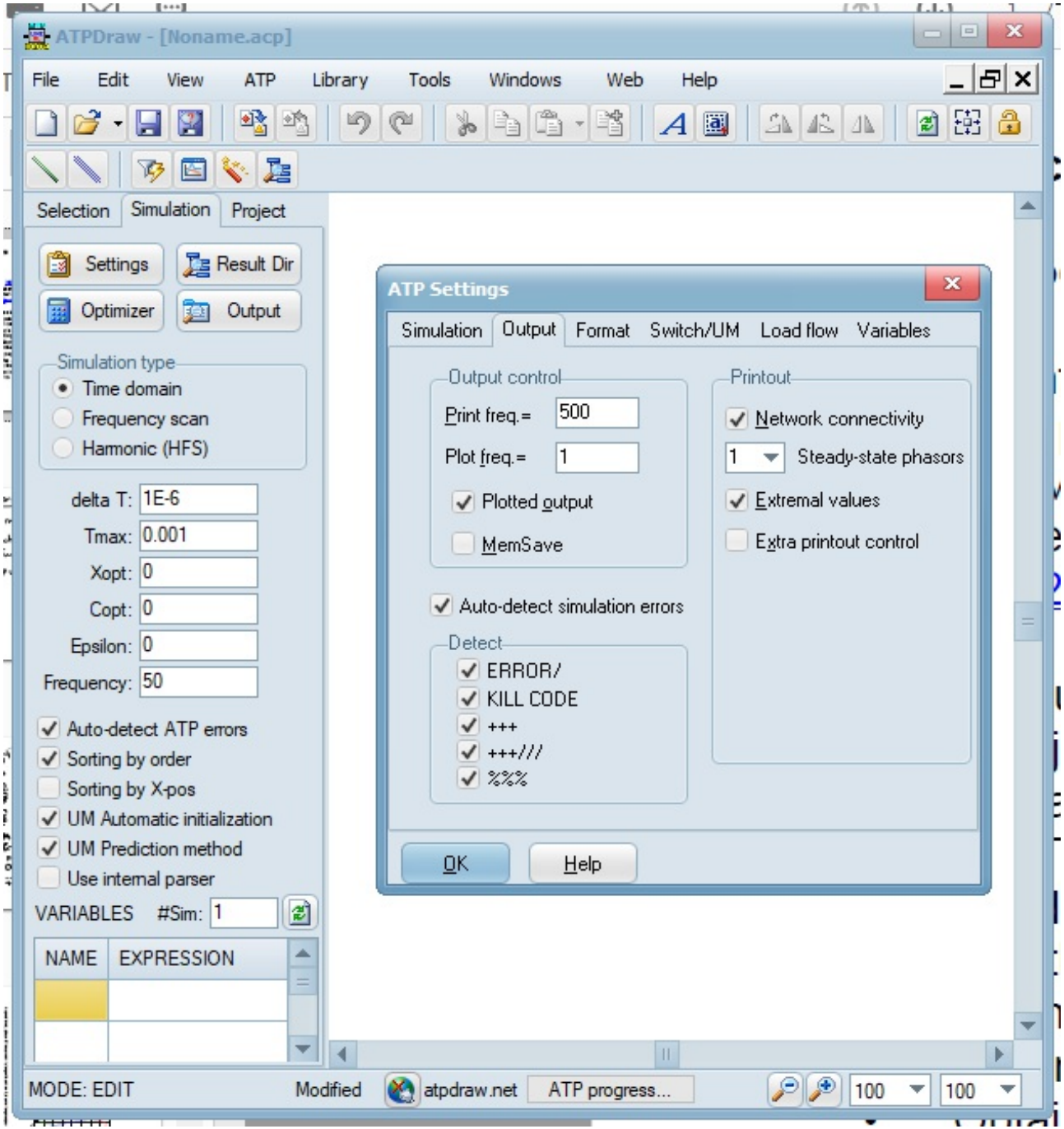
EE 5220 - Lecture 20 Wednesday Feb 21, 2024

Topics for Today:

- Course Info:
  - Web page: https://pages.mtu.edu/~bamork/ee5220/
  - Software - Matlab. ATP/EMTP [License - www.emtp.org] ATP tutorials posted on our course web page
  - EE5220-L@mtu.edu (participation = min half letter grade, 5%)

- HW#7 - due Tues March 13th 9am
- Term Project Week 8: (by Monday following) - complete reference list and fully-detailed table of contents, via e-mail to grader.
- Use of ATPDraw's Line Constants to obtain parameters, build line models.
  - Conductor Sag, NESC guidelines for minimum clearance
  - Weather-affected changes in parameters
- Use of Line Constants .lis output file to obtain detailed matrices, line parameters, propagation constants.
  - Obtaining the .lis file
  - Interpreting the matrices: Phase matrices; Sequence matrices
- Long-Line approximations, performance as fraction of wavelength
- Basics for lines vs. cables; traveling wave model (See Feb 19th video/ATP)

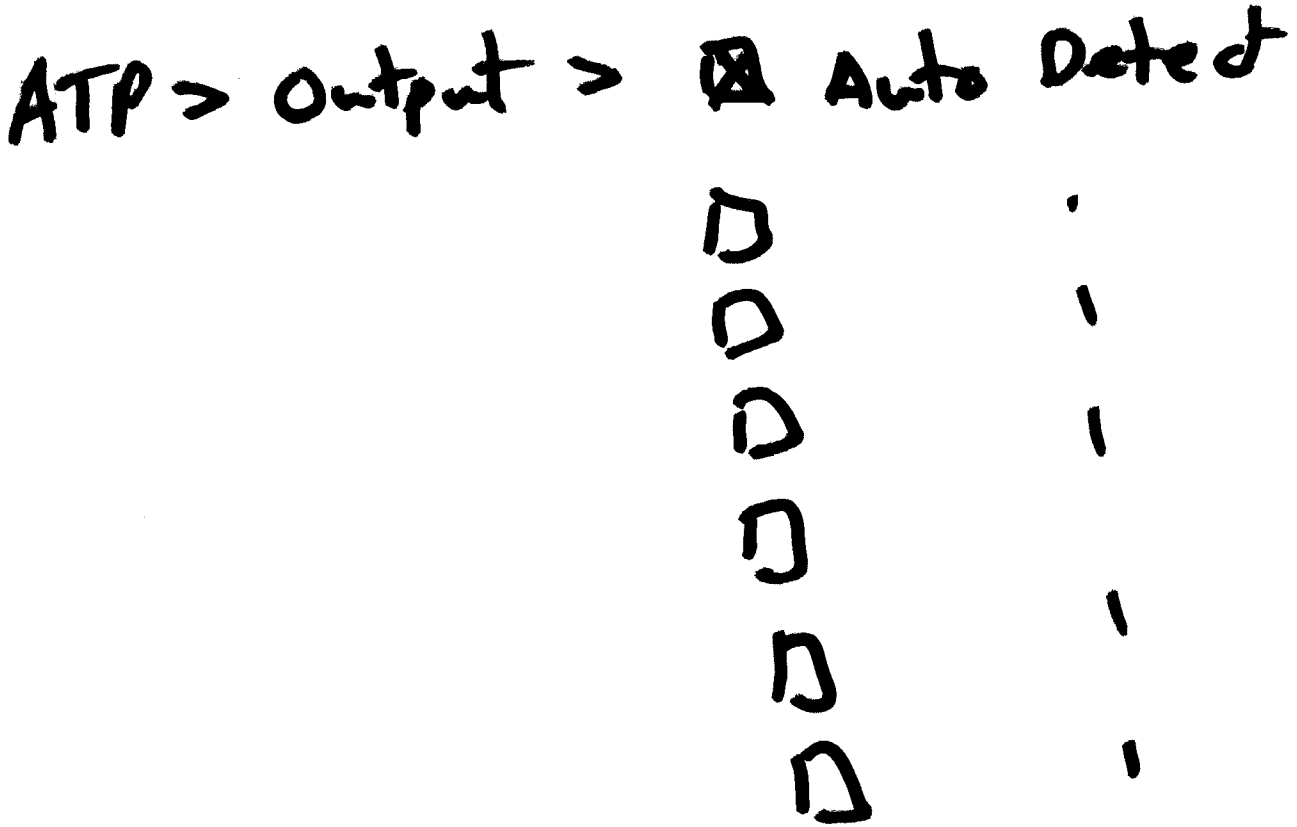
ATP Point of the Day: Enable all error/warning/caution messages for auto-display!!

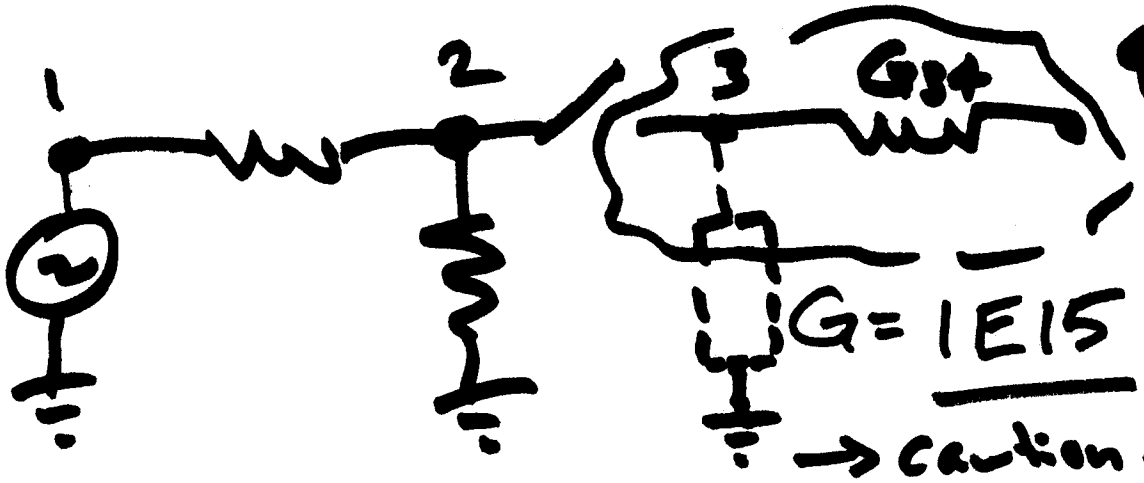

ATPDraw - [Noname.acp]
File Edit View ATP Library Tools Windows Web Help
Selection Simulation Project
Settings
Result Dir
Optimizer
Output
Simulation type
Time domain
Frequency scan
Harmonic (HFS)
delta T: 1E-6
Tmax: 0.001
Xopt: 0
Copt: 0
Epsilon: 0
Frequency: 50
Auto-detect ATP errors
Sorting by order
Sorting by X-pos
UM Automatic initialization
UM Prediction method
Use internal parser
VARIABLES #Sim: 1
NAME EXPRESSION
MODE: EDIT
Modified
atpdraw.net
ATP progress...
100
100
ATP Settings
Simulation Output Format Switch/UM Load flow Variables
Output control
Print freq.= 500
Plot freq.= 1
Plotted output
MemSave
Auto-detect simulation errors
Detect
ERROR/
KILL CODE
+++
+++///
%%%
Printout
Network connectivity
1 Steady-state phasors
Extremal values
Extra printout control
OK
Help

ATP Pointers

- Float Subnetwork - next page

- Auto-Detect Sim Errors
  - Turn on!





Row 3 ⇒

is singular

$\div 0 \Rightarrow$ crash!

$y_{33} = +\Sigma$ braches landing on Node 3.

$= +G_{34}$

$y_{34} = -\Sigma$ spanning admittances

$= -G_{34}$

In a given row, Σy's $= 0$ if no ground connection.

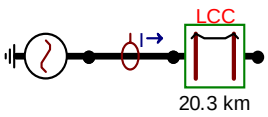
Row 3:

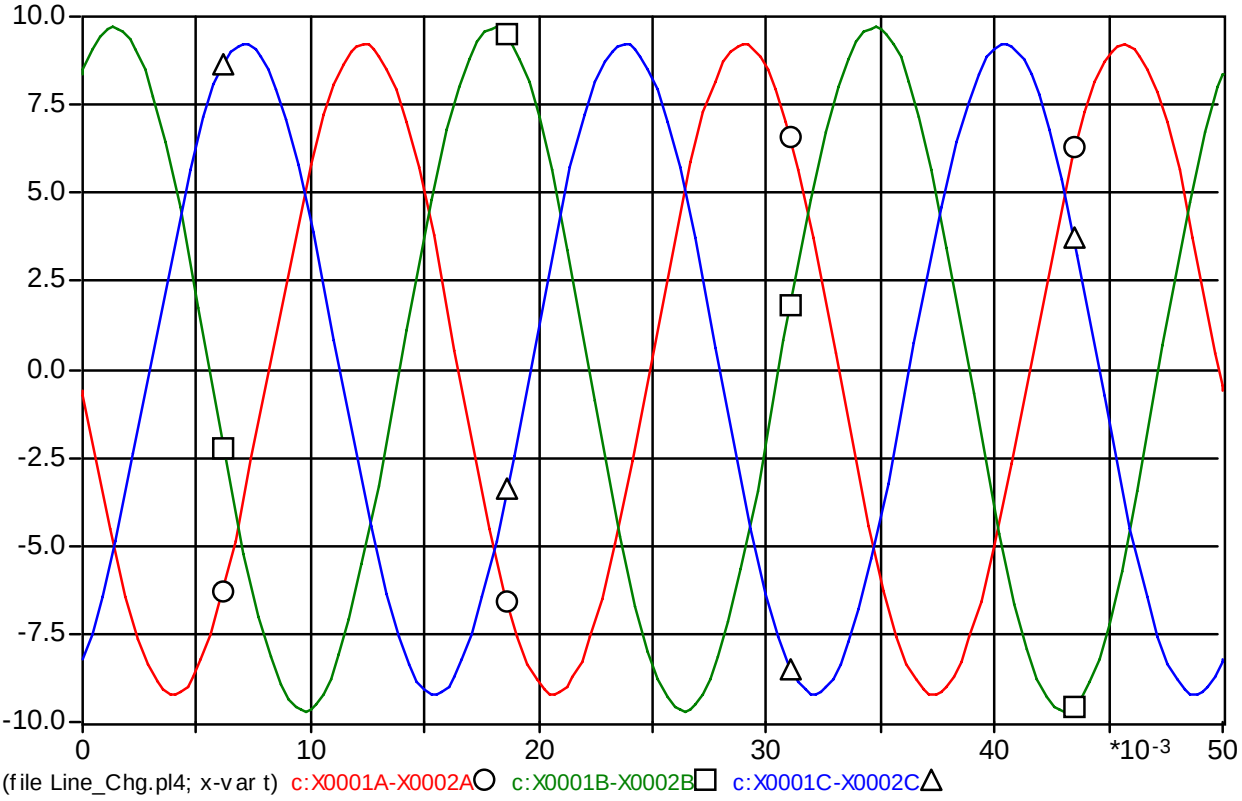
0	0	$+G_{34}$	$-G_{34}$
y_{31}	y_{32}	y_{33}	y_{34}

This implies singularity.

Line Charging Example: LCC_3b.alc (Coupled-PI, 60 Hz model).

Simulation file: Line_Chg.acp





As predicted, phase B line current is larger than A or C, due to larger capacitive coupling to phase B. Larger capacitive effect ==> smaller input impedance ==> higher current...

See Line Constants output log file, LCC_3b.lis, on following pages. Be sure to print these with fixed-pitch font so that columnar data is aligned. This file is created in atp\atpdraw\atp\ folder when you "build" the line model (from within Line Constants parameter/dialog box, click on Run ATP).

```
-   17   cards of disk file read into card cache cells  1   onward.
Alternative Transients Program (ATP),  Watcom translation.   All rights reserved by Can/Am user group of Portland, Oregon, USA.
 Date (dd-mth-yy) and time of day (hh.mm.ss) = 29-Feb-08  15.24.27   Name of disk plot file is  LCC_3B.pl4
Consult the 860-page ATP Rule Book of the Can/Am EMTP User Group in Portland,  Oregon, USA.  Source code date is 22 January 2002.
Total size of LABCOM tables =  7546726   INTEGER words.   VARDIM  List Sizes follow :   6002   10K  192K   900  320K  1200
  15K  120K  2250  3800  720  1200  72800  510  90K  800  90  254  120K  100K  3K  15K  192K  30  30K  160K  600  210K  300  60
```

Descriptive interpretation of input data cards.	Input data card images are shown below, all 80 columns, character by character
	0 1 2 3 4 5 6 7 8
	01234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
Comment card. KOMPAR > 0.	C data:LCC_3B.ATP
Marker card preceding new EMTP data case.	BEGIN NEW DATA CASE
Compute overhead line constants. Limit = 120	LINE CONSTANTS
Erase all of 0 cards in the punch buffer.	$ERASE
New XOPT, COPT = 6.00000000E+01 6.00000000E+01	$UNITS, 60., 60.
Pairs of 6-character bus names for each phase.	BRANCH IN___AOUT__AIN___BOUT__BIN___COUT__C
Request for metric (not English) units.	METRIC
Line conductor card. 3.330E-01 1.042E-01 4	10.333 0.10418 4 1.197 1. 55. 35. 18. 0.0 2
Line conductor card. 3.330E-01 1.042E-01 4	20.333 0.10418 4 1.197 28. 60.8 40.8 18. 0.0 2
Line conductor card. 3.330E-01 1.042E-01 4	30.333 0.10418 4 1.197 55. 55. 35. 18. 0.0 2
Line conductor card. 5.000E-01 2.400E+00 4	0 0.5 2.4 4 0.385 15. 81. 61. 0.0 0.0 0
Line conductor card. 5.000E-01 2.400E+00 4	0 0.5 2.4 4 0.385 42. 81. 61. 0.0 0.0 0
Blank card terminating conductor cards.	BLANK CARD ENDING CONDUCTOR CARDS
Frequency card. 1.000E+02 6.000E+01 2.030E+01	100. 60. 111111 111111 0 20.3 44

Line conductor table after sorting and initial processing.

Table Row	Phase Number	Skin effect R-type	Resistance R (ohm/km)	Reactance data specification X-type	X(ohm/km) or GMR	Diameter (cm)	Horizontal X (mtrs)	Avg height Y (mtrs)	Name
1	1	.33300	.10418	4	.000000	1.19700	0.910	41.667	
2	2	.33300	.10418	4	.000000	1.19700	27.910	47.467	
3	3	.33300	.10418	4	.000000	1.19700	54.910	41.667	
4	1	.33300	.10418	4	.000000	1.19700	1.090	41.667	
5	2	.33300	.10418	4	.000000	1.19700	28.090	47.467	
6	3	.33300	.10418	4	.000000	1.19700	55.090	41.667	
7	0	.50000	2.40000	4	.000000	.38500	15.000	67.667	
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 susceptance matrix, in units of [ohm-kmeter] for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

1	4.549349E+05							
2	5.796193E+04	4.611489E+05						
3	2.904493E+04	5.796193E+04	4.549349E+05					
4	2.926453E+05	5.824006E+04	2.915716E+04	4.549349E+05				
5	5.768579E+04	2.988593E+05	5.824006E+04	5.796193E+04	4.611489E+05			
6	2.893329E+04	5.768579E+04	2.926453E+05	2.904493E+04	5.796193E+04	4.549349E+05		
7	6.273758E+04	7.511599E+04	4.259954E+04	6.286548E+04	7.493095E+04	4.247403E+04	5.321400E+05	
8	4.178340E+04	7.388622E+04	6.355973E+04	4.190689E+04	7.407620E+04	6.343690E+04	7.778668E+04	5.321400E+05

Susceptance matrix, in units of [mhos/kmeter] for the system of physical conductors.
Rows and columns proceed in the same order as the sorted input.

1	3.778608E-06							
2	-8.368508E-08	3.792707E-06						
3	-2.884376E-08	-8.317809E-08	3.779960E-06					
4	-2.382750E-06	-8.581586E-08	-2.938220E-08	3.779552E-06				
5	-8.131578E-08	-2.369129E-06	-8.562109E-08	-8.336752E-08	3.792707E-06			
6	-2.831840E-08	-8.112390E-08	-2.382342E-06	-2.884193E-08	-8.348782E-08	3.779018E-06		
7	-1.272917E-07	-1.478392E-07	-6.273436E-08	-1.281108E-07	-1.455386E-07	-6.203392E-08	1.992176E-06	
8	-6.068211E-08	-1.422685E-07	-1.302669E-07	-6.135833E-08	-1.446100E-07	-1.295006E-07	-2.154518E-07	1.991177E-06

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

```
   1  3.643293E+05

   2  4.515578E+04  3.618017E+05

   3  2.043237E+04  4.503427E+04  3.640893E+05
```

Inverted susceptance matrix, in units of [ohm-kmeter] 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  4.371550E+05
      0.000000E+00

   1 -3.618781E+03  8.621409E+03
      6.476654E+03  1.493445E+04

   2 -3.618781E+03  3.265326E+05  8.621409E+03
     -6.476654E+03  0.000000E+00 -1.493445E+04
```

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

```
   1  2.792660E-06

   2 -3.341842E-07  2.847155E-06

   3 -1.153863E-07 -3.334109E-07  2.794294E-06
```

Susceptance matrix, in units of [mhos/kmeter] 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  2.289382E-06
      0.000000E+00

   1  2.685381E-08 -8.177182E-08
     -4.790199E-08 -1.415826E-07

   2  2.685381E-08  3.072363E-06 -8.177182E-08
      4.790199E-08  2.193008E-23  1.415826E-07
```

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

```
   1  1.585799E-01
      9.161533E-01

   2  5.335205E-02  1.579204E-01
      2.650855E-01  9.169840E-01

   3  5.351994E-02  5.335205E-02  1.585799E-01
      2.141735E-01  2.650855E-01  9.161533E-01

   4  5.373760E-02  5.335275E-02  5.352137E-02  1.585799E-01
      6.441420E-01  2.655672E-01  2.144247E-01  9.161533E-01

   5  5.335134E-02  5.307805E-02  5.335275E-02  5.335205E-02  1.579204E-01
      2.646068E-01  6.449727E-01  2.655672E-01  2.650855E-01  9.169840E-01

   6  5.351852E-02  5.335134E-02  5.373760E-02  5.351994E-02  5.335205E-02  1.585799E-01
      2.139232E-01  2.646068E-01  6.441420E-01  2.141735E-01  2.650855E-01  9.161533E-01

   7  5.227275E-02  5.196386E-02  5.218193E-02  5.227308E-02  5.196356E-02  5.218100E-02  2.450972E+00
      2.613432E-01  2.775767E-01  2.254437E-01  2.615609E-01  2.772711E-01  2.252056E-01  1.008814E+00

   8  5.217575E-02  5.196183E-02  5.227484E-02  5.217670E-02  5.196215E-02  5.227453E-02  5.088096E-02  2.450972E+00
      2.238908E-01  2.755436E-01  2.627413E-01  2.241264E-01  2.758580E-01  2.625327E-01  2.700313E-01  1.008814E+00
```

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

```
   1  6.635409E-01
     -1.972531E+00

   2 -2.034846E-04  6.691177E-01
      1.006290E-01 -1.990403E+00

   3  5.814223E-03  9.537902E-06  6.641024E-01
      6.540311E-02  1.002743E-01 -1.973428E+00

   4 -5.699559E-01 -7.072962E-04  5.683619E-03  6.639485E-01
      1.227857E+00  1.016166E-01  6.566408E-02 -1.973374E+00

   5  4.147604E-04 -5.645847E-01 -6.318118E-04 -6.409805E-05  6.691187E-01
      9.934170E-02  1.210408E+00  1.015886E-01  1.003022E-01 -1.990404E+00
```

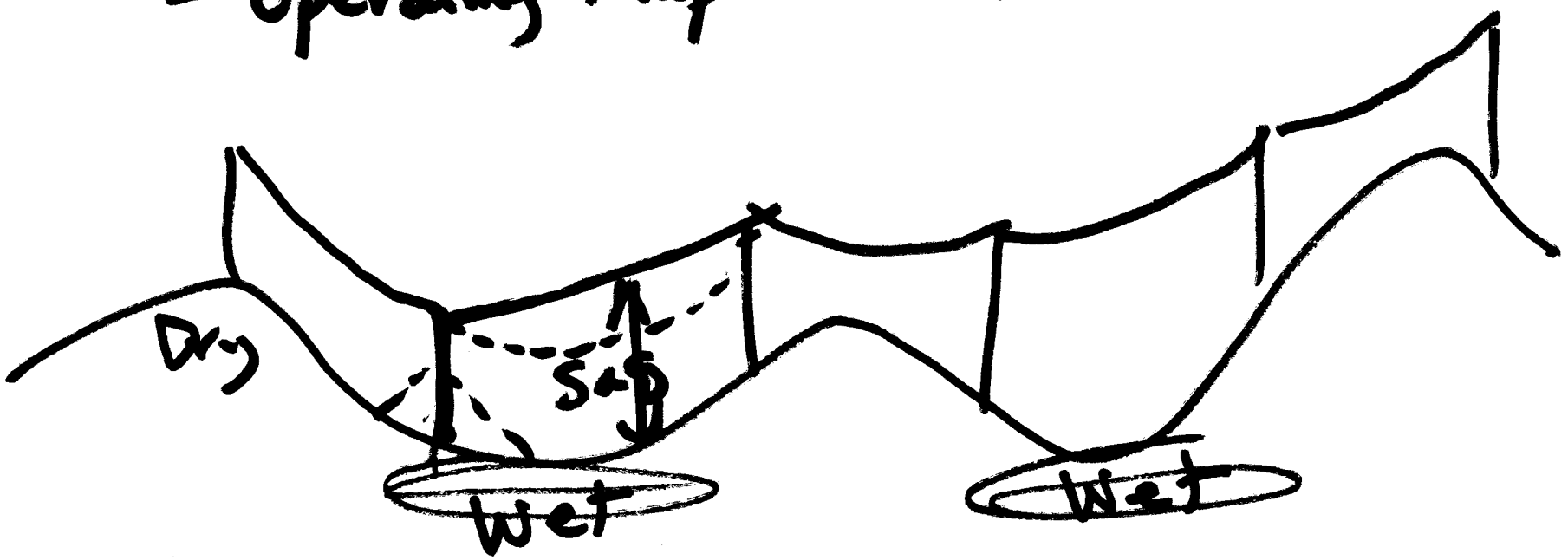
```
   6  5.941020E-03  4.892146E-04 -5.698013E-01  5.814883E-03 -1.271745E-04  6.636963E-01
      6.514757E-02  9.931377E-02  1.227803E+00  6.540305E-02  1.006009E-01 -1.972585E+00

   7 -3.826235E-02 -4.103578E-02 -2.594205E-02 -3.835165E-02 -4.066019E-02 -2.584631E-02  3.678260E-01
      1.611574E-02  1.707574E-02  1.353646E-02  1.611066E-02  1.709846E-02  1.353963E-02 -1.295084E-01

   8 -2.556308E-02 -4.013470E-02 -3.886552E-02 -2.565606E-02 -4.051901E-02 -3.878624E-02 -1.298829E-02  3.677574E-01
      1.345330E-02  1.701024E-02  1.626901E-02  1.345057E-02  1.698801E-02  1.627394E-02 -1.273678E-02 -1.295857E-01

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

   1  1.338254E-01
      7.457905E-01

   2  8.542610E-02  1.429545E-01
      2.270646E-01  7.388557E-01

   3  8.082529E-02  8.559932E-02  1.341662E-01
      1.798439E-01  2.269184E-01  7.455102E-01
        Both  "R"  and  "X"  are in  [ohms];   "C"  are in  [microMhos].

Impedance matrix,  in units of  [ohms/kmeter ]  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  3.048825E-01
      1.165937E+00

   1 -1.411331E-02 -2.911309E-02
     -2.753773E-03  1.696461E-02

   2  9.307584E-03  5.303180E-02  2.925462E-02
     -1.048399E-02  5.321098E-01  1.672600E-02
```

```
Sequence       Surge impedance       Attenuation   velocity    Wavelength   Resistance    Reactance   Susceptance
         magnitude(ohm) angle(degr.)    db/km        km/sec        km          ohm/km        ohm/km      mho/km
   Zero :  7.25537E+02 -7.32712E+00  1.84000E-03  2.28831E+05  3.81384E+03  3.04883E-01  1.16594E+00  2.28938E-06
Positive:  4.17193E+02 -2.84574E+00  5.52738E-04  2.94481E+05  4.90801E+03  5.30318E-02  5.32110E-01  3.07236E-06

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

   1  1.875775E-01
     -1.490192E+00

   2 -5.601184E-04  2.090670E-01
      4.018895E-01 -1.559992E+00

   3  2.325374E-02 -2.602338E-04  1.881962E-01
      2.616178E-01  4.017776E-01 -1.490408E+00

Inverted impedance matrix,  in units of  [mho-kmeter ]  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  2.099025E-01
     -8.033406E-01

   1 -2.022159E-02 -1.124957E-01
     -1.252160E-02  3.857806E-02

   2  2.059020E-02  1.874691E-01  8.965024E-02
     -1.082245E-02 -1.868626E+00  7.812573E-02
Request for flushing of punch buffer.             |$PUNCH

A listing of 80-column card images now being flushed from punch buffer follows.
================================================================================
12345678901234567890123456789012345678901234567890123456789012345678901234567890
================================================================================
C  <+++++>  Cards punched by support routine on  29-Feb-08  15.24.27  <+++++>
C LINE CONSTANTS
C $ERASE
C $UNITS,    60.,    60.
C BRANCH  IN___AOUT__AIN___BOUT__BIN___COUT__C
C METRIC
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
```

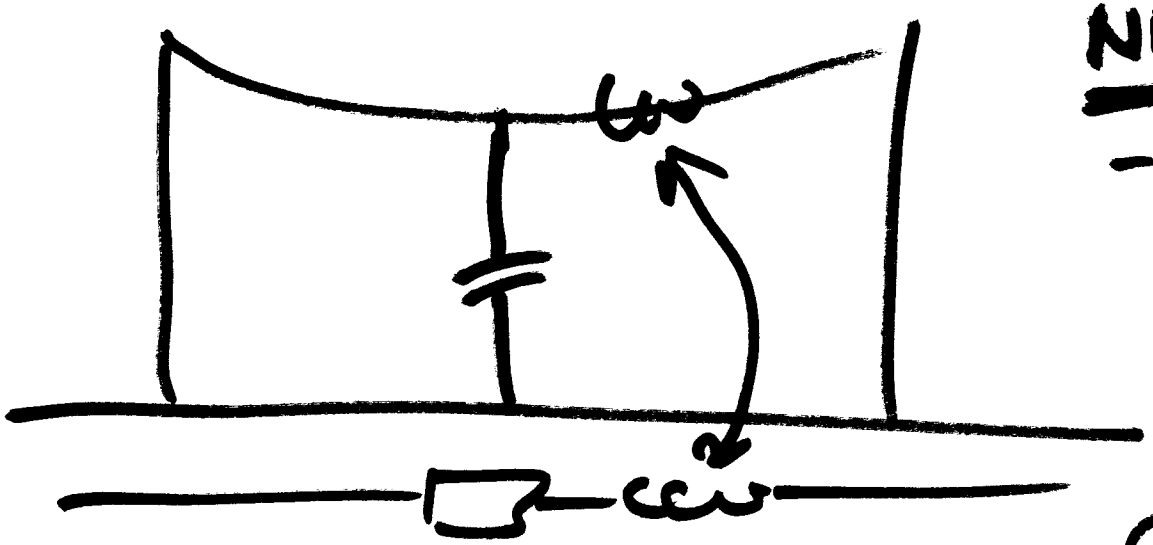
```
C   0  0.5     2.4 4           0.385     42.     81.     61.     0.0   0.0
C BLANK CARD ENDING CONDUCTOR CARDS
C     100.       60.           111111 111111 0    20.3              44
$VINTAGE, 1
 1IN___AOUT__A              2.71665557E+00  1.51395469E+01  5.66909987E+01
 2IN___BOUT__B              1.73414980E+00  4.60941126E+00 -6.78394003E+00
                            2.90197664E+00  1.49987705E+01  5.77972369E+01
 3IN___COUT__C              1.64075348E+00  3.65083164E+00 -2.34234185E+00
                            1.73766625E+00  4.60644445E+00 -6.76824125E+00
                            2.72357373E+00  1.51338568E+01  5.67241673E+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:      0.656     0.000     0.656
```

Weather Effects

- Rain, run-off, pooling
- Operating Temp: -40°F → 180°F



ρ (Ohm·m) - is not constant
- varies seasonally or w/ precipitation



NESC

- Clearances
  - Open field
  - Roads / RR
  - Bldgs.

C_{gnd}: decrease w/ height $\left[C \propto \ln \frac{r}{D} \right]$

$\Rightarrow$ Lucky to get within 5-10% of actual line parameters.