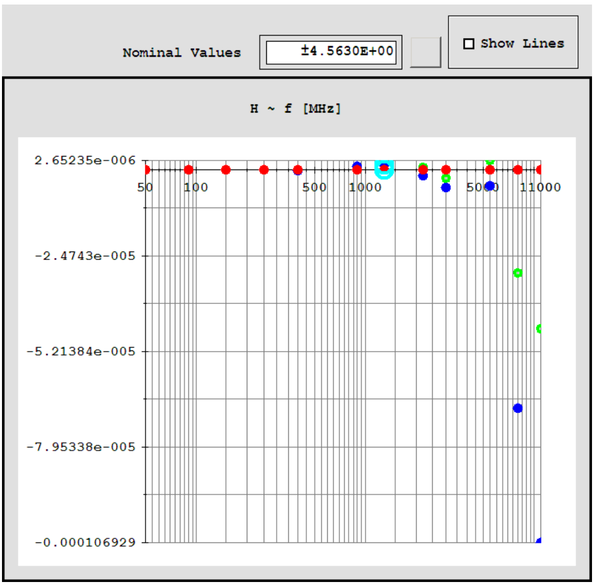


Fig. 20: H estimation and nominal values

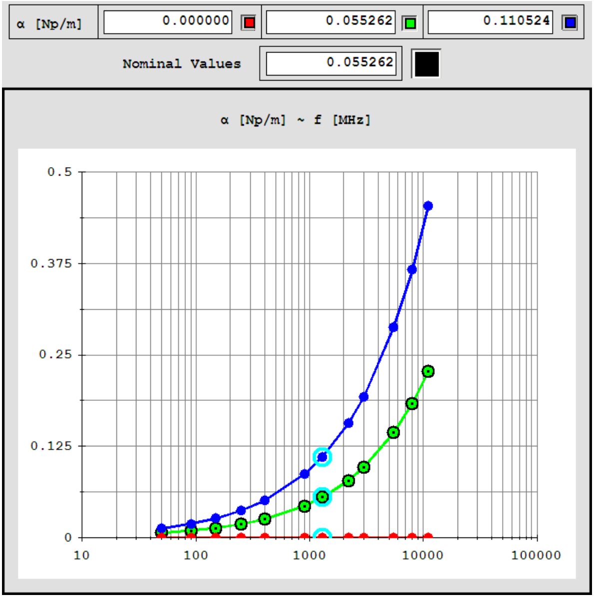


Fig. 21: α estimation and nominal values

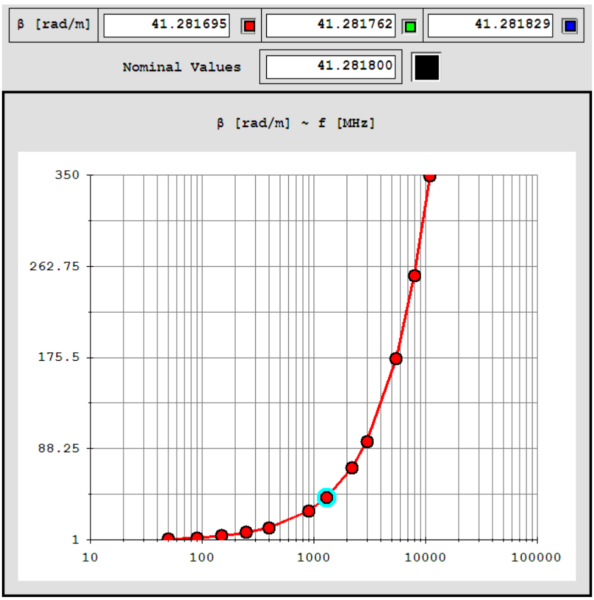


Fig. 22: β estimation and nominal values

α, β, R_0 , X_0 from Constant R, L, G, C

The next window of [tl-nomiva] concerns the investigation of the propagation characteristics behavior with frequency when the circuit coefficients remain constant. The question is, is there any possibility this case to be true in real transmission lines or it is simply a matter of theoretical research as a mathematical exercise?

Well, even if it is only an academic problem it has a considerable interest by itself. From the one hand, (1)-(4) show that if $X_0 = 0$ then R, L, G, C become frequency independent. But this means the Heaviside term is equal to zero. From the other hand, the C distributed circuit coefficient is almost constant over a wide frequency range and L has a small variation. Thus, R and G are the most variable coefficients, and G has in most cases rather small values compared with R [2]. In addition, as it is stated in [2], there is a range of low frequencies over which R, L, G, C can be considered effectively constants. Thus, it is worthwhile to examine the relation of all the four propagation characteristics with frequency as the four circuit coefficients take specific values.

The developed window of [Constant : (R,L,G,C)-->(α,β, Ro,Xo)~f] is shown in Fig. 23. It opens with the [Single] frequency as the default state and with some predefined values. The user may type the RLGC coefficients and the desired frequency or frequency range. When [Range] is activated then the text boxes contain the values of all the quantities at the middle frequency and the buttons for plots are enabled. In this figure the predefined values for RLGC was used and the range [0.001, 1000] [MHz] was selected. A in [dB/100m] is depicted in the chart with the [Draft-Min Max] enabled and with [Show Lines] unchecked.

Fig. 24 shows A of the line used in previous sections, with RLGC almost equal to their mean value at the lower frequency, to the whole permitted range, from 1 Hz to 100 GHz. Evidently there is a limit to what can be drawn in this application. The [wgnuplot A, β, Ro, Xo, mαβ, vf] produces the two triples of Fig. 25, where at the right top side of the plots the RLGC values are written. The white area indicates the band of the line operating frequency. In wgnuplot application the developed script plots the (12)-(16) as functions of frequency, that is, curves are plotted and not evaluation in specific number of points.

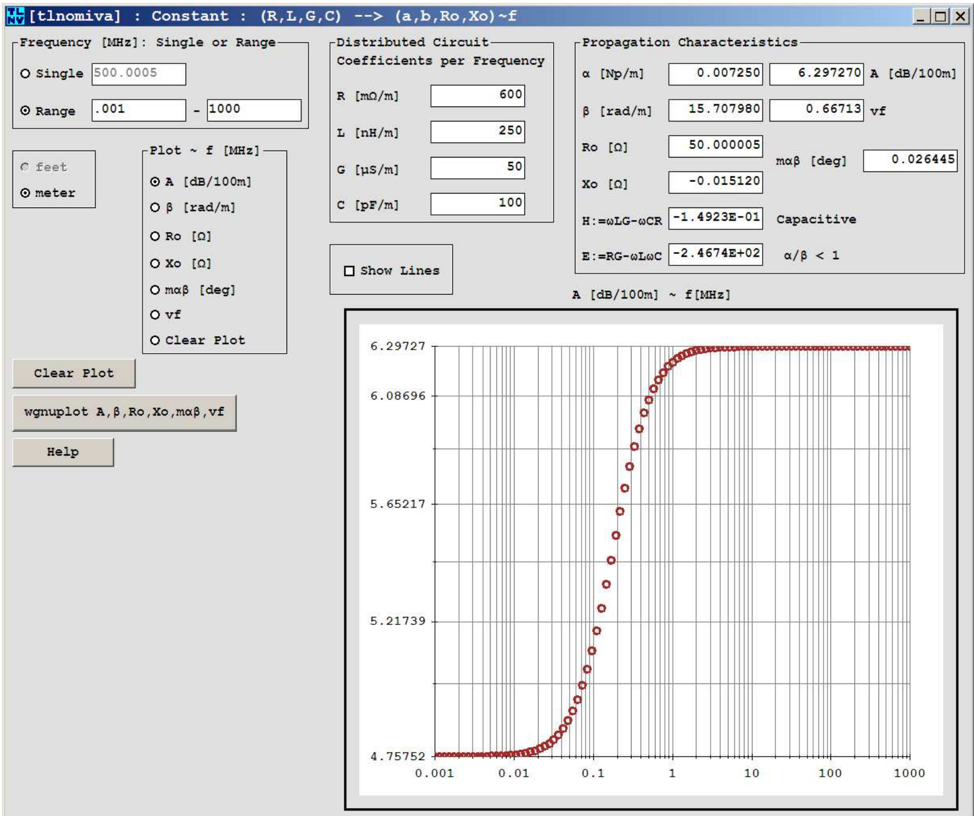


Fig. 23: [Constant : (R,L,G,C) --> (α,β,Ro,Xo,)~f] – [Range]

Thus, considering a much lower frequency range and a range for A between its minimum and maximum value, which substantially differ slightly, and plotting A function in wgnuplot, we get Fig. 26, where we distinguish the form of "S" we have seen before in Fig. 23 for the first line example.

Six text files are written in the directory of [tlnomiva], which are used from the [wgnuplot.exe], with specific filenames of obvious meaning:

A-function	B-function
Ro-function	Xo-fuction
mab-function	vf-function

In order to emulate the curve structure in the current version of [tlnomiva], the mentioned relations are evaluated in 100 points equally spaced in the logarithmic scale of frequency f in [MHz].

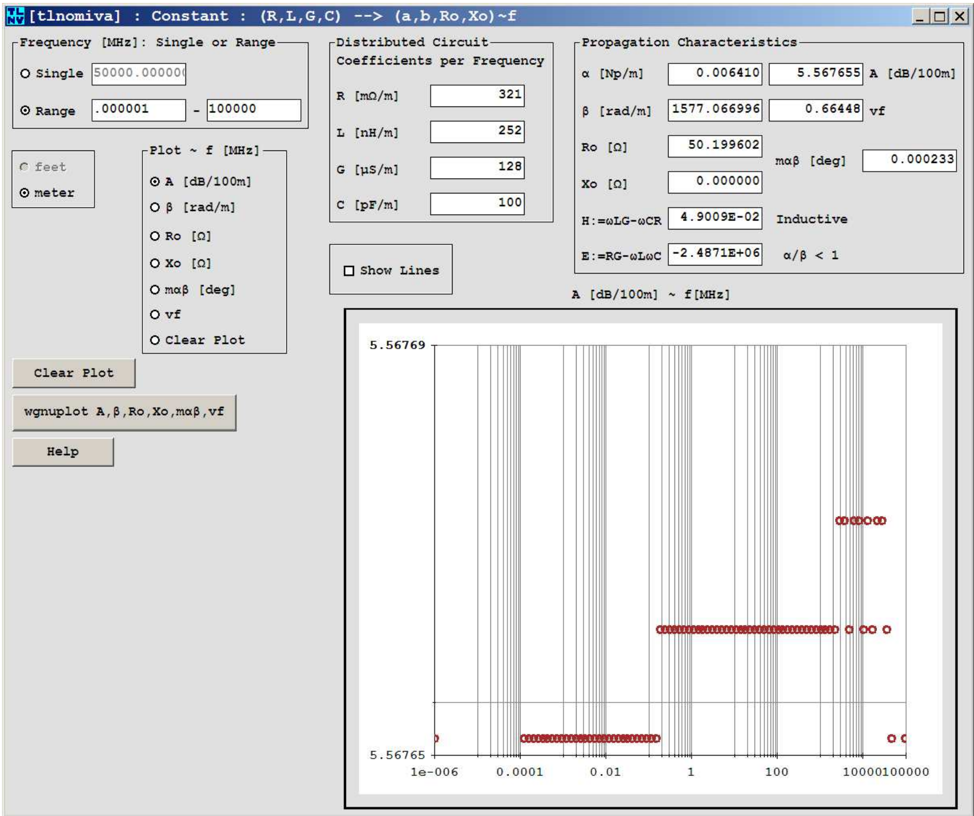


Fig. 24: A [dB/100m] versus f [MHz] with Draft-MinMax

A significant characteristic of this window is that when the [Range] is selected and one of the six quantities is plotted, then every change to the value of any of the four RLGC will immediately cause the change of the plot. All the other features are the same with the previous windows.

Using this feature of some kind of interaction and varying slightly by one (1) the value of C and particularly by varying the value of L significantly, we get Fig. 27 for a transmission line with R, L, G, C equal to 321 [mΩ/m], 111 [nH/m], 128 [μS/m] and 100 [pF/m], where the velocity factor seems to take values larger than its upper limit of unit (1) (red), from 2.6 [MHz] and above. A fact that needs further research, and restates the issue of line definition.

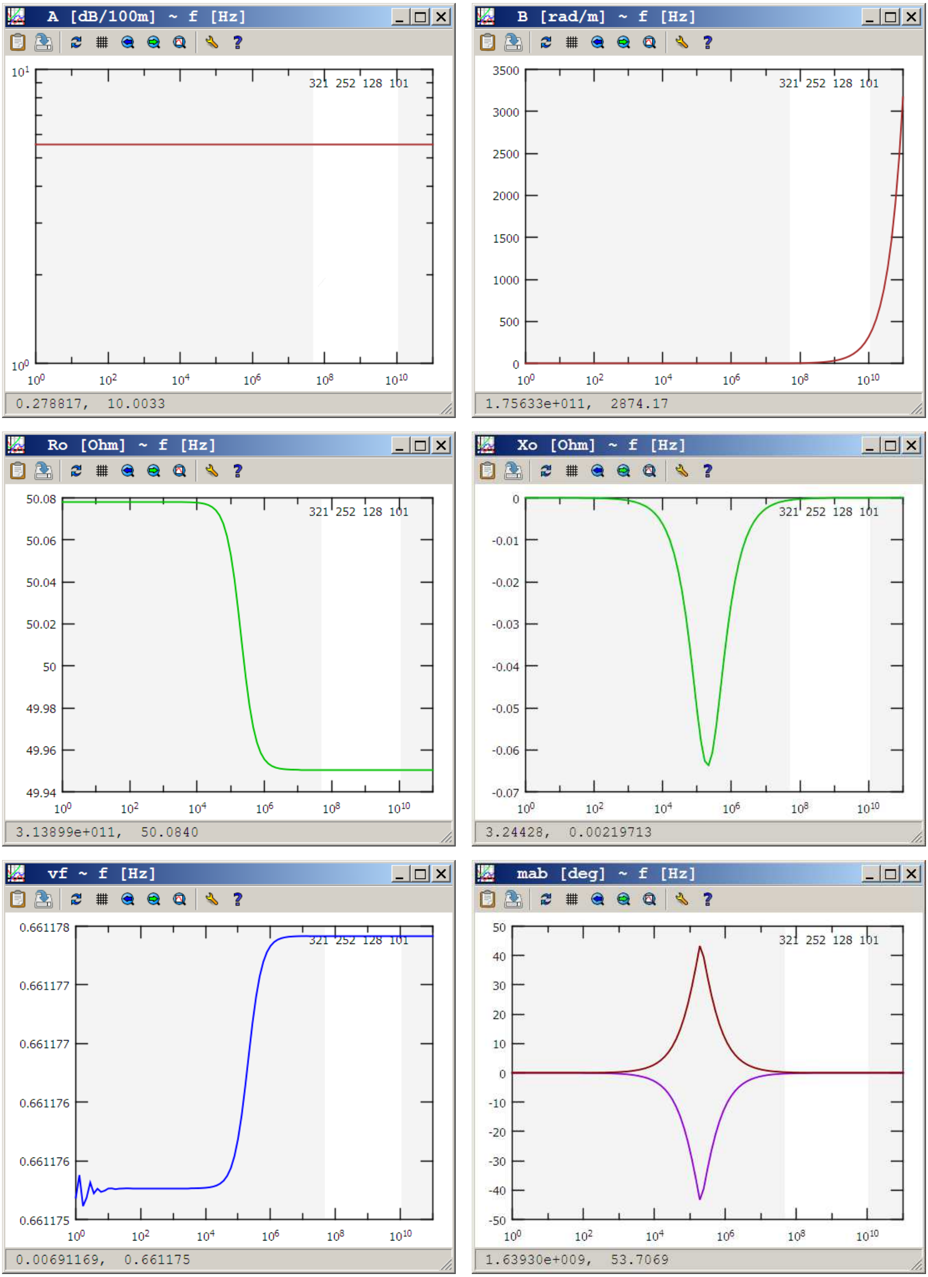


Fig. 25: A, β, R_0, X_0 vf, mαβ from [wgnuplot]

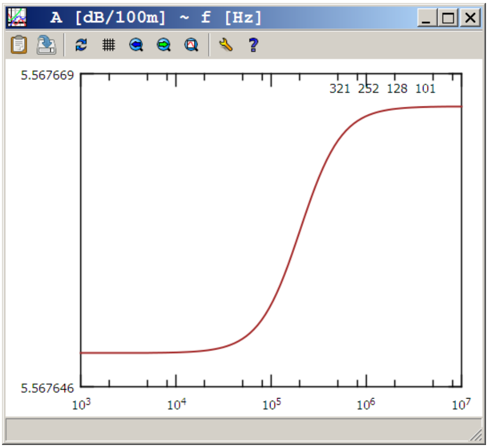


Fig. 26: A [dB/100m] versus f [MHz] from [wgnuplot]

Final Remarks

There are two important matters. The first concerns the application [tlnomiva] itself and the second the way that the available cable specifications can be exploited.

1. In order to avoid unpredicted errors in calculations, caused by the different notation of decimal symbol used in various local MS Windows versions, a decision has to be made. Thus, the dot "." was selected to be the decimal symbol, as well as, the comma "," as the digit grouping symbol – although the later is not used at all here. Notably, this choice is a mandatory requirement for [wgnuplot], which does not recognize comma as decimal symbol. Hence, the window of Fig. 28 appears on the screen just after opening the application when a non-dot definition exists in the Regional Settings of Control Panel.

2. The transmission line used to serve as an example of the features of the [tlnomiva], is the RG 214 cable and its specifications which are given in [5]. Since, only four (4) values for the attenuation factor A in [dB/100ft] are explicitly reported there, we decided to use the accompanying chart, which covers the whole operating frequency range from 50 [MHz] to 11 [GHz].

Fig. 29 shows a straight line for A in the logarithmic chart. Such a line can be represented by:

$$y = k\, x^{\lambda} \qquad (17)$$

that is:

$$= a\,\log(x) + b \tag{18}$$

where $a = \lambda$ and $b = \log(k)$, and from (17) and (18) we take:

$$y = 10^{b}\,x^{a} \tag{19}$$

Then, we graphically estimate the coordinates of the staring and ending points of the straight line in Fig. 29, as well as, we cross check the results by using the [Opti-Graph] application [6] as it is shown in Fig. 30. After that, we formulate and solve the following linear system:

$$\begin{aligned} \log(1.7) &= a\,\log(50) + b \\ \log(60) &= a\,\log(11000) + b \end{aligned} \tag{20}$$

and by using the Aurora Scientific Calculator SC 500 Plus [7], the solution for a and b is given, with nine (9) decimal digits, as follows:

$$a = +0.660727178$$

$$b = -0.892106736$$

from which we finally have:

$$A_{[\mathrm{dB/100m}]} = \frac{0.128201546}{0.3048}\, f_{[\mathrm{MHz}]}^{0.660727178}$$

In this way, since A has now an analytical expression in terms of frequency, we can determine as many points as we like, that is, for example, those of three (3) significant figures we put in the grid of Fig. 6.

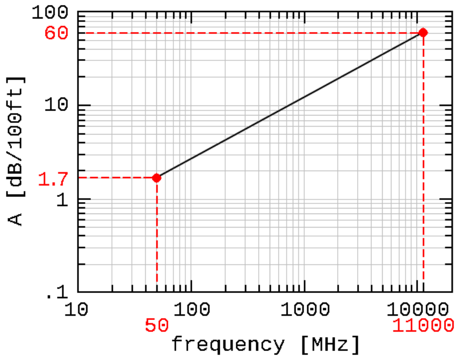


Fig. 29: Extracting analytical expression from a LogLog plot

Conclusion

The limits of what can be estimated or predicted using precise formulation from the nominal values without tolerance of A, vf, and Z_0, which are usually given nowdays as cable specifications for transmission lines, without taken into account the cut-off frequency, was investigated in this paper.

It seems that the curves for all the involved quantities have more or less the same form, as it was expected and explained by their defining expressions, with a possible differentiation of course in their slope. These curves are strongly depended on how wide is the considered frequency window. Therefore, it is most important to pay special attention in the operating frequency range in order to be sure that the model presented in this paper describes adequately the transmission line characteristics in accordance with its specifications.

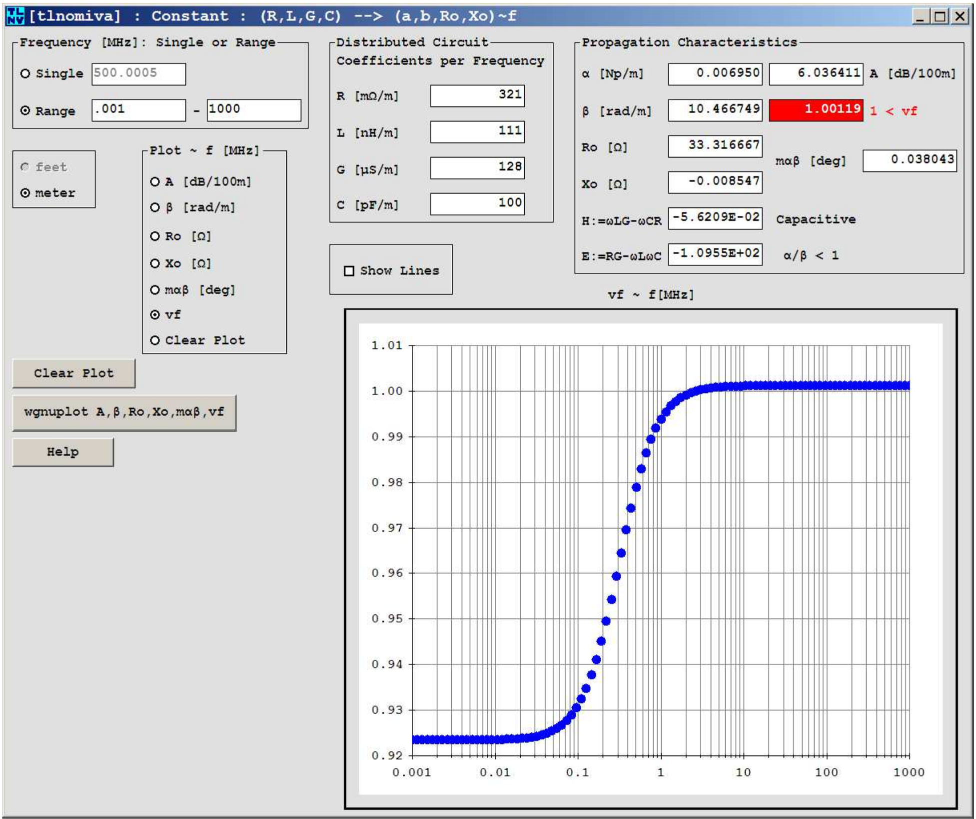


Fig. 27: RLGC for vf > 1

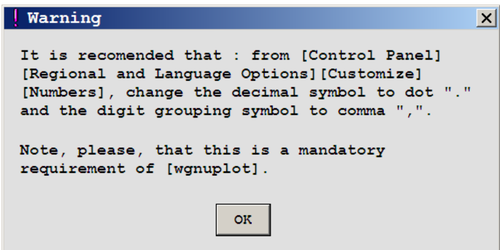


Fig. 28: Warning Message

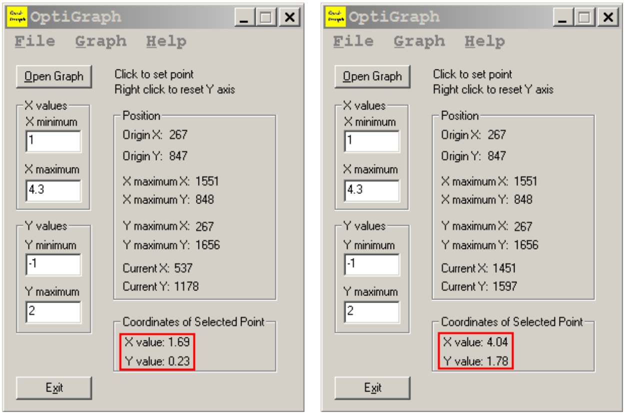


Fig. 30: [OptiGraph] : Starting and Ending points

The [tlnomiva] application is developed and presented as a research tool. The intention is to be used: (1) as a reference in the study of the already existing approximate techniques for finding the distributed circuit coefficients and the propagation characteristics, and 2) to be expandable in order to cover: (2a) not only the case of the RLCG theoretical calculation from the cable geometrical characteristics, but in addition (2b) the case of using the new approximation method for the determination of attenuation factor, which is under current development by the authors.

Finally, the whole of [tlnomiva] software, that is the MIT licensed source code, the installation package, as well as, its future improvements, updates and upgrades, can be always downloaded from the author's website address [8].

References

[1] Yannopoulou N., Zimourtopoulos P., "Transmission Lines – Part 1: A Precise Formulation within the Distributed Circuit Model", FunkTechnikPlus # Journal, Issue 9, Year 3, 2016, pp. 369 – 389, under revision with expanded additions
www.otoiser.org/index.php/ftpj/issue/view/2016.01.31

[2] Chipman R.A., "Transmission Lines", McGraw-Hill, 1968, pp. 15, 17, 26, 31 - 32, 42, 44, 47, 58 – 60

[3] gnuplot,
"Version 5.0 patchlevel 3 last modified 2016-02-04":
https://sourceforge.net/projects/gnuplot/files/gnuplot/

[4] "How To Programmatically Close a Single Instance of a Windows-Based Program",
https://support.microsoft.com/en-us/kb/176391

[5] "Detail, Specification Sheet: Cable, Radio Frequency, Flexible, Coaxial, 50 Ohms, M17/75-RG 214 and M17/75-RG365, MIL-DTL-17/75F, w/Amendment 2", 23 February 2010,
https://assist.dla.mil/online/start/

[6] Yap Chun Wei, Optical Graph Recognition and Manipulation Util for Win32, OptiGraph, Version 1.0, 28 January 2000 First release,
ftp://ftp.sk.debian.org/pub/pc/educult/

[7] Aurora Scientific Calculator SC 500 Manual,
www.arg.op4.eu/aurora/sc500p/

[8] [tlnomiva],
http://arg.op4.eu/software/tlnomiva/

*Active Links: 19.05.2016 - Inactive Links : FTP#J Link Updates: http://updates.ftpj.otoiser.org/

Previous Publication in FUNKTECHNIKPLUS # JOURNAL

"Transmission Lines – Part 1: A Precise Formulation within the Distributed Circuit Model", Issue 9, Year 3, pp. 369 – 390

*** About The Authors**

Nikolitsa Yannopoulou, Issue 9, Year 3, p. 390

yin@arg.op4.eu

Petros Zimourtopoulos, Issue 9, Year 3, p. 390

pez@arg.op4.eu

Insulating Properties of Graphene Oxide

D.G. Mitrakas, M.G. Danikas *

Department of Electrical and Computer Engineering,
Power Systems Laboratory,
Democritus University of Thrace, Xanthi, Greece

Abstract

Many researchers concentrated recently their efforts on the investigation of the physical properties of graphene, such as its electrical and thermal conductivity and its strength. Its flexibility and transparency opened new possibilities regarding numerous applications, such as electronics, energy storage devices, polymers and electrodes. Relatively little was reported w.r.t. the insulating properties of graphene oxide. It is the purpose of the present paper to investigate whether graphene oxide can be suitable as insulating material for high voltage applications.

Keywords

Graphene oxide, insulating properties, insulation lifetime, enclosed cavities

Introduction

Graphene concentrated the lights of publicity and the scientific interest of numerous researchers around the globe for its physical properties, such as the very high electrical and thermal conductivity and its strength. Its transparency and its flexibility opened new roads for many applications, such as, among others, composite polymers, transparent electrodes and storage energy devices. A. Geim and K. Novoselov received the Nobel prize in physics for "groundbreaking experiments regarding the two-dimensional material graphene" [1].

Properties of Graphene

A graphene film is –at the moment– the thinnest known material, the gases cannot penetrate it, and it has higher mechanical strength than stainless steel. Its properties open new inroads regarding novel applications. At room temperature, its thermal conductivity is very high, higher than that of diamond, and of the order of 5000 W m^{-1} K^{-1}. Graphene is almost transparent, absorbing only 2.3% of light. It is an excellent electrical conductor, having a high charge mobility of 200000 cm^2 V^{-1} s^{-1}. Such properties were recorded with very thin graphene samples of the highest quality and of small surface. It was also reported that graphene properties (such as electronic properties, thermal conductivity, hardness and elasticity) may change with the sample thickness [2].

Possible Applications of Graphene

Many industrial applications were proposed, such as energy storage devices, transistors, electrodes, composite polymers, nanocomposites, sensors etc. The quantity and morphology of graphene for each of the above applications may vary, depending on the application itself. For example, sensors or transparent electrodes require thin graphene films, whereas batteries, super-capacitors and synthetic polymers require quantities of nano-films or graphene platelets. Graphene dispersion in the matrices of the base polymer should be as good as possible.

Graphene Oxide as Insulating Material

The reply to the question whether graphene oxide is a good insulating material, is not easy to be given since the chemical structure of graphene oxide is sensitive to the temperature. The electrical conductivity of graphene oxide can be studied with the aid of dielectric spectroscopy [3]. Dielectric spectroscopy records the change of dielectric properties of a material with the frequency and the temperature. It gives indications as to the insulating properties of the material, taking into account the relaxation phenomena. The latter change the dielectric behavior of the material and allow the storage of more electric energy in the volume of the material.

It is evident that the conductivity of graphene oxide increase is a function of temperature and of frequency (Fig. 1a). The frequency spectrum is in the range of 0.1 Hz up to 10^6 Hz and the range of temperature is in the range of -40^0 C – 30^0 C. The slope of the conductivity curve with frequency decreases as the temperature increases. The dielectric constant takes low values and presents a rather small dependency on frequency at low temperatures. However, this changes at higher temperatures (Fig. 1b) (note the same ranges of frequency and temperature for Figs. 1a and 1b) [4].

Fig 2a shows the conductivity in the temperature range 40^0 C – 90^0 C. It shows a stepwise increase at lower frequencies and reaches a plateau value at higher frequencies. Fig. 2b shows a decrease of dielectric constant with frequency increase for the same temperature range as in Fig. 2a [4].

Fig. 3a shows conductivity changes from 100^0 C to 150^0 C. The conductivity plateau value appears also at higher temperatures. The transition from plateau value to the exponential increase moves to higher temperatures as the temperature increases. It is to be noted that conductivity increases dramatically as the temperature increases above 100^0 C. Fig. 3b shows that the dielectric constant chan-ges significantly as the frequency decreases [4].

Fig. 4 shows conductivity as a function of temperature at the frequency of 0.1 Hz. One may see three transitions from -40^0 C to 150^0 C. Two transitions from the region of insulating material to the region of semiconduction at about 10^0 C and 100^0 C and one transition from the region of semiconduction to the region of insulating material at 90^0 C. At room temperature electrical conductivity has semiconductive characteristics but at lower temperatures has insulating characteristics. Fig. 5 shows the variation of the dielectric constant with temperature at various frequencies [4].

It should be noted that graphene oxide is hydrophilic material and it is very sensitive to humidity variations. Its resistance is 10^8 Ω for relative humidity of 15% but it becomes ten times smaller when the relative humidity is 95%. The relationship of its resistance with humidity, renders the aforementioned material ideal as humidity sensor [5].

Graphene oxide can be selected to be added to polymer matrices because of its high mechanical strength and its high thermal conductivity. Pure graphene oxide is thermally unstable. The decomposition of graphene oxide nanosheets (GOn) is not valid for nanocomposites GO/PVDF because of the strong interactions between its constituents. Fig. 6 shows that the permittivity of such a nano-composite (GO/PVDF) with concentrations above 1 wt% is higher than that of pure PVDF.

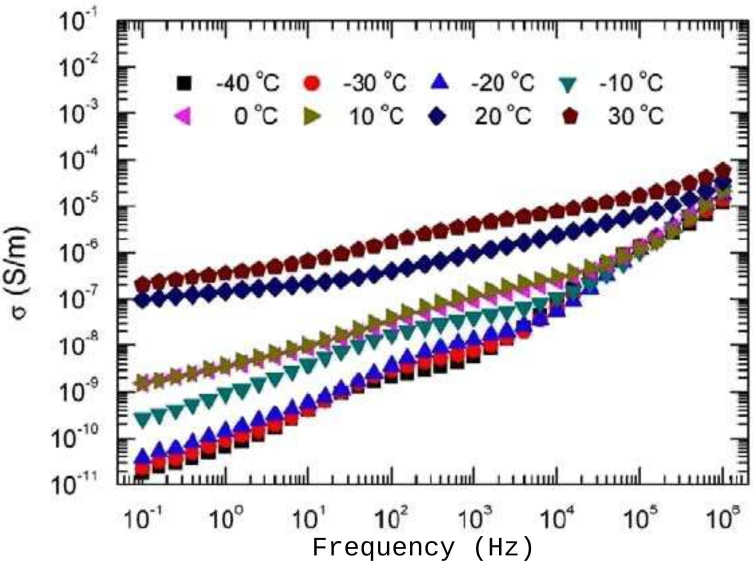


Fig. 1a Conductivity of graphene oxide with frequency and temperature

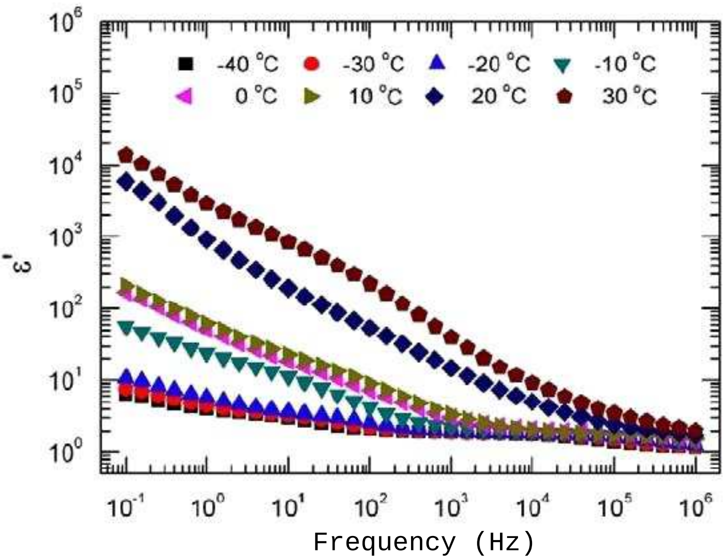


Fig. 1b Dielectric constant of graphene oxide with frequency and temperature

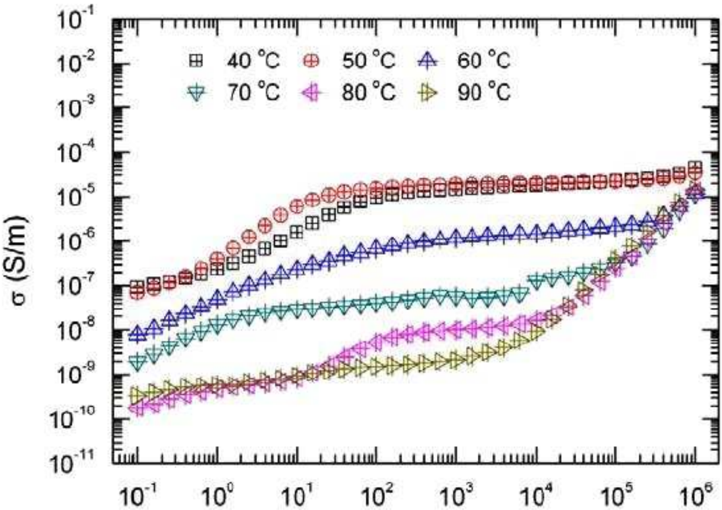


Fig. 2a Conductivity of graphene oxide with frequency and temperature

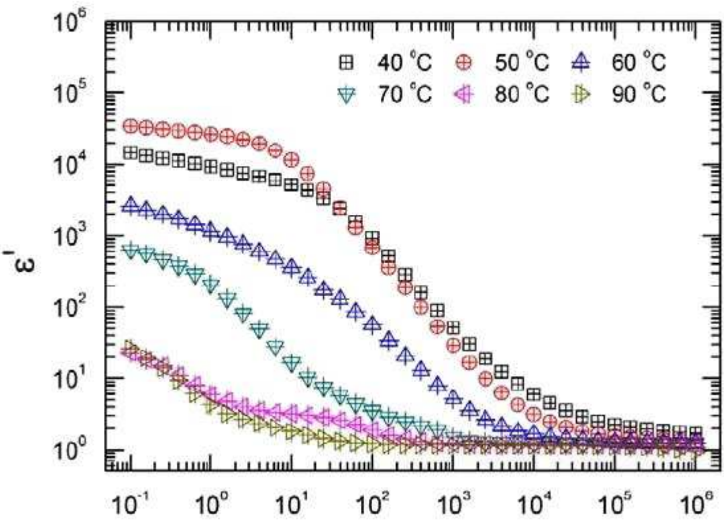


Fig. 2b Dielectric constant of graphene oxide with frequency and temperature

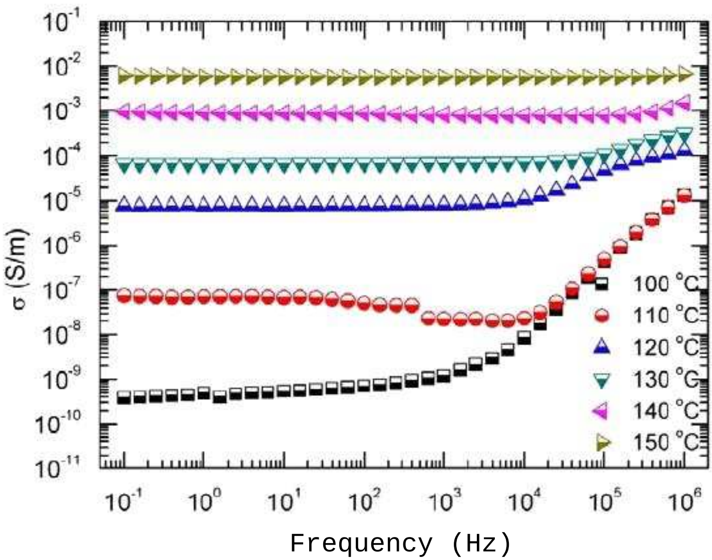


Fig. 3a Conductivity of graphene oxide with frequency and temperature

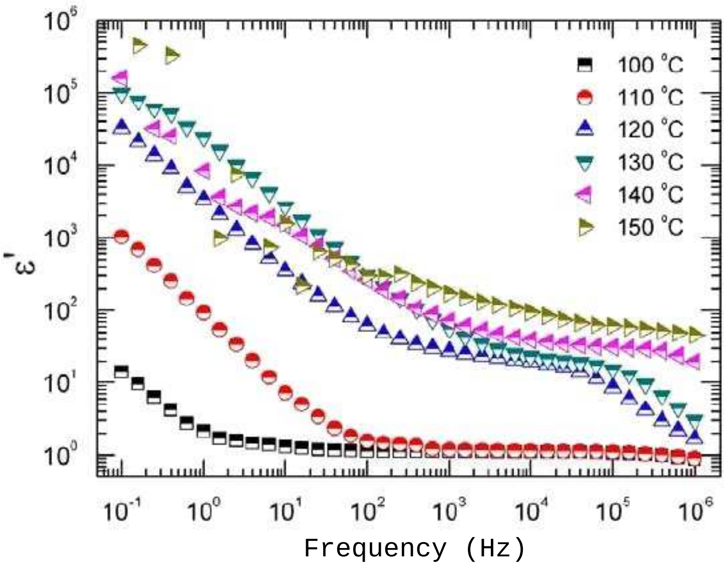
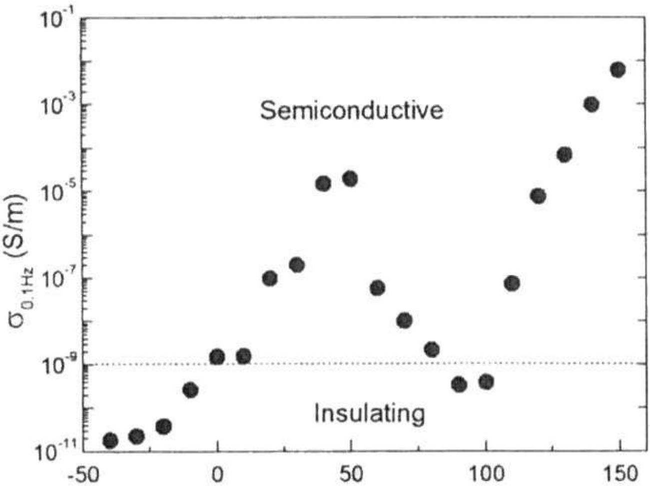
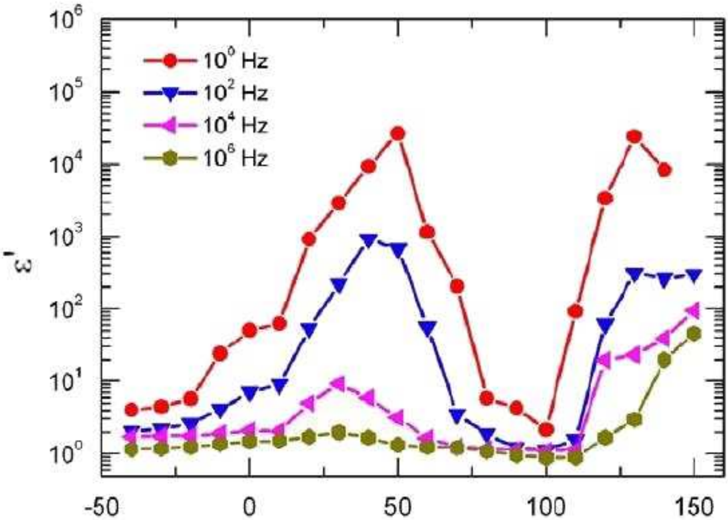


Fig. 3b Dielectric constant of graphene oxide with frequency and temperature



Temperature (^{0}C)

Fig. 4 Conductivity of graphene oxide with temperature at frequency 0.1 Hz



Temperature (^{0}C)

Fig. 5 Dielectric constant of graphene oxide

However, for concentrations GOn lower than 0.5 wt%, permittivity is lower than that of pure PVDF. Fig. 7 shows that the presence of GOn in various concentrations does not result in a change of electrical conductivity of the nanocomposite in relation to the pure PVDF at higher frequencies, whereas small differences (increase of conductivity) are observed as the frequency decreases [6].

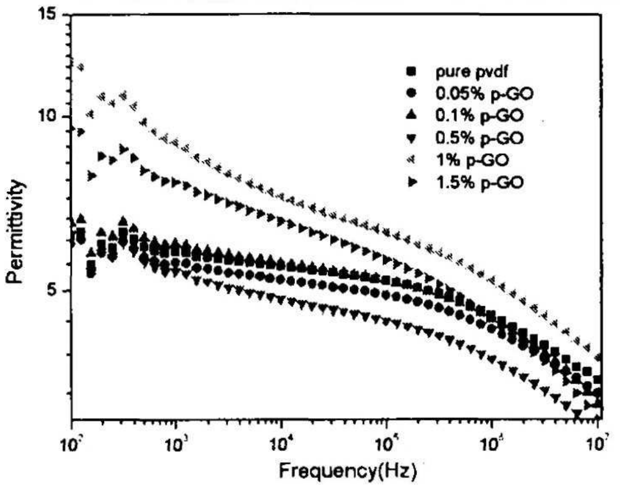


Fig. 6 Dielectric constant of Gon/PVDF

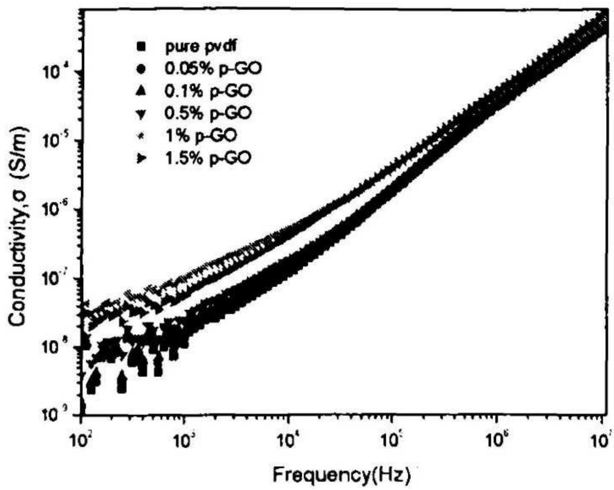


Fig. 7 Conductivity of GOn/PVDF

Graphene oxide in combination with silicon oxide may be used as thin coatings in XLPE. As evaluation index of such a combination the OIT (oxidative induction time) was used, an evaluation which is taken during accelerated ageing at 120^0 C. Fig. 8 shows OIT values as a function of time for the pure polymer, the combination XLPE- SiO_2 as well as for the combination XLPE-GO-SiO_2.

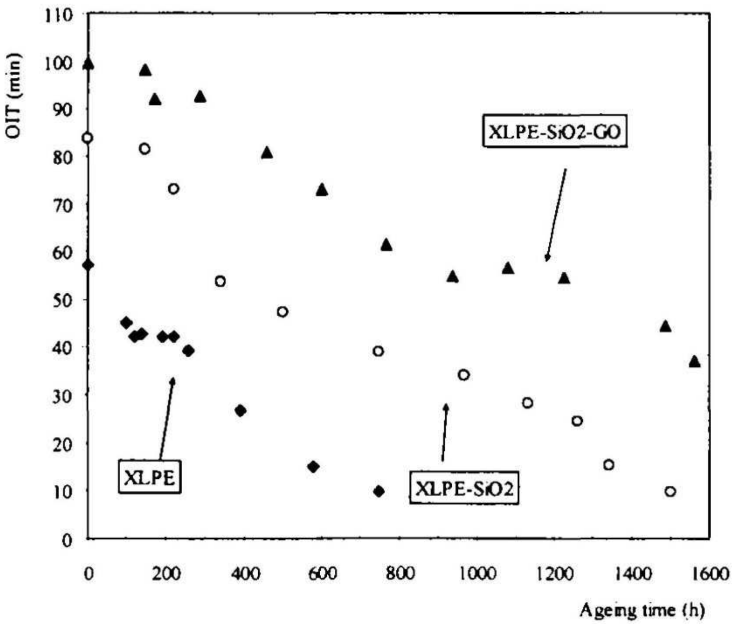


Fig. 8 Values of OIT with time

It is evident that such coatings contribute to the increase of resistance in the thermal oxidation. The presence of 0.5 wt% GO gives even more higher values of OIT. All coatings seem to increase the surface resistivity but the coating with GO is the better one. The presence of GO contributes to the hindrance of oxygen and of oxidation of the polymer. Moreover, the change in coating structure are adequate in improving the thermal stability of XLPE [7].

Work done with epoxy resin with graphene oxide up to 0.5 wt% showed that there is no difference between pure epoxy resin and the one with GO regarding the dielectric behavior. The addition of GO does not render any better the epoxy resin (Fig. 9) whereas there is a marked difference with epoxy resin nanocomposite after thermal treatment (Fig. 10) [8].

In general, for relatively low and higher voltages, it can be said that GO cannot be used as insulating material because for practical atmospheric conditions above 40^0 C, it does not show insulating behavior except for the temperature range between 90^0 C and 100^0 C and also below 10^0 C. Such temperature ranges, however, are very specific and do not generally satisfy ordinary industrial applications, especially in the high voltage industry. In very low voltages, i.e. in electronics applications, GO has in general a semiconducting character and as such is investigated in the scientific bibliography. In some specific cases, such as in very low humidity or in very low temperature, GO has an insulating behavior, which can have particular applications.

Cavity Considerations and Graphene Oxide

It is known that the electric field E_c inside an enclosed cavity in an insulating material of dielectric constant ε_r is given by the equation

$$E_c = 3\ \varepsilon_r\ E / (2\ \varepsilon_r + 1) \qquad (1)$$

where, E is the applied electric field to the insulating material.

It is also know that, assuming a uniform electric field E applied to the insulating material, the expected lifetime L is given by the equation

$$L = k\ (E\ d)^{-n} \qquad (2)$$

with k and n constants depending on the material and the quality of its construction, and d the thickness of the material.

Combining Equations (1) and (2), we have that

$$L = k\ [E_c\ d(2\varepsilon_r + 1) / 3\varepsilon_r]^{-n} \qquad (3)$$

which gives a relation between the lifetime of the material in terms of the thickness of the material.

Based on Fig. 11, and considering that in a sample the cavity has a radius R, the applied field to the sample is E, E_c is the field inside the cavity, d is the overall thickness of the sample and α as in Fig. 11, and having in mind that d = 2α + 2R, Equation (3) becomes]

$$L = k\ [2\ E_c\ (\alpha + R) * (2\varepsilon_r + 1) / 3\varepsilon_r]^{-n} \qquad (4)$$

Consequently we have a relation between the lifetime L and the radius R of the spherical cavity.

In the case of graphene oxide (GO), for temperature t = 90^0 C and from Fig. 2b, the dielectric constant is given as $\varepsilon_r = 2$, f = 50 Hz, with insulation thickness d = 0.1 mm, k = 4, n = 10, we finally get the curve of Fig. 12. This shows the change in lifetime in hours w.r.t. the electric field E_c inside the cavity in GO.

It is evident from Fig. 12, that as the electric field becomes larger, lifetime becomes shorter with a given cavity size.

In the case of GO, for power frequency, and various temperatures T = –10^0 C (from Fig. 1b we have $\varepsilon_r = 9$), T = 0^0 C (from Fig. 1b $\varepsilon_r = 15$), T = 10^0 C (from Fig. 1b, $\varepsilon_r = 21$), T = 90^0 C (from Fig. 2b $\varepsilon_r = 2$), T = 100^0 C (from Fig. 3b, $\varepsilon_r = 1.8$), we have correspondingly the lines L1, L2, L3, L4 and L5 in Fig. 13.

Fig. 13 shows the lifetimes in hours at various temperatures and in function of various electric field values inside the cavity in GO. We observe that lifetime changes w.r.t. temperature and therefore w.r.t. the dielectric constant of the material. Smaller dielectric constant means smaller lifetime.

From Equation (4), for a constant electric field value $E_c = 0.12$ kV/mm, k = 4, α = 1 mm, $\varepsilon_r = 2$, n = 10 and for different values of cavity radius, we find that the corresponding lifetime is

Tab. 1

R (mm)	L (hours)
0.2	6308812
0.1	15060285
0.05	23980986
0.01	35362772
0.005	37162029
0.001	38674015
0.0001	39023459

Cavities decrease the lifetime of insulation. By increasing the cavity radius R, lifetime decreases. As the cavity radius goes at about 0.001 mm and smaller, the difference in lifetimes becomes small or in other words, cavities of such magnitudes do not significantly decrease the lifetime of GO. It must be noted that the above Tab. 1 is rather qualitative rather than quantitative. It is evident from the above results that the electric behavior of GO depends on the temperature. In regions between 90^0 C –100^0 C as well as below 10^0 C, GO presents insulating behavior. In normal applications, however, under normal atmospheric conditions, its insulating behavior is lost.

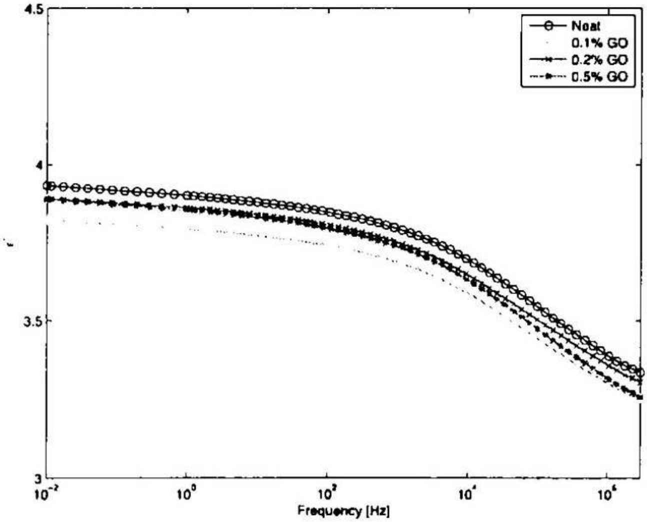


Fig. 9 Dielectric constant epoxy nanocomposite with GO at 20^{0} C

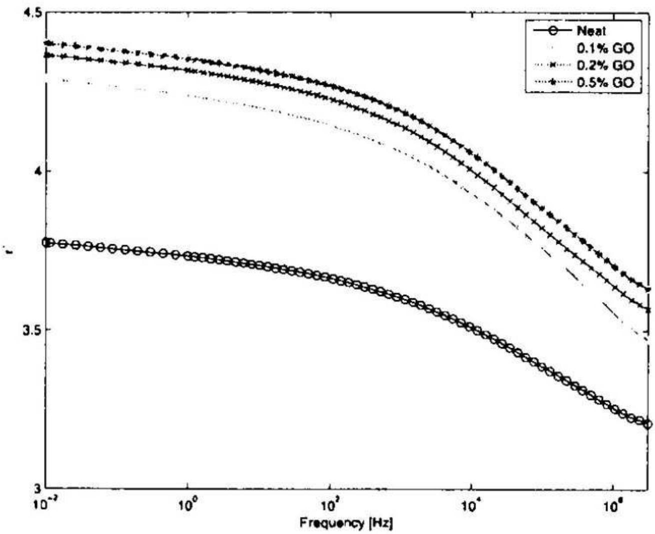


Fig. 10 Dielectric constant of epoxy nanocomposite with GO after thermal treatment

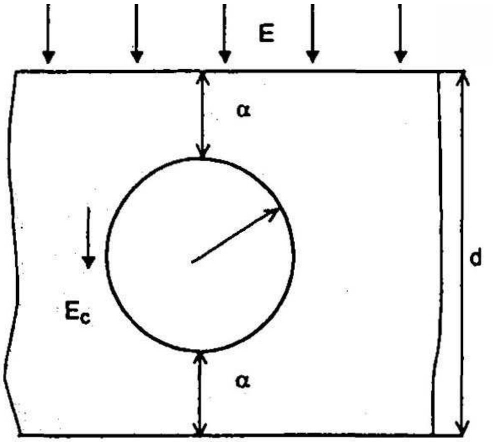


Fig. 11 Enclosed cavity in a solid dielectric

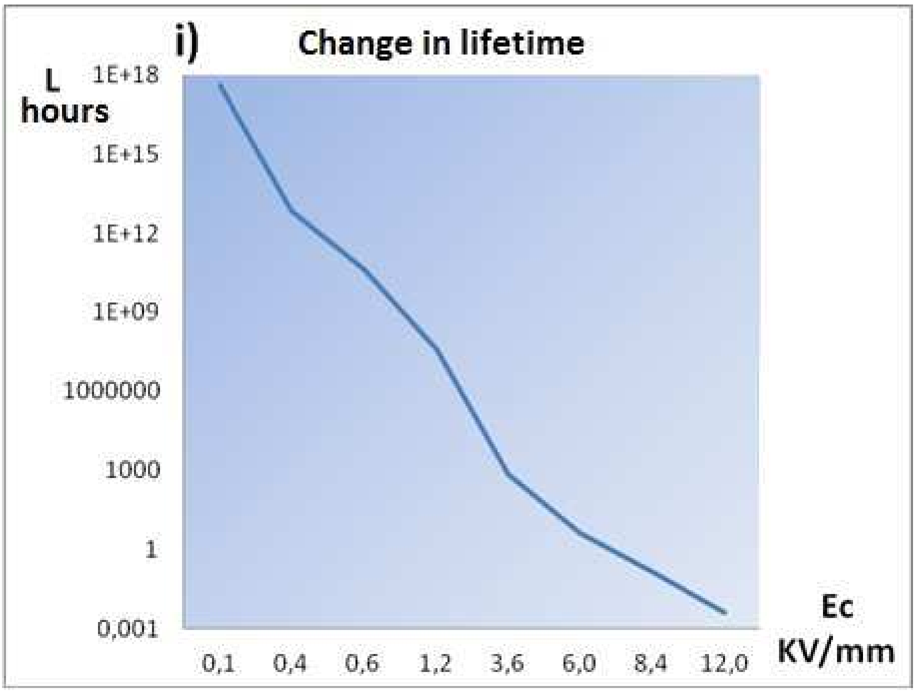


Fig. 12 Change in lifetime in (hours) with
the electric field E_C in (KV/mm)

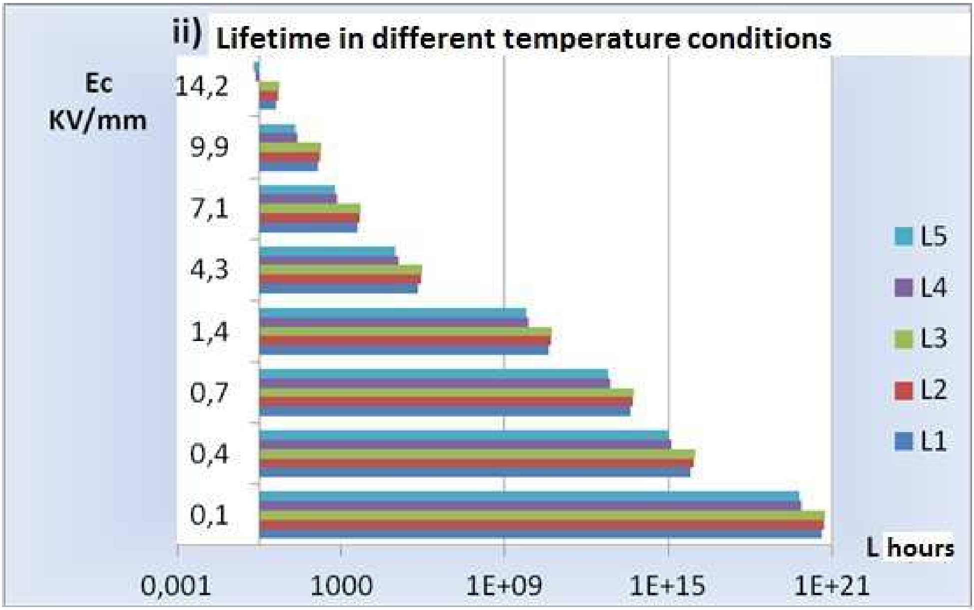


Fig. 13 Change in lifetime in (hours) with the electric field E_C in (KV/mm) and with different temperature conditions

Conclusion

Graphene is an excellent novel material for a variety of applications. However, graphene oxide is not suitable for high voltage applications since its insulating properties are confined to a small temperature range.

References

[1] http://www.nobelprize.org/nobel_prizes/physics/laureates/2010/

[2] Edwards R.S., Coleman K.S., "Graphene synthesis: Relationship to applications", Nanoscale, Vol. 5, 2013, pp. 38-51

[3] Huang X., Liu F., Jiang P., Tanaka T., "Is graphene oxide an insulating material?", Proceedings of the 2013

IEEE International Conference on Solid Dielectrics, 30th June – 4th July 2013, Bologna, Italy, pp. 904-907
[4] Huang X., Zhi C., Jiang P., Golberg D., Bando Y., Tanaka T., "Temperature-dependent electrical property transition of graphene oxide paper", Nanotechnology, Vol. 23, 2012, pp. 1-10
[5] Yao Y., Chen X., Zhu J., Zeng B., Wu Z., Li X., "The effect of ambient humidity on the electrical properties of graphene oxide", Nanoscale Research Letters, Vol. 7, 2012, pp. 363-370 http://link.springer.com/article/10.1186/1556-276X-7-363
[6] MLiu F., Huo R., Huang X., Jiang P., "Effect of processing method on the dielectric behaviour of graphene oxide/PVDF nanocomposites", Proceedings of the 2013 IEEE International Conference on Solid Dielectrics, 30th June – 4th July 2013, Bologna, Italy, 2013, pp. 919-922
[7] Cavallini A., Fabiani D., Saccani A., Toselli M., "Thermo-oxidative resistance of crosslinked PE coated by hybrid coatings containing graphene oxide", Proceedings of the 2013 IEEE International Conference on Solid Dielectrics, 30th June – 4th July 2013, Bologna, Italy, 2013, pp. 912-914
[8] Mancinelli P, Fabiani D., Saccani A., Toselli M., Heid T., Frechette M., Savoie S., David E., "Preparation and dielectric behavior of epoxy resin containing graphene oxide", Proceedings of the 2013 IEEE International Conference on Solid Dielectrics, 30th June – 4th July 2013, Bologna, Italy, 2013, pp. 915-918
[9] Danikas M.G., Vassiliadis G.E., "Models of partial discharges (PD) in enclosed cavities in solid dielectrics", Journal of Electrical Engineering, Vol. 54, No. 5-6, 2003, pp. 132-135

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* About The Authors

D.G. Mitrakas, received his degree from Democritus University of Thrace, Department of Electrical and Computer Engineering in May 2014. Since then, he is a self-employed electrical engineer with a particular interest in power systems applications.

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* The Hellenic Supreme Court of Civil and Penal Law:
www.areiospagos.gr/en — Court Rulings:Civil|A1|511|2008

FRONT COVER VIGNETTE

A faded synthesis of an anthemion rooted in a meandros

The thirteen-leaf is a symbol for a life tree leaf.
"Herakles and Kerberos", ca. 530–500 BC,
by Paseas, the Kerberos Painter,
Museum of Fine Arts, Boston.

www.mfa.org/collections/object/plate-153852

The simple meandros is a symbol for eternal immortality.
"Warrior with a phiale", ca. 480–460 BC,
by Berliner Maler,
Museo Archeologico Regionale "Antonio Salinas" di Palermo.

commons.wikimedia.org/wiki/File:Warrior_MAR_Palermo_NI2134.jpg