Electric Field Simulation for Insulated Lightning Current Downconductor

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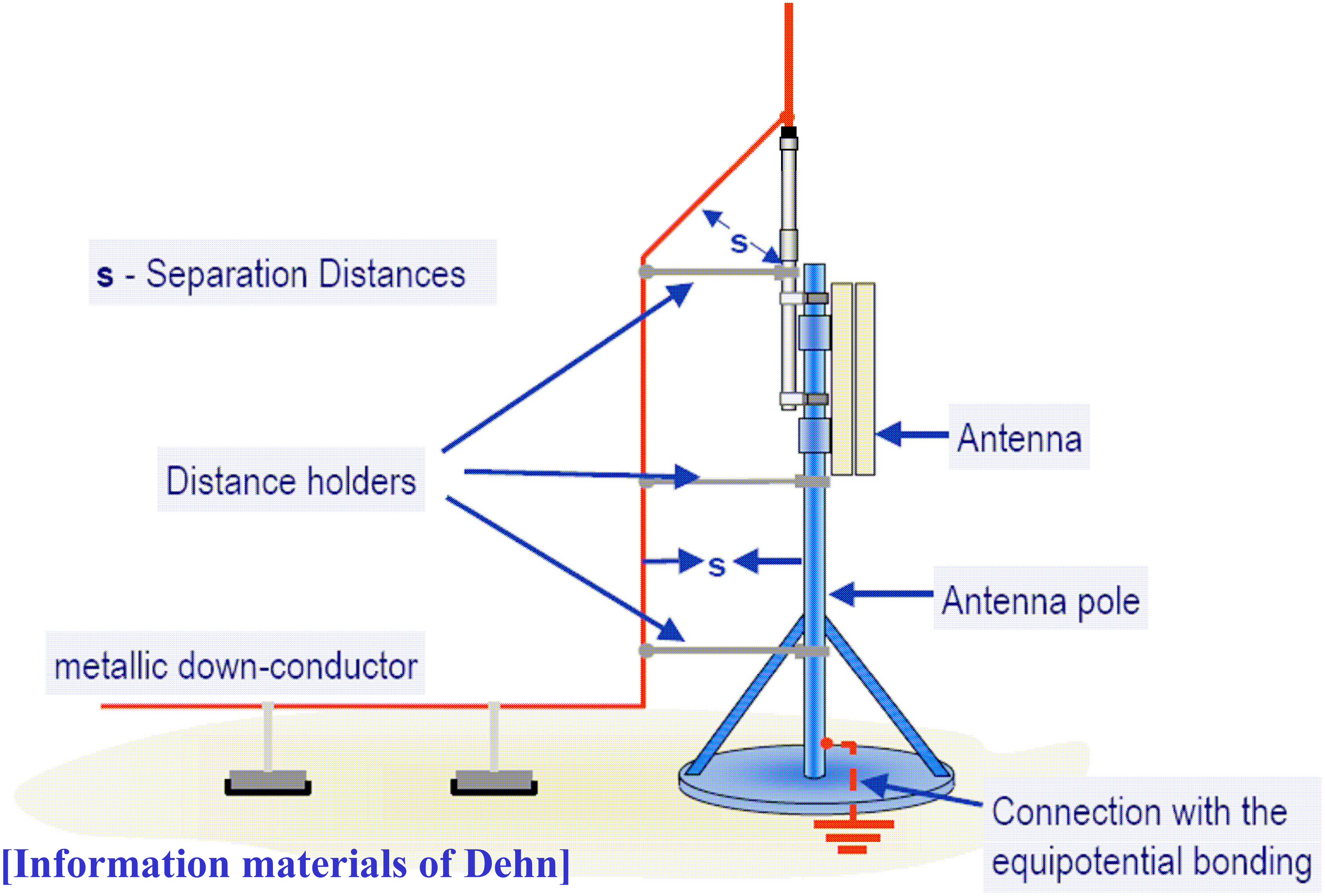
Outline

- Introduction on insulated downconductors
- Configuration of insulated downcondutor sealing part
- Model and simulation conditions
- Results
- Conclusions

Introduction on insulated downconductors

Protection of a cellular base station antenna by using insulating distance holders



s - Separation Distances

Distance holders

Antenna

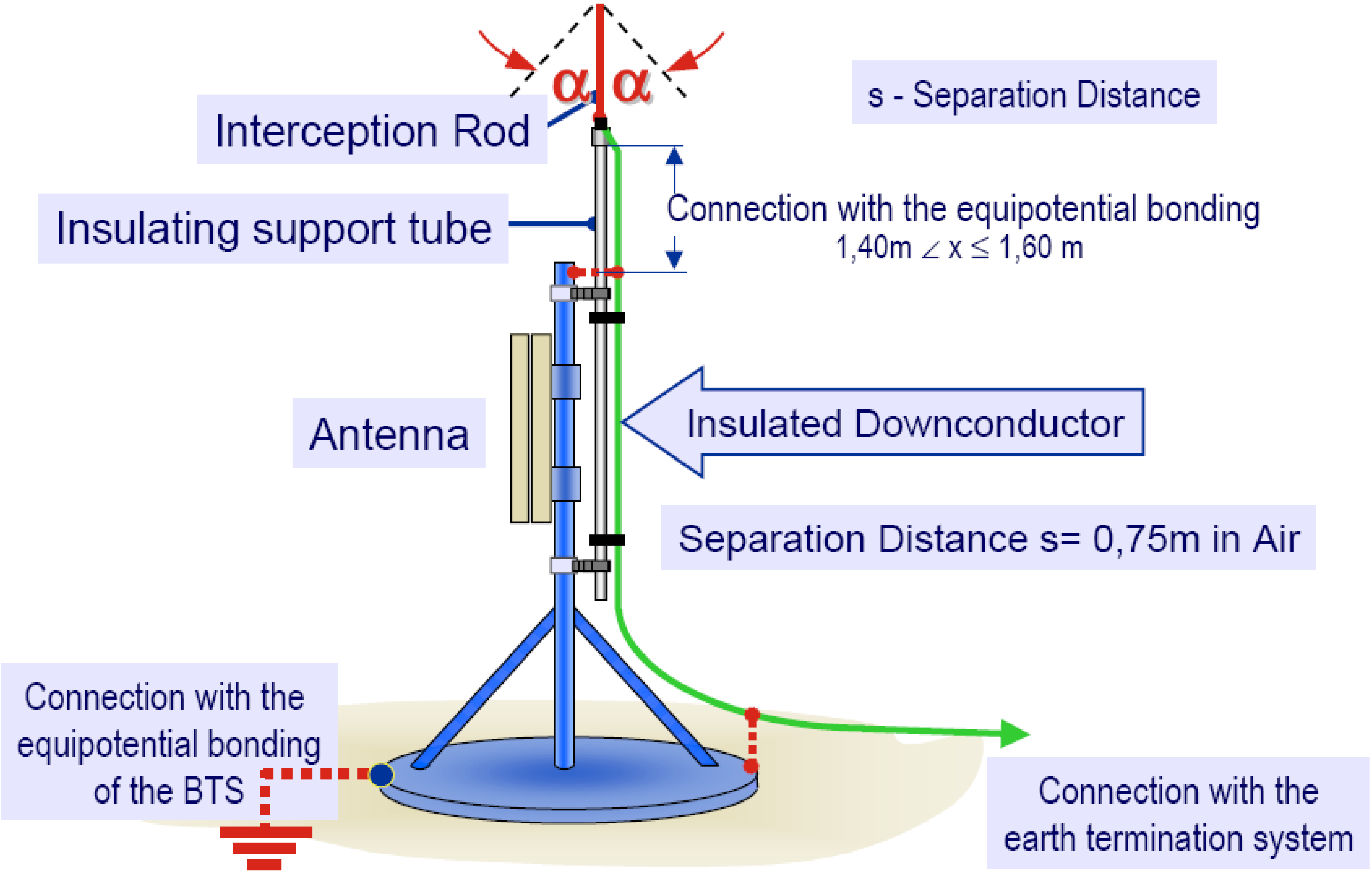
Antenna pole

metallic down-conductor

Connection with the equipotential bonding

[Information materials of Dehn]

Isolated Air-Termination using the insulated Downconductor



Interception Rod

s - Separation Distance

Insulating support tube

Connection with the equipotential bonding
1,40m ∠ x ≤ 1,60 m

Antenna

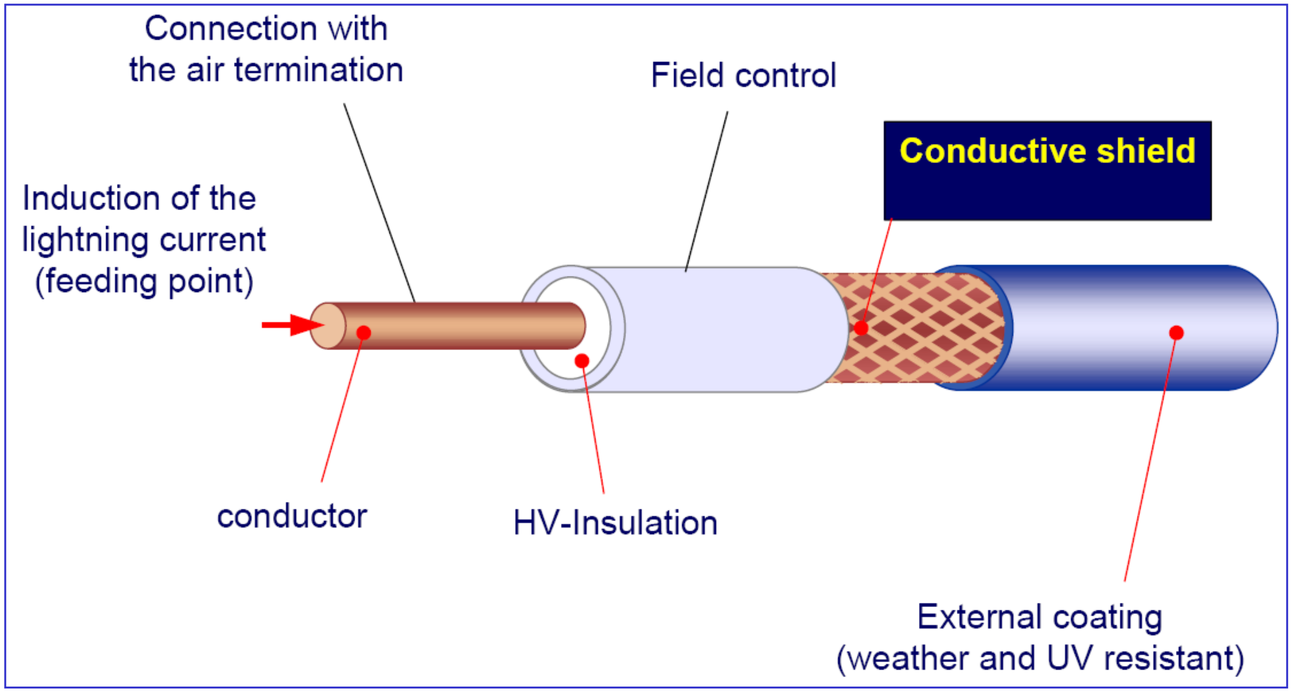
Insulated Downconductor

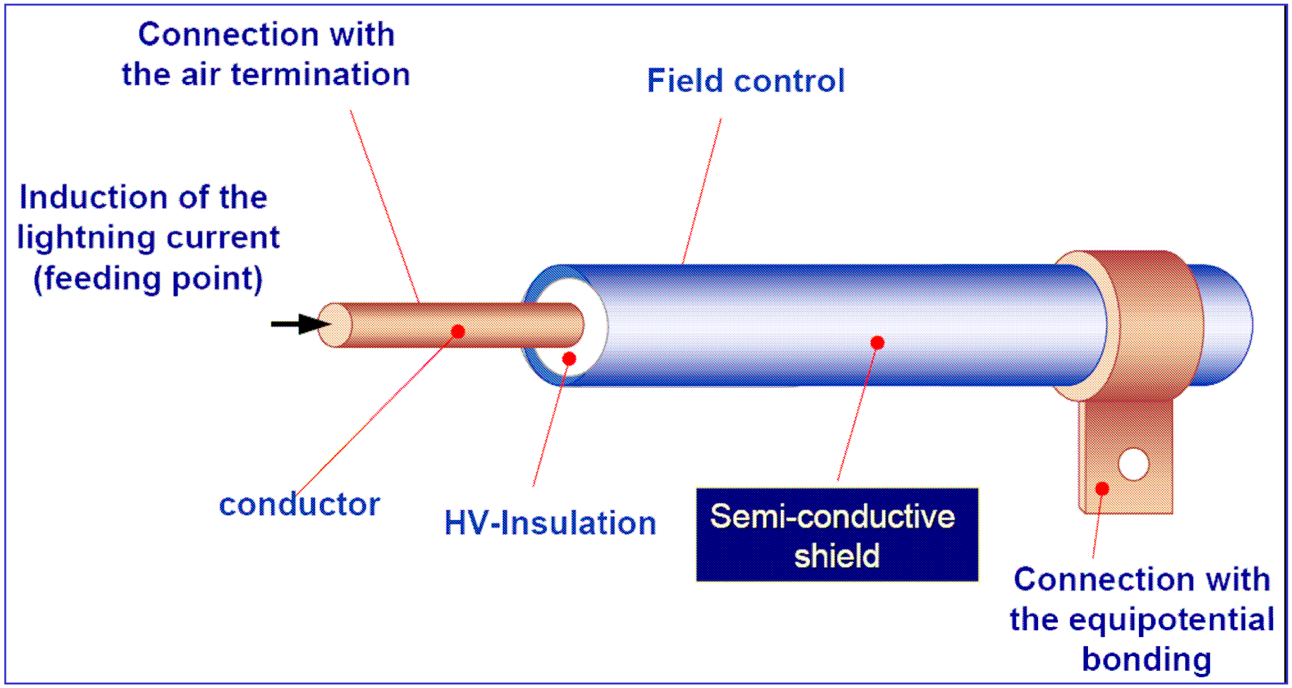
Separation Distance s= 0,75m in Air

Connection with the
equipotential bonding
of the BTS

Connection with the
earth termination system

[Information materials of Dehn]





Types of Insulated Downconductors

1. Coaxial Cable with Field Control (Semiconductive Shield) and Conductive Shield

2. Coaxial cable with a semiconductive shield

[Information materials of Dehn]

4th Intl. Symposium on Lightning Physics and Effects, COST, Vienna, 2009

Some studies on insulated downconductors

- Beierl O., Brocke R., Hasse P., Zischank W. Controlling separation distances with insulated downconducors, *ICLP-2004*, France, 2004.
- Brocke R., Zahlmann P. Requirements on insulated downconductors. *VIII SIPDA,* Brazil, 2005.
- D'Alessandro, F. On the applicability of insulated downconductors, *VIII SIPDA*, Brazil, 2005.
- Mimouni A., Paolone M., Rachidi F., Zweiacker P. On the Use of Shielded Cables in Lightning Protection Systems. *2nd Int. Symp. on Lightning Physics and Effects, COST, Austria, 2007.*

Goals of present study

- Simulation of electric field potential distribution at a sealing part of insulated downconductor (ID) by using FEM
- Variation of simulation conditions (frequency equivalent to first and subsequent strokes, different conductivity of semiconductive shield)
- Estimation of electric field strength in different insulation areas of ID and current to earthing clamp

Configuration of insulated downconductor sealing part

Insulated lightning conductor with a semiconductive outer jacket (ILCS) – ERICO


(a) (b)

Copper shield

Polyethylene insulator

Semiconductive layers

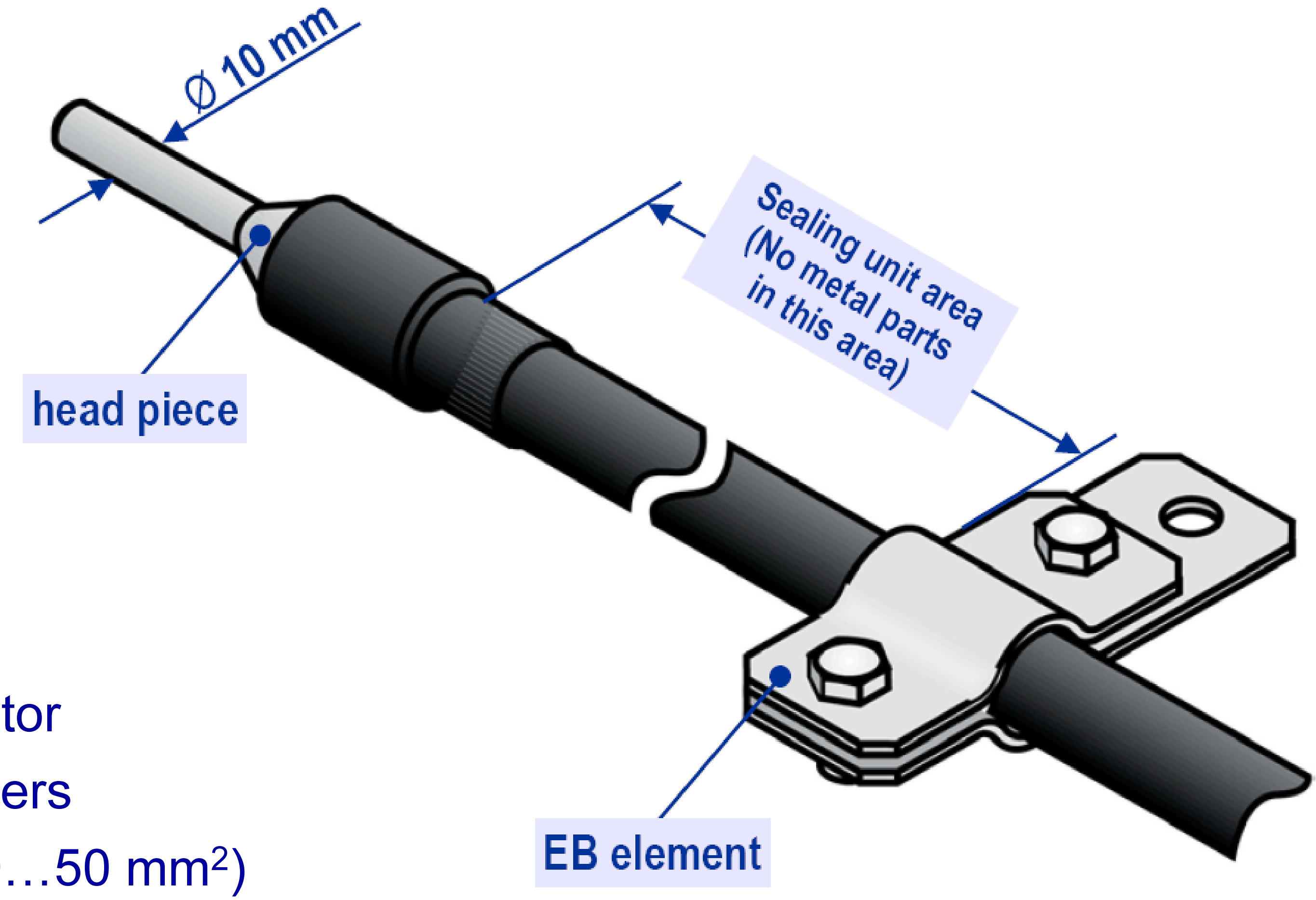
Inner conductor (> 50 mm^2) on filler

Outer cable diameter - 36 mm

U > 250 kV

From [D'Alessandro, 2005]

Sealing Unit
of DEHNconductor system HVI



No copper shield

Polyethylene insulator

Semiconductive layers

Inner conductor (19…50 mm^2)

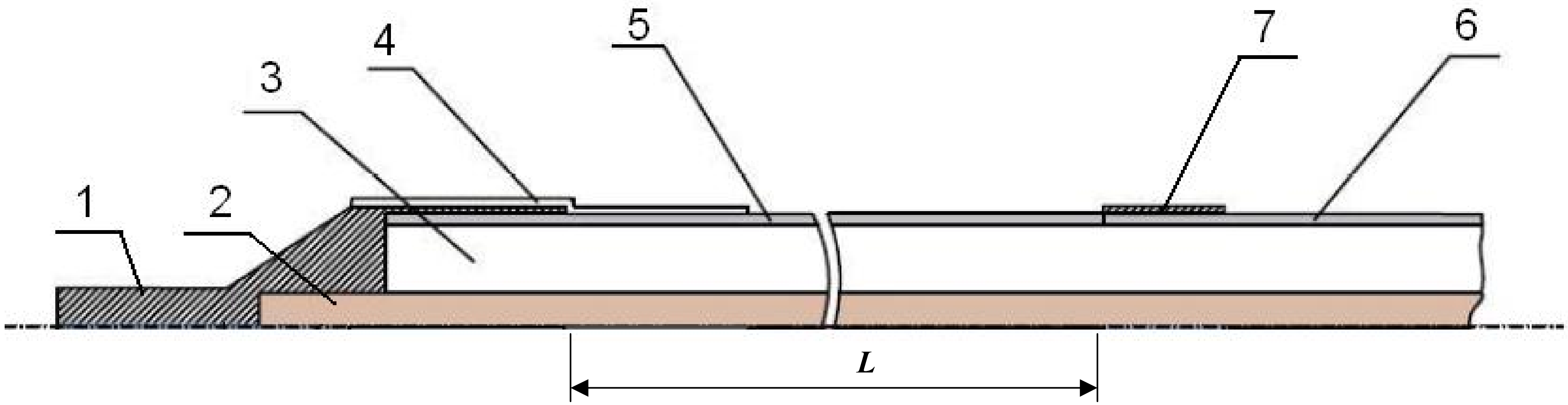
Outer cable diameter – 20…23 mm

U = 700 kV ("-"), 0.4/45 μs for 1400 mm

[Information materials of Dehn]

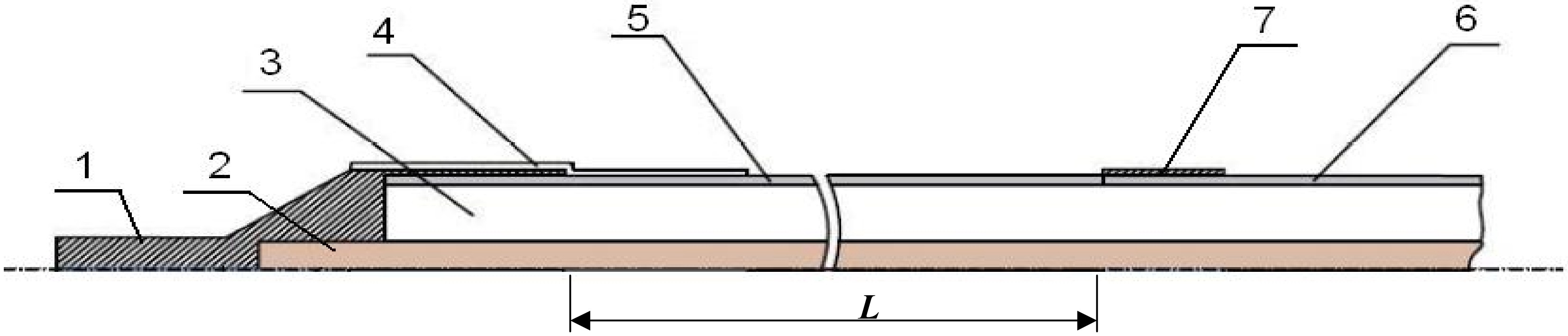
Model and simulation conditions

Model of downconductor with HV insulation



1 – head;
2 – inner conductor;
3 – HV insulation (PE);
4 – PVC insulation;
5,6 – sheaths;
7 – earthing clamp (equipotential bonding).

Simulation conditions



L = 1.45 м;

Sheaths (5,6) diameter 22 мм
(semiconductive: $\varepsilon_5 = \varepsilon_6 = 4$; σ_5 or $\sigma_6 = 10^{-14}$; 0.0001, 0.001, 0.01, 0.1, 1, 10, 100 S/m);

Inner conductor ~19…50 mm^2, copper;

HV insulation (PE) - $\varepsilon_3 = 2.3$, $\sigma_3 = 10^{-14}$ S/m ;

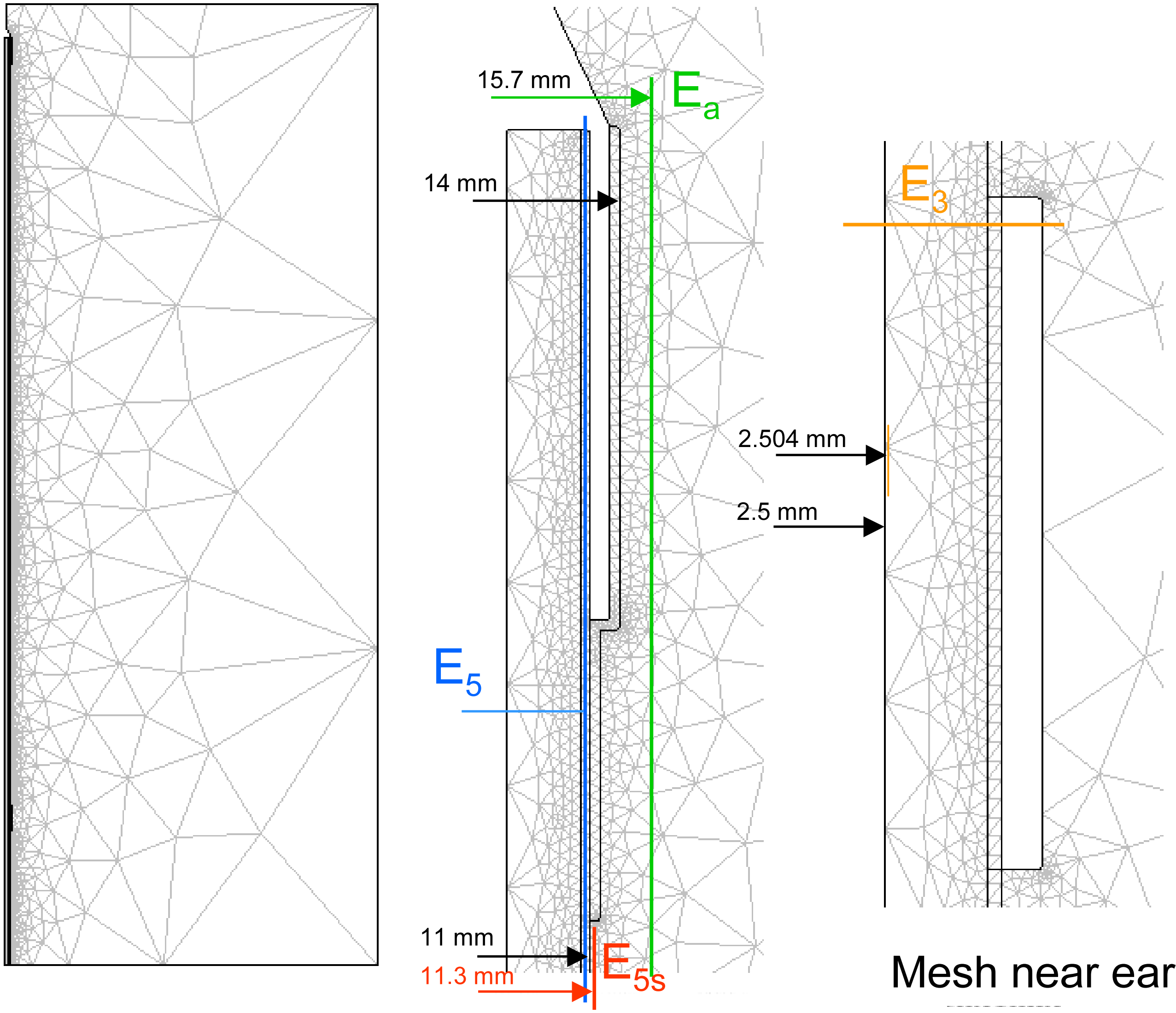
U = 100 kV;

f = 50 Hz; 25 kHZ, 250 kHZ

(1st) (Subs.)

Results

Mesh used in FEM



Mesh near PVC insulation

Mesh near earthing clamp

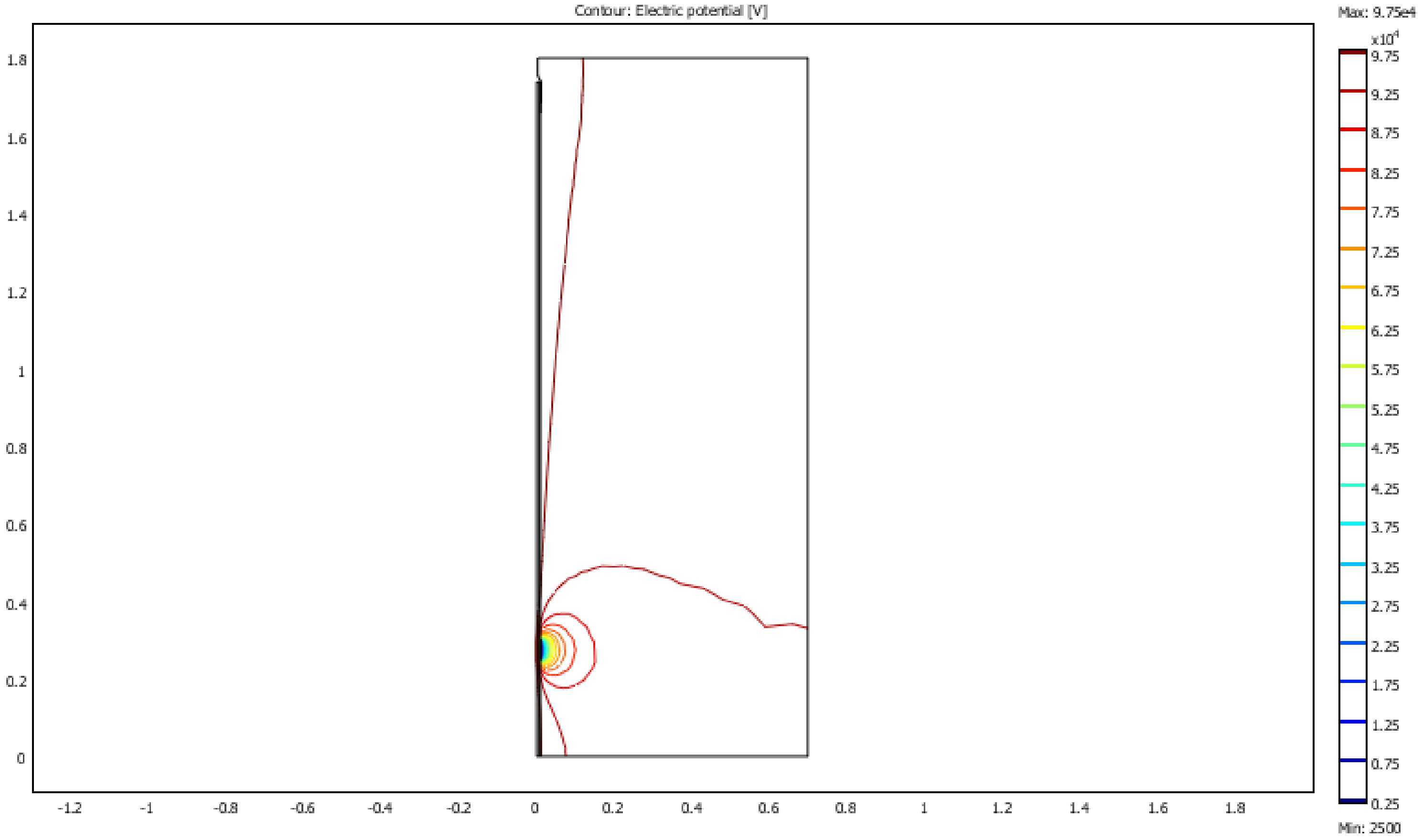
Some simulation results

(short Table)

Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
2_1	0.05	0.0001	0.0001	1.25E+06	2.70E+07	1.50E+06	2.00E+05		not complete
3	0.05	0.001	0.001	1.00E+06	2.55E+07	1.20E+06	7.50E+04		yes
4	0.05	0.01	0.01	1.00E+06	2.70E+07	1.20E+06	7.20E+04		yes
5	0.05	0.1	0.1	1.00E+06	2.70E+07	1.20E+06	7.20E+04	0.368	yes
6	0.05	1	1	1.00E+06	2.70E+07	1.20E+06	7.20E+04	3.680	yes
6_1	0.05	10	10	1.00E+06	2.70E+07	1.20E+06	7.20E+04	36.800	yes
10	25	0.01	0.01	1.85E+06	2.70E+07	2.50E+06	5.00E+05		not complete
11	25	0.1	0.1	1.00E+06	2.70E+07	1.20E+06	1.40E+05	0.987	yes
12	25	1	1	1.00E+06	2.70E+07	1.20E+06	7.20E+04	3.804	yes
12_1	25	10	10	1.00E+06	2.70E+07	1.20E+06	7.20E+04	36.813	yes
17	250	0.1	0.1	1.85E+06	2.60E+07	2.50E+06	5.00E+05		not complete
18	250	1	1	1.00E+06	2.70E+07	1.20E+06	1.34E+05	9.867	yes
19	250	10	10	1.00E+06	2.70E+07	1.20E+06	7.20E+04	38.037	yes

E_{s5} - along surface of sheath 5 (0.3 mm above);
E_3 - inside of HV insulation 3 (between 2 and 6/7);
E_a - in air;
E_5 - inside the sheath 5.

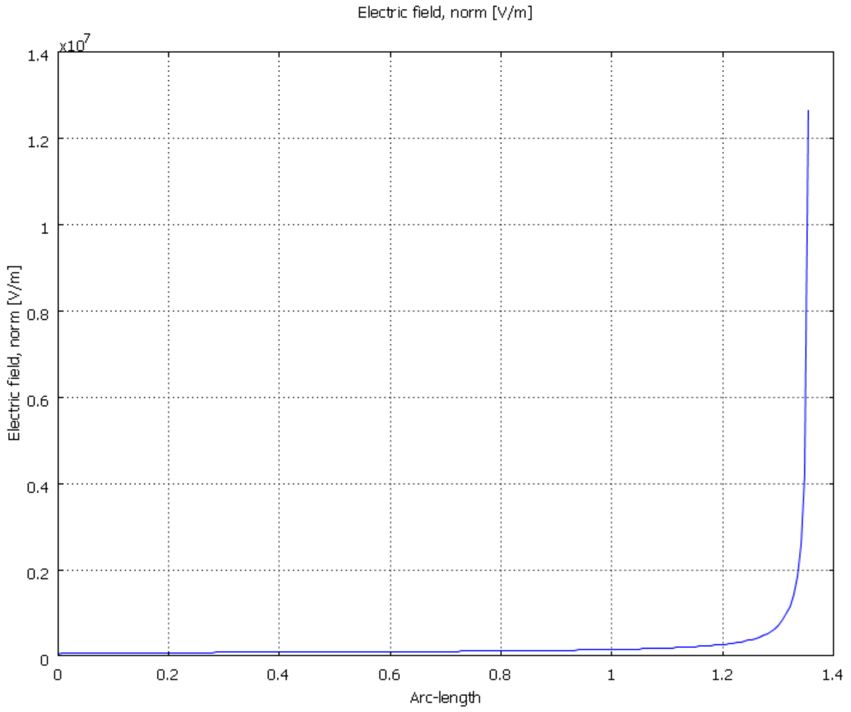
Electric potential distribution (var.7)



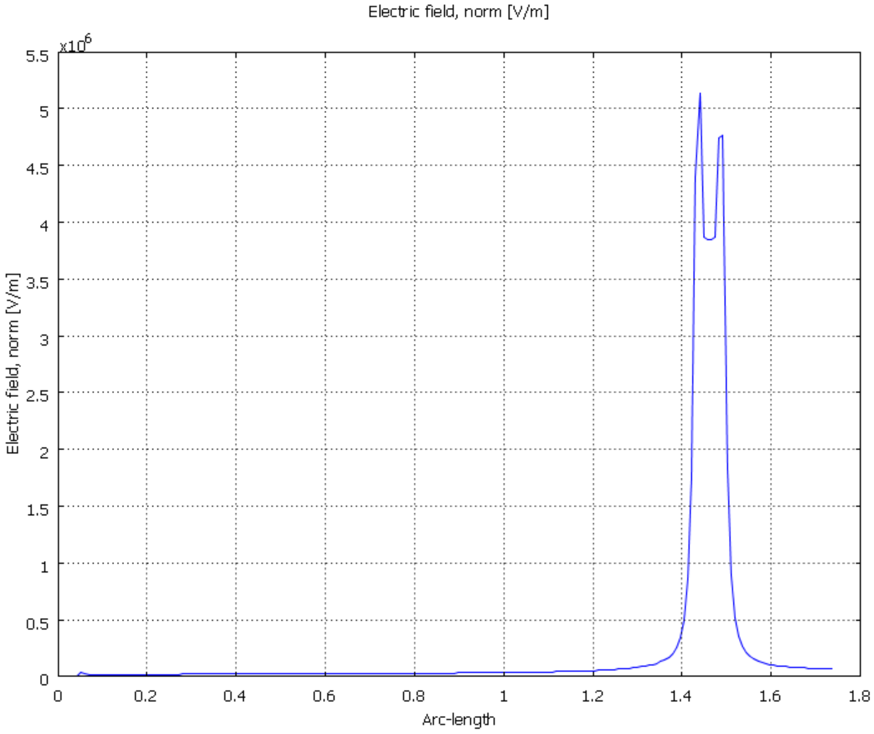
Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
7	25	10^{-14}	10^{-14}	1.20E+07	2.50E+07	7.00E+06	5.00E+06		no

Var.7

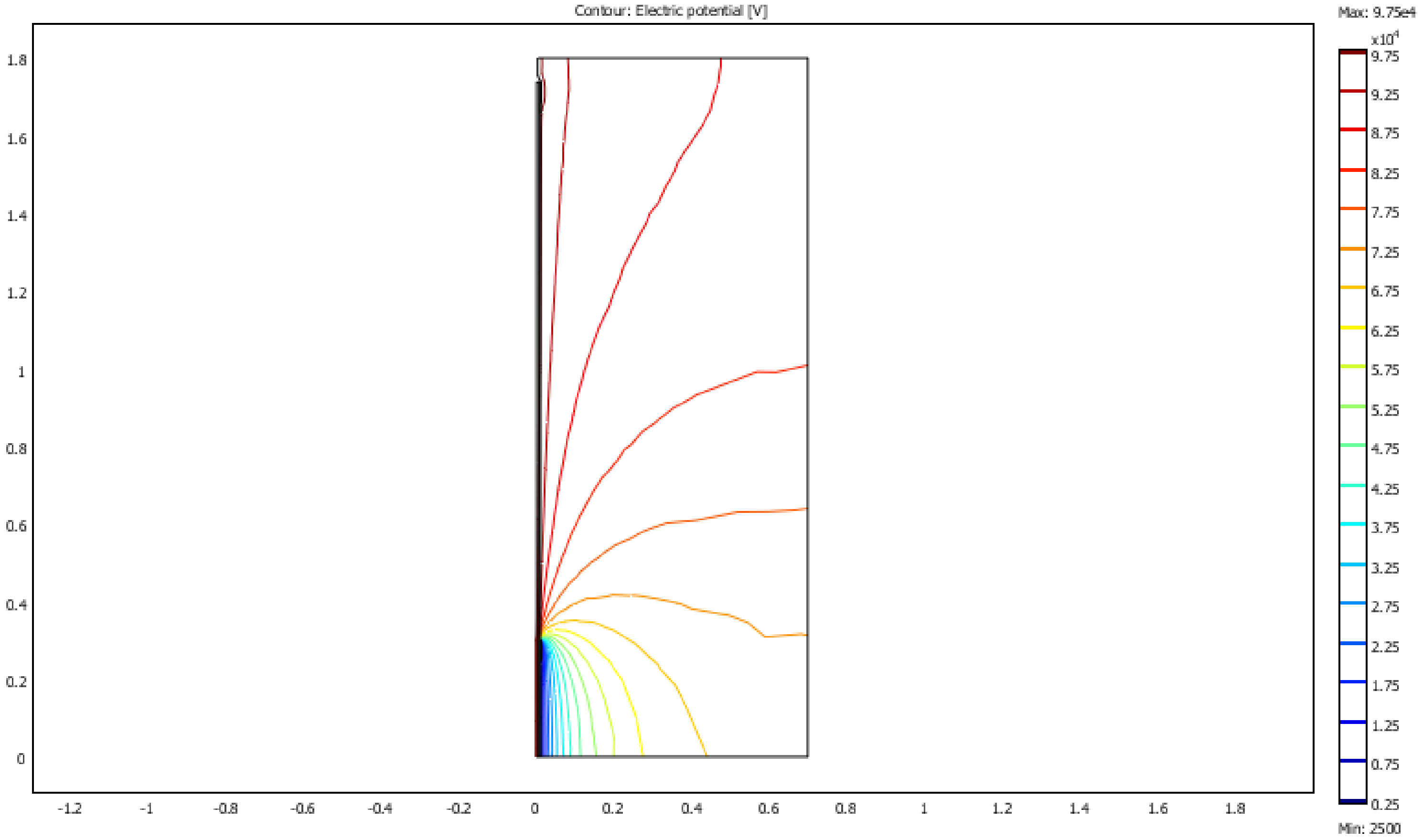
E_{s5}


Electric field, norm [V/m]
x10^7
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5


Electric field, norm [V/m]
x10^6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

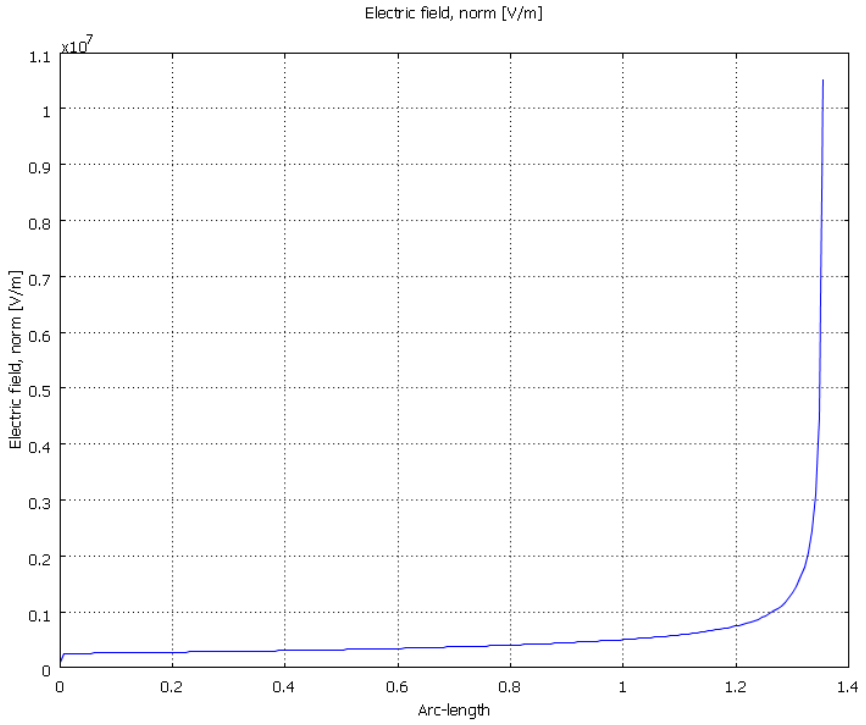
Electric potential distribution (var.8)



Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
8	25	10^{-14}	1	1.20E+07	2.70E+07	6.00E+06	4.50E+06		no

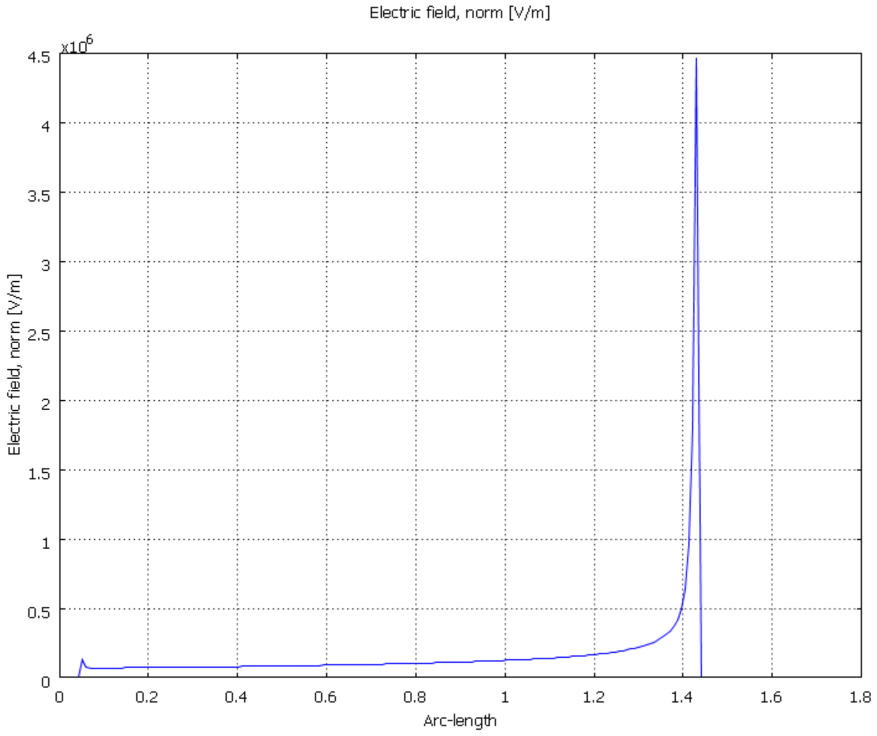
Var.8

E_{s5}



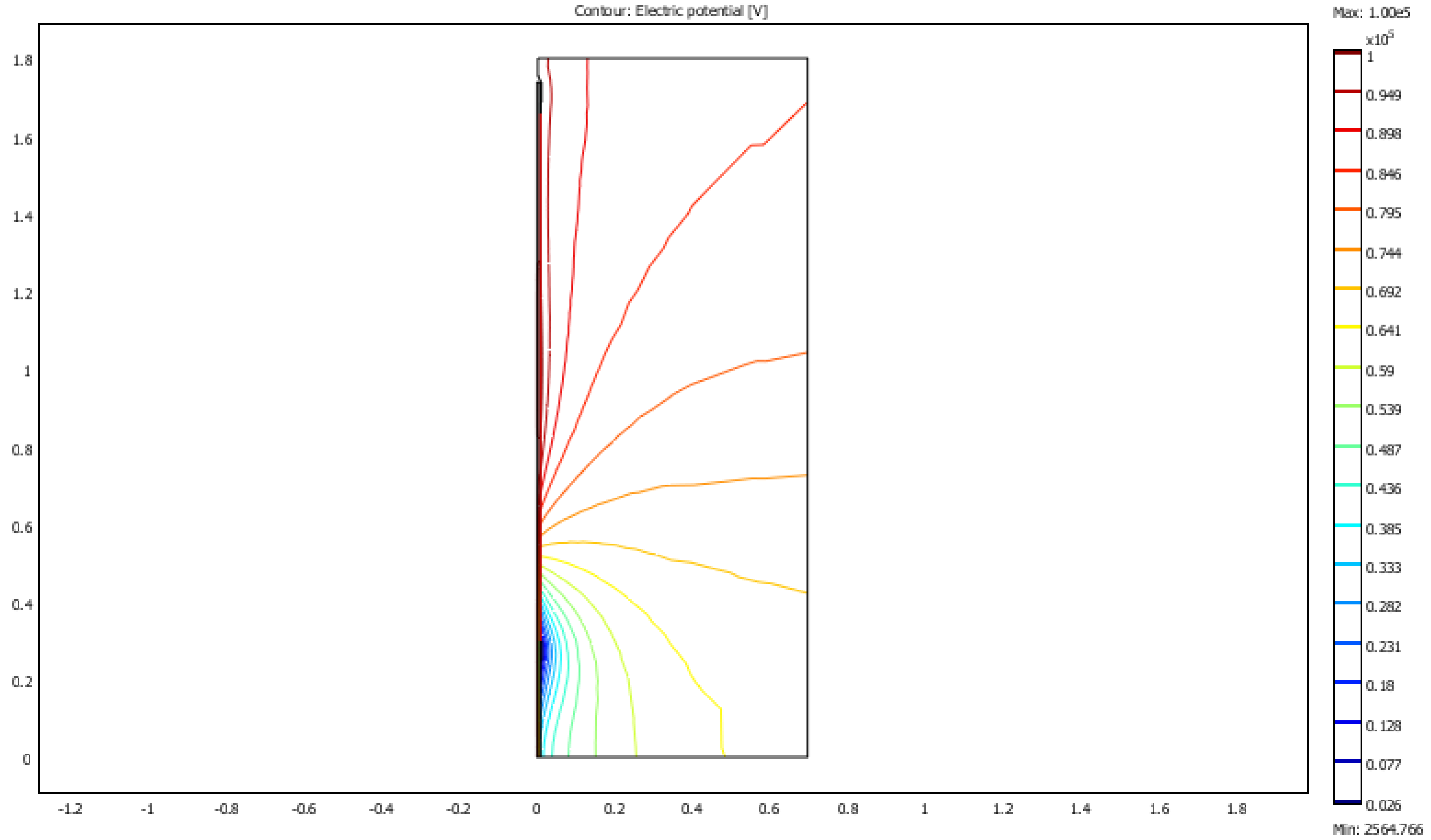
Electric field, norm [V/m]
x10^7
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5



Electric field, norm [V/m]
x10^6
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

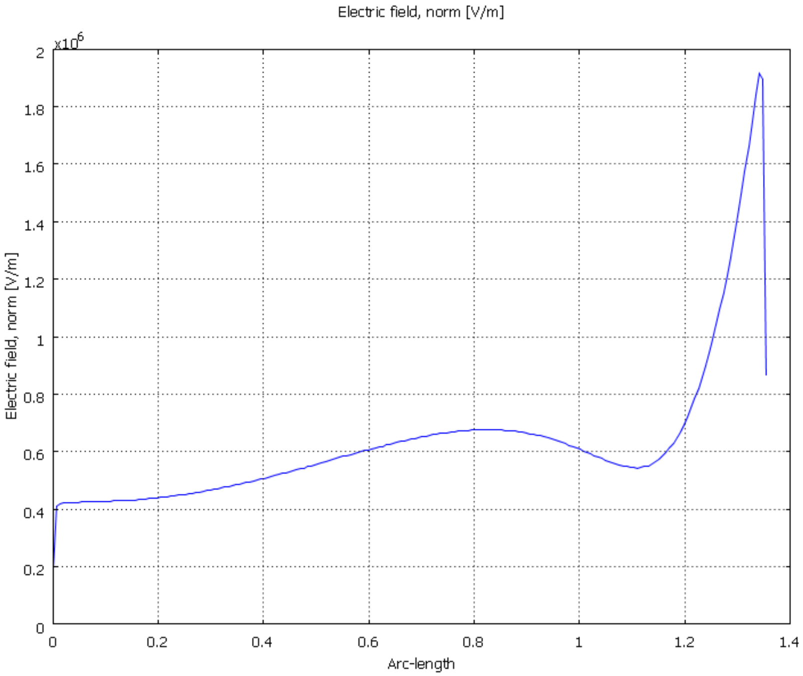
Electric potential distribution (var.10)



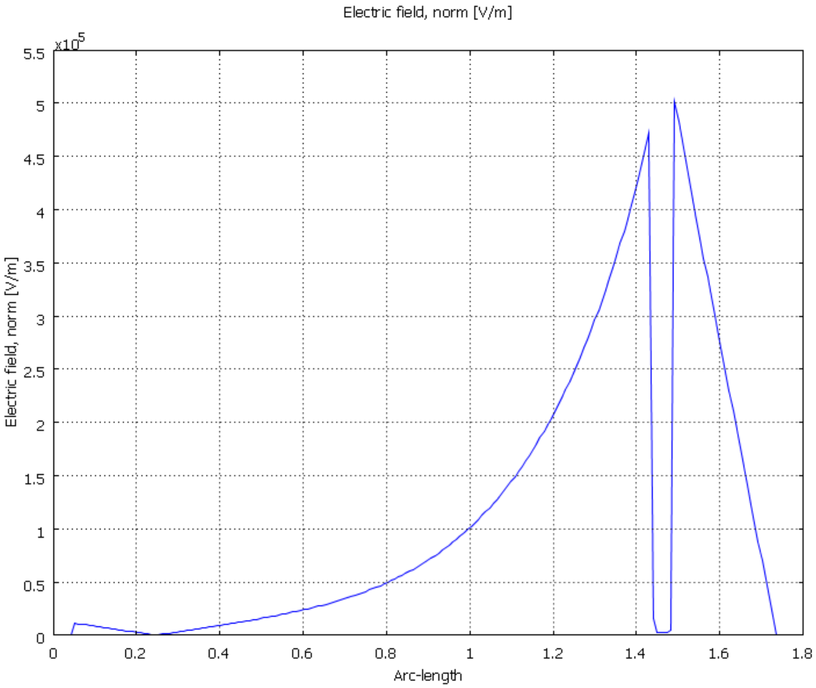
Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
10	25	0.01	0.01	1.85E+06	2.70E+07	2.50E+06	5.00E+05		not complete

Var.10

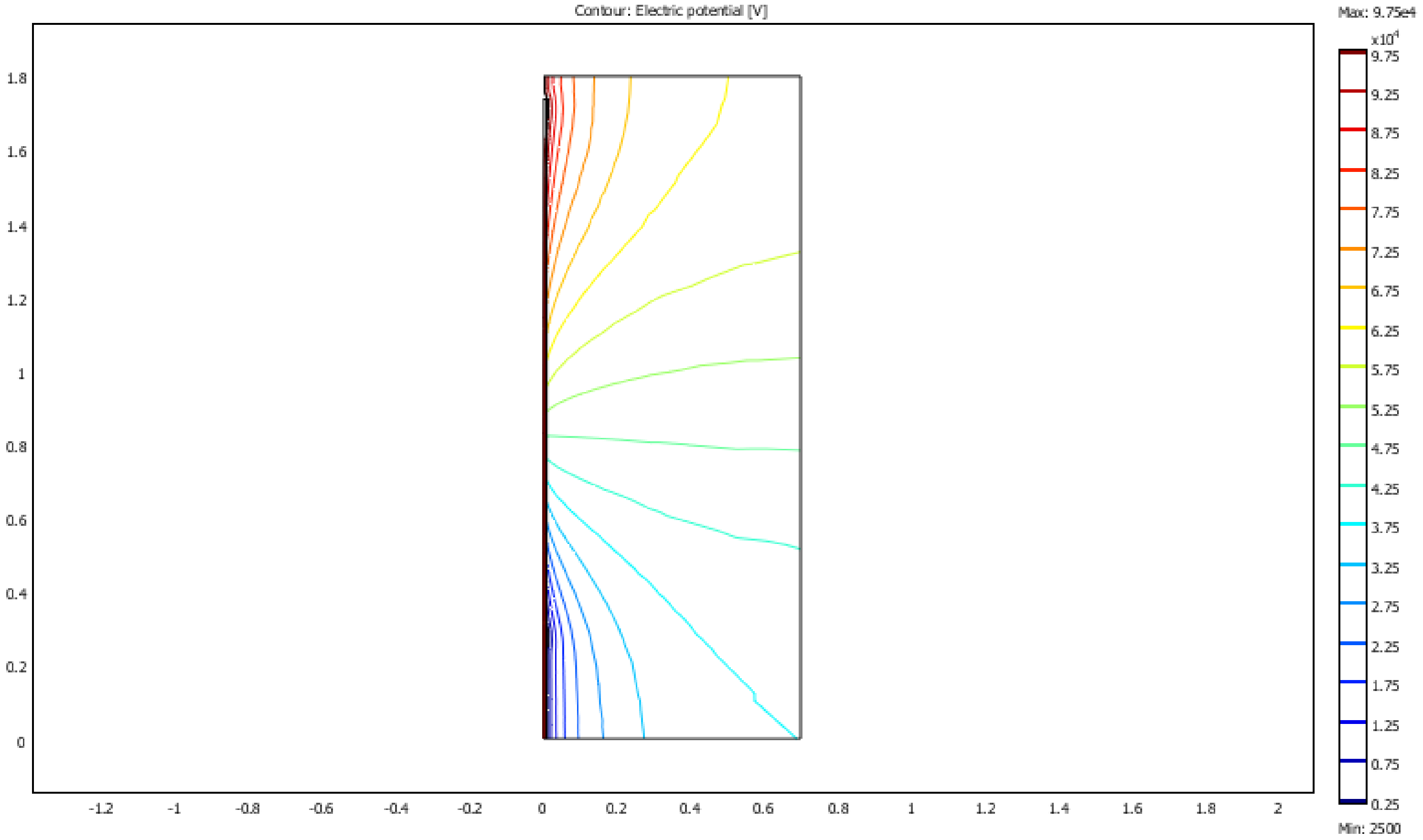
E_{s5}


Electric field, norm [V/m]
x10^6
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5


Electric field, norm [V/m]
x10^5
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

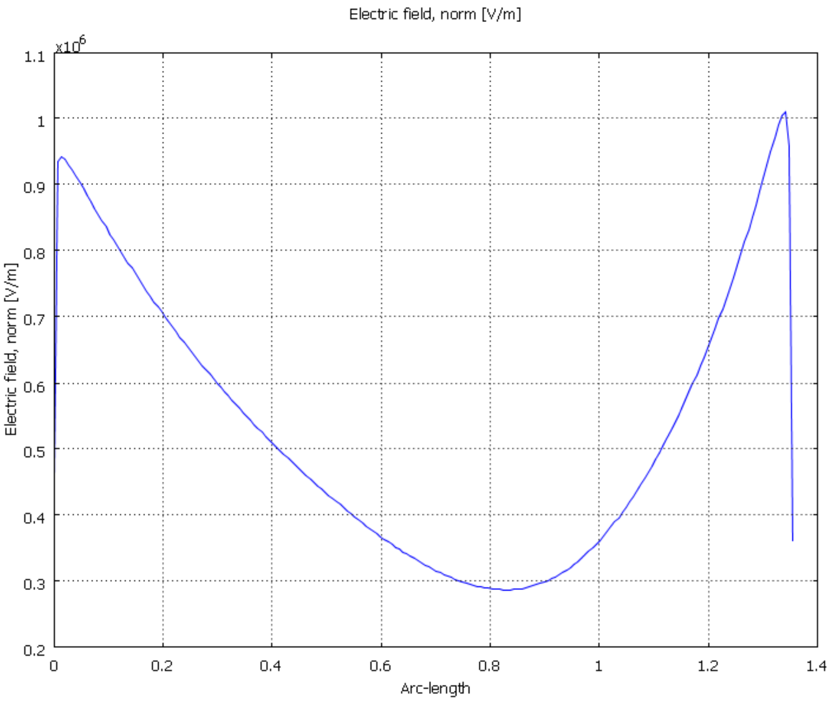
Electric potential distribution (var.11)



Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
11	25	0.1	0.1	1.00E+06	2.70E+07	1.20E+06	1.40E+05	0.987	yes

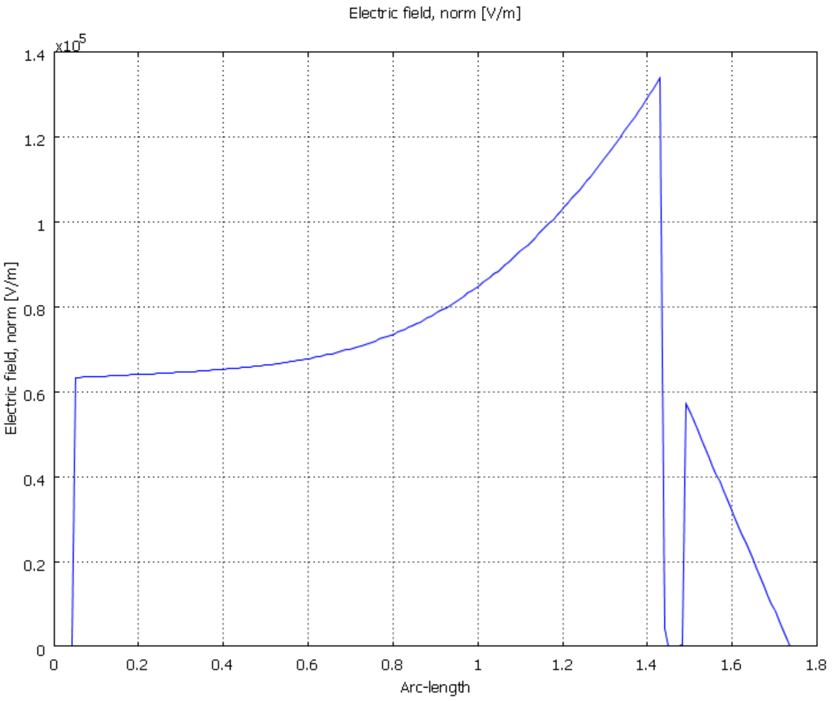
Var.11

E_{s5}



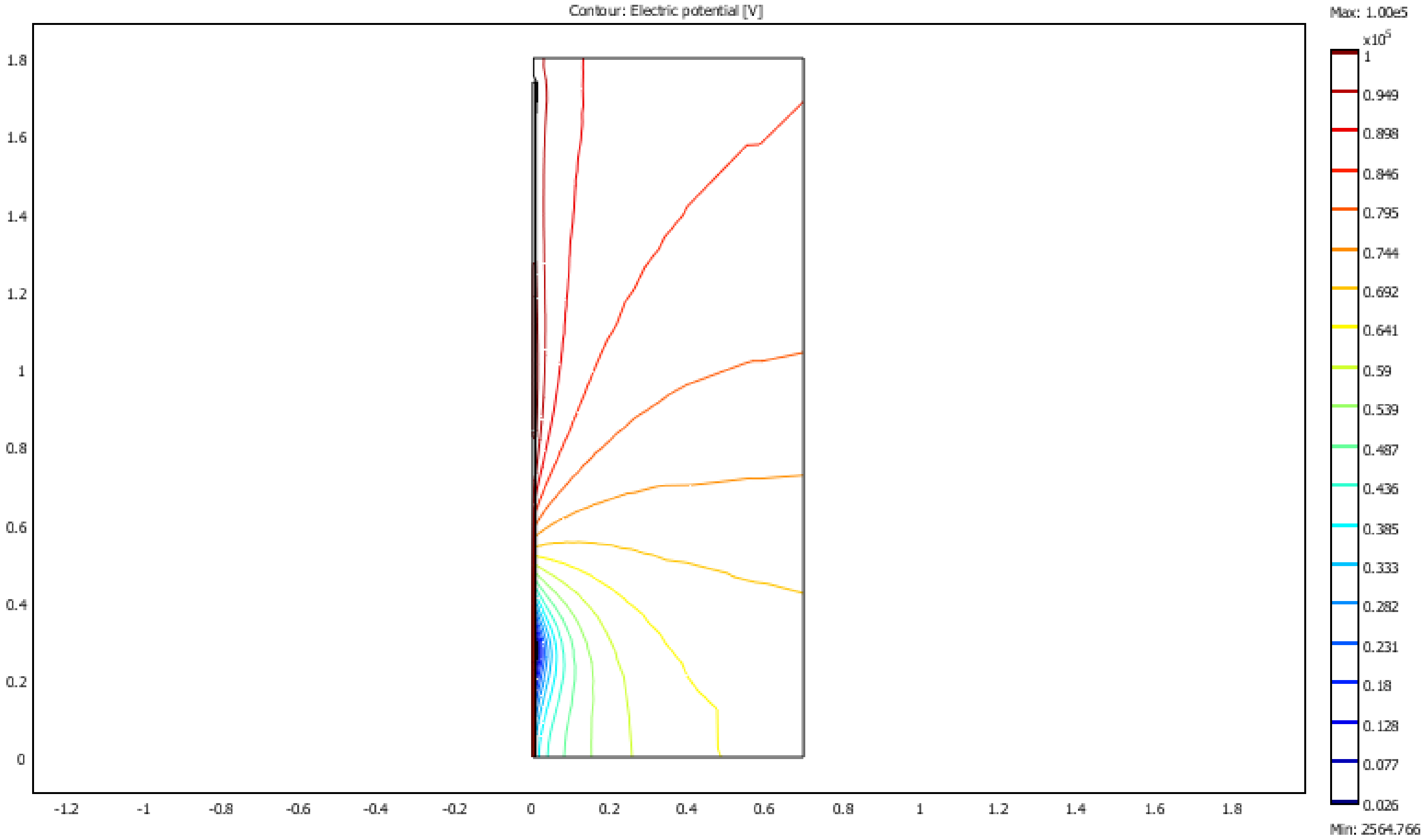
Electric field, norm [V/m]
x10^6
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5



Electric field, norm [V/m]
x10^5
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

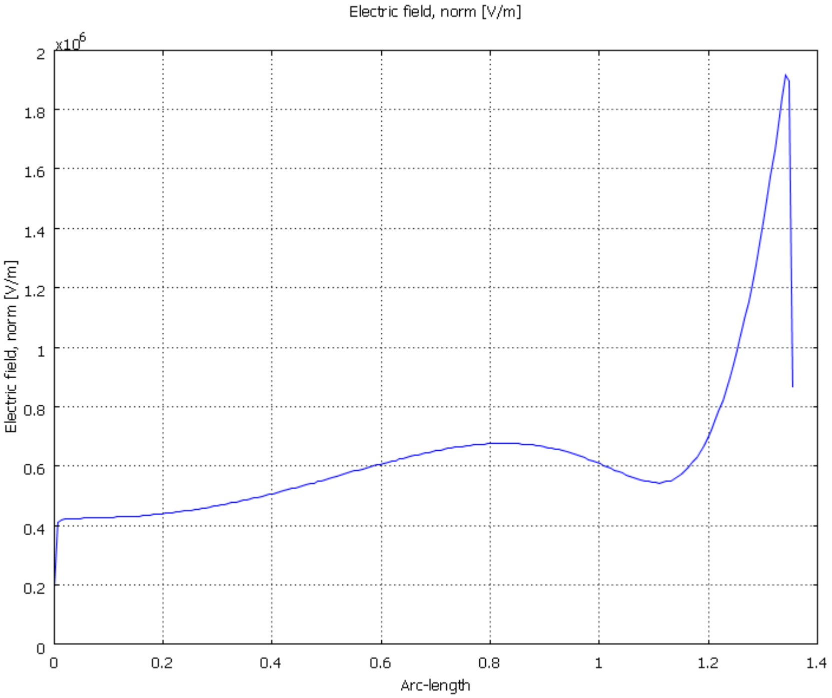
Electric potential distribution (var.17)



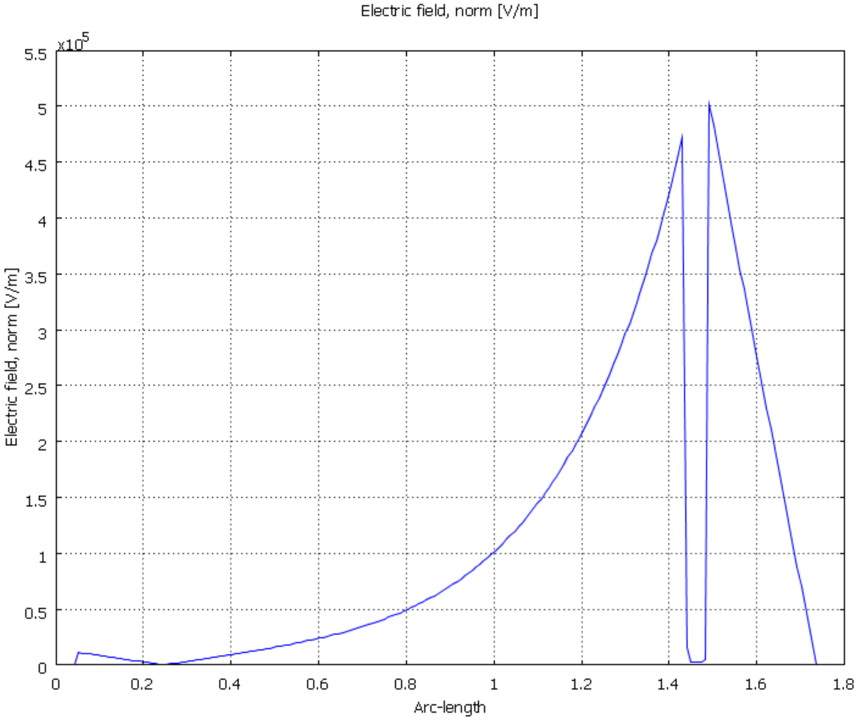
Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
17	250	0.1	0.1	1.85E+06	2.60E+07	2.50E+06	5.00E+05		not complete

Var.17

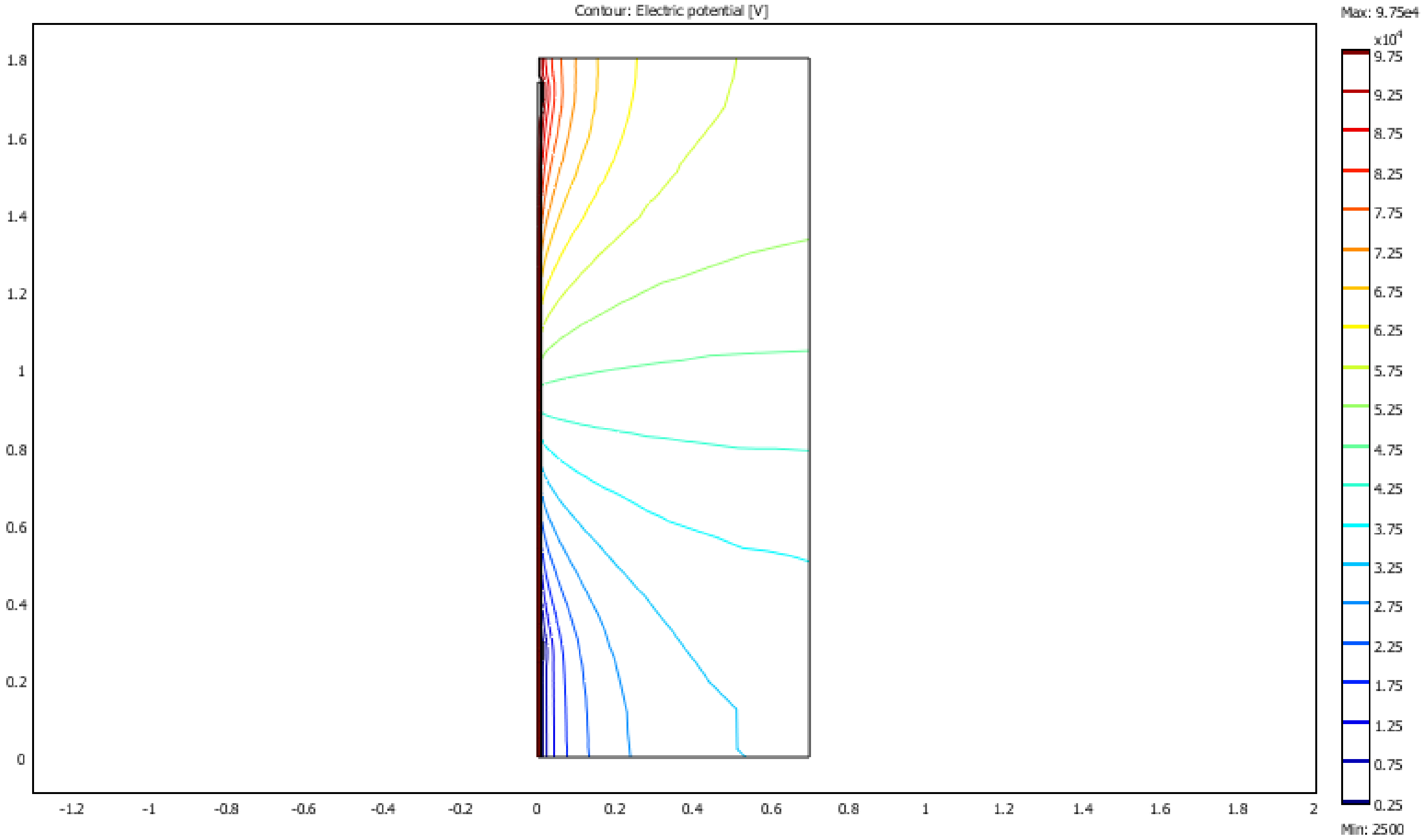
E_{s5}


Electric field, norm [V/m]
x10^6
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5


Electric field, norm [V/m]
x10^5
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

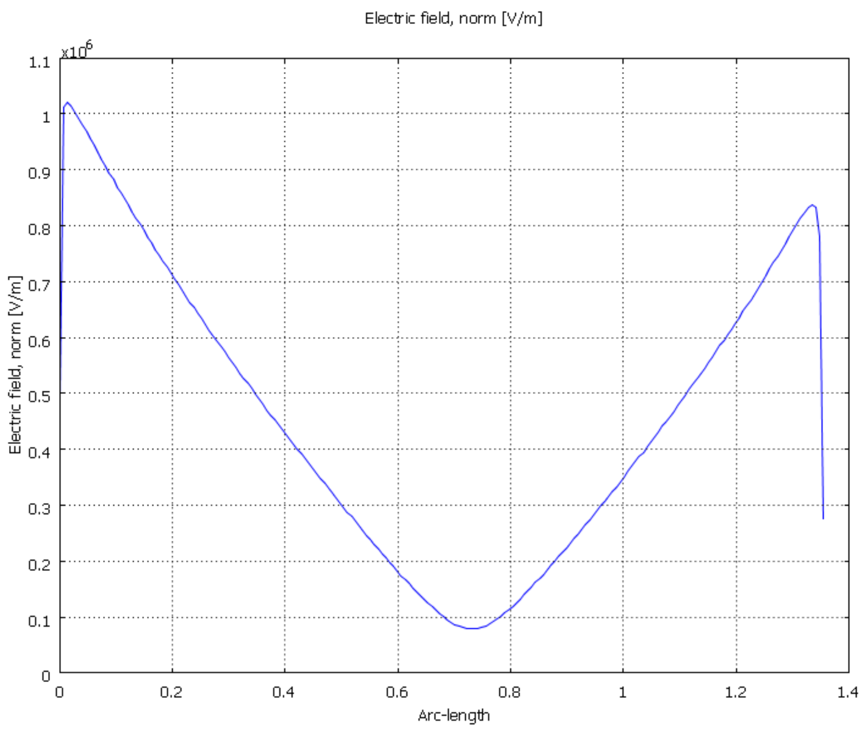
Electric potential distribution (var.19)



Var.	f, kHz	Conductivity, S/m		Electrical strength max, V/m				Current to clamp 7, A	Homogeneous distribution
		σ_5	σ_6	E_{s5}	E_3	E_a	E_5		
19	250	10	10	1.00E+06	2.70E+07	1.20E+06	7.20E+04	38.037	yes

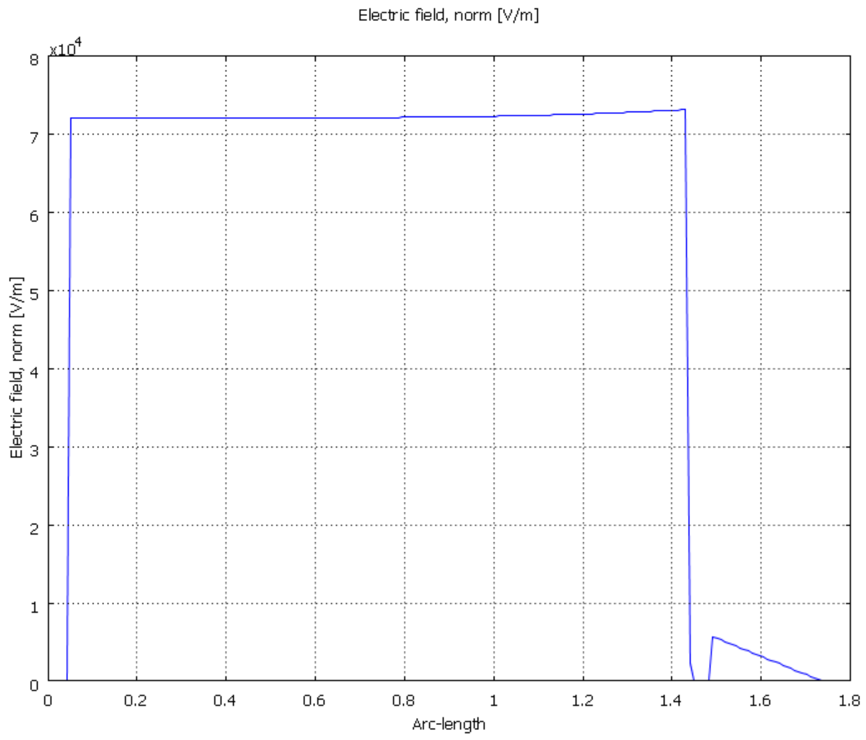
Var.19

E_{s5}



Electric field, norm [V/m]
x10^6
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Arc-length

E_5



Electric field, norm [V/m]
x10^4
8
7
6
5
4
3
2
1
0
Electric field, norm [V/m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Arc-length

Conclusions

- For unchanged characteristics (ε_5, ε_6, σ_5,σ_6) of sheaths (5, 6), the electric potential distributions are varying for different frequencies of *U.*

- For given $\varepsilon_5=\varepsilon_6 =4$ and $\sigma_5=\sigma_6 =\sigma_{56}$, the relatively homogeneous field distributions can be achieved along sheath (5) when:

  σ_{56}= 0.001 … 0.01 S/m – for f = 50 Hz;

  σ_{56}= 0. 1 … 1 S/m – for f = 25 kHz;

  σ_{56}= 1 … 10 S/m – for f = 250 kHz.

  For all considered frequencies, σ_{56}= 1 … 10 S/m provides practically homogeneous electric potential distributions.

- For achieved homogeneous distributions and U = 100 kV, estimated values of maximal electrical strengths are:

  E_{s5} = 10 kV/cm, E_3 = 270 kV/cm, E_a = 12 kV/cm, E_5 = 0.72 kV/cm.

  For σ_{56}= 10 S/m, current to earthing clamp (7) is about 40 A.

Thank you!