



Field and Corona Effects

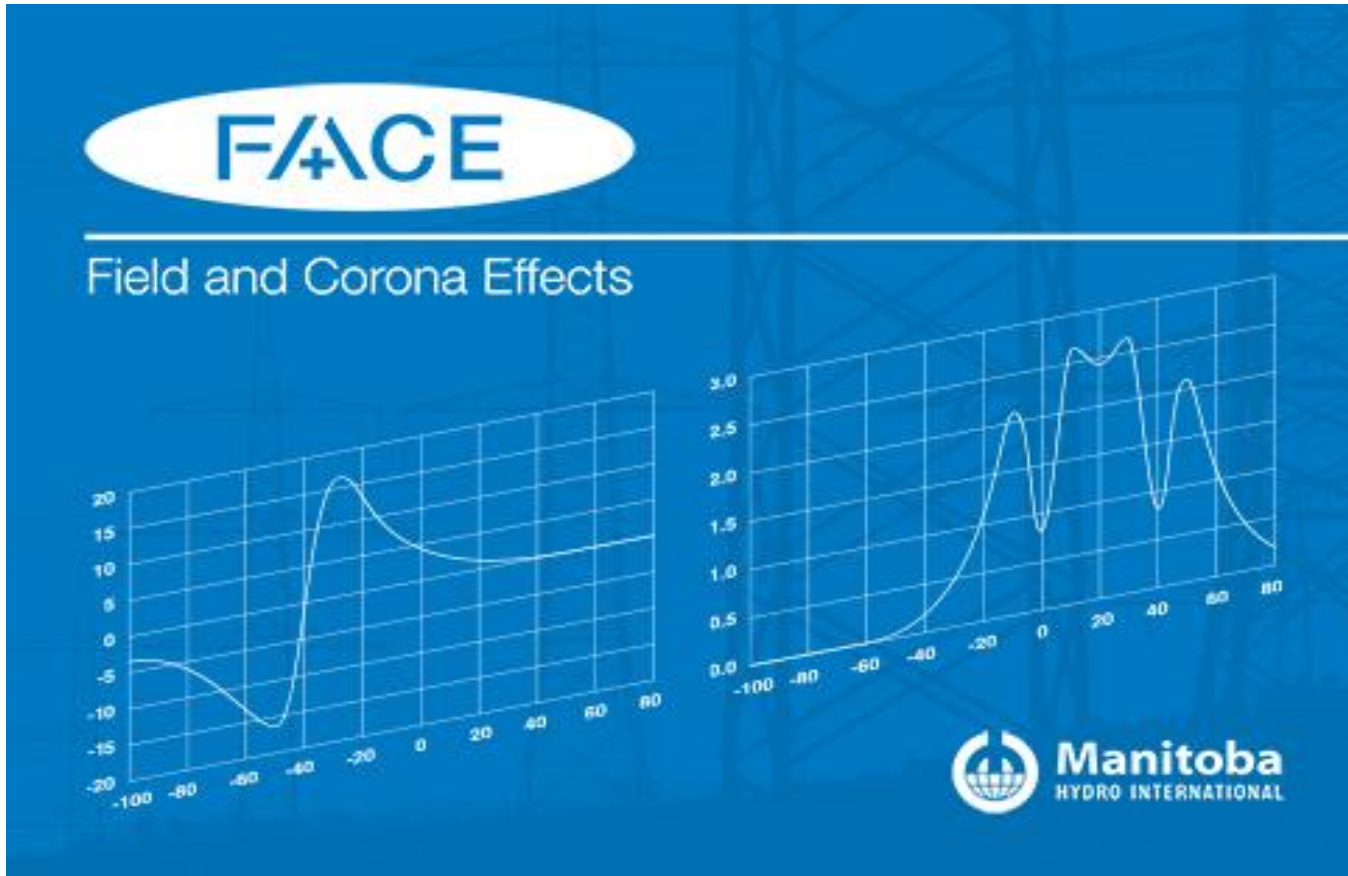
2018 FACE Presentation

Oct. 31, 2018

pscad.com



Welcome to F+ACE



Introduction

1. FACE (Field and Corona Effects) Basics
 1. What is FACE
 2. FACE History
 3. Salient Features
 4. Application Areas
2. User-Friendly and Intuitive GUI
3. Examples & Validations
4. Questions & Answers

1. FACE Basics: FACE ?

- Field and Corona performance is an important consideration when designing & operating HV lines
- Evaluates the overall environmental effects of HV AC, DC, or AC/DC hybrid power lines, namely
 - AN
 - RI
 - Corona Loss
 - Static electric and magnetic fields
 - Ion fields, ion currents, ion charges
- Produces Lateral profiles specified by users

1. FACE Basics: FACE History

- FACE Development was initiated at MH Hydro in early 1980s',
- FACE Development & validations were continued at MHI (HVDC Research Centre) from 1987 – 1995,
- Significant improvements, 04/2006-07/2007,
 - RI, advanced computation method
 - Highly Efficient ionized field computation
- User friendly and intuitive GUI, 2016-now,
- Evolved to a commercial product.

1. FACE Basics: FACE Features

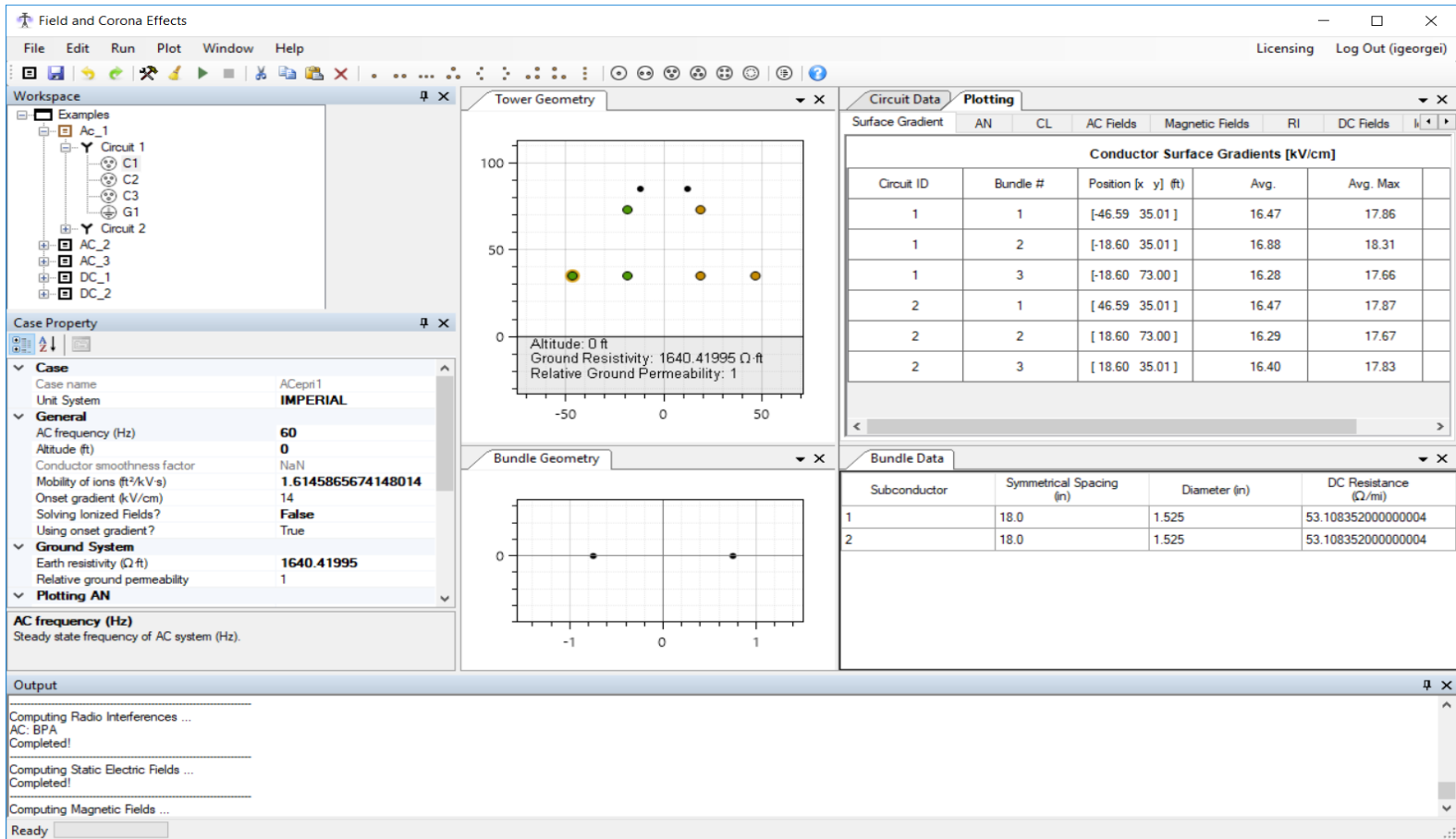
- Predicts the field and corona performance of AC, DC, or **AC/DC hybrid power lines**,
- Employed a **higher-order successive image method** for the field computation
 - & Subconductors as separate conductors internally,
- Implemented Generation Functions developed by EPRI, BPA, EDF, IREQ ... for user's selections through GUI,
- Most advanced RI computation: semi-analytical method, frequency domain model transform technique.
- Highly efficient solution method for ionized fields
- Asymmetrical bundles can be handled easily

1. FACE Basics: Application Areas

- Existing transmission line studies, and monitoring
- AC, DC, or DC/AC transmission lines design
- Converting AC to DC and Vice Versa



2. FACE GUI



The screenshot displays the FACE GUI interface with the following components:

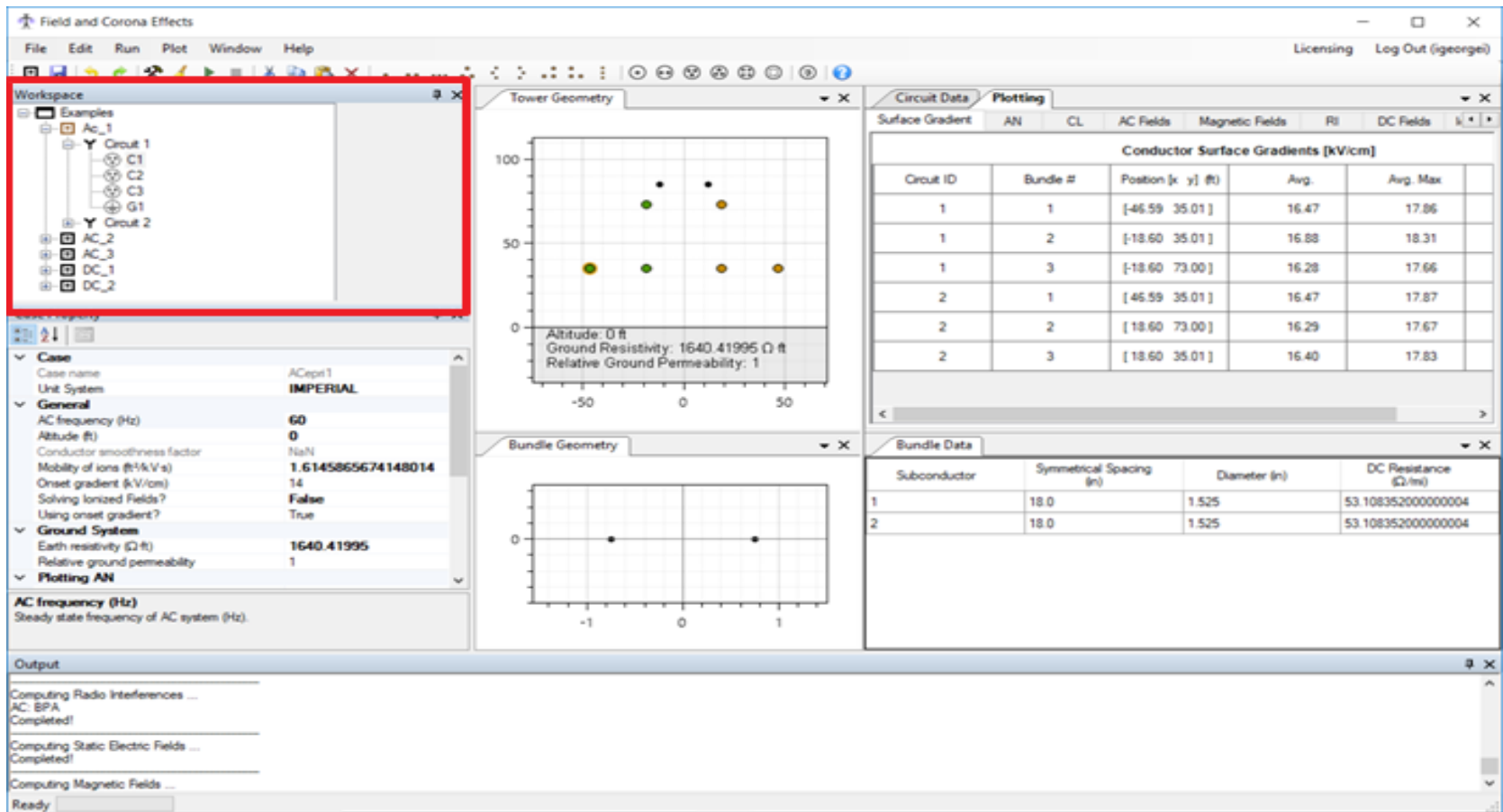
- Workspace:** A tree view showing a project named 'Ac_1' containing two circuits (Circuit 1 and Circuit 2) and several conductors (AC_2, AC_3, DC_1, DC_2).
- Case Property:**
 - Case name: ACept1
 - Unit System: IMPERIAL
 - General:** AC frequency (Hz): 60, Altitude (ft): 0, Conductor smoothness factor: NaN, Mobility of ions (ft²/kV·s): 1.6145865674148014, Onset gradient (kV/cm): 14, Solving Ionized Fields?: False, Using onset gradient?: True.
 - Ground System:** Earth resistivity (Ω ft): 1640.41995, Relative ground permeability: 1.
 - Plotting AN:** AC frequency (Hz): Steady state frequency of AC system (Hz).
- Tower Geometry:** A scatter plot showing conductor positions. Text overlay: Altitude: 0 ft, Ground Resistivity: 1640.41995 Ω·ft, Relative Ground Permeability: 1.
- Circuit Data / Plotting:**

Conductor Surface Gradients [kV/cm]					
Circuit ID	Bundle #	Position [x y] (ft)	Avg.	Avg. Max	
1	1	[-46.59 35.01]	16.47	17.86	
1	2	[-18.60 35.01]	16.88	18.31	
1	3	[-18.60 73.00]	16.28	17.66	
2	1	[46.59 35.01]	16.47	17.87	
2	2	[18.60 73.00]	16.29	17.67	
2	3	[18.60 35.01]	16.40	17.83	
- Bundle Geometry:** A scatter plot showing bundle positions.
- Bundle Data:**

Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004
- Output:**
 - Computing Radio Interferences ... AC: BPA Completed!
 - Computing Static Electric Fields ... Completed!
 - Computing Magnetic Fields ... Ready

2. FACE GUI: Workspace Window

- Workspace- users can define multiple projects



The screenshot displays the FACE GUI interface. The **Workspace** window is highlighted with a red border, showing a tree view of projects under 'Examples', including 'Ac_1' (with sub-items C1, C2, C3, G1) and 'Circuit 2' (with sub-items AC_2, AC_3, DC_1, DC_2).

The **Tower Geometry** plot shows a 2D coordinate system with points representing tower bundles. The **Bundle Geometry** plot shows a similar coordinate system for individual bundle positions.

The **Circuit Data** window is active, showing the **Plotting** tab. It contains two tables:

Conductor Surface Gradients [kV/cm]				
Circuit ID	Bundle #	Position [x y] (ft)	Avg.	Avg. Max
1	1	[-46.59 35.01]	16.47	17.86
1	2	[-18.60 35.01]	16.88	18.31
1	3	[-18.60 73.00]	16.28	17.66
2	1	[46.59 35.01]	16.47	17.87
2	2	[18.60 73.00]	16.29	17.67
2	3	[18.60 35.01]	16.40	17.83

Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004

The **Case** window shows the following parameters:

- Case name: ACcept1
- Unit System: IMPERIAL
- General: AC frequency (Hz) 60, Altitude (ft) 0, Conductor smoothness factor NaN, Mobility of ions (ft²/V·s) 1.6145865674148014, Onset gradient (kV/cm) 14, Solving ionized fields? False, Using onset gradient? True
- Ground System: Earth resistivity (Ω ft) 1640.41995, Relative ground permeability 1
- Plotting AN: (checked)
- AC frequency (Hz): Steady state frequency of AC system (Hz).

The **Output** window shows the following status:

```

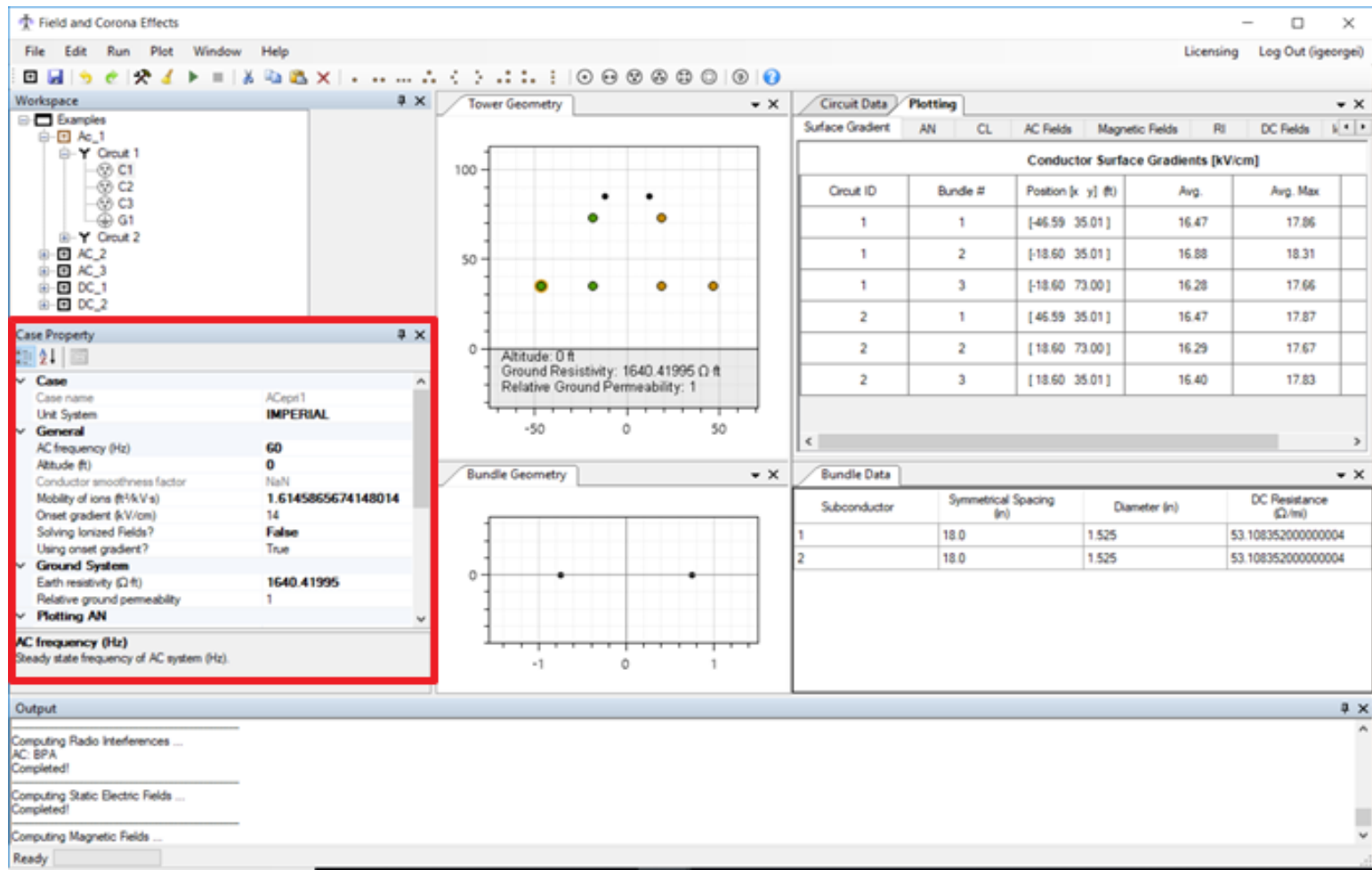
Computing Radio Interferences ...
AC: BPA
Completed!

Computing Static Electric Fields ...
Completed!

Computing Magnetic Fields ...
Ready
    
```

2. FACE GUI: Case Property Window

- Case Property – users can edit parameters for a selected project



Case Property

Case name: ACepr1
 Unit System: IMPERIAL

General

AC frequency (Hz): 60
 Altitude (ft): 0
 Conductor smoothness factor: NaN
 Mobility of ions (ft/kV): 1.6145865674148014
 Onset gradient (kV/cm): 14
 Solving Ionized Fields: False
 Using onset gradient: True

Ground System

Earth resistivity (Ω ft): 1640.41995
 Relative ground permeability: 1

Plotting AN

AC frequency (Hz)
 Steady state frequency of AC system (Hz)

Tower Geometry

Altitude: 0 ft
 Ground Resistivity: 1640.41995 Ω ft
 Relative Ground Permeability: 1

Conductor Surface Gradients [kV/cm]

Circuit ID	Bundle #	Position [x y] (ft)	Avg.	Avg. Max
1	1	[-46.59 35.01]	16.47	17.86
1	2	[-18.60 35.01]	16.88	18.31
1	3	[-18.60 73.00]	16.28	17.66
2	1	[46.59 35.01]	16.47	17.87
2	2	[18.60 73.00]	16.29	17.67
2	3	[18.60 35.01]	16.40	17.83

Bundle Data

Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004

Output

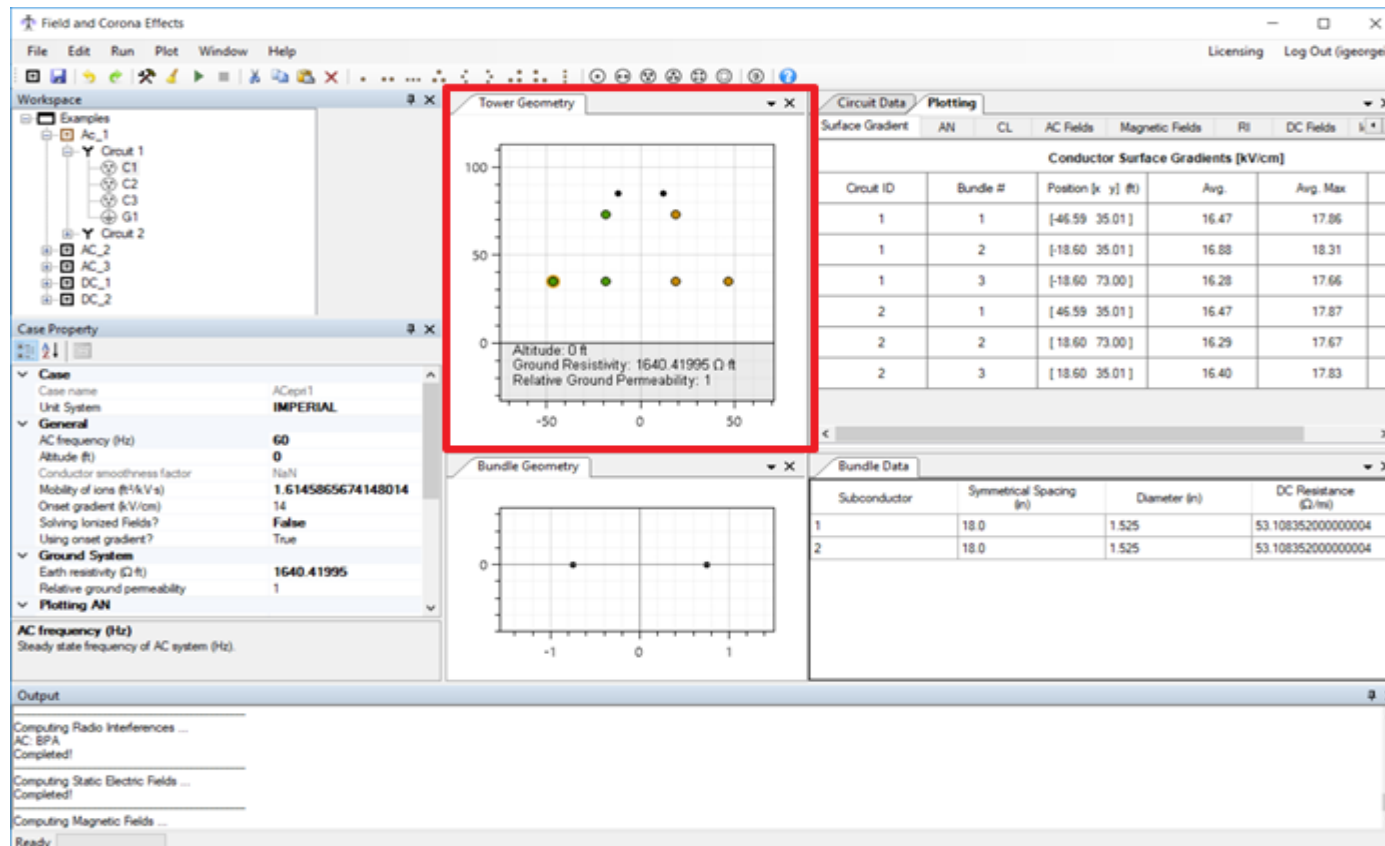
Computing Radio Interferences ...
 AC, BPA
 Completed!

Computing Static Electric Fields ...
 Completed!

Computing Magnetic Fields ...
 Ready

2. FACE GUI: Tower Geometry Window

- Tower Geometry Window shows cross-section that includes bundle and ground wire placement



Case Property

Case name: ACcept1
Unit System: IMPERIAL

General

AC frequency (Hz): 60
Altitude (ft): 0
Conductor smoothness factor: NaN
Mobility of ions (#kV/s): 1.6145865674148014
Onset gradient (kV/cm): 14
Solving Ionized Fields?: False
Using onset gradient?: True

Ground System

Earth resistivity (Ω ft): 1640.41995
Relative ground permeability: 1

Plotting AN

AC frequency (Hz):
Steady state frequency of AC system (Hz):

Conductor Surface Gradients [kV/cm]

Circuit ID	Bundle #	Position [x, y] (ft)	Avg.	Avg. Max
1	1	[-46.59, 35.01]	16.47	17.86
1	2	[-18.60, 35.01]	16.88	18.31
1	3	[-18.60, 73.00]	16.28	17.66
2	1	[46.59, 35.01]	16.47	17.87
2	2	[18.60, 73.00]	16.29	17.67
2	3	[18.60, 35.01]	16.40	17.83

Bundle Data

Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004

Output

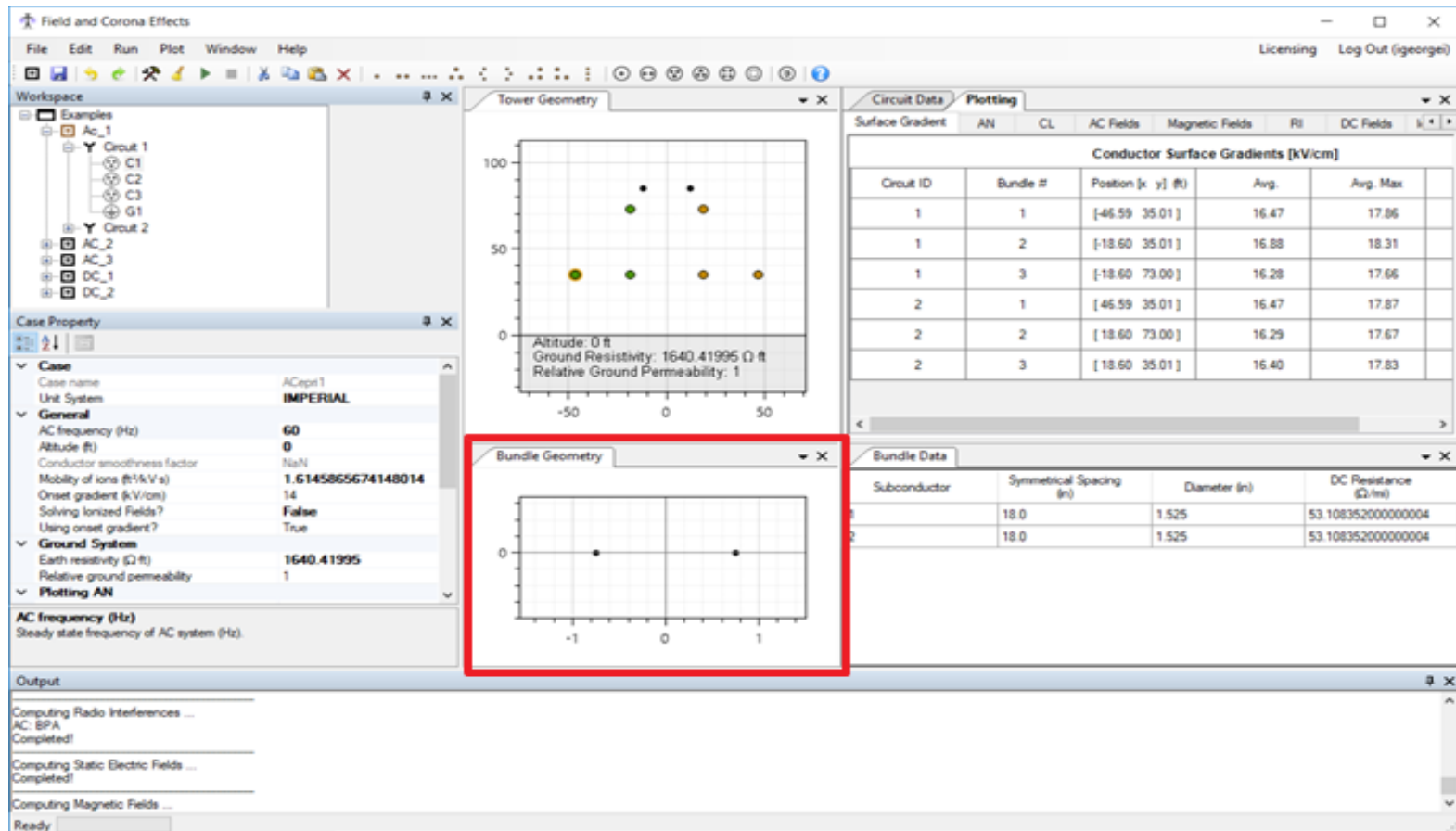
Computing Radio Interferences ...
AC: BPA
Completed!

Computing Static Electric Fields ...
Completed!

Computing Magnetic Fields ...
Ready

2. FACE GUI: Bundle Geometry Window

- Bundle Geometry Window show a cross-section that includes subconductor placement



The screenshot displays the FACE GUI interface. The 'Bundle Geometry' window is highlighted with a red border. It shows a cross-section plot with two subconductors positioned at approximately x = -0.5 and x = 0.5 on a scale from -1 to 1. The 'Tower Geometry' window shows a plot of conductor positions with a grid from -50 to 50 on the x-axis and 0 to 100 on the y-axis. The 'Circuit Data' window displays a table of conductor surface gradients.

Conductor Surface Gradients [kV/cm]				
Circuit ID	Bundle #	Position [x y] (ft)	Avg.	Avg. Max
1	1	[-46.59 35.01]	16.47	17.86
1	2	[-18.60 35.01]	16.88	18.31
1	3	[-18.60 73.00]	16.28	17.66
2	1	[46.59 35.01]	16.47	17.87
2	2	[18.60 73.00]	16.29	17.67
2	3	[18.60 35.01]	16.40	17.83

Bundle Data			
Subconductor	Symmetrical Spacing (m)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004

Case Property

- Case name: ACcpr1
- Unit System: IMPERIAL
- General:
 - AC frequency (Hz): 60
 - Altitude (ft): 0
 - Conductor smoothness factor: NaN
 - Mobility of ions (#/kV·s): 1.6145865674148014
 - Onset gradient (kV/ions): 14
 - Solving Ionized Fields?: False
 - Using onset gradient?: True
- Ground System:
 - Earth resistivity (Ω ft): 1640.41995
 - Relative ground permeability: 1
- Plotting AN

AC frequency (Hz)
Steady state frequency of AC system (Hz)

Output

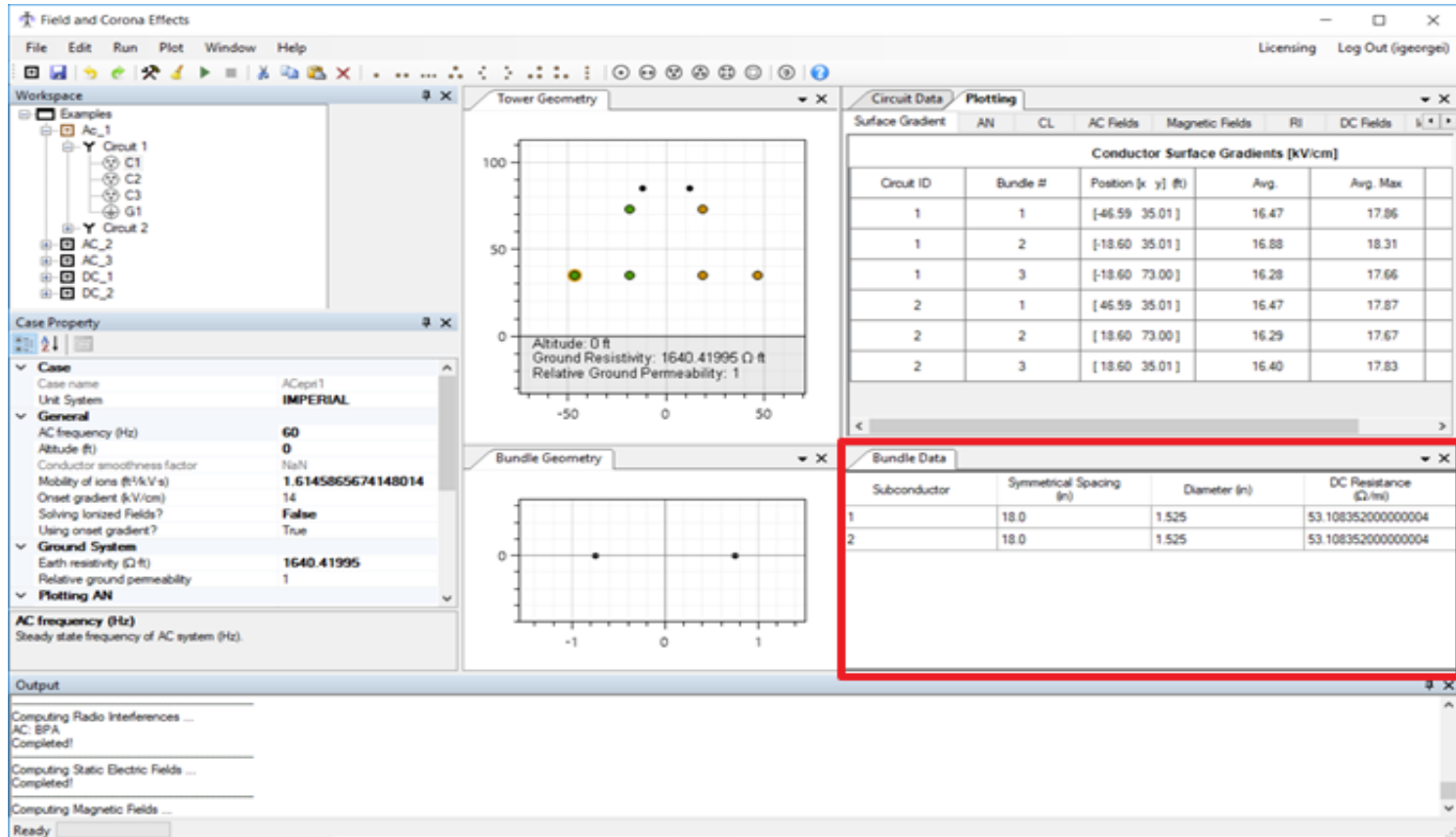
Computing Radio Interferences ...
AC BPA
Completed!

Computing Static Electric Fields ...
Completed!

Computing Magnetic Fields ...
Ready

2. FACE GUI: Bundle Data Window

- Bundle Data Window shows the data for bundles and their individual sub conductors



The screenshot shows the FACE GUI interface. The 'Bundle Data' window is highlighted with a red border and contains the following table:

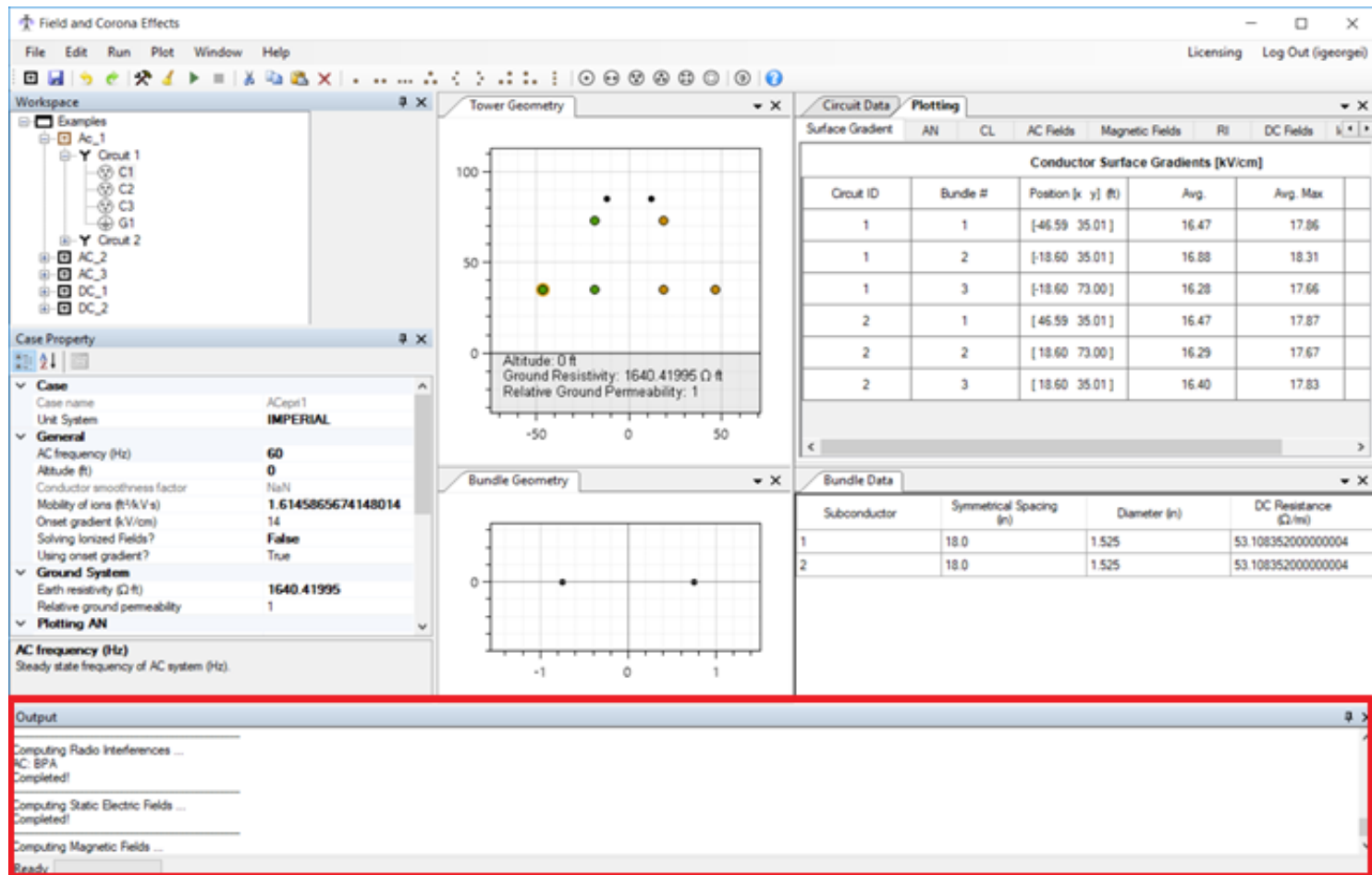
Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/ft)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004

Other visible windows in the screenshot include:

- Workspace:** Shows a tree view of the project structure with 'Examples', 'Ac_1', 'Circuit 1', 'C1', 'C2', 'C3', 'G1', 'Circuit 2', 'AC_2', 'AC_3', 'DC_1', and 'DC_2'.
- Case Property:** Displays case details such as 'Case name: ACcept1', 'Unit System: IMPERIAL', 'AC frequency (Hz): 60', 'Altitude (ft): 0', 'Ground System: Earth resistivity (Ω ft): 1640.41995', and 'Plotting AN'.
- Tower Geometry:** A plot showing the tower structure with a grid. Text below the plot indicates: 'Altitude: 0 ft', 'Ground Resistivity: 1640.41995 Ω ft', and 'Relative Ground Permeability: 1'.
- Bundle Geometry:** A plot showing the bundle geometry with a grid.
- Circuit Data / Plotting:** A table showing 'Conductor Surface Gradients [kV/cm]' with columns for Circuit ID, Bundle #, Position [x y] (ft), Avg., and Avg. Max.
- Output:** Shows the status of various computations: 'Computing Radio Interferences ... AC: EPA Completed!', 'Computing Static Electric Fields ... Completed!', and 'Computing Magnetic Fields ...'.

2. FACE GUI: Output Window

- Output Window shows code, simulation results, and error messages



The screenshot displays the FACE software interface with several panels:

- Workspace:** A tree view showing the project structure with components like AC_1, AC_2, AC_3, DC_1, DC_2, and various circuit bundles (C1, C2, C3, G1).
- Case Property:** A panel with expandable sections:
 - Case:** Case name: ACepr1, Unit System: IMPERIAL
 - General:** AC frequency (Hz): 60, Altitude (ft): 0, Conductor smoothness factor: NaN, Mobility of ions (ft/kV/s): 1.6145865674148014, Onset gradient (kV/cm): 14, Solving Ionized Fields?: False, Using onset gradient?: True
 - Ground System:** Earth resistivity (Ω/ft): 1640.41995, Relative ground permeability: 1
 - Plotting AN:** (Expanded)
- Tower Geometry:** A scatter plot showing tower positions on a grid. Text below the plot: Altitude: 0 ft, Ground Resistivity: 1640.41995 Ω ft, Relative Ground Permeability: 1.
- Bundle Geometry:** A scatter plot showing bundle positions on a grid.
- Circuit Data / Plotting:** A table titled "Conductor Surface Gradients [kV/cm]":

Circuit ID	Bunde #	Position [x y] (ft)	Avg.	Avg. Max
1	1	[-46.59 35.01]	16.47	17.86
1	2	[-18.60 35.01]	16.88	18.31
1	3	[-18.60 73.00]	16.28	17.66
2	1	[46.59 35.01]	16.47	17.87
2	2	[18.60 73.00]	16.29	17.67
2	3	[18.60 35.01]	16.40	17.83
- Bundle Data:** A table with columns: Subconductor, Symmetrical Spacing (ft), Diameter (in), DC Resistance (Ω/mi):

Subconductor	Symmetrical Spacing (ft)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000004
2	18.0	1.525	53.108352000000004
- Output:** A text window at the bottom showing simulation progress:


```

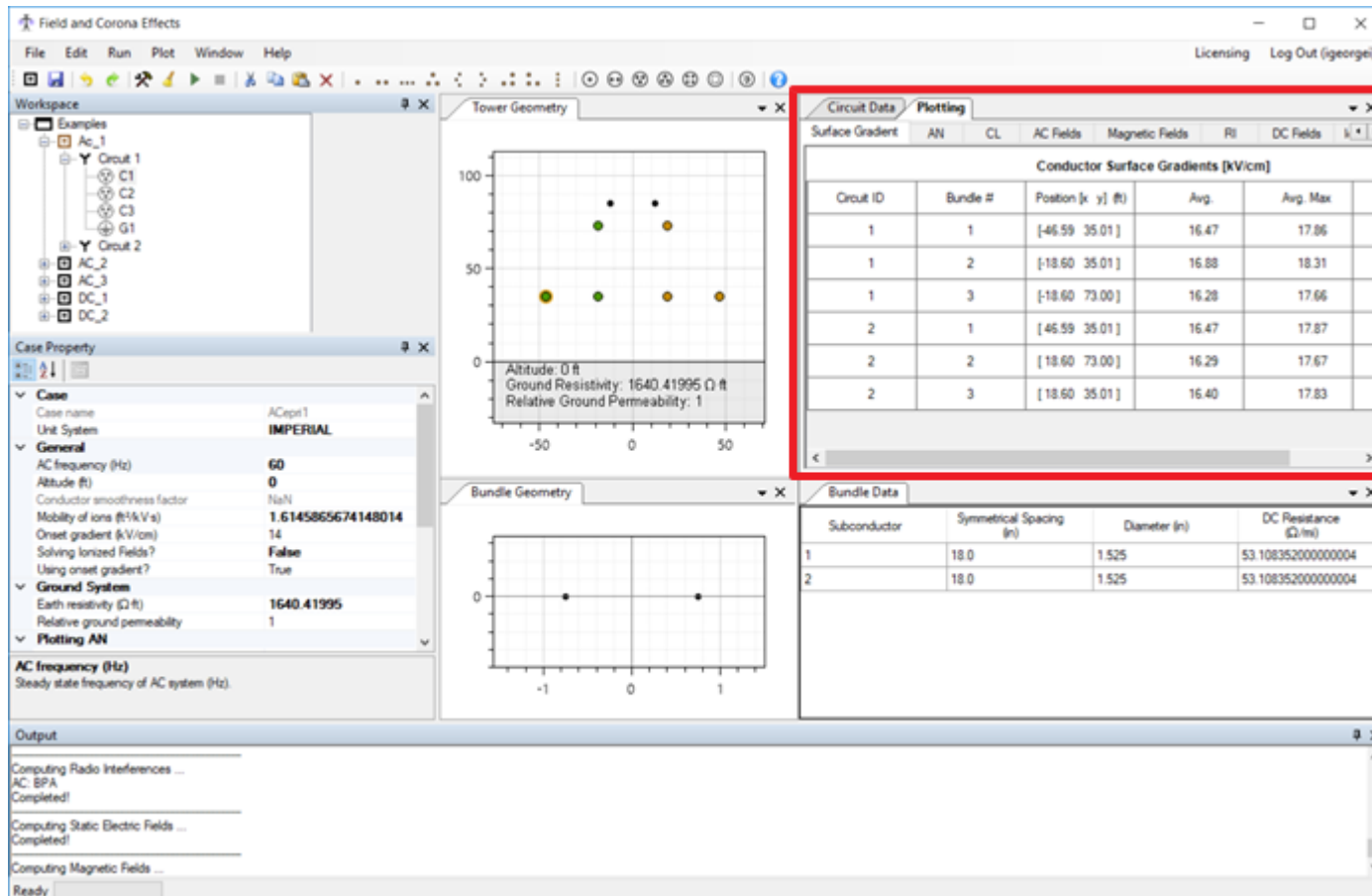
      Computing Radio Interferences ...
      AC BPA
      Completed!

      Computing Static Electric Fields ...
      Completed!

      Computing Magnetic Fields ...
      Ready
      
```

2. FACE GUI: Plotting Window

- Plotting Window where simulation results are displayed and navigated



The screenshot shows the FACE GUI interface. The 'Plotting' window is highlighted with a red border and contains a table titled 'Conductor Surface Gradients [kV/cm]'. The table lists data for six different conductor configurations. Below the table is a 'Bundle Data' window showing subconductor details.

Circuit ID	Bundle #	Position [x, y] (ft)	Avg.	Avg. Max
1	1	[-46.59 35.01]	16.47	17.86
1	2	[-18.60 35.01]	16.88	18.31
1	3	[-18.60 73.00]	16.28	17.66
2	1	[46.59 35.01]	16.47	17.87
2	2	[18.60 73.00]	16.29	17.67
2	3	[18.60 35.01]	16.40	17.83

Subconductor	Symmetrical Spacing (in)	Diameter (in)	DC Resistance (Ω/mi)
1	18.0	1.525	53.108352000000000004
2	18.0	1.525	53.108352000000000004

3. Examples & Validations

- Surface Gradient
- AN
- RI
- CL
- Static Electric Fields
- Static Magnetic Fields
- Ionized Fields

3. Examples & Validations: Surface Gradients

- IEEE Committee Paper: "A Survey of Methods for Calculating Transmission Line Conductor Surface Voltage Gradients," IEEE Trans., PAS, vol. 98, 1979. Total 13 Cases
- IEEE Committee Paper, "A Comparison of Methods for Calculating Audible Noise of High Voltage Transmission Lines," IEEE Trans., PAS, vol.101, no.10, pp. 4090-4099, Oct. 1982. 20 AC and 4 DC Cases
- Robert G. Olsen, Steven D. Schennum and Vernon L. Chartier, "Comparison of Several Methods for Calculating Power line Electromagnetic Interference levels and Calibration with Long Term Data," IEEE Transactions on Power Delivery, Vol. 7, No. 2, **April** 1992. Total 9 AC Cases

3. Examples & Validations: Surface Gradients

[28] IEEE Committee Paper, "A Survey of Methods for Calculating Transmission Line Conductor Surface Voltage Gradients," IEEE Trans., PAS, vol. 98, pp. 1996-2014, 1979.

Case	SF	FACE Results		Successive Images(17) IEEE Results		Successive Images(18) IEEE Results		Error			
		C.P	O.P	C.P	O.P	C.P	O.P	C.P	O.P	C.P	O.P
1	A	15.51	14.67	15.51	14.66	15.51	14.62	0	0.01	0	0.05
	AM	15.51	14.67	15.51	14.79	15.51	14.68	0	-0.12	0	-0.01
	MB	15.51	14.67	15.51	14.79	15.51	14.68	0	-0.12	0	-0.01
2	A	14.69	13.59	14.69	13.59	14.69	13.53	0	0	0	0.06
	AM	15.67	14.49	15.64	14.46	15.64	14.4	0.03	0.03	0.03	0.09
	MB	15.67	14.65	15.64	14.47	15.64	14.59	0.03	0.18	0.03	0.06
3a	A	14.49	14.21	14.49	14.17	14.49	14.17	0	0.04	0	0.04
	AM	15.5	15.2	15.46	15.12	15.46	15.12	0.04	0.08	0.04	0.08
	MB	15.58	15.2	15.56	15.12	15.56	15.12	0.02	0.08	0.02	0.08
3b	A	14.57	14.2	14.57	14.2	14.57	14.16	0	0	0	0.04
	AM	15.58	15.18	15.56	15.24	15.54	15.1	0.02	-0.06	0.04	0.08
	MB	15.67	15.18	15.68	15.32	15.65	15.1	-0.01	-0.14	0.02	0.08
4a	A	15.37	15.27	15.37	15.27	15.36	15.26	0	0	0.01	0.01
	AM	16.74	16.63	16.68	16.59	16.67	16.56	0.06	0.04	0.07	0.07
	MB	16.74	16.77	16.68	16.63	16.67	16.75	0.06	0.14	0.07	0.02
4b	A	14.98	15.35	14.98	15.35	14.97	15.33	0	0	0.01	0.02
	AM	16.31	16.72	16.26	16.68	16.25	16.64	0.05	0.04	0.06	0.08
	MB	16.31	16.86	16.26	16.81	16.25	16.83	0.05	0.05	0.06	0.03
5	A	14.43	13.51	15.23	14.21	15.22	14.15	-0.8	-0.7	-0.79	-0.64
	AM	16.04	15.03	16.91	15.77	16.89	15.71	-0.87	-0.74	-0.85	-0.68
	MB	17.12	16.19	17.03	15.92	16.9	15.87	0.09	0.27	0.22	0.32
6a	A	18.54	17.23	18.54	17.23	18.53	17.15	0	0	0.01	0.08
	AM	21.08	19.6	21.06	19.58	21.05	19.48	0.02	0.02	0.03	0.12
	MB	21.08	19.83	21.18	19.75	21.05	19.48	-0.1	0.08	0.03	0.35
6b	A	18.54	17.05	18.54	16.95	18.53	16.95	0	0.1	0.01	0.1
	AM	21.09	19.39	21.06	19.26	21.05	19.26	0.03	0.13	0.04	0.13
	MB	21.09	19.64	21.17	19.54	21.05	19.54	-0.08	0.1	0.04	0.1
7	A	13.72	12.41	13.72	12.31	13.7	12.31	0	0.1	0.02	0.1
	AM	16.58	14.99	16.62	15.04	16.59	14.91	-0.04	-0.05	-0.01	0.08
	MB	16.62	15.58	16.84	15.37	16.63	15.5	-0.22	0.21	-0.01	0.08
8	A	11.43	10.4	11.43	10.4	11.41	10.33	0	0	0.02	0.07
	AM	14.22	12.94	14.29	13.01	14.28	12.92	-0.07	-0.07	-0.06	0.02
	MB	14.26	13.44	14.48	13.3	14.3	13.39	-0.22	0.14	-0.04	0.05
9 (DC)	A	17.47		17.46		17.46		0.01		0.01	
	AM	19.21		19.13		19.13		0.08		0.08	
	MB	19.42		19.18		19.4		0.24		0.02	
10 (DC)	A	16.16		16.16		16.15		0		0.01	
	AM	20.49		20.59		20.55		-0.1		-0.06	
	MB	21.39		21.13		21.58		0.26		-0.19	

A: Average AM: Average Maximum

MB: Maximum Bundle Gradient

C.P: Center Phase

O.P.: Outer Phase

3. Examples & Validations: Surface Gradients

[31] IEEE Committee Paper, "A Comparison of Methods for Calculating Audible Noise of High Voltage Transmission Lines," IEEE Trans., PAS, vol.101, no.10, pp. 4090-4099, Oct. 1982.

		AC Cases																		DC Cases					
Cases		1	2	3	4	5	6	7	8	9	10	11			12	13	14	15	16	17	18	19	20	21	22
												a	b	c											
n=		1	2	3	4	3	4	4	4	4	4	6	10	8	8	7	6	8	8	12	16	4	6	6	4
Ref 1	Phase Max	15.8	16.9	15.8	17.6	18.3	18.4	16.2	19.8	17.4	22.6	21.80	-	-	14.9	15.9	12.8	14.9	12.5	13.8	13	28.2	25.9	24	21.7
	A Avg-Max	15.8	16.7	15.6	16.6	17.8	18.2	16	19.6	17.1	22.3	21.60	-	-	14.5	15.5	12.4	14.5	12.2	13.5	12.5	27.6	25	23.5	21.1
	Phase Max	16.8	17.9	16.8	16.9	17.2	19.8	17.3	21.1	18.4	24.5	-	15.9	-	15.5	14.9	13.4	15.5	13	14.6	13.4				
	B Avg-Max	16.8	17.9	16.8	16.1	16.6	19.8	17.3	21.1	18.4	24.5	-	15.7	-	15.4	14.6	13.1	15.4	12.9	14.4	13.3				
	Phase Max	15.8	16.9	15.8	17.6	17.1	18.4	16.2	19.8	17.4	22.6	-	-	18.3	14.9	15.9	12.8	14.9	12.5	13.8	13				
	C Avg-Max	15.8	16.7	15.8	16.5	16.4	18.2	16	19.6	17.1	22.3	-	-	-	14.5	15.5	12.4	14.5	12.1	13.5	12.5				
FACE Results	Phase Max	15.82	16.94	15.87	17.46	18.22	18.53	16.24	19.9	17.44	22.55	21.49			14.84	15.72	12.68	14.83	12.48	14.03	12.91	27.84	25.86	23.96	21.65
	A Avg-Max	15.82	16.8	15.7	16.5	17.8	18.3	16.05	19.67	17.22	22.27	21.2			14.54	15.48	12.41	14.46	12.15	13.59	12.44	27.37	25.01	23.44	21.28
	Phase Max	16.84	17.92	16.88	16.83	17.11	19.83	17.3	21.12	18.44	24.55		16.02		15.41	14.81	13.1	15.01	12.93	14.44	13.31				
	B Avg-Max	16.84	17.92	16.87	16.09	16.69	19.83	17.3	21.11	18.43	24.53		15.86		15.38	14.6	13.09	14.73	12.9	14.39	13.26				
	Phase Max	15.82	16.94	15.87	17.46	17.03	18.53	16.24	19.9	17.44	22.55			17.83	14.84	15.72	12.68	14.83	12.48	14.03	12.91				
	C Avg-Max	15.82	16.8	15.7	16.5	16.42	18.3	16.05	19.67	17.22	22.27			17.51	14.54	15.48	12.41	14.46	12.15	13.59	12.44				
Errors		0.02	0.04	0.07	0.14	0.08	0.13	0.04	0.1	0.04	0.05	0.31			0.06	0.18	0.12	0.07	0.02	0.23	0.09	0.36	0.04	0.04	0.05
		0.02	0.1	0.1	0.1	0	0.1	0.05	0.07	0.12	0.03	0.40			0.04	0.02	0.01	0.04	0.05	0.09	0.06	0.23	0.01	0.06	0.18
		0.04	0.02	0.08	0.07	0.09	0.03	0	0.02	0.04	0.05		0.12		0.09	0.09	0.3	0.49	0.07	0.16	0.09				
		0.04	0.02	0.07	0.01	0.09	0.03	0	0.01	0.03	0.03		0.16		0.02	0	0.01	0.67	0	0.01	0.04				
		0.02	0.04	0.07	0.14	0.07	0.13	0.04	0.1	0.04	0.05			0.47	0.06	0.18	0.12	0.07	0.02	0.23	0.09				
		0.02	0.1	0.1	0	0.02	0.1	0.05	0.07	0.12	0.03				0.04	0.02	0.01	0.04	0.05	0.09	0.06				
Max. error		0.04	0.1	0.1	0.14	0.09	0.13	0.05	0.1	0.12	0.05	0.40	0.16	0.47	0.09	0.18	0.3	0.67	0.07	0.23	0.09	0.36	0.04	0.06	0.18

3. Examples & Validations: Surface Gradients

Robert G. Olsen, Steven D. Schennum and Vernon L. Chartier, "Comparison of Several Methods for Calculating Power line Electromagnetic Interference levels and Calibration with Long Term Data," IEEE Transactions on Power Delivery, Vol. 7, No. 2, April 1992

Case #	Paper			FACE Avg. Max			Error		
	A	B	C	A	B	C	A	B	C
1	14.97	14.25	15.06	14.94	14.2	14.94	-0.03	-0.05	-0.12
	14.98	14.13	14.88	15.03	14.2	14.94	0.05	0.07	0.06
2	15.07	15.93	15.07	15.07	15.93	15.07	0	0	0
3	15.42	16.21	15.42	15.42	16.21	15.42	0	0	0
4	16.19	17.29	16.19	16.2	17.3	16.2	0.01	0.01	0.01
5	13.36	15.16	14.92	13.36	15.17	14.94	0	0.01	0.02
	11.69	13.95	12.5	11.67	13.82	12.5	-0.02	-0.13	0
6	19.5	20.95	19.5	19.51	20.96	19.51	0.01	0.01	0.01
7	17.42	16.95	17.7	17.4	16.96	17.72	-0.02	0.01	0.02
	17.74	16.95	17.37	17.72	16.96	17.4	-0.02	0.01	0.03
8	17.24	17.45	16.13	17.25	17.45	16.13	0.01	0	0
	16.7	18.14	17.62	16.71	18.15	17.63	0.01	0.01	0.01
9	18.37	19.8	18.37	18.38	19.81	18.38	0.01	0.01	0.01

3. Examples & Validations: AN (audible noise)

- IEEE Committee Paper, “A Comparison of Methods for Calculating Audible Noise of High Voltage Transmission Lines,” IEEE Trans., PAS, vol.101, no.10, pp. 4090-4099, Oct. 1982.
 - 20 AC and 4 DC Cases
- Comparison to BPA free software (From Teshmont)
 - 8 DC Cases

3. Examples & Validations: AN (audible noise)

[31] IEEE Committee Paper, “A Comparison of Methods for Calculating Audible Noise of High Voltage Transmission Lines,”
IEEE Trans., PAS, vol.101, no.10, pp. 4090-4099, Oct. 1982.

		AC Cases																				
Case #		1	2	3	4	5	6	7	8	9	10	11a	11b	11c	12	13	14	15	16	17	18	
n		1	2	3	4	3	4	4	4	4	4	6	10	8	8	7	6	8	8	12	16	
ref 1	BPA	L50	61.2	54.3	45.6	50.5	51.5	54.8	50.9	57.7	55.1	61.1	61.2	54.6	58.1	52	57.1	52.2	55.2	54.5	52.4	51.4
	GE	L5	65.7	61.2	51.2	55.8	56.5	58.1	56	59.8	59.3	60.5	61.6	59	61.2	58.1	62.3	58.2	61.3	60.9	59	58.8
		L50	60.3	55.1	46.6	51.9	52.8	55.7	54.4	58.2	56.6	59.9	61.2	54.7	58.6	52.9	58.4	52.8	56.7	55.4	54.1	53.9
	IREQ	L5	53.5	53.9	51.7	55.8	57.6	57.7	56	59.3	58.9	60.2	60.5	59.7	60.6	58.5	62.3	60.3	62	63.2	59	59.8
FACE	BPA	L5	63.55	56.1	47.42	52.56	53.74	57.3	53.48	60.05	57.18	63.64	62.63	54.54	59.86	54.69	59.49	54.99	58.5	57.36	55.26	54.1
		L50	60.05	52.6	43.92	49.06	50.24	53.8	49.98	56.55	53.68	60.14	59.13	51.04	56.36	51.19	55.99	51.49	55	53.86	51.76	50.6
	GE	L5	64.45	59.48	49.48	54.34	55.12	57.08	55.05	58.68	57.88	59.49	59.83	55.4	59.67	57.2	61.19	57.45	61.11	60.04	58.35	58
		L50	59.01	53.39	44.91	50.4	51.42	54.67	51.34	57.03	55.17	58.96	59.22	51.22	56.88	51.97	57.28	52.02	56.64	54.67	53.42	53.15
	IREQ	L5	52.3	52.34	50.26	56	56.05	56.74	55.17	58.23	57.51	59.48	59.24	56.28	59.81	58.05	61.66	60.06	61.77	62.43	59.57	59.84
		L50	48.8	48.84	46.76	52.5	52.55	53.24	51.67	54.73	54.01	55.98	55.74	52.78	56.31	54.55	58.16	56.56	58.27	58.93	56.07	56.34
ERROR	BPA		1.15	1.7	1.68	1.44	1.26	1	0.92	1.15	1.42	0.96	2.07	3.56	1.74	0.81	1.11	0.71	0.2	0.64	0.64	0.8
	GE L5		1.25	1.72	1.72	1.46	1.38	1.02	0.95	1.12	1.42	1.01	1.77	3.6	1.53	0.9	1.11	0.75	0.19	0.86	0.65	0.8
	GE L50		1.29	1.71	1.69	1.5	1.38	1.03	3.06	1.17	1.43	0.94	1.98	3.48	1.72	0.93	1.12	0.78	0.06	0.73	0.68	0.75
	IREQ		1.2	1.56	1.44	0.2	1.55	0.96	0.83	1.07	1.39	0.72	1.26	3.42	0.79	0.45	0.64	0.24	0.23	0.77	-0.57	-0.04

3. Examples & Validations: RI (Radio Interference)

- Robert G. Olsen, Steven D. Schennum and Vernon L. Chartier, “Comparison of Several Methods for Calculating Power line Electromagnetic Interference levels and Calibration with Long Term Data,” IEEE Transactions on Power Delivery, Vol. 7, No. 2, **April 1992.**
Total 9 AC Cases
- Comparison to BPA Software results (provided by Teshmont)
 - 8 DC Cases

3. Validations: Static Electric & Magnetic Fields

- Comparison to BPA Software Results (provided by Teshmont)
 - Static Electric Fields: 8 DC cases
 - Magnetic Fields: 8 DC Cases

3. Validations: Static Electric & Magnetic Fields

Case 2-a

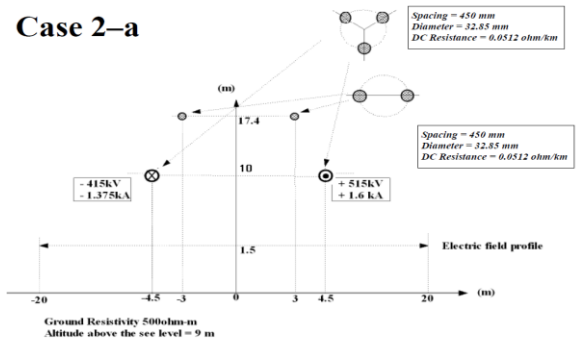
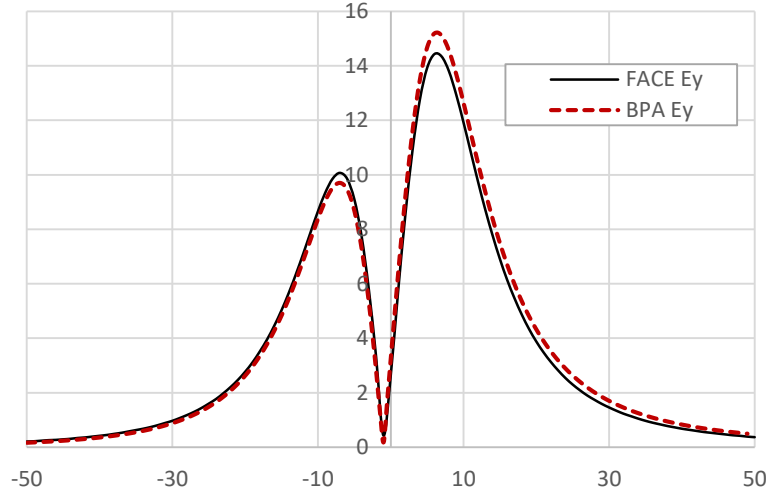
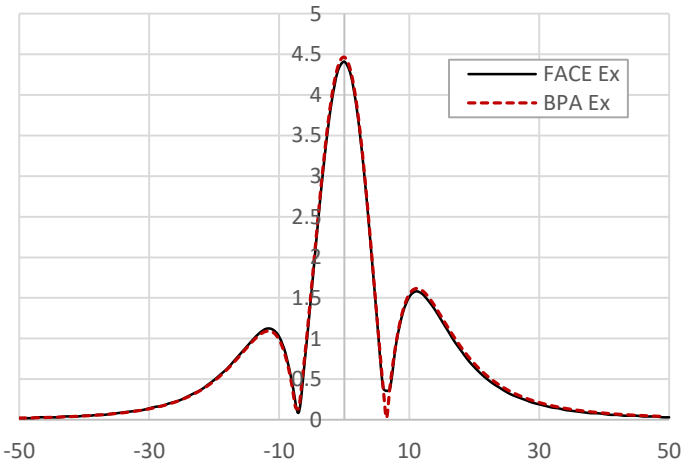
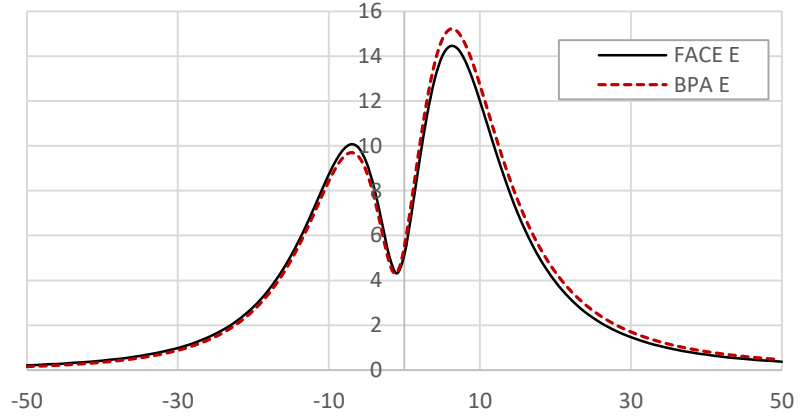
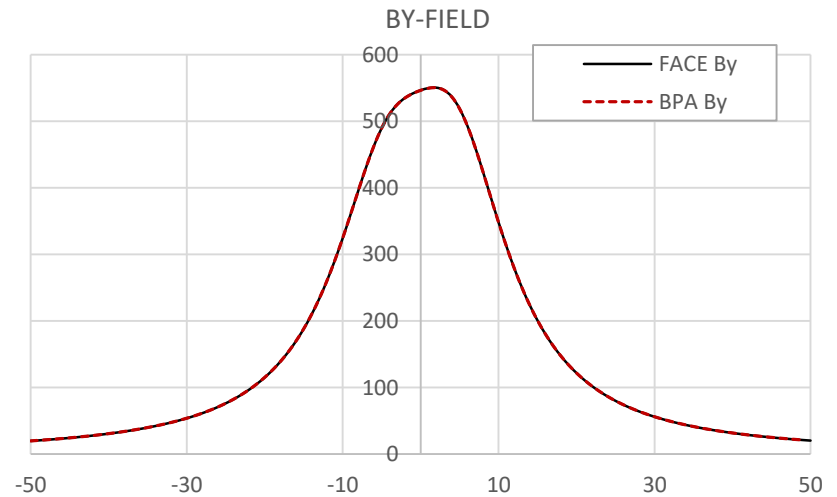
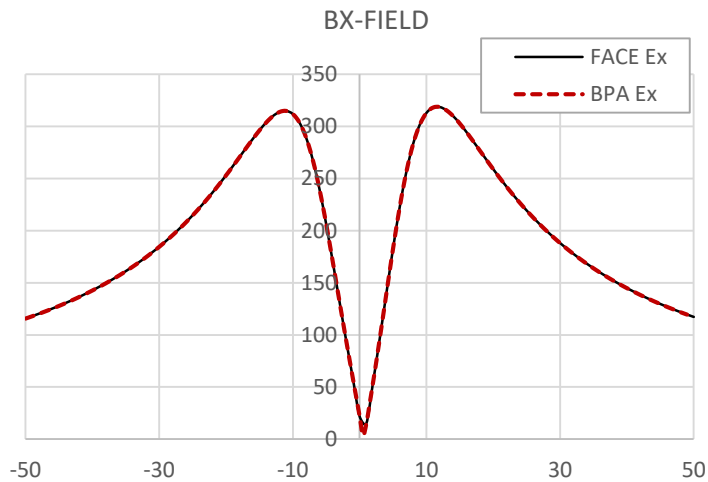
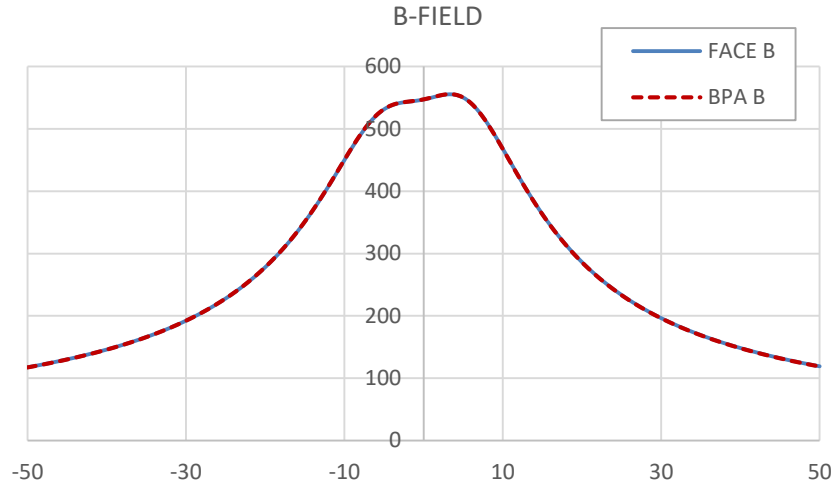


Figure 1.5. Case 2-a diagram, one possible upgrade to a bipolar scheme.



3. Validations: Static Electric & Magnetic Fields



3. Validations: Ionized Field Computation

- [Theory & Solutions: Online help](#)
- Validation Examples: MH Bipole 1 & 2

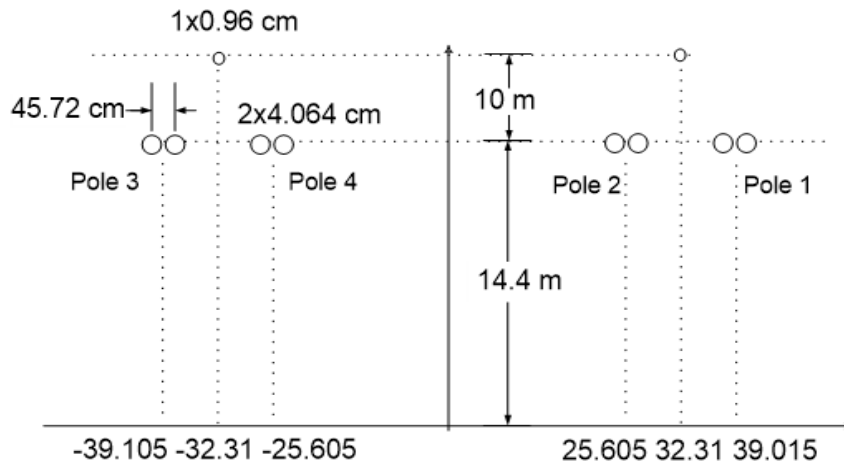


TABLE 1. OPERATING VOLTAGES IN kV FOR TWO CASES CONSIDERED

	Pole 1	Pole 2	Pole 3	Pole 4
Case 1	-450	450	-450	0
Case 2	-440	440	-470	470

Fig. 1. Geometry of the Manitoba Nelson River

3. Validations: Case 1, Ion trajectories

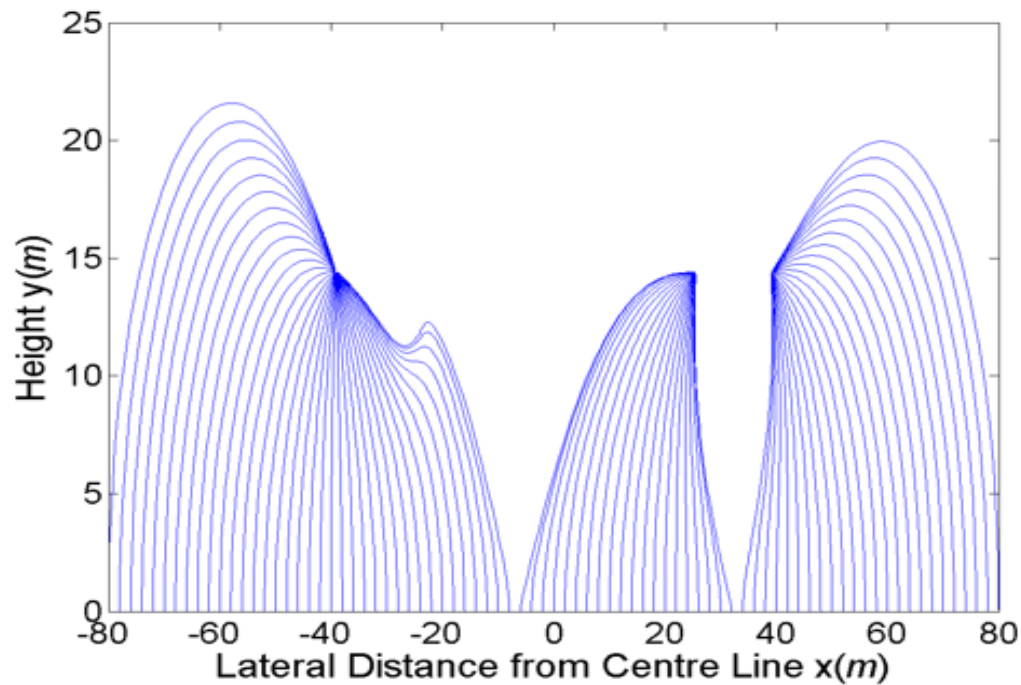


Fig. 4a. Ion trajectories at Ground Level in Case 1.

3. Validations: Case 1, Simulation Results

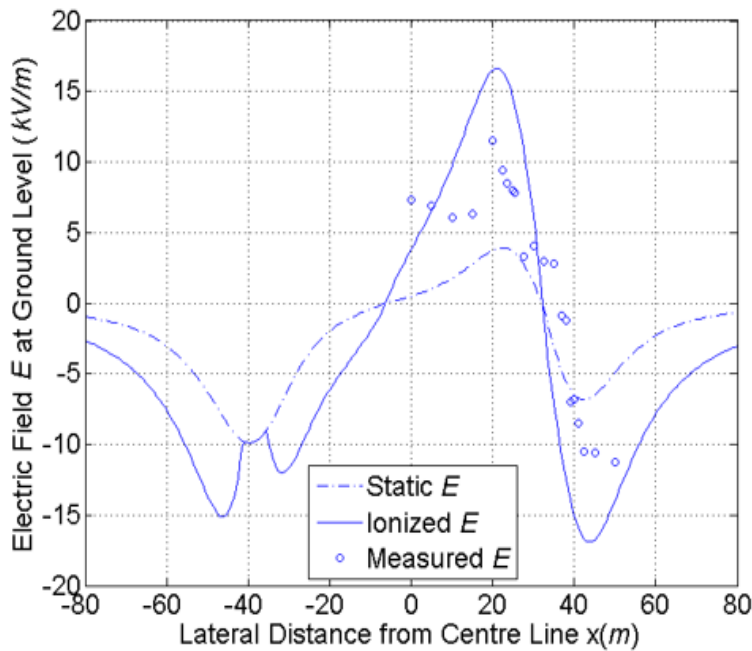


Fig. 4b. Electric Field Profile at Ground Level for Case 1.

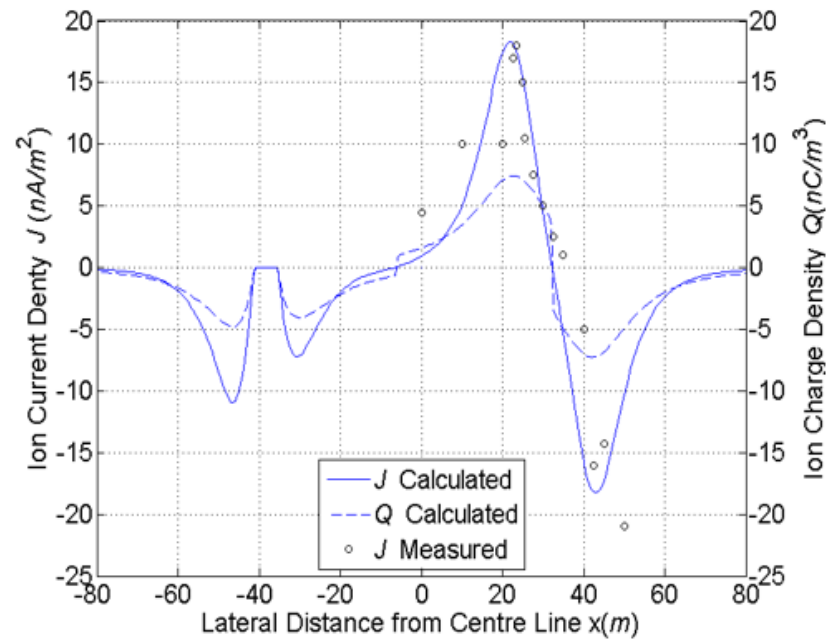


Fig. 5. Ion Current and Charge Densities at Ground Level for Case 1.

3. Validations: Case 2, Ion Trajectories

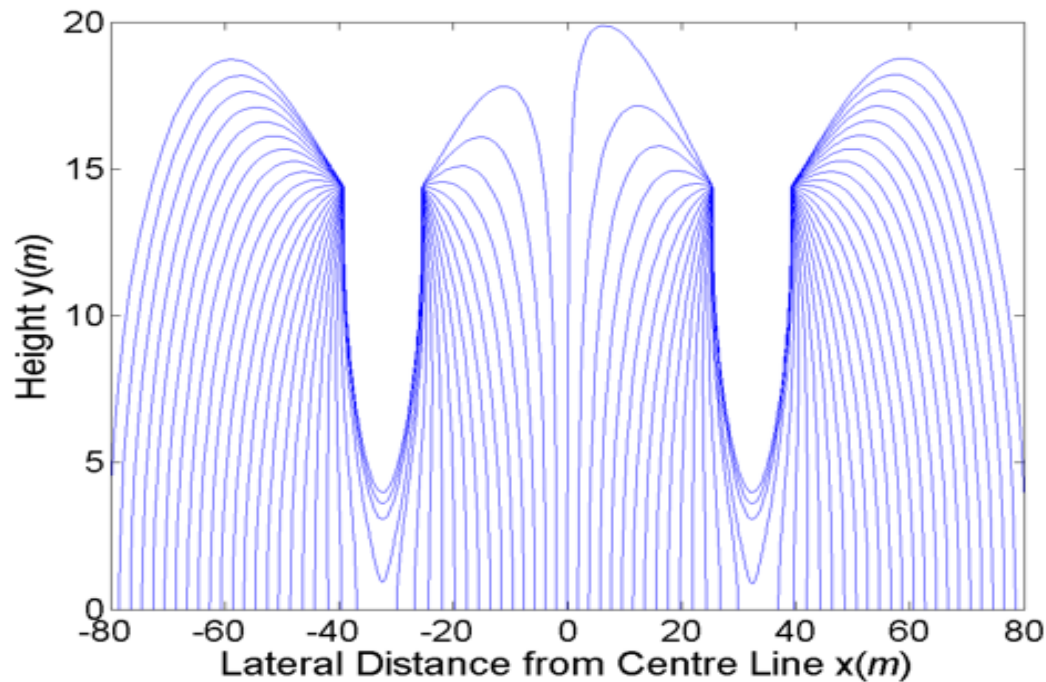


Fig. 11(a). Ion Trajectories $h = 1.5 \text{ m}$ for case 2.

3. Validations: Case 2, Simulation Results

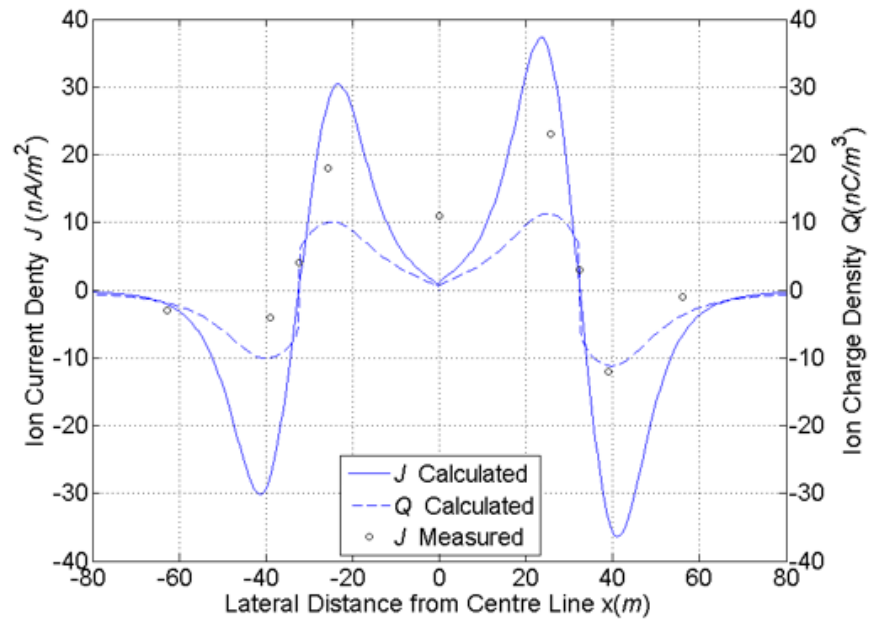
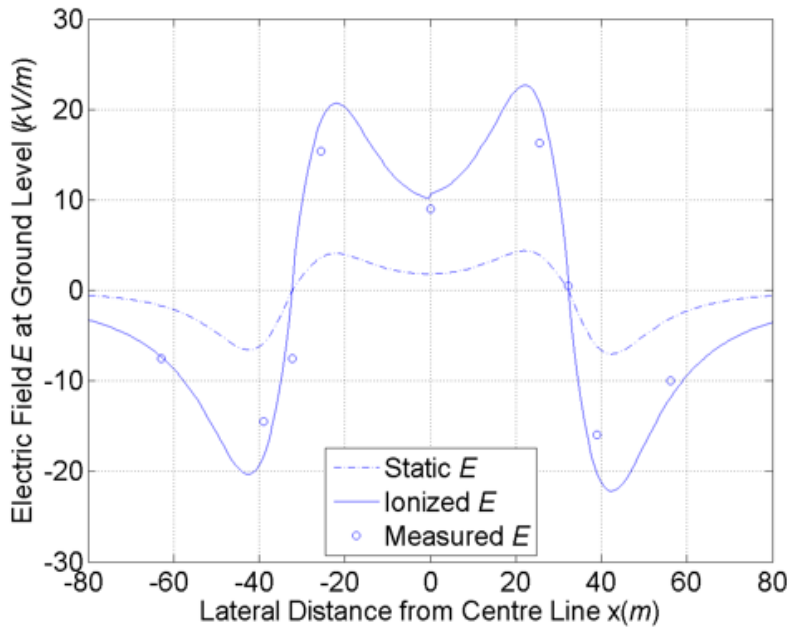
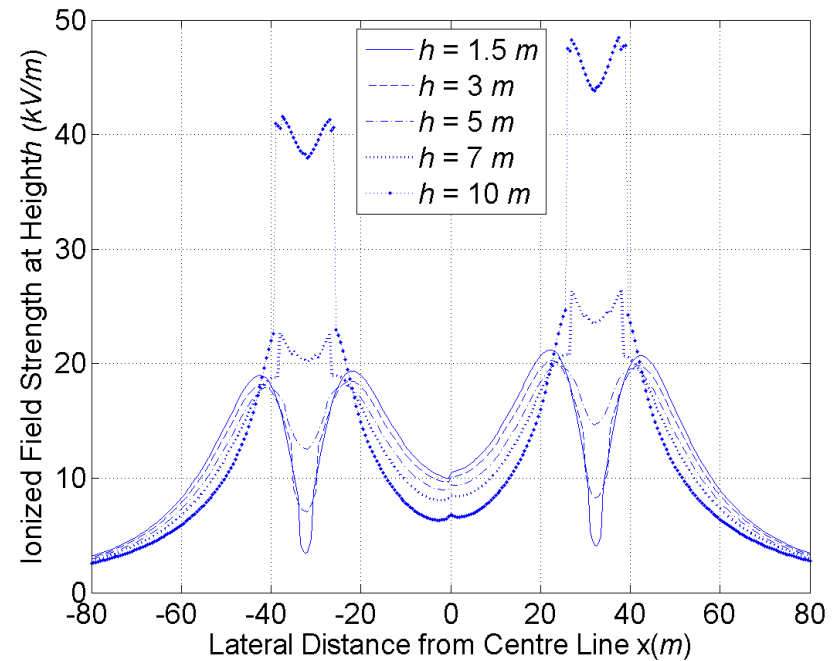
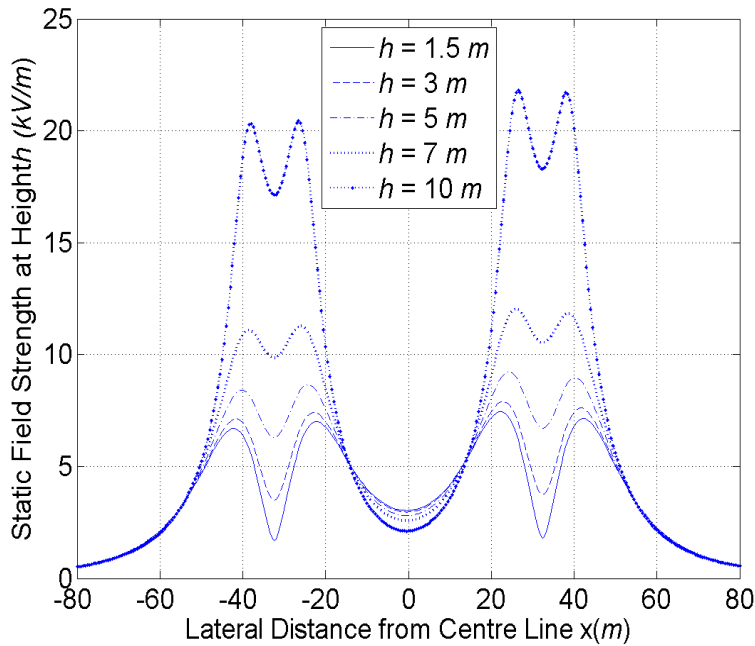


Fig. 9. Electric Field Profile at Ground Level for Case 2 Fig. 10. Ion Current and Charge Densities at Ground Level for Case 2.

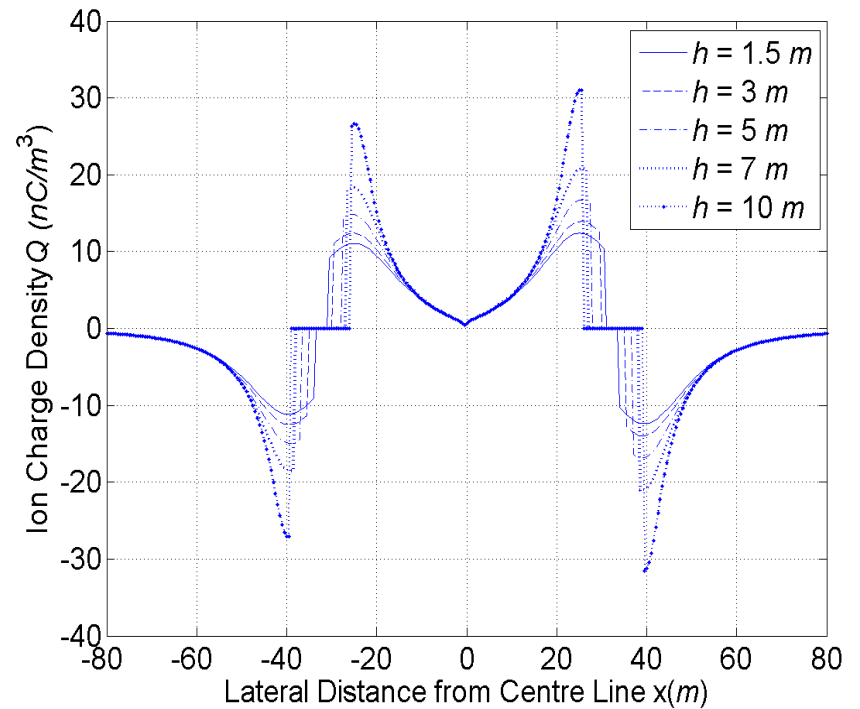
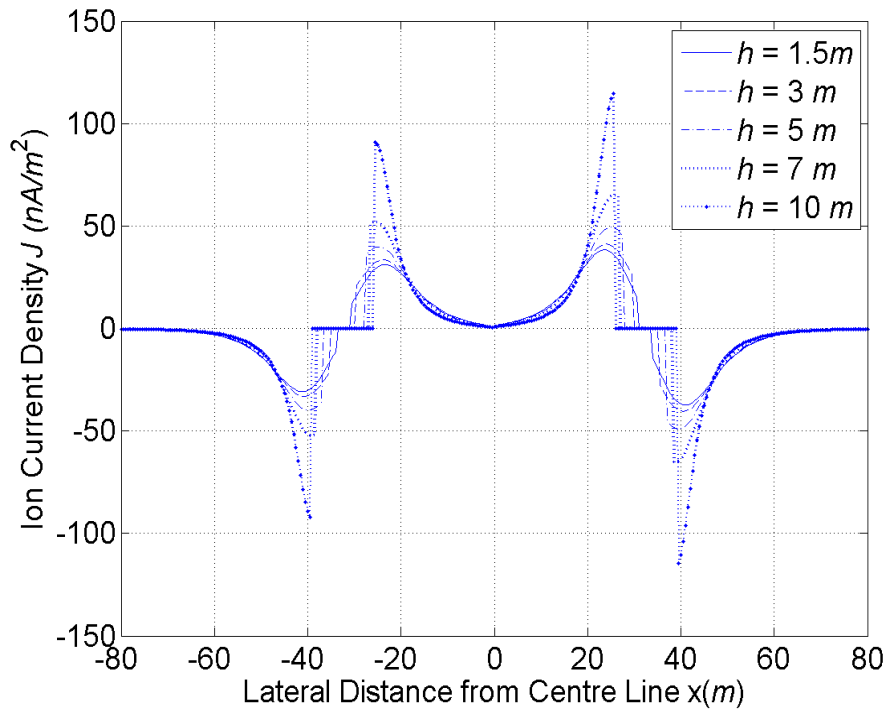
3. Validations: Case 2, at various meas. height h

- Demonstrate Robustness & Efficiency



3. Validations: Case 2, at various meas. height h

- Demonstrate Robustness & Efficiency



Questions & Answers

Thank you

Wujun Quan, Ph.D. , P. Eng.

Sr. Research & Study Engineer

