ECE 524

TRANSIENTS IN
POWER SYSTEMS

SESSION no.  33
*alc - line constants
 Cáhde) input data

In same directory as *atp

For your case

C:\tools\prog\atpcomp\atp

→ *pch

* lib — what is actually incorporated into

your case
Distributed Parameter Line: EMTDC: Steps 1, 2 stay same

- Two interface options:
  - Step 1: Connect Interface Component into Circuit
  - Step 2: Then copy in TLINE configuration component
    - Can be connect to interface components or
    - Directly connected

Distributed Parameter Line: EMTDC: Steps 3, 4—stay same

- Step 3: Next choose Edit:
- Step 4: Copy Line Model and Options Box from Master Library:
  - In this case choose Bergeron (others later)
Bergeron Options

**Bergeron Model Options**
- Travel Time Interpolation: On
- Reflectionless Line (infinite length): No

**Step 5 changes:**
- Now select Ground Component and Required Tower Components
- Ground component:
  - Ground Resistivity: 100.0 [ohm*m]
  - Relative Ground Permeability: 1.0

ECE524
Lecture 32
Spring 2018
Step 5 changes:

- Copy tower components from master library.

Tower Data

- Tower Name: SH6
- Height of Lowest Conductor (Near End of Tower): 30 m
- Vertical Distance of Conductor Above Outer Conductor: 5 m
- Horizontal Spacing Between Phases: 10 m
- Relative X Position of Tower Center on Right of Way: 30 m
- Short Conductance: 1.00 (in [ohm])
- Show Graphics of Cond. Sag?: Yes
- Is the Circuit Totally Transposed?: No
- How Many Ground Wires?: 0
- Eliminate Ground Wires?: Yes

Tower Data

- Tower: SH6
- Conductors: chukar
- Ground Wires: 1/2"Hg3StrengthSteel
- 0 m
Conductor Data

Universal Tower Geometry

- Alternate option:

<table>
<thead>
<tr>
<th>Cond.</th>
<th>Connection Phasing</th>
<th>X (from lower centre)</th>
<th>Y (at tower)</th>
<th>Ground Wires: 1/2&quot; High Strength Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>-5 [m]</td>
<td>30 [m]</td>
<td>Eliminated -2.5 [m] 40 [m]</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0 [m]</td>
<td>30 [m]</td>
<td>Eliminated 2.5 [m] 40 [m]</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>5 [m]</td>
<td>30 [m]</td>
<td></td>
</tr>
</tbody>
</table>
Extracting Symmetrical Components Data from ATP and EMTDC Line Constants Program Results

**Using ATP/ATPDraw (option 1)**

- Use Bergeron transmission model from Lecture 30 (with a 60 Hz output frequency).
  - Run the line constants program within LCC to generate an output file
  - Note the file name that the line model is saved to.

- Two files will be created, one with an extension L30.pch and the other L30.lib
- The L30.lib file is the one read by ATP when executing the overall system model

![Line/Cable Data: L30](image)
- Now close the LCC window (if you made any changes it may rerun the case)
- Under the ATP pulldown menu of the main program window:
  - Select View LIS file or press the <F5> key on your keyboard

  ![ATP pulldown menu](image)

- If you have run the ATPDraw case previously a text file will be opened in the editor
- If you haven't run a case, there won't be an open file
- Now go to the file menu in the text editor program and
  → chose "Open"
- Change the file type to "Library files (*.lib)"

  ![Open File dialog box](image)

- Select the L30.lib file (choose the file you saved for the line you are modeling)
- Assuming your LCC case ran correctly, you should get the following file if you had an untransposed Bergeron line
  - The line modal parameters are in the lines starting "-1", "-2", etc
  - The modal transformation matrix for the currents, "$T_i$" starts after the "$VINTAGE$, 0
  - Note since I selected "Real Transformation Matrix" the imaginary parts of $T_i$ are 0.

KARD 3 3 4 4 5 5
KARG 1 4 2 5 3 6
KBEC 3 9 3 9 3 9
KEND 8 14 8 14 8 14
KTEX 1 1 1 1 1 1

```
$VINTAGE, 1
-1IN_AOUT_A 3.64219E-01 7.82535E+02 2.12364E+05-1.00000E+02 1 3
-2IN_BOUT_B 7.25364E-02 4.32512E+02 2.91389E+05-1.00000E+02 1 3
-3IN_COUT_C 7.17897E-02 3.81826E+02 2.93912E+05-1.00000E+02 1 3

$VINTAGE, 0
0.59866938 -0.70710678 -0.41186567
0.00000000 0.00000000 0.00000000
0.55401871 0.00000000 0.81285506
0.00000000 0.00000000 0.00000000
0.58866938 0.70710678 -0.41186567
0.00000000 0.00000000 0.00000000

$EOF
ARG, IN_A, IN_B, IN_C, OUT_A, OUT_B, OUT_C
```

From the above (units of length in km since units had been selected as Metric):

\[
R_{m0} := 3.64219 \cdot 10^{-1} \frac{\text{ohm}}{\text{km}} \quad R_{m1} := 7.25364 \cdot 10^{-2} \frac{\text{ohm}}{\text{km}} \quad R_{m2} := 7.17897 \cdot 10^{-2} \frac{\text{ohm}}{\text{km}}
\]

\[
Z_{m0} := 7.82535 \cdot 10^2 \text{ohm} \quad Z_{m1} := 4.32512 \cdot 10^2 \text{ohm} \quad Z_{m2} := 3.81826 \cdot 10^2 \text{ohm}
\]

\[
\nu_{m0} := 2.12364 \cdot 10^5 \frac{\text{km}}{\text{sec}} \quad \nu_{m1} := 2.91389 \cdot 10^5 \frac{\text{km}}{\text{sec}} \quad \nu_{m2} := 2.93912 \cdot 10^5 \frac{\text{km}}{\text{sec}}
\]

- Recall that

\[
Z_m = \sqrt{\frac{L_m}{C_m}} \quad \text{and} \quad \nu_m = \frac{1}{\sqrt{L_m C_m}}
\]

- Rearranging

\[
L_m = C_m Z_m^2 \quad \text{then} \quad C_m = \frac{1}{\nu_m^2 L_m} = \frac{1}{\nu_m^2 C_m Z_m^2}
\]
or: \[ C_m^2 = \frac{1}{\nu_m^2 \cdot Z_m^2} \]
then: \[ C_m = \frac{1}{\nu_m \cdot Z_m} \]

\[ C_{m0} := \frac{1}{(\nu_{m0} \cdot Z_{m0})} \]
\[ C_{m0} = 6.017 \cdot \frac{nF}{\text{km}} \]

\[ L_{m0} := C_{m0} \cdot Z_{m0}^2 \]
\[ L_{m0} = 3.685 \cdot \frac{mH}{\text{km}} \]

\[ C_{m1} := \frac{1}{(\nu_{m1} \cdot Z_{m1})} \]
\[ C_{m1} = 7.935 \cdot \frac{nF}{\text{km}} \]

\[ L_{m1} := C_{m1} \cdot Z_{m1}^2 \]
\[ L_{m1} = 1.484 \cdot \frac{mH}{\text{km}} \]

\[ C_{m2} := \frac{1}{(\nu_{m2} \cdot Z_{m2})} \]
\[ C_{m2} = 8.911 \cdot \frac{nF}{\text{km}} \]

\[ L_{m2} := C_{m2} \cdot Z_{m2}^2 \]
\[ L_{m2} = 1.299 \cdot \frac{mH}{\text{km}} \]

- Current transformation matrix (only show the real part since the imaginary terms are 0)

\[
T_{i\_untrans} := \begin{pmatrix}
0.58866938 & -0.70710678 & -0.41186567 \\
0.55401871 & 0 & 0.81285506 \\
0.58866938 & 0.70710678 & -0.41186567 \\
\end{pmatrix}
\]

- Recall \[ T_e \cdot T_i^T = d \begin{pmatrix}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
\end{pmatrix} \]
just let \( d = 1 \)

\[
I := \begin{pmatrix}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
\end{pmatrix}
\]

\[
T_{e\_untrans} := I \left( T_{i\_untrans}^T \right)^{-1} \]
\[
T_{e\_untrans} = \begin{pmatrix}
0.575119 & -0.707107 & -0.391985 \\
0.582814 & 0 & 0.833002 \\
0.575119 & 0.707107 & -0.391985 \\
\end{pmatrix}
\]
As a check

\[
\begin{pmatrix}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{pmatrix}
\]

Now we can find the ABC domain matrices for R, L and C per unit length, using equations (18) and (19) from the lecture handout.

\[
R'_{\text{untrans}} := T_{\text{e\_untrans}} \cdot T_{\text{i\_untrans}}^{-1}
\]

\[
R'_{\text{untrans}} = \begin{pmatrix}
0.1678 & 0.0986 & 0.0952 \\
0.0986 & 0.1735 & 0.0986 \\
0.0952 & 0.0986 & 0.1678
\end{pmatrix} \text{ ohm/km}
\]

\[
L'_{\text{untrans}} := T_{\text{e\_untrans}} \cdot T_{\text{i\_untrans}}^{-1}
\]

\[
L'_{\text{untrans}} = \begin{pmatrix}
2.1606 & 0.8109 & 0.6763 \\
0.8109 & 2.1531 & 0.8109 \\
0.6763 & 0.8109 & 2.1606
\end{pmatrix} \text{ mH/km}
\]

\[
C'_{\text{untrans}} := T_{\text{i\_untrans}} \cdot T_{\text{e\_untrans}}^{-1}
\]

\[
C'_{\text{untrans}} = \begin{pmatrix}
7.5642 & -1.0207 & -0.3705 \\
-1.0207 & 7.7347 & -1.0207 \\
-0.3705 & -1.0207 & 7.5642
\end{pmatrix} \text{ nF/km}
\]
\[
a := 1 \cdot e^{j \cdot 120 \text{deg}}
\]
\[
A_{012} := \begin{pmatrix}
1 & 1 & 1 \\
1 & a^2 & a \\
1 & a & a^2
\end{pmatrix}
\]

Length := 100km \quad \omega := 2 \cdot \pi \cdot 60 \text{Hz}

\[
Z_{\text{ABC\_untran}} := (R'_{\text{untran}} + j \cdot \omega \cdot L'_{\text{untran}}) \cdot \text{Length}
\]

\[
Z_{\text{ABC\_untran}} = \begin{pmatrix}
9.8641 + 30.5714i & 17.353 + 81.1699i & 9.8641 + 30.5714i \\
\end{pmatrix} \Omega
\]

\[
Z_{012\_untran} := A_{012}^{-1} \cdot Z_{\text{ABC\_untran}} \cdot A_{012}
\]

\[
Z_{012\_untran} = \begin{pmatrix}
36.4698 + 139.1165i & 1.2312 - 1.0638i & -1.5368 - 0.5344i \\
-1.5368 - 0.5344i & 7.2184 + 52.4788i & -2.9948 + 1.7697i \\
1.2312 - 1.0638i & 3.03 + 1.7087i & 7.2184 + 52.4788i
\end{pmatrix} \Omega
\]

**Using ATP/ATPDraw (option 2)**

- If all we want are the symmetrical components, and not the ABC matrices we can also select that the line be transposed (using the Bergeron model):
  - even if real line not transposed
- Now the Library file from ATPDraw's LCC program gives us
  - The modal transformation matrix is assumed to be Bergeron now
  - The modal values are the same as the symmetrical components expressed per unit length

```
KARD 3 3 4 4 5 5
KARG 1 4 2 5 3 6
KBEG 3 9 3 9 3 9
KEND 8 14 8 14 8 14
KTEX 1 1 1 1 1 1
/DIRANCH
$VINTAGE, 1
-1IN_AOUT_A
-2IN_BOUT_B
-3IN_COUT_C
$VINTAGE, -1,
$EOF
ARG, IN_A, IN_B, IN_C, OUT_A, OUT_B, OUT_C
```

\[
R_{0b} := 3.64602 \cdot 10^{-1} \text{ ohm per km} \\
R_{1b} := 7.21726 \cdot 10^{-2} \text{ ohm per km} \\
R_{2b} := R_{1b}
\]
\[ Z_{c0} := 7.83401 \cdot 10^2 \text{ohm} \quad Z_{c1} := 4.06483 \cdot 10^2 \text{ohm} \quad Z_{c2} := Z_{c1} \]

\[ v_0 := 2.12287 \cdot 10^5 \text{ km/s} \quad v_1 := 2.92004 \cdot 10^5 \text{ km/s} \]

\[ C_{0b} := \frac{1}{(v_0 \cdot Z_{c0})} \quad C_{0b} = 6.013 \cdot \frac{nF}{\text{km}} \]

\[ L_{0b} := C_{0b} \cdot Z_{c0}^2 \quad L_{0b} = 3.69 \cdot \frac{mH}{\text{km}} \]

\[ C_{1b} := \frac{1}{(v_1 \cdot Z_{c1})} \quad C_{1b} = 8.425 \cdot \frac{nF}{\text{km}} \]

\[ L_{1b} := C_{1b} \cdot Z_{c1}^2 \quad L_{1b} = 1.392 \cdot \frac{mH}{\text{km}} \]

\[ Z_{0_{\text{trans}}} := (R_{0b} + j \cdot \omega \cdot L_{0b}) \cdot \text{Length} \quad \Rightarrow \quad Z_{0_{\text{trans}}} = (36.4602 + 139.1207i) \Omega \]

\[ Z_{1_{\text{trans}}} := (R_{1b} + j \cdot \omega \cdot L_{1b}) \cdot \text{Length} \quad \Rightarrow \quad Z_{1_{\text{trans}}} = (7.2173 + 52.4789i) \Omega \]

- Compare to earlier result

\[ Z_{012_{\text{untran,0,0}}} = (36.47 + 139.12i) \Omega \]

\[ Z_{012_{\text{untran,1,1}}} = (7.2184 + 52.4788i) \Omega \]

- Percent Error

\[
\frac{|Z_{012_{\text{untran,0,0}}} - Z_{0_{\text{trans}}}|}{|Z_{012_{\text{untran,0,0}}}|} = 0.0073\% \\
\frac{|Z_{012_{\text{untran,1,1}}} - Z_{1_{\text{trans}}}|}{|Z_{012_{\text{untran,1,1}}}|} = 0.0022\%
\]

**Using ATP/ATPDraw (option 3)**
- As a final option, we can select the coupled-pi model instead of the Bergeron line model
- This gives the impedance matrix (multiplied times the length of the line segment)
- You don't need to select Matrix Output
$X_{OP} = 60$

KTEX 1 1 1 1 1 1
/BRANCH
$UNITs, 60., 0.0$
$QVINTAGE, 1$
$UNITs, 60., 0.0,$

1IN_AOUT_A 1.68555974E+01 8.14217225E+01 7.56415560E-01
2IN_BOUT_B 9.82048936E+00 3.05887622E+01 -1.02071952E-01
3IN_COUT_C 1.71835144E+01 8.12356005E+01 7.73467197E-01
9.60195472E+00 2.54645456E+01 -3.70513091E-02
9.82048936E+00 3.05887622E+01 -1.02071952E-01
1.68555974E+01 8.14217225E+01 7.56415560E-01

$QVINTAGE, -1,$
$UNITs, -1., -1., { Restore values that existed b4 preceding $UNITs$
$UNITs, -1., -1.$
$SEOF$

ARG, IN_A, IN_B, IN_C, OUT_A, OUT_B, OUT_C

- Result is the lower triangular parts of the R, L and C matrix (multiplied times length of the line)
- Matrix is symmetric

\[
R_{pi} := \begin{pmatrix}
1.68555974 \times 10^1 & 9.82048936 & 9.60195472 \\
9.82048936 & 1.71835144 \times 10^1 & 9.82048936 \\
9.60195472 & 9.82048936 & 1.68555974 \times 10^1
\end{pmatrix} \text{ ohm}
\]

Compare to the initial results for the untransposed Bergeron line

\[
R'_{\text{untran}\cdot\text{Length}} = \begin{pmatrix}
9.8641 & 17.353 & 9.8641 \\
\end{pmatrix} \text{ ohm}
\]

So there is some noticeable difference.

- Now look at the inductance matrix (the pi model in ATPDraw gives the result in ohms, not mH)

\[
X_{L_{pi}} := \begin{pmatrix}
8.14217225 \times 10^1 & 3.05887622 \times 10^1 & 2.54645456 \times 10^1 \\
3.05887622 \times 10^1 & 8.12356005 \times 10^1 & 3.05887622 \times 10^1 \\
2.54645456 \times 10^1 & 3.05887622 \times 10^1 & 8.14217225 \times 10^1
\end{pmatrix} \text{ ohm}
\]

\[
L'_{\text{untran}\cdot\text{Length}\cdot\omega} = \begin{pmatrix}
81.4521 & 30.5714 & 25.4949 \\
30.5714 & 81.1699 & 30.5714 \\
25.4949 & 30.5714 & 81.4521
\end{pmatrix} \Omega
\]

Again there are differences.
\[ Z_{012} \text{_pi} := A_{012}^{-1} \left( R_{\text{pi}} + j \cdot X_{\text{L\_pi}} \right) \cdot A_{012} \]

\[
Z_{012} \text{_pi} = \begin{pmatrix}
36.4602 + 139.1211i & 1.3344 - 0.9808i & -1.5166 - 0.6653i \\
-1.5166 - 0.6653i & 7.2173 + 52.479i & -2.994 + 1.7706i \\
1.3344 - 0.9808i & 3.0304 + 1.7076i & 7.2173 + 52.479i
\end{pmatrix} \Omega
\]

\[ Z_{012} \text{untran} = \begin{pmatrix}
36.4698 + 139.1165i & 1.2312 - 1.0638i & -1.5368 - 0.5344i \\
-1.5368 - 0.5344i & 7.2184 + 52.4788i & -2.9948 + 1.7697i \\
1.2312 - 1.0638i & 3.03 + 1.7087i & 7.2184 + 52.4788i
\end{pmatrix} \Omega
\]

- Percent Error

\[
\frac{\left| Z_{012} \text{untran}_{0,0} - Z_{012} \text{pi}_{0,0} \right|}{\left| Z_{012} \text{untran}_{0,0} \right|} = 0.0074\% \\
\frac{\left| Z_{012} \text{untran}_{1,1} - Z_{012} \text{pi}_{1,1} \right|}{\left| Z_{012} \text{untran}_{1,1} \right|} = 0.0023\%
\]

- So while the error is visible visually looking at the matrices, the percent error is very small.
- In both cases here it is close to what we observed with the Bergeron line case.
- Error would be even smaller if we had used the full transformation matrix for the untransposed line, instead of just the real part.

- Now look at the capacitance matrix (the pi model in ATPDraw gives the result in uF)

\[
C_{\text{pi}} := \begin{pmatrix}
7.56415560 \cdot 10^{-1} & -1.02071952 \cdot 10^{-1} & -3.70513091 \cdot 10^{-1} \\
-1.02071952 \cdot 10^{-1} & 7.73467197 \cdot 10^{-1} & -1.02071952 \cdot 10^{-1} \\
-3.70513091 \cdot 10^{-2} & -1.02071952 \cdot 10^{-1} & 7.56415560 \cdot 10^{-1}
\end{pmatrix} \mu F
\]

\[
C_{\text{untran\_length}} = \begin{pmatrix}
0.7564 & -0.1021 & -0.0371 \\
-0.1021 & 0.7735 & -0.1021 \\
-0.0371 & -0.1021 & 0.7564
\end{pmatrix} \mu F
\]

Even better match than the series impedance.
Using PSCAD/EMTDC

- Again, use the line modelled in lecture 30
- Enter the mode to edit the line constants data

Line Model General Data

Name of Line: TLine

Steady State Frequency: 60.0 [Hz]

Length of Line: 100.0 [km]

Number of Conductors: 3

Bergeron Model Options

Travel Time Interpolation: On
Reflectionless Line (ie Infinite Length): No

Tower: ECE 524 L30
Conductors: ECE 524 L30 example
Ground_Wires: 0.95 in steel

0 [m]

---

- Notice the 5 tabs at the bottom of the window above
  - By default, we are normally in the Editor
- Choose the one labelled Output
- Result is a table with various matrix outputs...

=====================================================================
PSCAD LINE CONSTANTS PROGRAM OUTPUT FILE (*.out)

NOTE: This file is auto-generated. Any manual changes will be lost once the Line Constants Program is re-run.
=====================================================================

Display Format: M,N denotes a complex number M + jN

PHASE DOMAIN DATA @ 60.00 Hz:
SERIES IMPEDANCE MATRIX (Z) [ohms/m]:

0.171166117E-03, 0.817350229E-03
0.992600162E-04, 0.292914072E-03
0.992600162E-04, 0.292914072E-03

SHUNT ADMITTANCE MATRIX (Y) [mhos/m]:

0.100000000E-10, 0.286420166E-08
0.000000000E+00, 0.299755139E-09
0.000000000E+00, 0.299755139E-09

LONG-LINE CORRECTED SERIES IMPEDANCE MATRIX [ohms]:

0.169585888E+02, 0.814106712E+02
0.980814972E-01, 0.291091223E+02
0.980814972E-01, 0.291091223E+02

LONG-LINE CORRECTED SHUNT ADMITTANCE MATRIX [mhos]:

0.109674787E-05, 0.286912075E-03
0.337912478E-07, 0.299214282E-04
0.337912478E-07, 0.299214282E-04

MODAL DOMAIN DATA @ 60.00 Hz:

Y EIGENVECTOR (MODAL TRANSFORMATION) MATRIX (Yi):

0.816496581E+00, 0.000000000E+00
-0.408248290E+00, 0.832667266E-16
-0.408248290E+00, -0.277655756E-16
0.577350269E+00, -0.194289295E-16
-0.577350269E+00, -0.166533454E-15
0.577350269E+00, 0.000000000E+00
-0.154465040E+00, -0.153988330E+00
-0.599143067E+00, 0.153988330E+00
0.754608107E+00, 0.000000000E+00

Y EIGENVALUE VECTOR:

-0.104885172E+01, -0.147188163E+00
0.200722264E+01, -0.538319081E+00
0.104885172E+01, -0.147188163E+00

MODAL IMPEDANCE MATRIX [ohms/m]:

0.719061007E-04, 0.524346317E-03
0.000000000E+00, 0.000000000E+00
0.524346317E-03, 0.140317837E-02
-0.216804343E-18, 0.325260652E-18
0.852154982E-04, -0.113416505E-03
0.136746089E-03, 0.464868158E-03

MODAL ADMITTANCE MATRIX [mhos/m]:

-0.229253863E-09, 0.311200526E-08
0.000000000E+00, 0.000000000E+00
-0.770689879E-09, 0.490521769E-09
0.000000000E+00, 0.000000000E+00
-0.770689879E-09, 0.490521769E-09

MODAL CHARACTERISTIC IMPEDANCE VECTOR (Z0) [ohms]:

0.409606561E+03, -0.431252754E+02
0.794047832E+03, -0.101064497E+03
0.361862789E+03, -0.950045140E+02

MODAL TRAVEL TIME VECTOR [ms]:

0.342450354E+00
0.476738722E+00
0.342450354E+00

MODAL VELOCITY VECTOR [m/s]:

0.292013131E+09
0.209758501E+09
0.292013131E+09
From the sequence impedance matrix we get:

\[ Z_{0\_psc}\text{d} := (0.369686149 \times 10^{-3} + j \times 0.140317837 \times 10^{-2}) \text{ohm/m} \]

\[ Z_{0\_psc}\text{d\_Length} = (36.9686 + 140.3178i) \Omega \]

\[ Z_{1\_psc}\text{d} := (0.719061007 \times 10^{-4} + j \times 0.524436157 \times 10^{-3}) \text{ohm/m} \]

\[ Z_{1\_psc}\text{d\_Length} = (7.1906 + 52.4436i) \Omega \]

- Comparison of results

\[ \frac{|Z_{012\_untran\_0,0} - Z_{0\_psc}\text{d\_Length}|}{|Z_{012\_untran\_0,0}|} = 0.9045\% \]

\[ \frac{|Z_{012\_untran\_1,1} - Z_{1\_psc}\text{d\_Length}|}{|Z_{012\_untran\_1,1}|} = 0.0847\% \]

- Closer match in the positive sequence than in zero sequence
- Possible sources of error
- PSCAD/EMTDC used the imaginary part of the transformation matrix (but that should not cause this much error)
- The two programs model the effect of the earth somewhat differently.