CALCULATION OF ELECTRIC FIELDS **ELECFLD.MCD**

Work Order Account ....:
Client ....:
Project ....:
Feature ....:Compute and Plot Electric Field
Item ....:
By/Date ....:Paul Dorvel 7/19/10
Checked/Date ....:
Approved/Date ....:

Goal of new version

Validation : SCE Fields 2D program set up for same circuit configuration, loading, phasing and other values, computes E within 0.3%. This small error is likely due to time sampling and calculation point differences. 7-19-10

PROBLEM STATEMENT
Compute and plot electric fields from a transmission line based on EPRI Red Book Chapter 8 Methods pp330-332. Also compute space potential especially for evaluating ADSS placement in the HV space. See Step 7. This version of the calculation reduces the printed calculated results, uses nested arrays to control indices, uses programs to compute the Potential Coefficients, time varying EX and EY, and other results, and expands the input of wires to an array of wire data. I include references to previous version Steps with more printed results.

Step 1.0 - SET Origin to 1,1 for convenience

$\text{ORIGIN} \equiv 1$ $\quad$ $\text{unit\_L} := \text{ft}$ $\quad$ **Enter "ft" or "m"**

Step 2.0 - DEFINE constants

$\varepsilon_0 = 8.85419 \cdot \frac{\text{pF}}{\text{m}}$ **permittivity of free space (farad/m) built in constant**

$\mu_0 = 0.00126 \cdot \frac{\text{mH}}{\text{m}}$ **permeability of free space (henry/m)built in constant.**

$f := 60 \cdot \text{Hz}$ **system frequency in Hz**

$\omega := 2\pi \cdot f$ **convert to radians** $\omega = 376.99112\,\text{s}^{-1}$

$\sigma := 0.005 \cdot \frac{\text{siemens}}{\text{m}}$ **earth conductivity [Carson Adjustment Only]**

$\gamma := \sqrt{(j \cdot \omega \cdot \mu_0) \cdot (\sigma + j \cdot \omega \cdot \varepsilon_0)}$ **Carson correction factor EPRI Eq 8.4.7**

$\gamma = (0.00109 + 0.00109j)\,\text{m}^{-1}$

Step 3.0 - DEFINE project elements

Step 3.1 ENTER Number of Circuits and Centerline Offsets

The test set up is for one circuit and no offset, i.e. centered on the ROW.

$$LINES := \begin{pmatrix} 1 & 1 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 0 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \\ 6 & 0 & 0 \\ 7 & 0 & 0 \\ 8 & 0 & 0 \\ 9 & 0 & 0 \\ 10 & 0 & 0 \end{pmatrix}$$

Column 1 is Line ID

Column 2 is number of power circuits on LINE. 0 (zero) in Column 2 will be interpreted as NA or no line. Note that neutral lines for E shielding can be entered, using 1 in col 2 using 0 kV.

Column 3 is CL offset of line relative to ROW center or some arbitrary but fixed reference point. Use feet or meters consistently but no units in matrix itself.

This space reserved for expansion of LINES

Borrowed from magnetic field computation. Allows for several lines to be modeled in a corridor. In this test case only 1 line with 1 circuit is being set up.

Main data input array. See descriptions below and above table

Step 3.2 INPUT Corridor and Circuit information

Fill in the following matrix/table according to descriptions of entries below. Add rows for each circuit/wire required to be modeled. ID1 is the only one of the first three columns that is used in calculations at this time. Note that the table below is printed out in entirety at the end for checking.

ID1 ID2 ID3 x y kV θ dia bun

DA :=

	1	2	3	4	5	6	7	8	9
1	1	1	1	-16	35	230	120	0.93	1
2	1	1	2	0	35	230	240	0.93	1
3	1	1	3	16	35	230	0	0.93	1
4	1	2	0	-10	45	0	0	0.5	0
5	1	2	0	10	45	0	0	0.5	0
6	0	0					0	0	...

Input is the same as for previous computation for comparison of results

NOTE that if you use feet ... sistent. Enter unit values in Table DA but do not put units in matrix above!! Insert later. See legend below. Room left to expand DA later.

ID1 is the line identification, same as in column 1 in LINES
ID2 is the circuit identification and is repeated for each wire belonging to ckt
ID3 is phase/wire identification using 1-2-3 nomenclature, arbitrary not used
X is the horizontal distance from wire to CL Ref of its line, + or -, in ft or m
Y is the height above grade of the wire, in ft or m, including sag adjustments
kV is the line-to-line voltage in kV rms.
θ is the phase angle of the current in degrees. Later converted to radians.
dia is wire diameter in inches
bun is # of wires in phase bundle, assume 18 in spacing 0= no bundle 1 wire

Extra space provided for expanding DA Matrix

Step 3.3- EXPRESS all voltages in complex notation

Step 3.3.1 EXTRACT number of transmission or distribution lines from Matrix LINES

```
Line_no := | p ← 0
           | for i ∈ 1 .. rows(LINES)
           |   | p ← p + 1  if LINES_{i,2} ≠ 0
           |   | p ← p  otherwise
```

borrowed from B field program to extract # LINES. Working OK.

$Line\_no = 1$

Step 3.3.2 EXTRACT number of wires from Matrix DA

```
Wire_no := | p ← 0
           | for i ∈ 1 .. rows(DA)
           |   | p ← p + 1  if DA_{i,1} ≠ 0
           |   | p ← p  otherwise
```

borrowed from B field program to extract # wires from all lines. Limits search to lines in DA (ID1) not equal 0

$Wire\_no = 5$

Step 3.3.3 SET UP limits for computation over time and wire number

$NC := Wire\_no = 5$ **Total number of wires to consider**

$b\_max := 50$ **Number of time increments to consider. Include at least 2 full 60 Hz cycles. 20ms/cycle approximately. Use 50ms for max time.**

$b := 1, 2 .. b\_max$ **Set range for counting through the time increments.**

$t_b := b \cdot ms$ **Set time increment t_b**

$$\frac{1}{60Hz} = 16.66667 \cdot ms$$

$i := 1 .. NC$ **Set range for counting through the wires**

Step 3.3.4 -COMPUTE circuit voltages.

Below DA<6> is the line voltage in column 6; DA<7> is the phase angle in column 7. t is the time interval increasing per settings above for b and t_b. VV is a matrix with NC rows, one for each wire, and b_max columns, one for each time interval as defined above by b and t_b. Convert L-L voltage to L-G values.

$$VV := \left| \begin{array}{l} \text{for } i \in 1..NC \\ \quad \left| \begin{array}{l} \text{for } j \in 1..b\_max \\ \quad \left| \begin{array}{l} X_{i,j} \leftarrow \dfrac{\left(DA^{\langle 6\rangle}\right)_i}{\sqrt{3}} \cdot \left[\cos\left[\omega \cdot t_j + \left(DA^{\langle 7\rangle}\right)_i \cdot deg\right] + j \cdot \sin\left[\omega \cdot t_j + \left(DA^{\langle 7\rangle}\right)_i \cdot deg\right]\right] \\ \text{continue} \end{array} \right. \\ \text{continue} \end{array} \right. \\ X \cdot kV \end{array} \right.$$

Different. Extracts voltage from column 6 and angle from column 7 in DA. Allows for handling more circuits and lines.

Same wire "1" for two successive time intervals

$VV_{1,1} = (-104 + 82j) \cdot kV$ $\qquad VV_{1,2} = (-127.12299 + 38.38069j) \cdot kV$

Step 3.4 ASSIGN units to X,Y, and dia and calculate bundle radius for computations

$$\begin{pmatrix} X \\ Y \\ DIA \end{pmatrix} := \left| \begin{array}{l} \text{for } a \in 1..NC \\ \quad \left| \begin{array}{l} A_a \leftarrow \left(DA^{\langle 4\rangle}\right)_a \cdot unit\_L \\ B_a \leftarrow \left(DA^{\langle 5\rangle}\right)_a \cdot unit\_L \\ C_a \leftarrow \dfrac{18in}{2 \cdot \sin\left[\dfrac{\pi}{\left(DA^{\langle 9\rangle}\right)_a}\right]} \quad \text{if } \left(DA^{\langle 9\rangle}\right)_a > 1 \\ C_a \leftarrow \left(DA^{\langle 8\rangle}\right)_a in \quad \text{if } \left(DA^{\langle 9\rangle}\right)_a \le 1 \end{array} \right. \\ \begin{pmatrix} A \\ B \\ C \end{pmatrix} \end{array} \right.$$

Added to give units to X,Y wire coordinates and diameters of wires in DA columns 4, 5, 8 and 9.

Note that the bundle spacing is directly input in this sub program. Better is to add a column <10> to DA.

$$X = \begin{pmatrix} -16 \\ 0 \\ 16 \\ -10 \\ 10 \end{pmatrix} \cdot ft \qquad Y = \begin{pmatrix} 35 \\ 35 \\ 35 \\ 45 \\ 45 \end{pmatrix} \cdot ft \qquad DIA = \begin{pmatrix} 0.927 \\ 0.927 \\ 0.927 \\ 0.5 \\ 0.5 \end{pmatrix} \cdot in$$

Step 4.0 - INPUT Basic Corridor Parameters

$X_{start} := -125 \cdot unit\_L$ — Start point of computations. IMPORTANT MAKE X_{start} < Row_l.

$ROW_l := -100 \cdot unit\_L$ — Left edge of ROW, reference same as for circuits

$ROW_r := 100 \cdot unit\_L$ — Right edge of ROW, reference same as for circuits

$\Delta x := 2 \cdot unit\_L$ — increment for calculation across right-of-way, horizontal direction. IMPORTANT: Make so ROW values above are divisible by X_{incr}; 1 is a good choice for X_{incr}.

$N_{incr} := 200$ — Number of increments at which to compute B field. IMPORTANT: Make X_{start}+N_{incr}*X_{incr} > Row_r.

$k := 1 .. N_{incr} + 1$ $\qquad$ $j := 1 .. NC$

Borrowed from B field document.
Logical tests below working OK.

Check if Corridor Parameters are OK

$OK1 := if(X_{start} < ROW_l, \text{"OK"}, \text{"NG-Decrease Xstart"}) = \text{"OK"}$

$OK2 := if[(X_{start} + N_{incr} \cdot \Delta x) > ROW_r, \text{"OK"}, \text{"NG-Try Other Values"}] = \text{"OK"}$

$OK3 := if(mod(ROW_l, \Delta x) = 0 \wedge mod(ROW_r, \Delta x) = 0, \text{"OK"}, \text{"NG-Vary ROW or Xincr"}) = \text{"OK"}$

$Y_m := 1 \cdot m$ — height of computations, typically fixed at 3-ft or 1-m above ground

$X_{stop} := X_{start} + \Delta x \cdot N_{incr}$ $\qquad$ $X_{stop} = 275 \cdot ft$ $\qquad$ End point of computations

$CL := 0ft$ — Input location of right of way centerline, marker only

COMPUTE COUNTER INDICES FOR ROW POINTS AND CENTERLINE

$RL_{ctr} := \left|\frac{X_{start} - ROW_l}{unit\_L}\right| = 25$ $\qquad$ $CL_{ctr} := RL_{ctr} + \left|\frac{ROW_l}{unit\_L}\right| = 125$ $\qquad$ $RR_{ctr} := \left|CL_{ctr} + \frac{ROW_r}{unit\_L}\right| = 225$

Step 4.1 -COMPUTE a 1- dimensional array of measurement points across corridor. Also add function DD(k) to find specific values for k.

$Dist_k := X_{start} + \Delta x \cdot (k - 1)$ $\qquad$ $DD(k) := X_{start} + \Delta x \cdot (k - 1)$

Step 5.0 - DEVELOP Maxwell Potential Coefficients, [P]

$$P_{i,j} := \text{if}\left[i = j, \frac{\ln\left(4 \cdot \frac{Y_i}{DIA_i}\right)}{2 \cdot \pi \cdot \varepsilon_0}, \frac{\ln\left[\sqrt{\frac{(X_i - X_j)^2 + (Y_i + Y_j)^2}{(X_i - X_j)^2 + (Y_i - Y_j)^2}}\right]}{2 \cdot \pi \cdot \varepsilon_0}\right]$$

P is processing OK. DA column values for X and Y replaced in Step 3.4 with X, Y directly.

$$P = \begin{pmatrix} 83.79534 & 16.76911 & 9.80263 & 21.53987 & 12.34372 \\ 16.76911 & 83.79534 & 16.76911 & 19.44135 & 19.44135 \\ 9.80263 & 16.76911 & 83.79534 & 12.34372 & 21.53987 \\ 21.53987 & 19.44135 & 12.34372 & 93.49759 & 17.06855 \\ 12.34372 & 19.44135 & 21.53987 & 17.06855 & 93.49759 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

Step 5.1 TAKE Inverse of P for capacitance/length

$$P^{-1} = \begin{pmatrix} 13096 & -1752 & -624 & -2428 & -778 \\ -1752 & 13486 & -1752 & -1834 & -1834 \\ -624 & -1752 & 13096 & -778 & -2428 \\ -2428 & -1834 & -778 & 11977 & -1305 \\ -778 & -1834 & -2428 & -1305 & 11977 \end{pmatrix} \cdot \frac{pF}{mi}$$

Note that all inverse P off diagonal values are negative implying a reduction in charge from voltages on other wires.

Step 6.0 - CALCULATE Charge Q from [Q]= [P]$^{-1}$*[V]

Compute linear charge density on conductors as a function of voltage and wire coordinates only. Time dependency related to b. P^{-1} nxn matrix multiplies VV wire voltage vector (n rows)and sums all to compute charge on each wire due to all other wires at b moment of time. Each row of QM is associated with one wire,i, and each column with one time position,b.

```
QM := | Q ← 0
      | for i ∈ 1 .. NC
      |   | for b ∈ 1 .. b_max
      |   |   Q ← P^-1·(VV)
      |   | continue
      | Q
```

Compute charge on each wire due other wires voltage for time intervals b. Appears to be computing correctly. Units are correct.

Below is the voltage VV$^{<1>}$ column [at time point b=1]. Also shown is the product [P^{-1}]*VV$^{<1>}$ that is the charge QM distribution on the wires at b=1.

$$VV^{\langle 1\rangle} = \begin{pmatrix} -104.06709 + 82.48256j \\ -19.39845 - 131.36603j \\ 123.46554 + 48.88347j \\ 0 \\ 0 \end{pmatrix} \cdot kV \quad P^{-1} \cdot VV^{\langle 1\rangle} = \begin{pmatrix} -0.874 + 0.795j \\ -0.184 - 1.244j \\ 1.066 + 0.509j \\ 0.119 + 0.002j \\ -0.114 + 0.036j \end{pmatrix} \cdot \frac{\mu C}{m} \quad QM^{\langle 1\rangle} = \begin{pmatrix} -0.9 + 0.8j \\ -0.2 - 1.2j \\ 1.1 + 0.5j \\ 0.1 + 0j \\ -0.1 + 0j \end{pmatrix} \cdot \frac{\mu C}{m}$$

Step 7.0- COMPUTE the X,Y-component of E Field for each wire, measuring point and time point defined by b. The program used below will create a large nested array of time varying computation b, for each point in right of way k, where i effect has been totalized at each b,k point.

Step 7.1- COMPUTE EXF the horizontal component and EYF the vertical component of electric field at each position k, for each time position b. The contributions from all i wires are summed for EXF and EYF.

This is crux of new computation. EX and EY are 3-dimensional arrays in i,b,k. These computation compute the H and V component contributions from each wire, at each k point and for each time position. See Step 3.10 for EXF old computation.

$$EXF_{i,b,k} := \left| \begin{array}{l} \text{for } i \in 1..NC \\ \quad \text{for } b \in 1..b\_max \\ \quad\quad \text{for } k \in 1..N_{incr}+1 \\ \quad\quad\quad X_k \leftarrow k \cdot \Delta x + X_{start} \\ \quad\quad\quad A_{i,b,k} \leftarrow \frac{QM_{i,b}}{2\pi \cdot \varepsilon_0} \cdot (X_k - X_i) \cdot \left[\frac{1}{\left[(X_i - X_k)^2 + (Y_i - Y_m)^2\right]} - \frac{1}{\left[(X_i - X_k)^2 + (Y_i + Y_m)^2\right]} \right] \\ \quad\quad\quad \text{continue} \\ \quad\quad \text{continue} \\ A_{i,b,k} \end{array} \right.$$

See Step 3.11 for EYF old computation. Same equation.

$$EYF_{i,b,k} := \left| \begin{array}{l} \text{for } i \in 1..NC \\ \quad \text{for } b \in 1..b\_max \\ \quad\quad \text{for } k \in 1..N_{incr}+1 \\ \quad\quad\quad X_k \leftarrow k \cdot \Delta x + X_{start} \\ \quad\quad\quad A_{i,b,k} \leftarrow \frac{QM_{i,b}}{2\pi \cdot \varepsilon_0} \cdot \left[\frac{Y_m - Y_i}{\left[(X_i - X_k)^2 + (Y_i - Y_m)^2\right]} - \frac{Y_m + Y_i}{\left[(X_i - X_k)^2 + (Y_i + Y_m)^2\right]} \right] \\ \quad\quad\quad \text{continue} \\ \quad\quad \text{continue} \\ A_{i,b,k} \end{array} \right.$$

Step 7.2 NOW COMPUTE the total horizontal (EXT) and vertical (EYT) components of electric field contribution from all wires i at each time interval b and position k pair.

$$EXT_{b,k} := \sum_{i=1}^{NC} EXF_{i,b,k} \qquad EYT_{b,k} := \sum_{i=1}^{NC} EYF_{i,b,k}$$

In this Step 7.2 all wire contributions at each b,k step are summed, eliminating the i index.

Step 8.0 COMPUTE MAXIMUM Values at each spatial point "k" based on Appendix 8.1 of Deno

Step 8.1 SUMMARIZE equations required for analysis

Horizontal field component (X)

$$HX_{b,k} := \sqrt{\left(\mathrm{Re}\left(EXT_{b,k}\right)\right)^2 + \left(\mathrm{Im}\left(EXT_{b,k}\right)\right)^2}$$

Vertical field component (Y)

$$VY_{b,k} := \sqrt{\left(\mathrm{Re}\left(EYT_{b,k}\right)\right)^2 + \left(\mathrm{Im}\left(EYT_{b,k}\right)\right)^2}$$

Phase angle for X component

$$\theta_{b,k} := \mathrm{atan}\left(\frac{\mathrm{Im}\left(EXT_{b,k}\right)}{\mathrm{Re}\left(EXT_{b,k}\right)}\right)$$

Phase angle for Y component

$$\phi_{b,k} := \mathrm{atan}\left(\frac{\mathrm{Im}\left(EYT_{b,k}\right)}{\mathrm{Re}\left(EYT_{b,k}\right)}\right)$$

Use EXT, EYT

Basic equation for magnitude of E field

$$E^2 = HX^2 \cdot \cos(\omega \cdot t + \theta)^2 + VY^2 \cdot \cos(\omega \cdot t + \phi)^2$$

$\frac{d}{dt}E^2$ **is set equal to 0 to find times t a[...] components are extremes.**

This development of formula for extreme values of E field are the Same as before.

Solution to this is given below which is also set = 0

$$\tan(2 \cdot \omega \cdot t) + \frac{\left(HX^2 \cdot \sin(2 \cdot \theta) + VY^2 \cdot \sin(2 \cdot \phi)\right)}{\left(HX^2 \cdot \cos(2 \cdot \theta) + VY^2 \cdot \cos(2 \cdot \phi)\right)}$$

Step 8.2 COMPUTE ω*t at which the fields are a maximum and minimum value on the field ellipse.

Explicit solution for ω*t is given below. The result is one possibility for an extreme value of H, min or max. There are four values of ω*t that satisfy the equation, corresponding to each of four quadrant points on the field ellipse.

Compute the first value of ω*t and corresponding time t.

$$\omega t1_{b,k} := \frac{1}{2}\,\mathrm{atan}\left[\frac{-\left[\left(HX_{b,k}\right)^2\cdot\sin\left(2\cdot\theta_{b,k}\right)+\left(VY_{b,k}\right)^2\cdot\sin\left(2\cdot\phi_{b,k}\right)\right]}{\left(HX_{b,k}\right)^2\cdot\cos\left(2\cdot\theta_{b,k}\right)+\left(VY_{b,k}\right)^2\cdot\cos\left(2\cdot\phi_{b,k}\right)}\right] \qquad t1_{b,k} := \frac{\omega t1_{b,k}}{\omega}$$

And the other angles and times are defined as follows.

$$\omega t2_{b,k} := \omega t1_{b,k} + \frac{\pi}{2} \qquad t2_{b,k} := \frac{\omega t2_{b,k}}{\omega}$$

$$\omega t3_{b,k} := \omega t1_{b,k} + \pi \qquad t3_{b,k} := \frac{\omega t3_{b,k}}{\omega}$$

$$\omega t4_{b,k} := \omega t1_{b,k} + \frac{3\pi}{2} \qquad t4_{b,k} := \frac{\omega t4_{b,k}}{\omega}$$

Step 8.3 COMPUTE Maximum and Minimum values of total E Field as it traces the field ellipse at each point k at a time point b.

Step 8.3.1 SUBSTITUTE values of t found above and define four separate ω*t values

$$E\_MAG\_Axis1_{b,k} := \sqrt{\left(HX_{b,k}\right)^2\cdot\cos\left(\omega\cdot t1_{b,k}+\theta_{b,k}\right)^2+\left(VY_{b,k}\right)^2\cdot\cos\left(\omega\cdot t1_{b,k}+\phi_{b,k}\right)^2}$$

Same

$$E\_MAG\_Axis2_{b,k} := \sqrt{\left(HX_{b,k}\right)^2\cdot\cos\left(\omega\cdot t2_{b,k}+\theta_{b,k}\right)^2+\left(VY_{b,k}\right)^2\cdot\cos\left(\omega\cdot t2_{b,k}+\phi_{b,k}\right)^2}$$

$$E\_MAG\_Axis3_{b,k} := \sqrt{\left(HX_{b,k}\right)^2\cdot\cos\left(\omega\cdot t3_{b,k}+\theta_{b,k}\right)^2+\left(VY_{b,k}\right)^2\cdot\cos\left(\omega\cdot t3_{b,k}+\phi_{b,k}\right)^2}$$

$$E\_MAG\_Axis4_{b,k} := \sqrt{\left(HX_{b,k}\right)^2\cdot\cos\left(\omega\cdot t4_{b,k}+\theta_{b,k}\right)^2+\left(VY_{b,k}\right)^2\cdot\cos\left(\omega\cdot t4_{b,k}+\phi_{b,k}\right)^2}$$

Note that ω*t 1 and 3 are the minimum pair while ω*t 2 and 4 are maximum pair. This relationship may not always hold but there will be two similar pairs. But values for 1 and 2 [or any consecutive pair] will contain a minimum and a maximum.

Step 8.3.2 SELECT maximum value of extremes 1 and 2 below for each b,k combination

$$E\_MAX_{b,k} := \max\left(E\_MAG\_Axis1_{b,k}, E\_MAG\_Axis2_{b,k}\right)$$

Same

Step 8.3.3 SELECT the maximum value at each position k by selecting the maximum value while varying b, the time interval. This program eliminates the time index b.

```
E_MX_k := | A_k ← 0
          | for b ∈ 0, 1 .. (b_max − 1)
          |    | b ← b + 1
          |    | A_k ← E_MAX_b,k  if E_MAX_b,k > A_k
          |    | A_k  otherwise
          | A_k
```

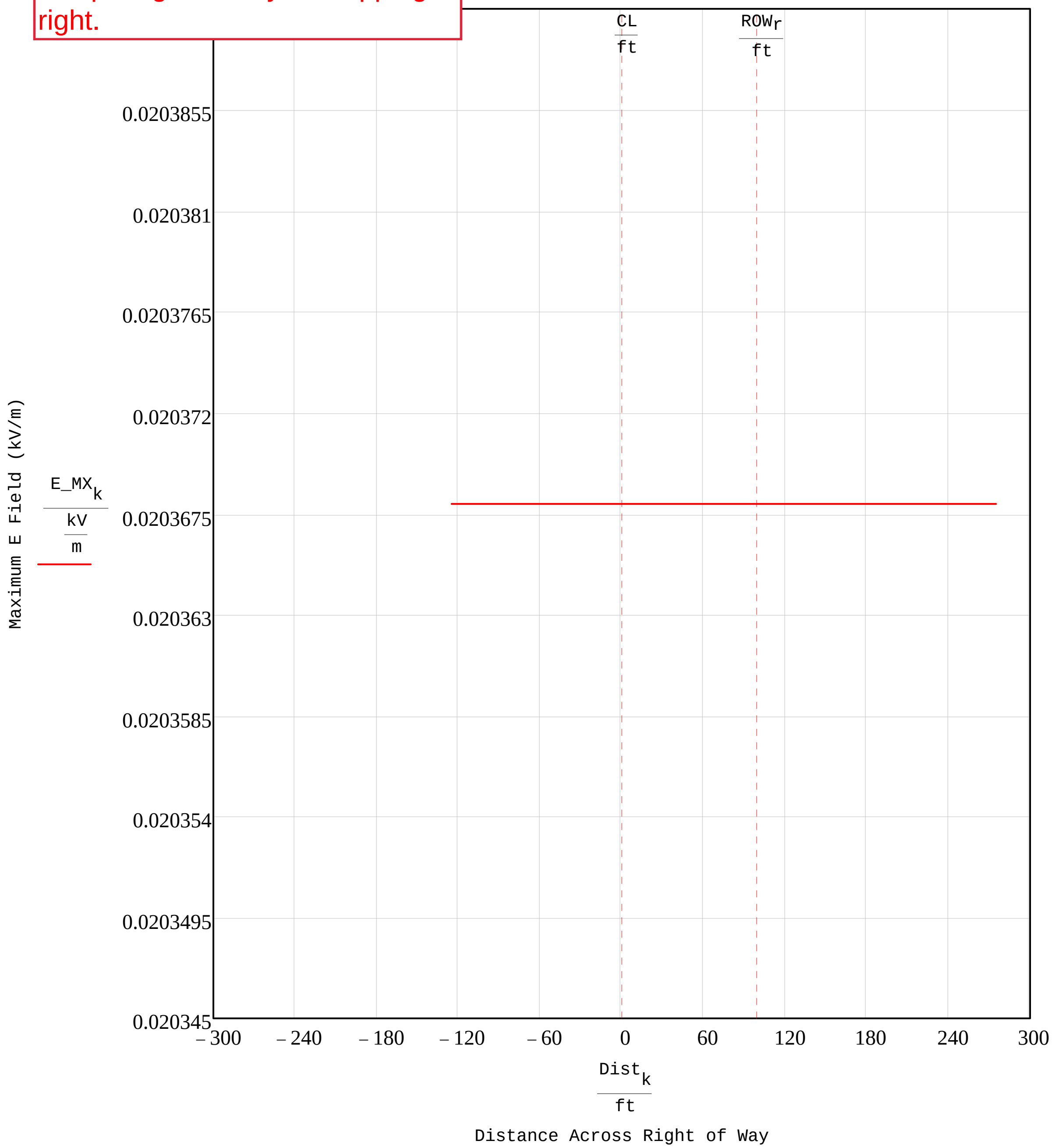
Same. Selects the maximum E value at each k position across the ROW.

Step 8.4 PLOT maximum values of total E Field as it traces the field ellipse at each point k across the corridor.

MX := max(E_MX) MX = $0.02037 \cdot \frac{kV}{m}$ U := match(MX, E_MX) Peak4 :=

Does NOT plot OK. Constant value indicates some step is not computing correctly or stepping right.

Maximum E Field vs Distance



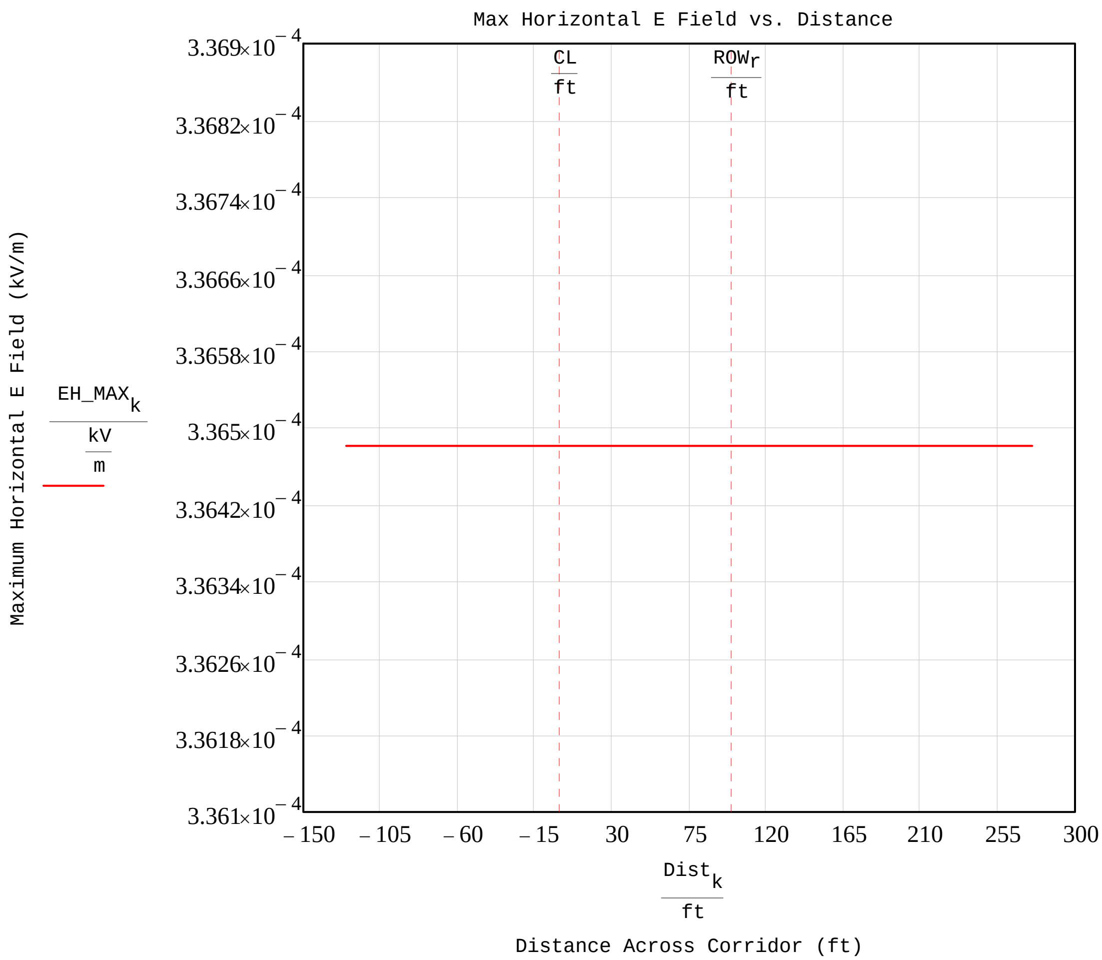
Step 8.5 COMPUTE and PLOT Separate Maximum Horizontal (X) Component

$HX2_{b,k} := \sqrt{Re(EXT_{b,k})^2 + Im(EXT_{b,k})^2}$

Does NOT plot OK. Constant value indicates some step is not computing correctly or stepping right.

```
EH_MAX_k := | HMAX_k ← 0
            | for b ∈ 0, 1 .. (b_max − 1)
            |    | b ← b + 1
            |    | HMAX_k ← HX2_b,k  if HX2_b,k > HMAX_k
            |    | HMAX_k  otherwise
            | HMAX_k
```

$HX := max(EH\_MAX)$ $\quad HX = 0.00034 \cdot \frac{kV}{m}$ $\quad M := match(HX, EH\_MAX)$ $\quad Peak3 := (DD(M))$



Step 8.6 COMPUTE and PLOT Separate Maximum Vertical (Y) Field Component

$$VY2_{b,k} := \sqrt{Re(EYT_{b,k})^2 + Im(EYT_{b,k})^2}$$

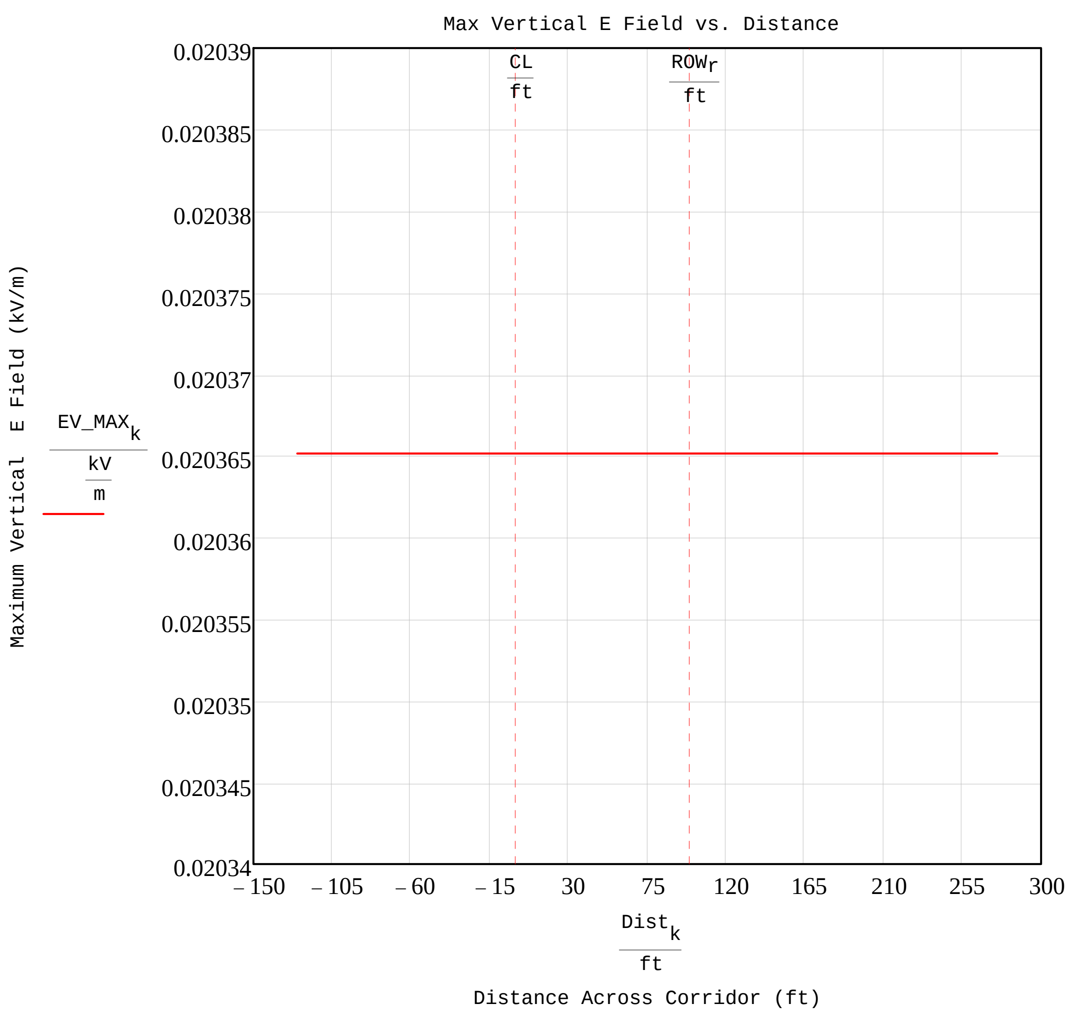
$VY2_{1,1} = 0.02037 \frac{kV}{m}$

$VY2_{1,50} = 0.02037 \frac{kV}{m}$

```
EV_MAX_k := | VMAX_k ← 0
            | for b ∈ 0, 1 .. (b_max − 1)
            |   | b ← b + 1
            |   | VMAX_k ← VY2_b,k  if VY2_b,k > VMAX_k
            |   | VMAX_k  otherwise
            | VMAX_k
```

Does NOT plot OK. Constant value indicates some step is not computing correctly or stepping right.

$VX := max(EV\_MAX)$ $VX = 0.02037 \cdot \frac{kV}{m}$ $Z := match(VX, EV\_MAX)$ $Peak1 := DD(Z)$



STEP 9.0 COMPUTE Space Potential VR from Q values in Step 6.0 above

Step 9.1 SET UP Line Voltages

$DA^{<6>}$ is the Line to Line voltage of wire. $DA^{<7>}$ is the phase angle of wire.

$$VMX_i := \frac{1 \cdot kV}{\sqrt{3}} \cdot \left(DA^{\langle 6 \rangle}\right)_i \cdot e^{j\left[(DA)^{\langle 7 \rangle}\right]_i deg}$$

$$VMX = \begin{pmatrix} -66.39528 + 115j \\ -66.39528 - 115j \\ 132.79056 \\ 0 \\ 0 \end{pmatrix} \cdot kV$$

Line to ground voltages

Step 9.2 COMPUTE Line Charges Q from P

$$QSP := P^{-1} \cdot VMX$$

$$QSP = \begin{pmatrix} -0.51948 + 1.06103j \\ -0.62868 - 1.08891j \\ 1.17862 + 0.08063j \\ 0.11171 - 0.04245j \\ -0.09261 + 0.07552j \end{pmatrix} \cdot \frac{\mu C}{m}$$

$$QSP_{REAL} := Re(QSP) = \begin{pmatrix} -0.51948 \\ -0.62868 \\ 1.17862 \\ 0.11171 \\ -0.09261 \end{pmatrix} \cdot \frac{\mu C}{m}$$

$$QSP_{IMAG} := Im(QSP) = \begin{pmatrix} 1.06103 \\ -1.08891 \\ 0.08063 \\ -0.04245 \\ 0.07552 \end{pmatrix} \cdot \frac{\mu C}{m}$$

Step 9.3 EXPRESS Intermediate dimensional parameters using the same notation as BPA

Set up coordinates for conductors:

$X2 := X$ $\quad$ $Y2 := Y$

Express real, imaginary and total space potential in terms of x, y

$$VR2(x,y) := \frac{1}{\varepsilon_0}\cdot\sum_{i=1}^{NC}\left[QSP_{REAL_i}\cdot\left[\ln\left[\frac{\sqrt{(X_i - x\cdot ft)^2 + (Y_i - y\cdot ft)^2}}{Y_m}\right] - \ln\left[\frac{\sqrt{(X_i - x\cdot ft)^2 + (Y_i + y\cdot ft)^2}}{Y_m}\right]\right]\right]$$

$$VI2(x,y) := \frac{1}{\varepsilon_0}\cdot\sum_{i=1}^{NC}\left[QSP_{IMAG_i}\cdot\left[\ln\left[\frac{\sqrt{(X_i - x\cdot ft)^2 + (Y_i - y\cdot ft)^2}}{Y_m}\right] - \ln\left[\frac{\sqrt{(X_i - x\cdot ft)^2 + (Y_i + y\cdot ft)^2}}{Y_m}\right]\right]\right]$$

$$VT2(x,y) := \frac{\sqrt{VR2(x,y)^2 + VI2(x,y)^2}}{kV}$$

Step 9.4 SET UP boundaries for contour plot of space potential.

Step 9.4.1 EXTRACT limits of X and Y conductor positions.

$Xmin := Round(min(X), 1\cdot ft)$ $\quad$ $Ymin := Round(min(Y), 1\cdot ft)$ $\quad$ $Xmin = -16\cdot ft$ $\quad$ $Ymin = 35\cdot ft$

$Xmax := Round(max(X), 1\cdot ft)$ $\quad$ $Ymax := Round(max(Y), 1\cdot ft)$ $\quad$ $Xmax = 16\cdot ft$ $\quad$ $Ymax = 45\cdot ft$

Step 9.4.2 SPECIFY deltas to compute bounds of plot from limits above. Note vary these values to expand the plot area.

$\delta X := 10\cdot ft$ $\quad$ $\delta Y := 20\cdot ft$

Step 9.4.3 COMPUTE left, right X and lower,upper Y boundaries for plot. Note that you can also alter the plot area by adding an appropriate multiplication factor in front of δx or δy.

$XL := \frac{Xmin - 1\delta X}{ft}$ $\quad$ $XR := \frac{Xmax + 1\delta X}{ft}$ $\quad$ $YU := \frac{Ymax + 1\delta Y}{ft}$ $\quad$ $YL := \frac{Ymin - 1\delta Y}{ft}$

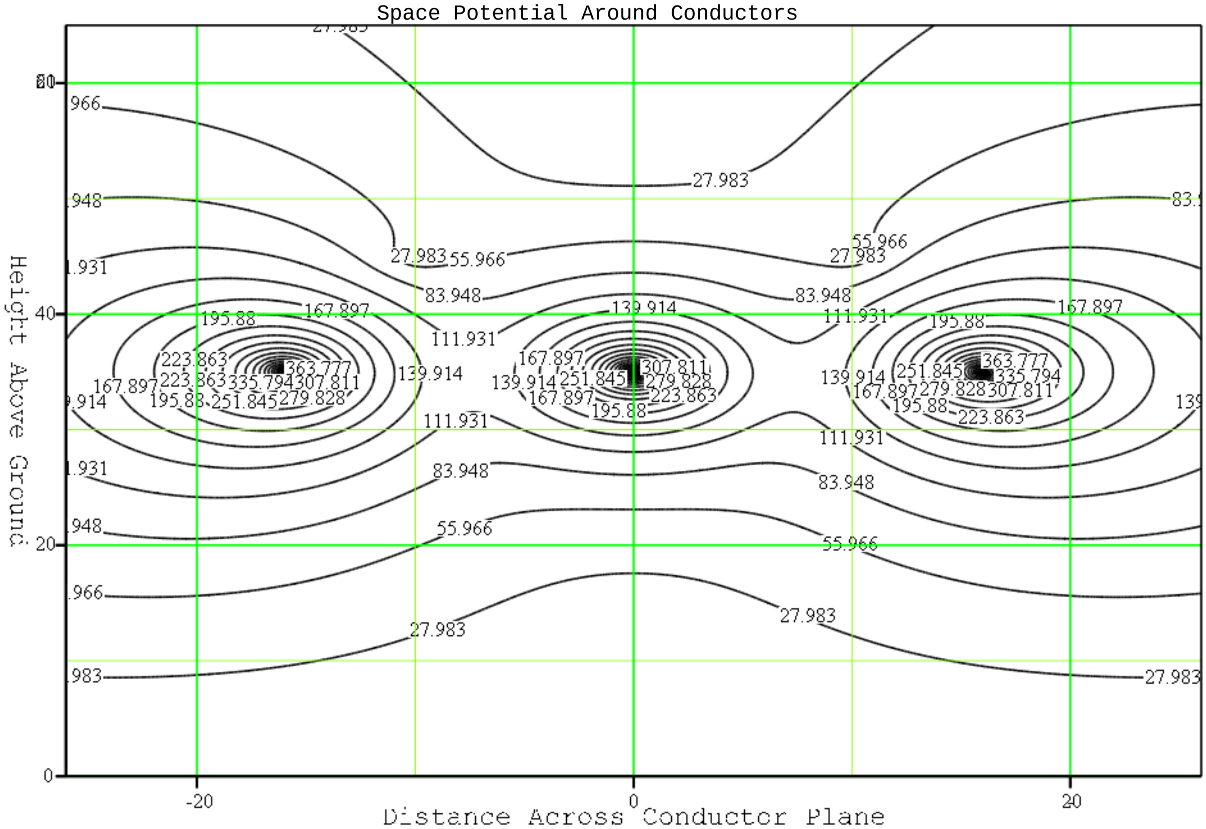
$XL = -26$ $\quad$ $XR = 26$ $\quad$ $YU = 65$ $\quad$ $YL = 15$

Step 9.5 CREATE Mesh for grid and produce the contour plot. See the description of input for the CreateMesh command below. You can directly vary all the inputs to the right of the function (VTT),e.g. replace say XL with a number. The electric potential is often used to pick the most appropriate ADSS jacket and position on the structure.

VTT := CreateMesh(VT2, XL, XR, 0, YU, 200, 200)

electric potential is plotting OK and as expected but it's same calculation as previous document.

Space Potential Around Conductors



VTT