EE 5200 - Lecture 18 Fri Oct 10, 2019

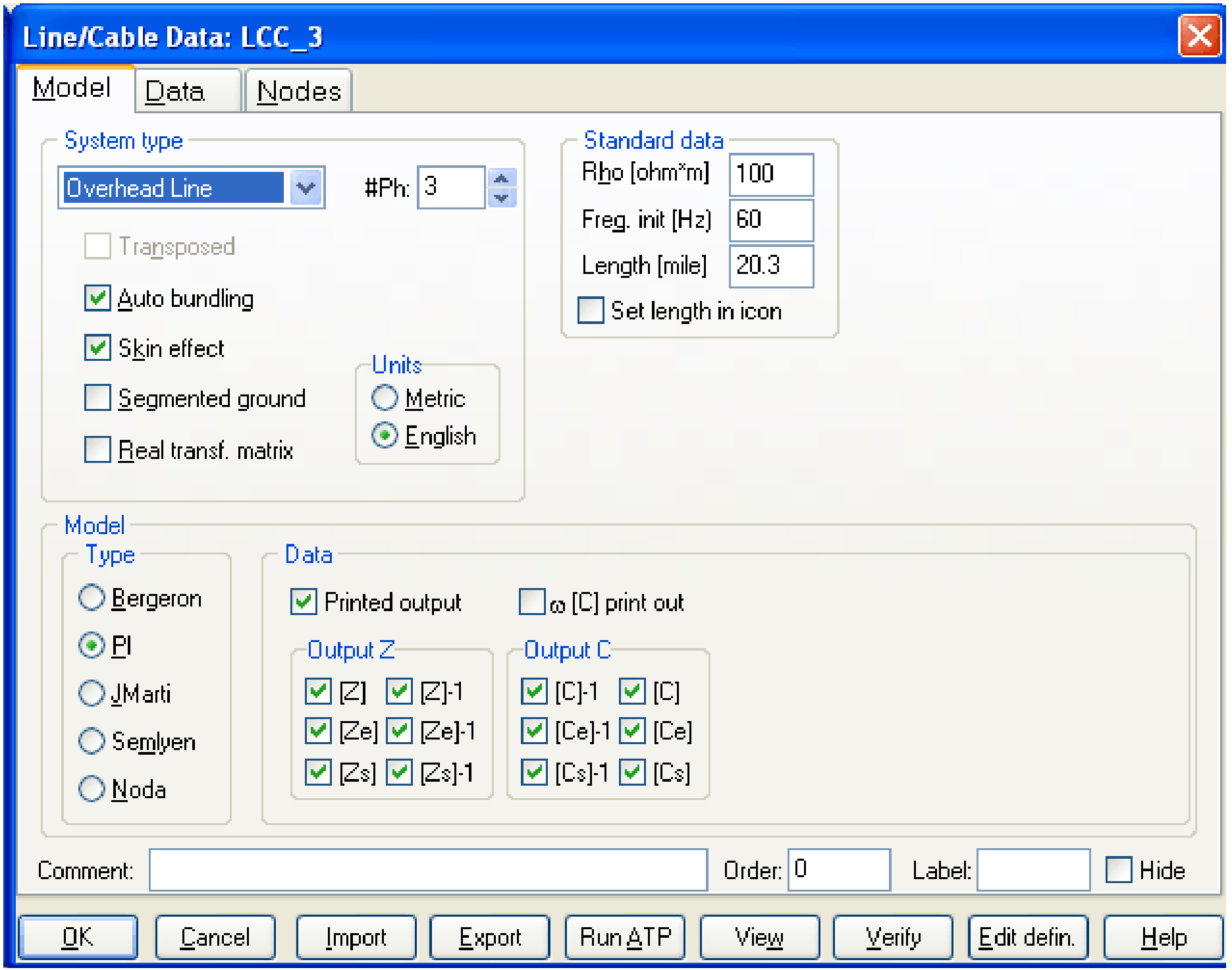
Topics for Today:

- Announcements
  - Term Project proposal due latest 9am Mon Oct 14th
  - Line Constants - using ATP and Matlab in upcoming Hmwks.
  - Office: EERC 614. Phone: 906.487.2857
  - Recommended problems from Ch.4,5 solutions posted
  - Next: Transmission Line C Parameters, Chapter 6

Chapter 5 - Series Inductance of Transmission Lines

- Review of mutual inductance concepts - recap
- Mutual inductance between 2 conductors
- Inductance matrix for group of conductors
- ATPDraw Line Constants
- Traditional methods for per-phase parameters
  - Geometric mean “averaging” of effective radius and phase spacing. Single-circuit, double-circuit.
  - Use of tables - standard 1-foot phase spacing.

Next: Chapter 6 - Capacitance


Line/Cable Data: LCC_3
Model
Data
Nodes
System type
Overhead Line
#Ph: 3
Transposed
Auto bundling
Skin effect
Segmented ground
Real transf. matrix
Units
Metric
English
Standard data
Rho [ohm*m] 100
Freq. init [Hz] 60
Length [mile] 20.3
Set length in icon
Model
Type
Bergeron
PI
JMarti
Semlyen
Noda
Data
Printed output
ω [C] print out
Output Z
[Z] [Z]-1
[Ze] [Ze]-1
[Zs] [Zs]-1
Output C
[C]-1 [C]
[Ce]-1 [Ce]
[Cs]-1 [Cs]
Comment:
Order: 0
Label:
Hide
OK
Cancel
Import
Export
Run ATP
View
Verify
Edit defin.
Help

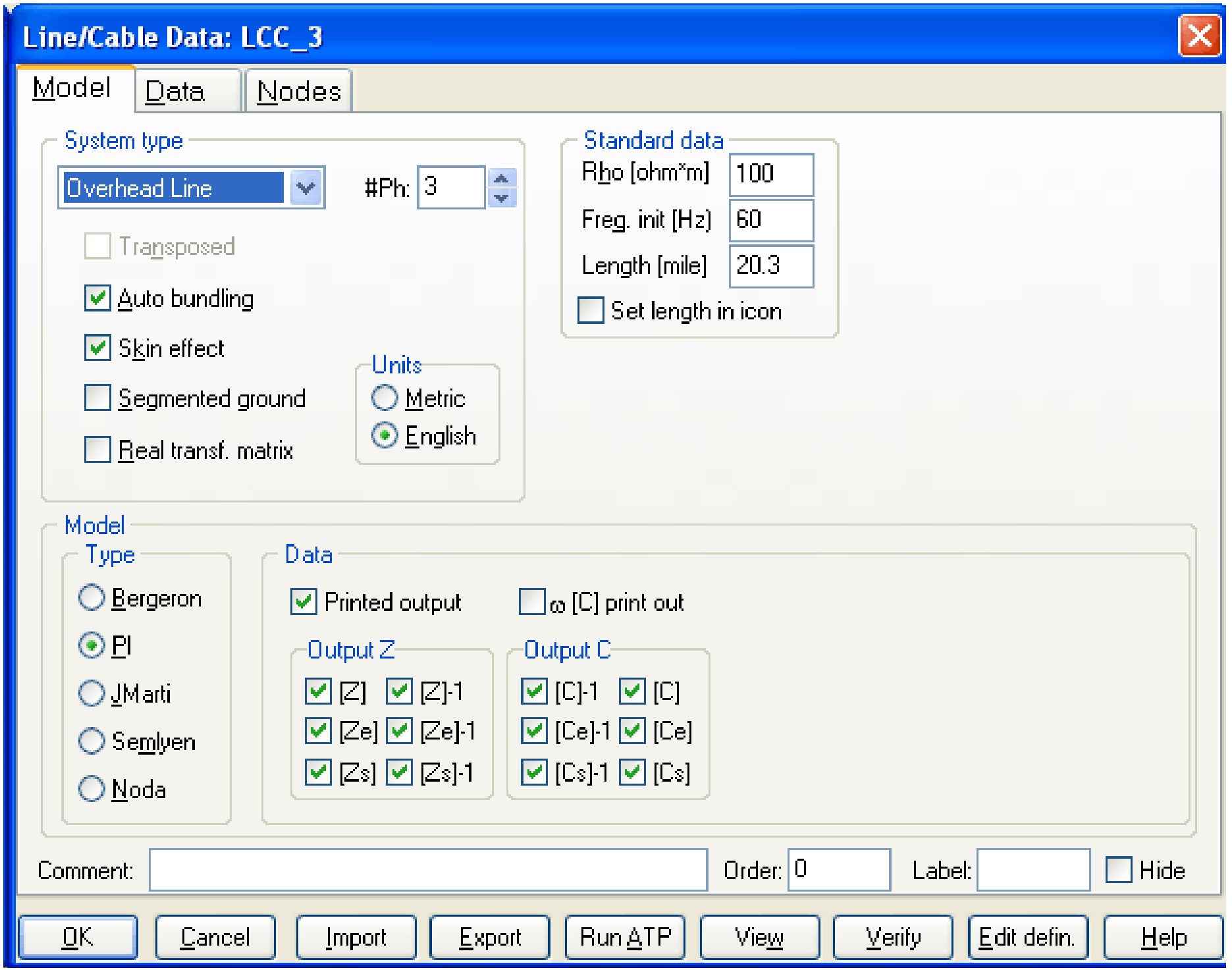
Line/Cable Data: LCC_3

Model | Data | Nodes

#	Ph.no.	Rin [inch]	Rout [inch]	Resis [ohm/mile DC]	Horiz [feet]	Vtower [feet]	Vmid [feet]	Separ [inch]	Alpha [deg]	NB
1	1	0.2	0.5985	0.10418	1	55	35	18	0	2
2	2	0.2	0.5985	0.10418	28	60.8	40.8	18	0	2
3	3	0.2	0.5985	0.10418	55	55	35	18	0	2
4	0	0	0.1925	2.4	15	81	61	0	0	0
5	0	0	0.1925	2.4	42	81	61	0	0	0

Add row | Delete last row | Insert row copy | ↑ Move ↓

OK | Cancel | Import | Export | Run ATP | View | Verify | Edit defin. | Help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[C]-1 [C]
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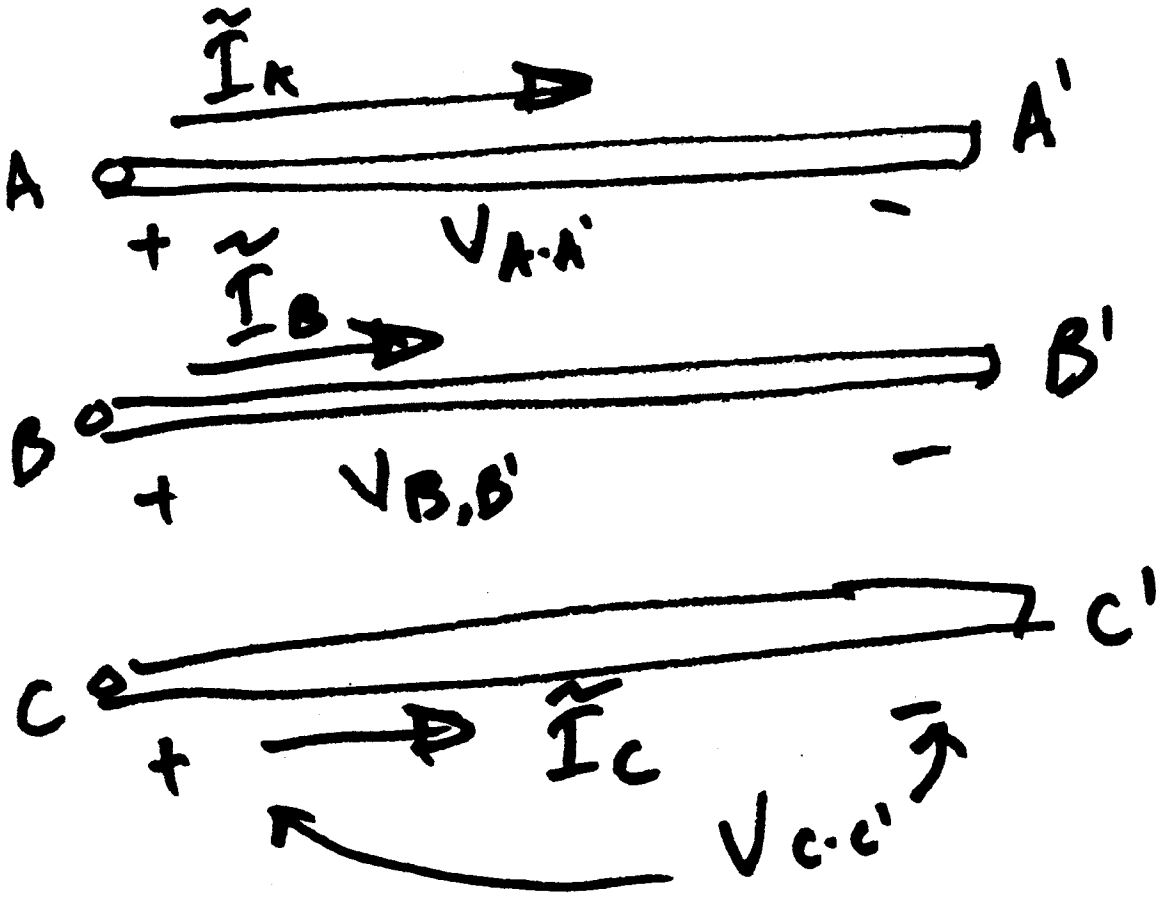
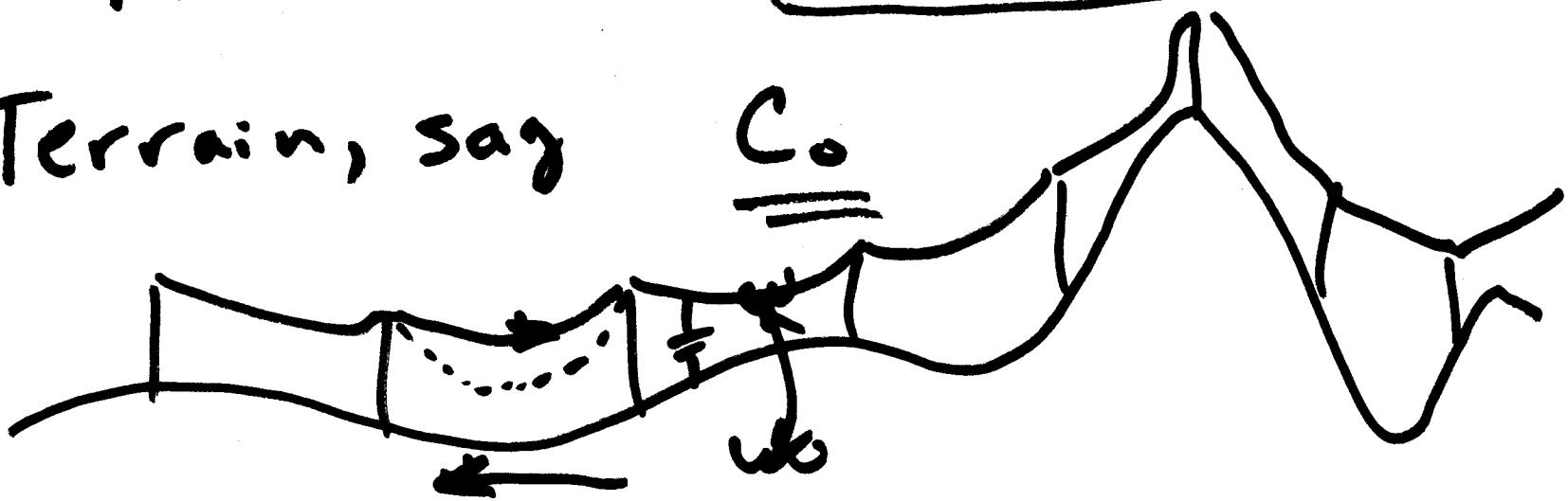


$$\tilde{V}_{B\text{-}B'} = \tilde{I}_A j\omega L_{BA} + \tilde{I}_B j\omega L_{BB} + \tilde{I}_C j\omega L_{BC}$$

Bare "OHD" lines.

5-10% parameter variation

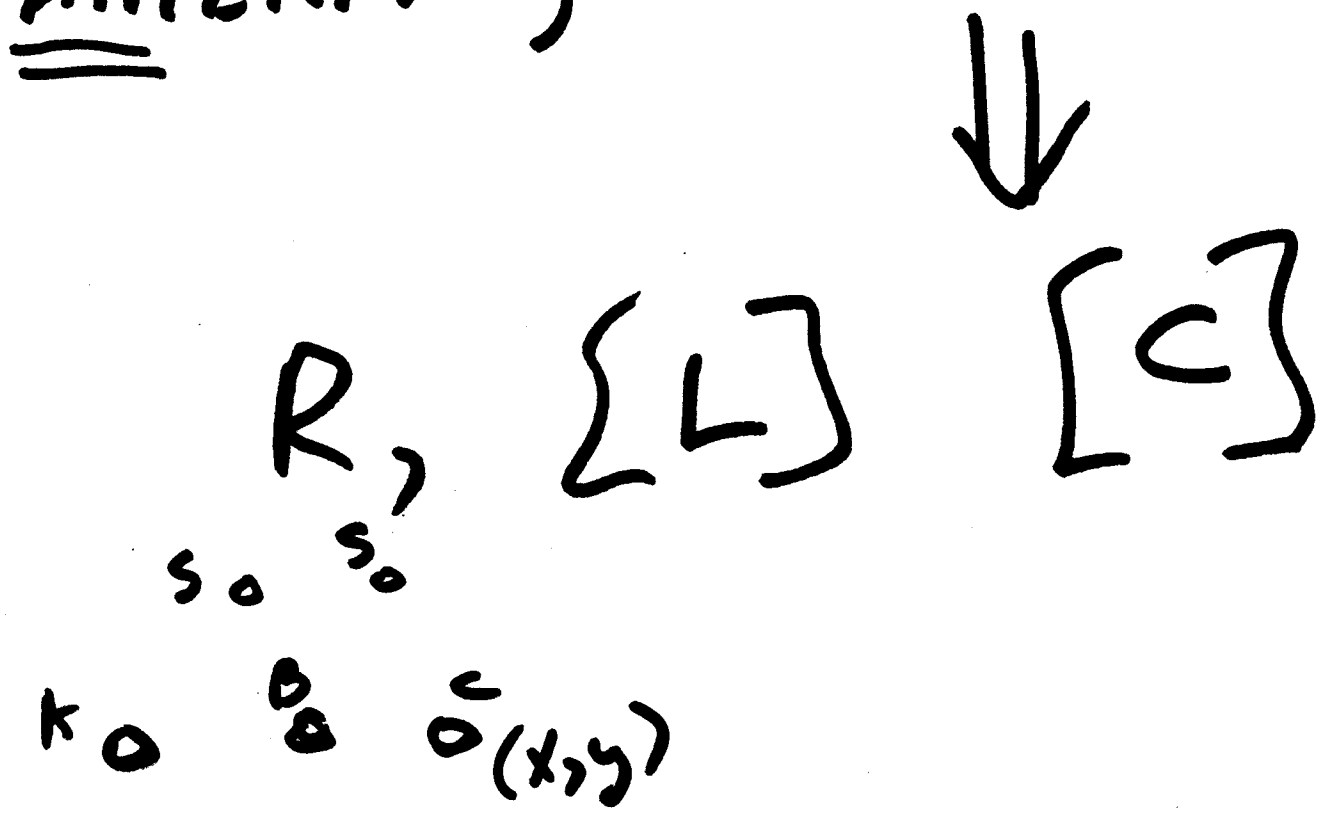
- Wind - L & C (transient)
- Temp, Sag $\Rightarrow$ C (C_o) to gnd.
- Rainfall, seasonal variations in ρ of earth.
  Rule of thumb $\rho = 100\ \Omega\text{-m}$.
- Terrain, Sag C_o



Computational Tools:

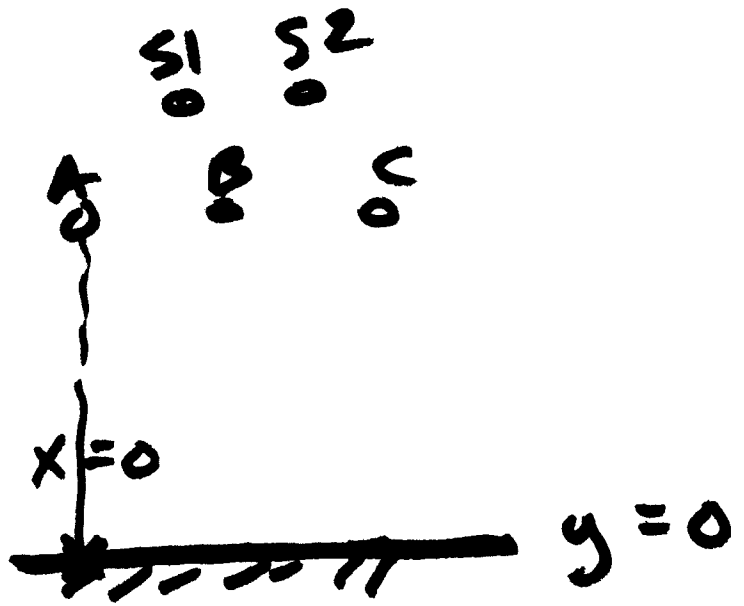
- Aspen
- ATP/EMTP

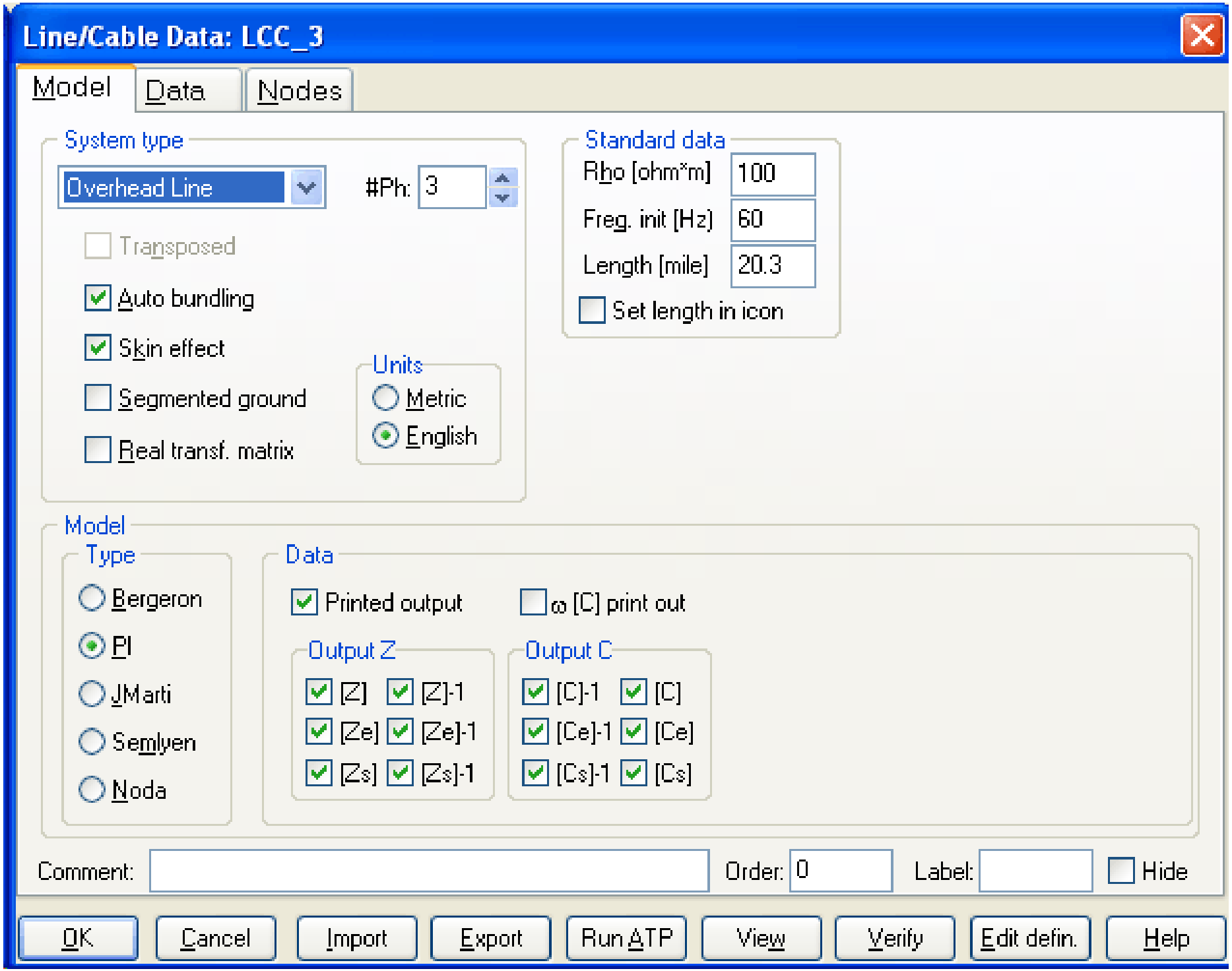
) "Line Constants"



Line Constants

- ATP Draw GUI
- ASPEN
- CAPE
- Others
  :
  :

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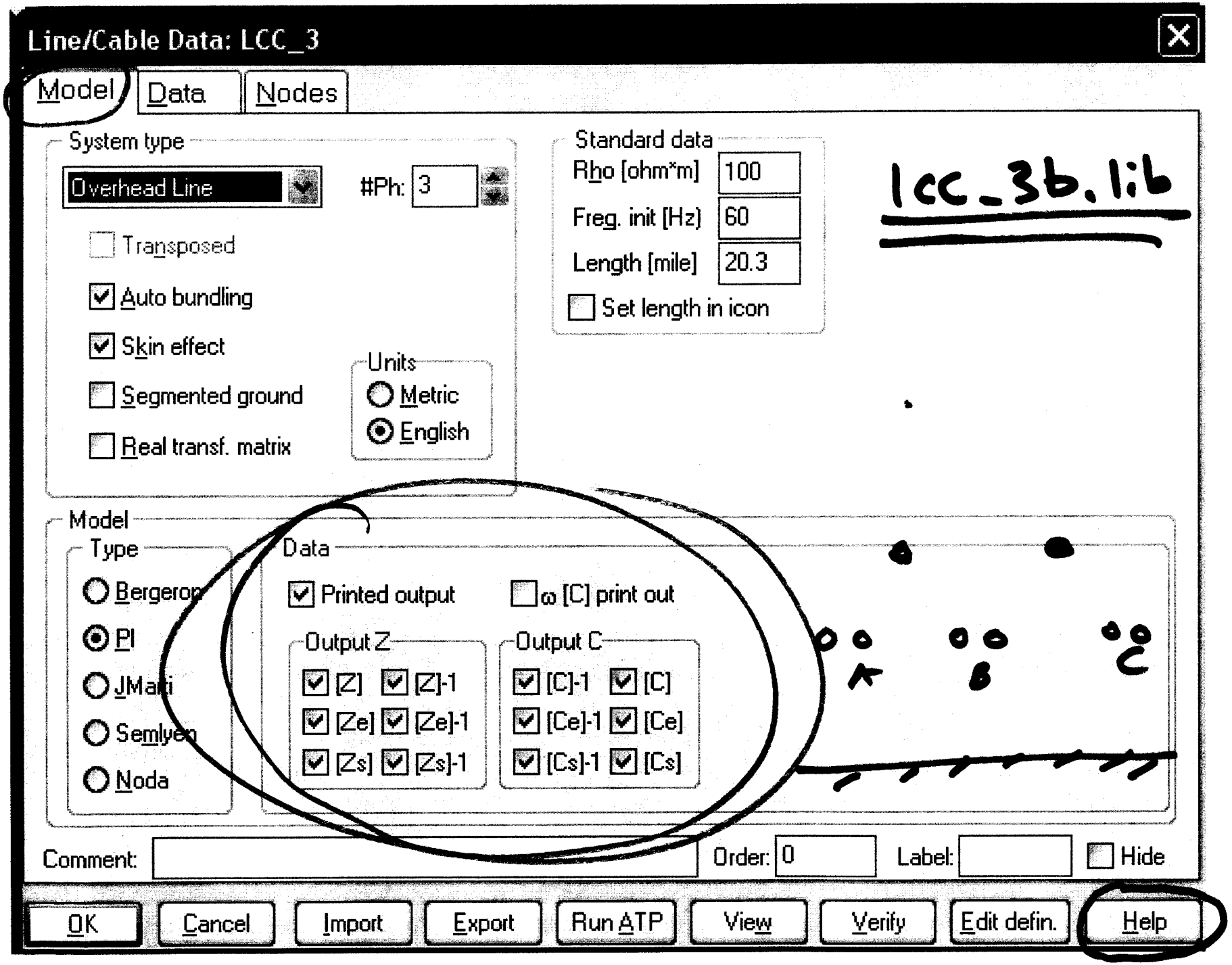
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lcc_3b.lib
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1	1	0.2	0.5985	0.10418	1	55	35	18	0	2
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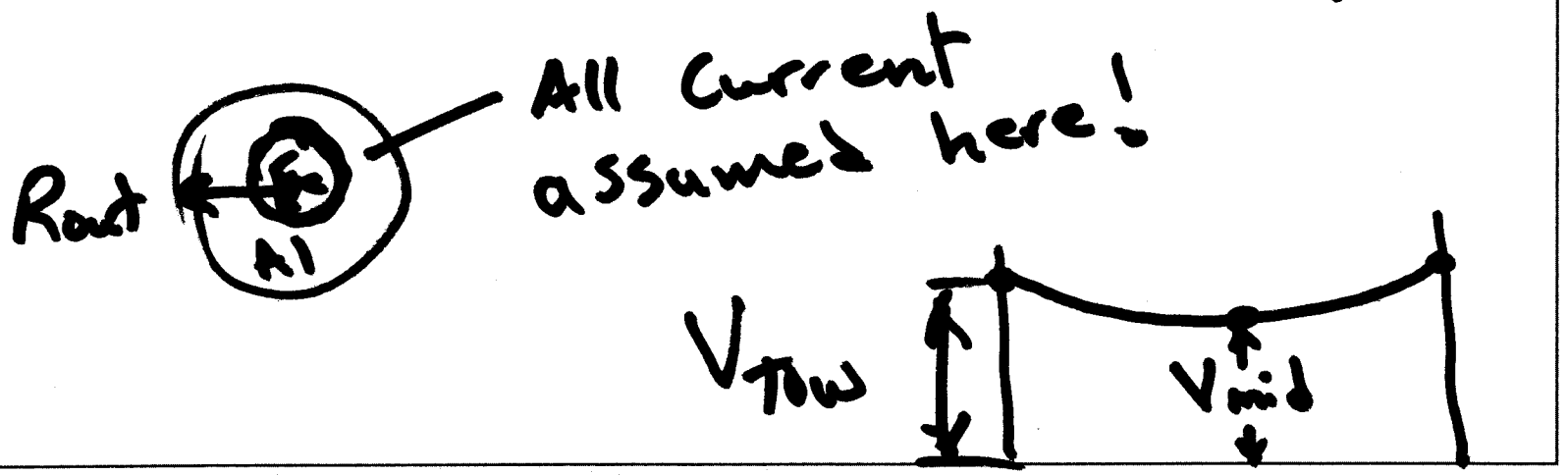

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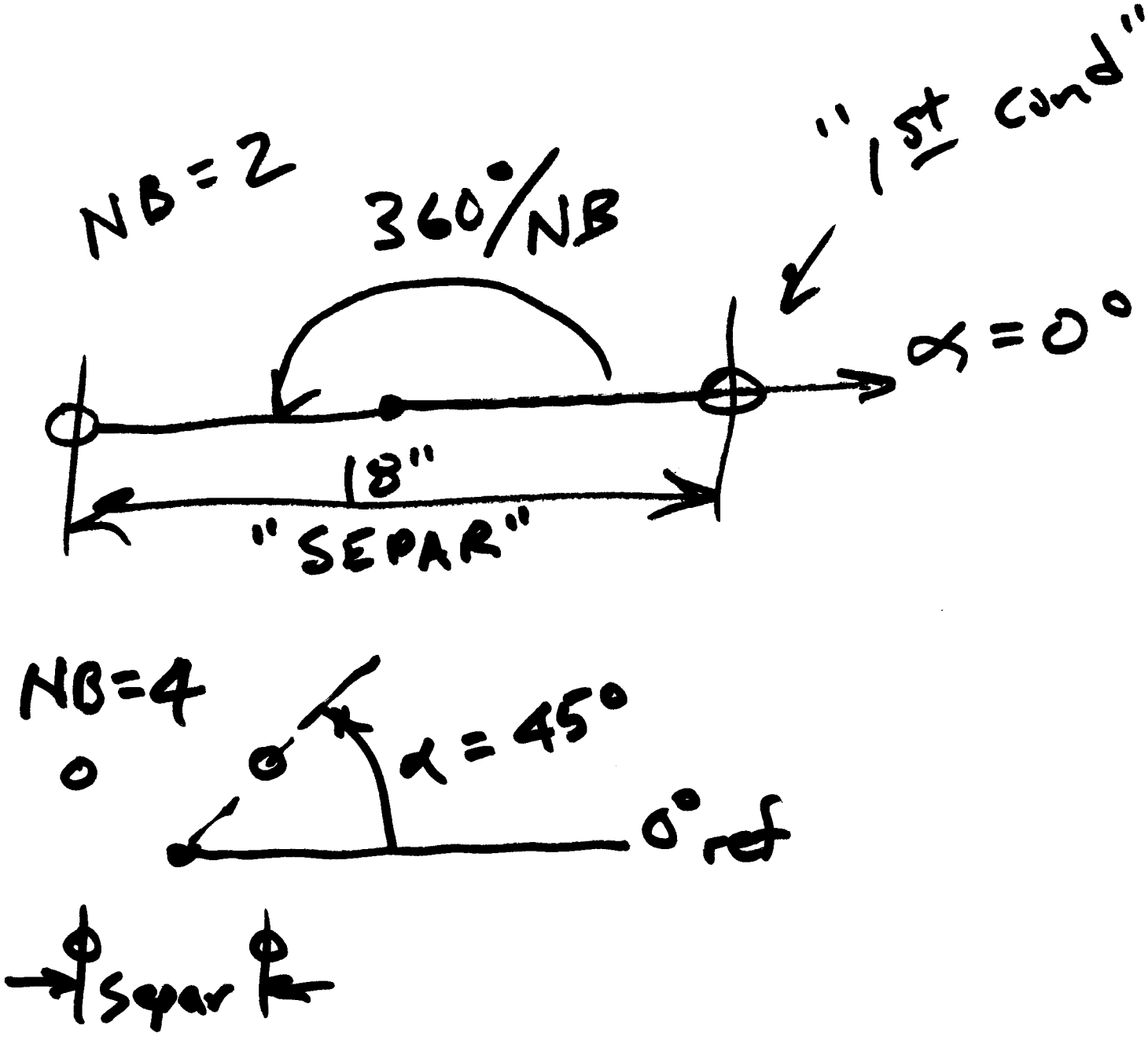

NB=2
360°/NB
"1st cond"
α=0°
18"
"SEPAR"
NB=4
0
α=45°
0° ref
Separ

8 0 .50000 2.40000 4 .000000 .38500 42.000 67.667

Matrices are for earth resistivity = 1.00000000E+02 ohm-meters and frequency 6.00000000E+01 Hz. Correction factor = 1.00000000E+06

Inverted capacitance matrix, in units of [daraf-mile] for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

1	8.288752E+07						
2	1.357766E+07	8.434315E+07					
3	6.803816E+06	1.357766E+07	8.288752E+07				
4	4.487274E+07	1.413539E+07	7.027245E+06	8.288752E+07			
5	1.305243E+07	4.632796E+07	1.413539E+07	1.357766E+07	8.434315E+07		
6	6.590051E+06	1.305243E+07	4.487274E+07	6.803816E+06	1.357766E+07	8.288752E+07	
7	1.458486E+07	1.775285E+07	1.008753E+07	1.483442E+07	1.739186E+07	9.842532E+06	1.009729E+08
8	9.682490E+06	1.714329E+07	1.499245E+07	9.923541E+06	1.751396E+07	1.475279E+07	1.822164E+07	1.009729E+08

Capacitance matrix, in units of [farads/mile] for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

1	1.733113E-08						
2	-6.680492E-10	1.752654E-08					
3	-1.935543E-10	-6.498339E-10	1.739392E-08				
4	-8.946758E-09	-7.839015E-10	-2.167591E-10	1.739001E-08			
5	-5.593927E-10	-8.783201E-09	-7.820676E-10	-6.513856E-10	1.752645E-08		
6	-1.740217E-10	-5.577119E-10	-8.942772E-09	-1.934746E-10	-6.660682E-10	1.733519E-08	
7	-8.738231E-10	-1.067983E-09	-3.912844E-10	-9.031449E-10	-9.667442E-10	-3.689744E-10	1.083026E-08
8	-3.603305E-10	-9.404067E-10	-9.195961E-10	-3.816450E-10	-1.043221E-09	-8.924532E-10	-1.320868E-09	1.082162E-08

Inverted capacitance matrix, in units of [daraf-mile] for the system of equivalent phase conductors.
Rows and columns proceed in the same order as the sorted input.

1	6.121014E+07	
2	9.989092E+06	6.021977E+07

Z

A-B-C

3 4.401543E+06 9.955975E+06 6.114284E+07

Inverted capacitance matrix, in units of [daraf-mile] for symmetrical components of the equivalent phase conductor
Rows proceed in the sequence (0, 1, 2), (0, 1, 2), etc.; columns proceed in the sequence (0, 2, 1), (0, 2, 1), etc.

0-1-2

0 7.708865E+07
0.000000E+00

1 -7.439389E+05 2.016718E+06
1.346519E+06 3.492440E+06

2 -7.439389E+05 5.274204E+07 2.016718E+06
-1.346519E+06 3.725290E-09 -3.492440E+06

Capacitance matrix, in units of [farads/mile] for the system of equivalent phase conductors.
Rows and columns proceed in the same order as the sorted input.

1 1.682763E-08

2 -2.662729E-09 1.748659E-08

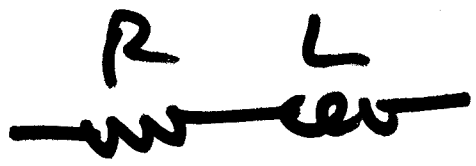
3 -7.778097E-10 -2.655681E-09 1.684357E-08

Capacitance matrix, in units of [farads/mile] for symmetrical components of the equivalent phase conductor
Rows proceed in the sequence (0, 1, 2), (0, 1, 2), etc.; columns proceed in the sequence (0, 2, 1), (0, 2, 1), etc.

0 1.298845E-08
0.000000E+00

1 1.993228E-10 -7.360892E-10
-3.585056E-10 -1.273882E-09

2 1.993228E-10 1.908467E-08 -7.360892E-10
3.585056E-10 1.378634E-25 1.273882E-09



Impedance matrix, in units of [ohms/mile] for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

8x8

1 1.982217E-01
1.354313E+00

2 9.212920E-02 1.978328E-01
5.634167E-01 1.354742E+00

3 9.228364E-02 9.212920E-02 1.982217E-01
4.818419E-01 5.634167E-01 1.354313E+00

4 9.233752E-02 9.213064E-02 9.228657E-02 1.982217E-01

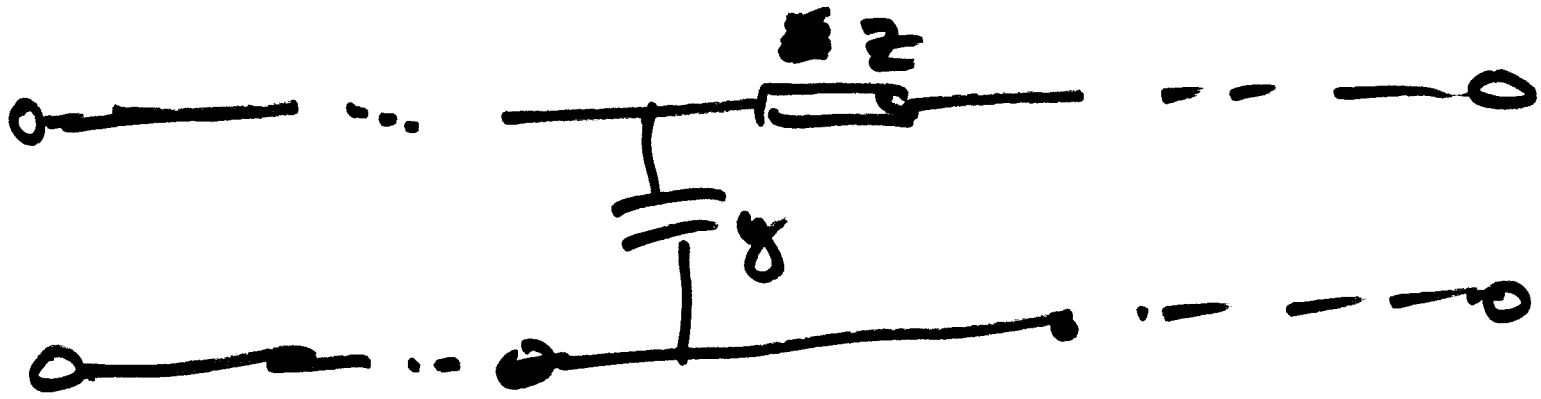
```
      9.166584E-01  5.700288E-01  4.852594E-01  1.354313E+00

   5  9.212769E-02  9.194861E-02  9.213064E-02  9.212920E-02  1.978328E-01
      5.571314E-01  9.170881E-01  5.700288E-01  5.634167E-01  1.354742E+00

   6  9.228064E-02  9.212769E-02  9.233752E-02  9.228364E-02  9.212920E-02  1.982217E-01
      4.785180E-01  5.571314E-01  9.166584E-01  4.818419E-01  5.634167E-01  1.354313E+00

   7  9.146885E-02  9.128028E-02  9.144649E-02  9.146956E-02  9.127963E-02  9.144447E-02  2.490758E+00
      5.545482E-01  5.833176E-01  4.994354E-01  5.574689E-01  5.792197E-01  4.962372E-01  1.499562E+00

   8  9.144308E-02  9.127916E-02  9.146999E-02  9.144515E-02  9.127986E-02  9.146933E-02  9.061913E-02  2.490758E+00
      4.941324E-01  5.763910E-01  5.593134E-01  4.972978E-01  5.806071E-01  5.565147E-01  5.678543E-01  1.499562E+00

Inverted impedance matrix,  in units of [ mho-mile   ]  for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

   1  2.973586E-01
     -1.386333E+00

   2  4.204826E-04  3.077296E-01
      1.118389E-01 -1.419344E+00

   3  6.143706E-03  1.290039E-03  3.004317E-01
      6.882177E-02  1.087845E-01 -1.394970E+00

   4 -2.235265E-01 -2.509374E-03  5.709808E-03  3.001881E-01
      7.680662E-01  1.199931E-01  7.012786E-02 -1.394861E+00

   5  3.293388E-03 -2.146897E-01 -2.389224E-03  1.186833E-03  3.077358E-01
      1.022567E-01  7.394793E-01  1.199345E-01  1.088381E-01 -1.419349E+00

   6  6.459130E-03  3.403938E-03 -2.232755E-01  6.148486E-03  5.486563E-04  2.976169E-01
      6.779436E-02  1.022010E-01  7.679550E-01  6.882000E-02  1.117783E-01 -1.386446E+00

   7 -4.423456E-02 -4.827817E-02 -2.801326E-02 -4.459372E-02 -4.526097E-02 -2.766971E-02  3.435087E-01
      2.251800E-02  2.439818E-02  1.774185E-02  2.257375E-02  2.396485E-02  1.766989E-02 -1.538692E-01

   8 -2.737320E-02 -4.453463E-02 -4.527484E-02 -2.769395E-02 -4.761238E-02 -4.499232E-02 -1.915598E-02  3.433656E-01
      1.752930E-02  2.378673E-02  2.286499E-02  1.760046E-02  2.423900E-02  2.282469E-02 -1.403749E-02 -1.539893E-01

Impedance matrix,  in units of [ ohms/mile   ]  for the system of equivalent phase conductors.
Rows and columns proceed in the same order as the sorted input.

   1  2.361625E-01
      9.883991E-01

   2  1.939530E-01  2.596600E-01
      4.036624E-01  9.619036E-01
```

A-B-C

```
   3  1.822608E-01  1.943738E-01  2.370190E-01
      3.349045E-01  4.031578E-01  9.874252E-01
   Both  "R"  and  "X"  are in  [ ohms] ;   "C"  are in  [ microFarads] .

Impedance matrix,  in units of  [ ohms/mile   ]  for symmetrical components of the equivalent phase conductor
Rows proceed in the sequence  (0, 1, 2),  (0, 1, 2),  etc.;  columns proceed in the sequence  (0, 2, 1),  (0, 2, 1),
etc.

   0  6.246722E-01
      1.740392E+00

   1 -1.862922E-02 -4.694597E-02
      3.197923E-03  2.737576E-02

   2  6.333332E-03  5.408463E-02  4.718379E-02
     -1.662431E-02  5.986677E-01  2.694656E-02

Sequence      Surge impedance       Attenuation   velocity    Wavelength   Resistance    Reactance    Susceptance
          Magnitude(ohm) angle(degr.)    db/mile     miles/s      miles      ohm/mile     ohm/mile     mho/mile
   Zero :  6.14520E+02 -9.87219E+00  4.48104E-03  1.27170E+05  2.11950E+03  6.24672E-01  1.74039E+00  4.89653E-06
Positive:  2.89046E+02 -2.58109E+00  8.13451E-04  1.81463E+05  3.02439E+03  5.40846E-02  5.98668E-01  7.19475E-06

Inverted impedance matrix,  in units of  [ mho-mile   ]  for the system of equivalent phase conductors.
Rows and columns proceed in the same order as the sorted input.

   1  1.504937E-01
     -1.245061E+00

   2  2.391330E-03  1.860860E-01
      4.429269E-01 -1.359734E+00

   3  2.446113E-02  2.853409E-03  1.514977E-01
      2.755640E-01  4.426983E-01 -1.245506E+00

Inverted impedance matrix,  in units of  [ mho-mile   ]  for symmetrical components of the equivalent phase conductor
Rows proceed in the sequence  (0, 1, 2),  (0, 1, 2),  etc.;  columns proceed in the sequence  (0, 2, 1),  (0, 2, 1),
etc.

   0  1.824964E-01
     -5.093076E-01

   1 -1.791397E-02 -1.427496E-01
     -5.017631E-03  5.209471E-02

   2  1.276374E-02  1.527905E-01  1.164537E-01
     -1.224519E-02 -1.670497E+00  9.754828E-02
Request for flushing of punch buffer.              |$PUNCH

A listing of 80-column card images now being flushed from punch buffer follows.
================================================================================
```

0-1-2

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789
================================================================================
C  <++++++>  Cards punched by support routine on  11-Oct-08  19.52.32  <++++++>
C LINE CONSTANTS
C $ERASE
C $UNITS,    60.,    0.0
C BRANCH  IN___AOUT__AIN___BOUT__BIN___COUT__C
C ENGLISH
C   10.333 0.10418 4           1.197      1.     55.     35.     18.    0.0
C   20.333 0.10418 4           1.197     28.    60.8    40.8     18.    0.0
C   30.333 0.10418 4           1.197     55.     55.     35.     18.    0.0
C   0  0.5     2.4 4           0.385     15.     81.     61.     0.0    0.0
C   0  0.5     2.4 4           0.385     42.     81.     61.     0.0    0.0
C BLANK CARD ENDING CONDUCTOR CARDS
C     100.       60.           111111 111111 1    20.3              44
$VINTAGE, 1
 1IN___AOUT__A             4.79409867E+00  2.00645027E+01  3.41600955E-01
 2IN___BOUT__B             3.93724567E+00  8.19434771E+00 -5.40534006E-02
                           5.27109703E+00  1.95266429E+01  3.54977709E-01
 3IN___COUT__C             3.69989467E+00  6.79856065E+00 -1.57895377E-02
                           3.94578731E+00  8.18410360E+00 -5.39103337E-02
                           4.81148567E+00  2.00447309E+01  3.41924409E-01
$VINTAGE, -1,
=========<  End of LUNIT7 punched cards as flushed by  $PUNCH  request  >=======

Blank card terminating frequency cards.          |BLANK CARD ENDING FREQUENCY CARDS
Blank card ending  "LINE CONSTANTS"  cases.      |BLANK CARD ENDING LINE CONSTANT
Total case timing (CP, I/O, tot), sec:      1.125     0.000     1.125
```



$$z = R + jX \ /m$$

$$y = j\omega C \ /m$$

$$\bar{Z}_c = \sqrt{\frac{z}{y}}$$

$$\bar{\gamma} = \sqrt{zy}$$