B. SPATARO – M. ZOBOV

DAΦNE I.C.E IMPEDANCE

Frascati 12 July, 2004

Purpose

- To make ICE transparent for the beam as much as possible in order to
  - Avoid the ICE to act as an antenna (Machine Advisory Committee)
  - Eliminate resonant part of the coupling impedance due to mismatch with the external feedthroughs

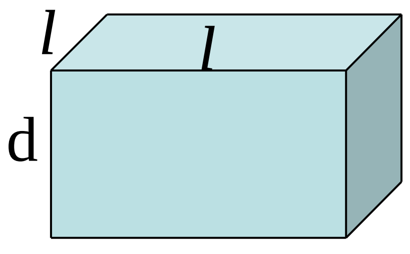
Principal Idea

To use for the ICE a material with a high "resistivity per square"

defines the skindepth

$$R_\circ = \rho \frac{l}{S} = \rho \frac{l}{dl} = \frac{\rho}{d}$$

defines ICE thickness



R_o does not depend on the the material length and must have high resistivity ρ and small thickness d.

In this case we can expect that the skin depth will be much bigger than the ICE thickness d to provide ICE transparency

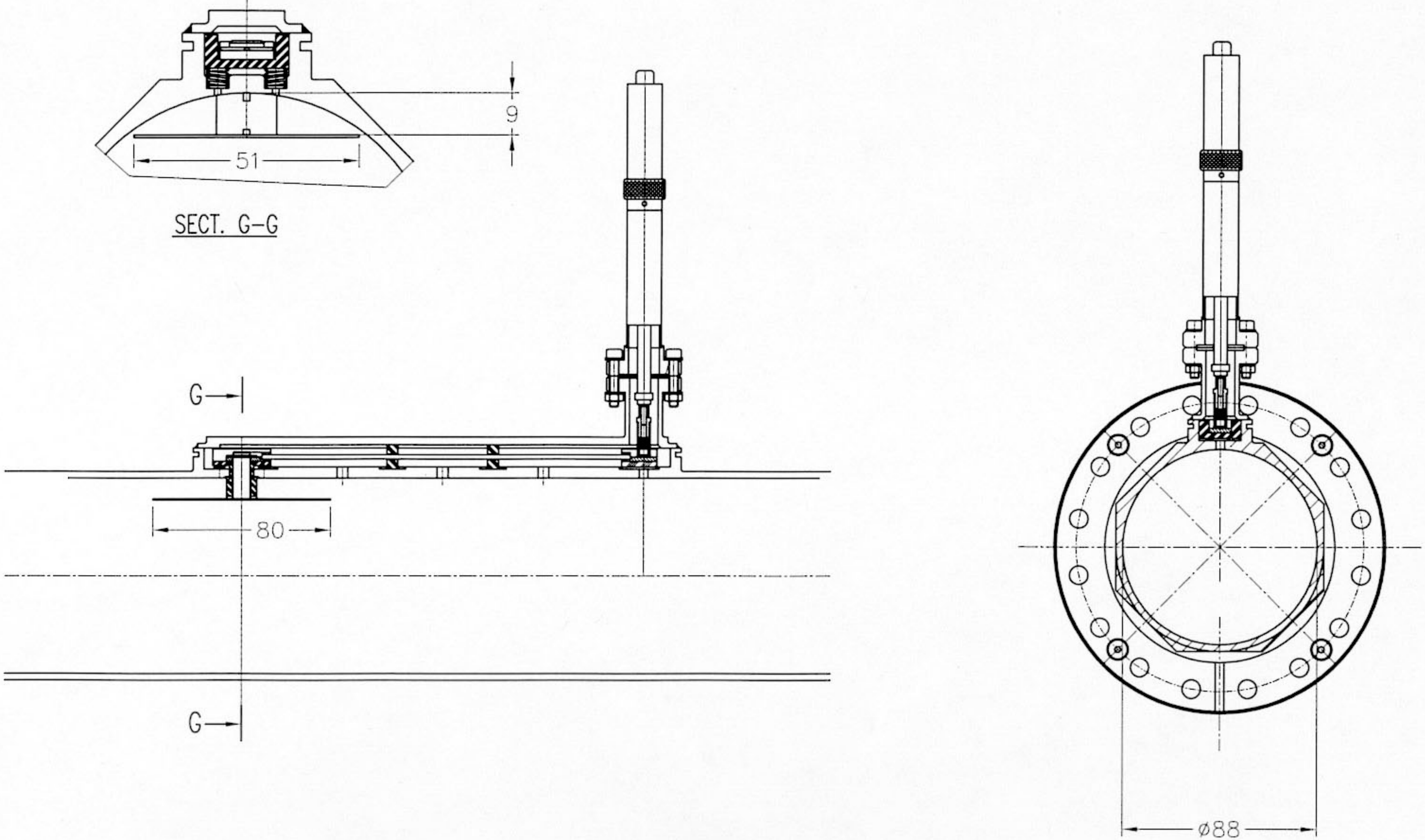
ICE Material

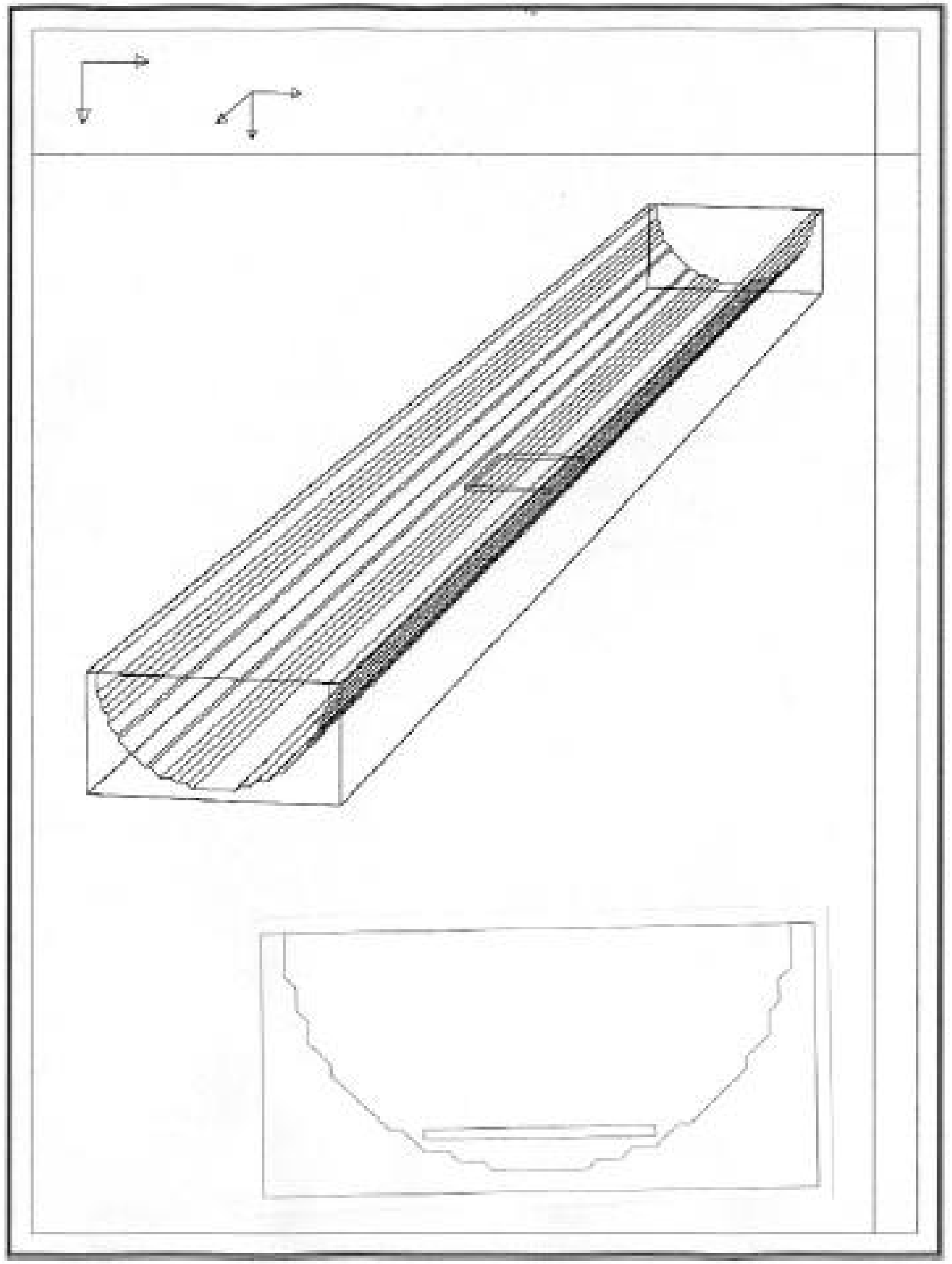
A highly resistive paste with a thickness d of 25 μm and the resistivity per square ρ/d of the order of 10^5 is painted on a dielectric material with $\varepsilon = 9$ (alumina)

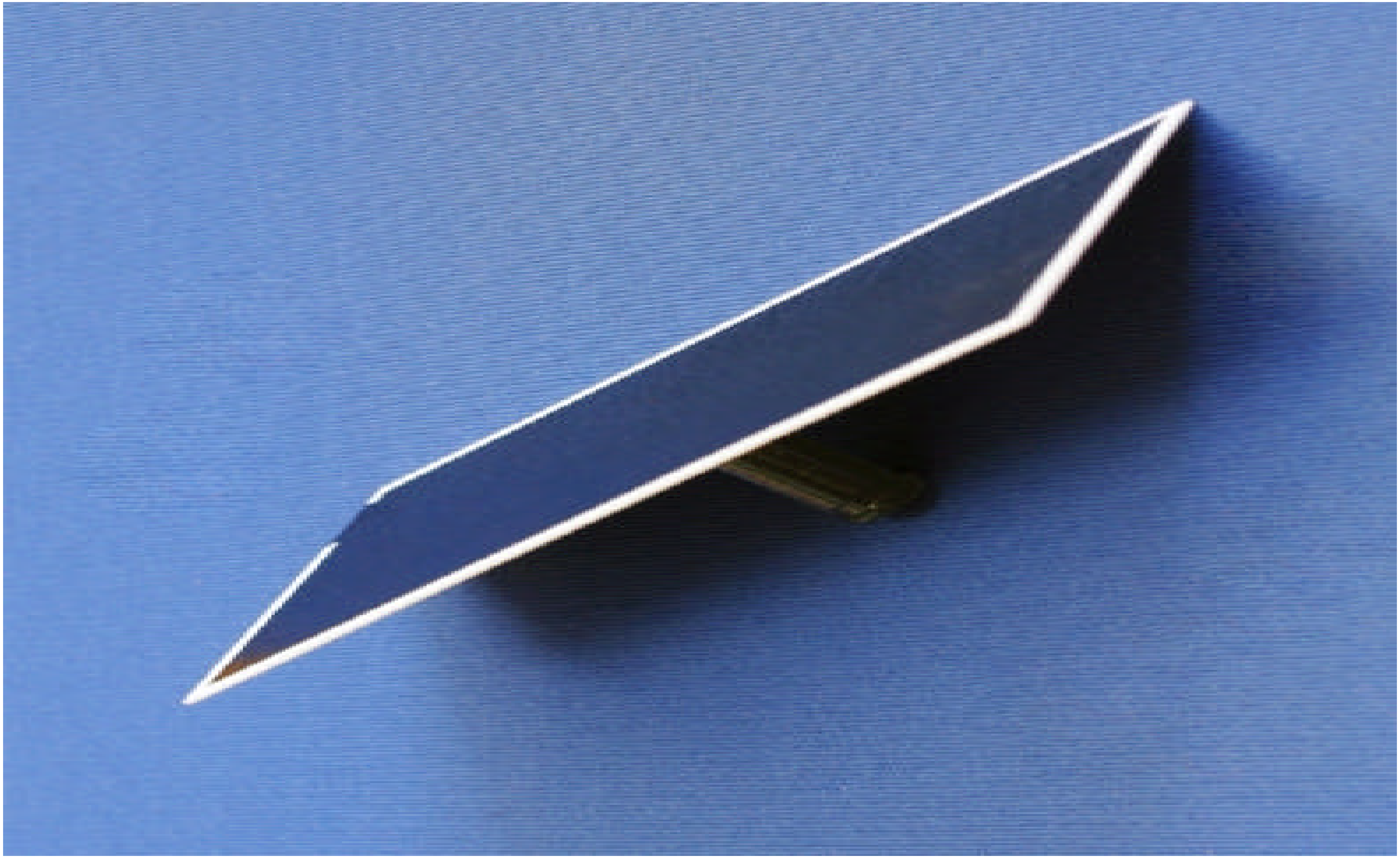
The skin depth estimated at a typical bunch spectrum frequency of 1 GHz is:

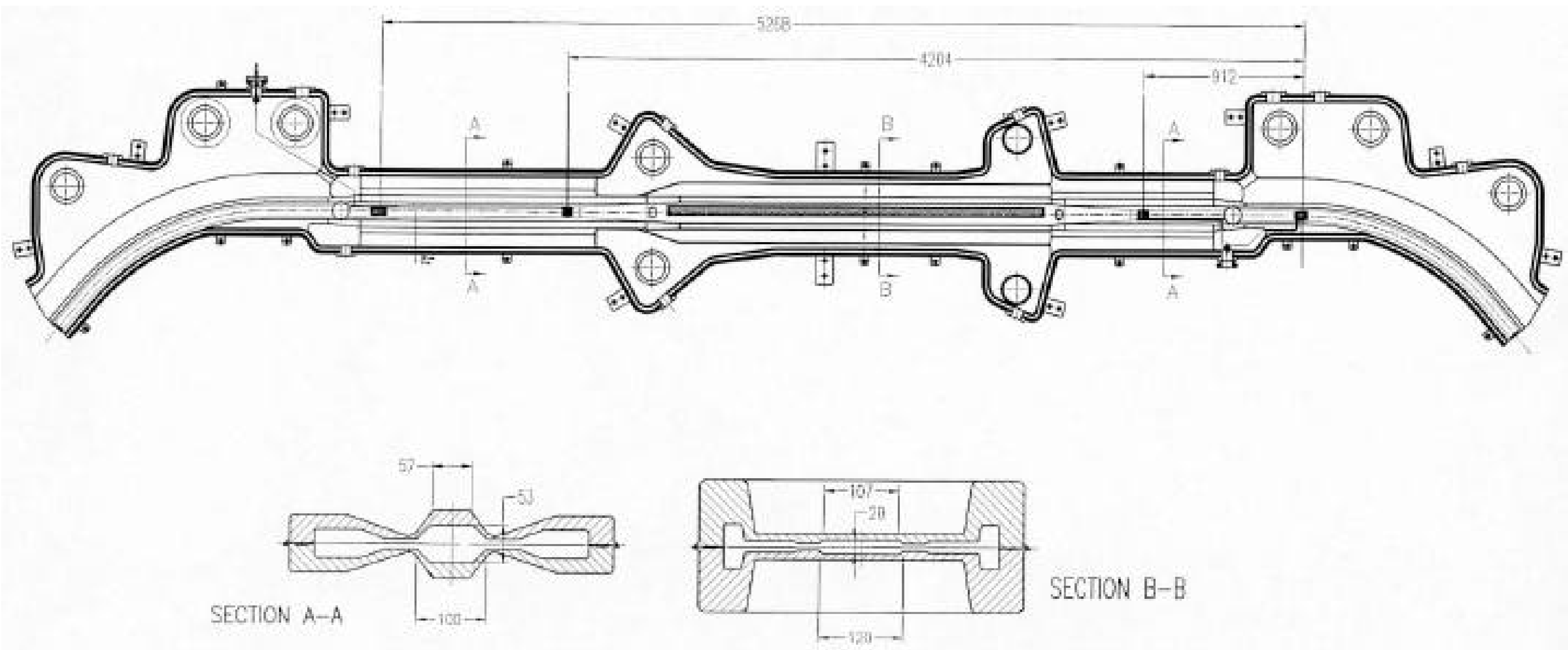
$$\delta_s = \sqrt{\frac{2\rho c}{Z_0 \omega}} = 2.5\times 10^{-2} m \rightarrow 1000d$$

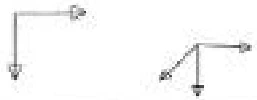
i.e. the skin depth is much larger than the layer thickness thus making the layer transparent at RF frequencies

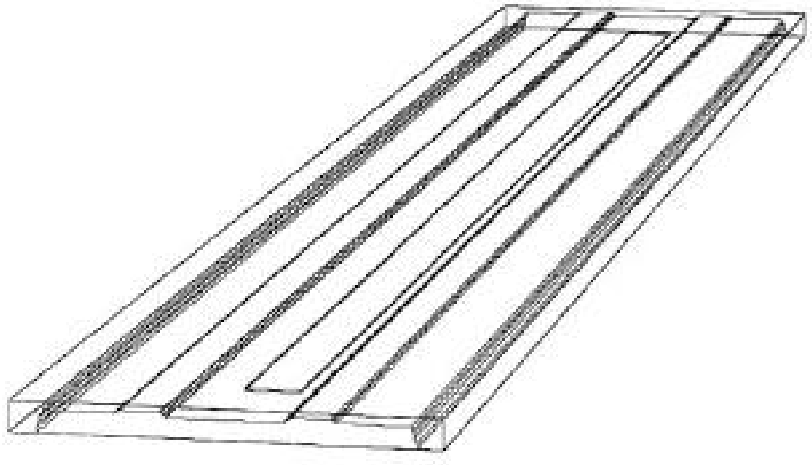

9
51
SECT. G–G
G
80
G
ø88

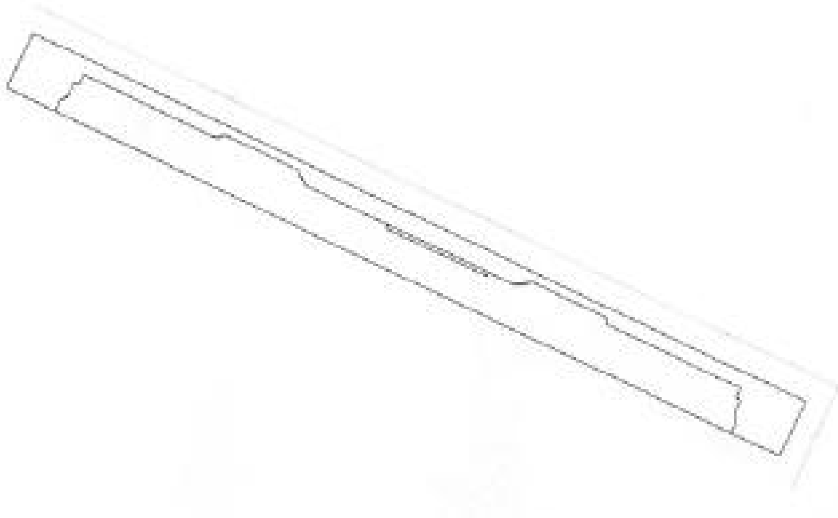


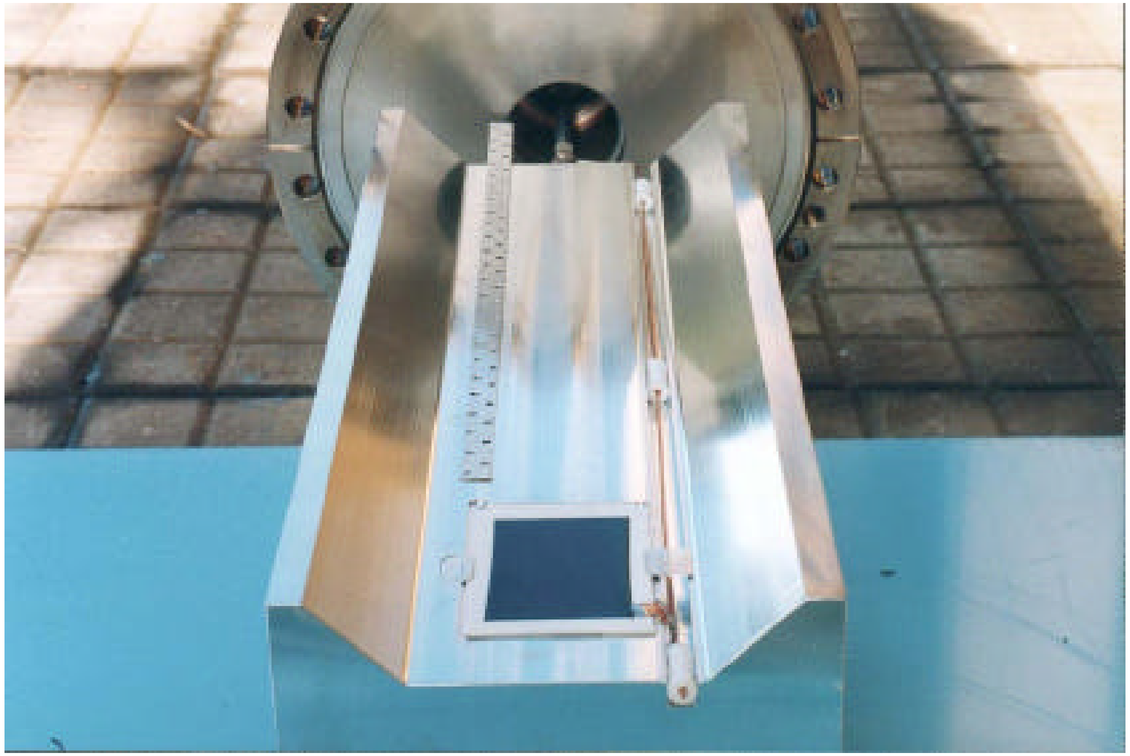


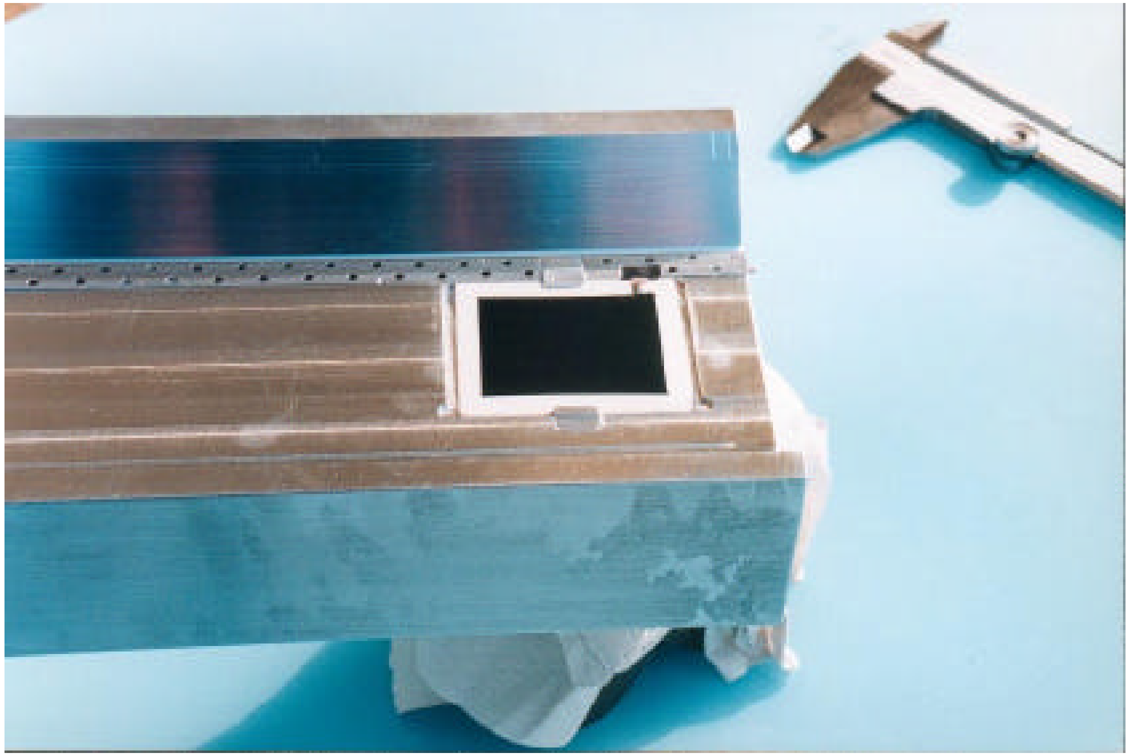

4204
912
A
A
B
B
A
A
57
100
SECTION A-A
SECTION B-B

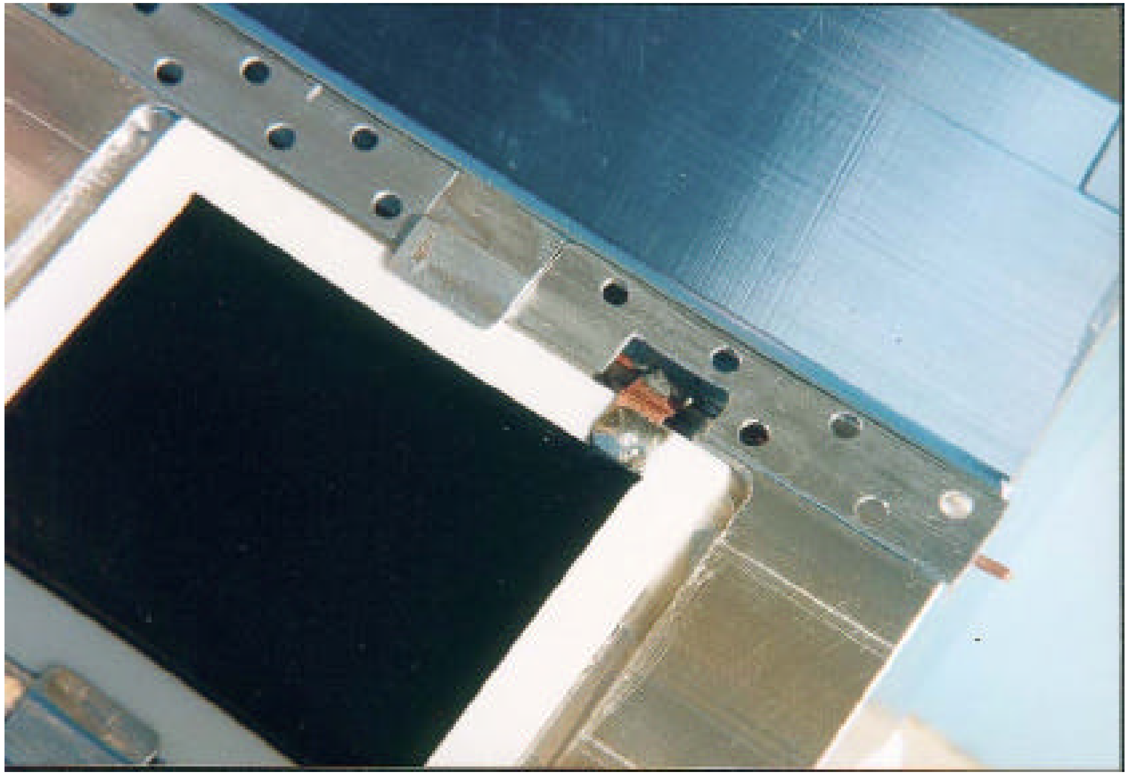




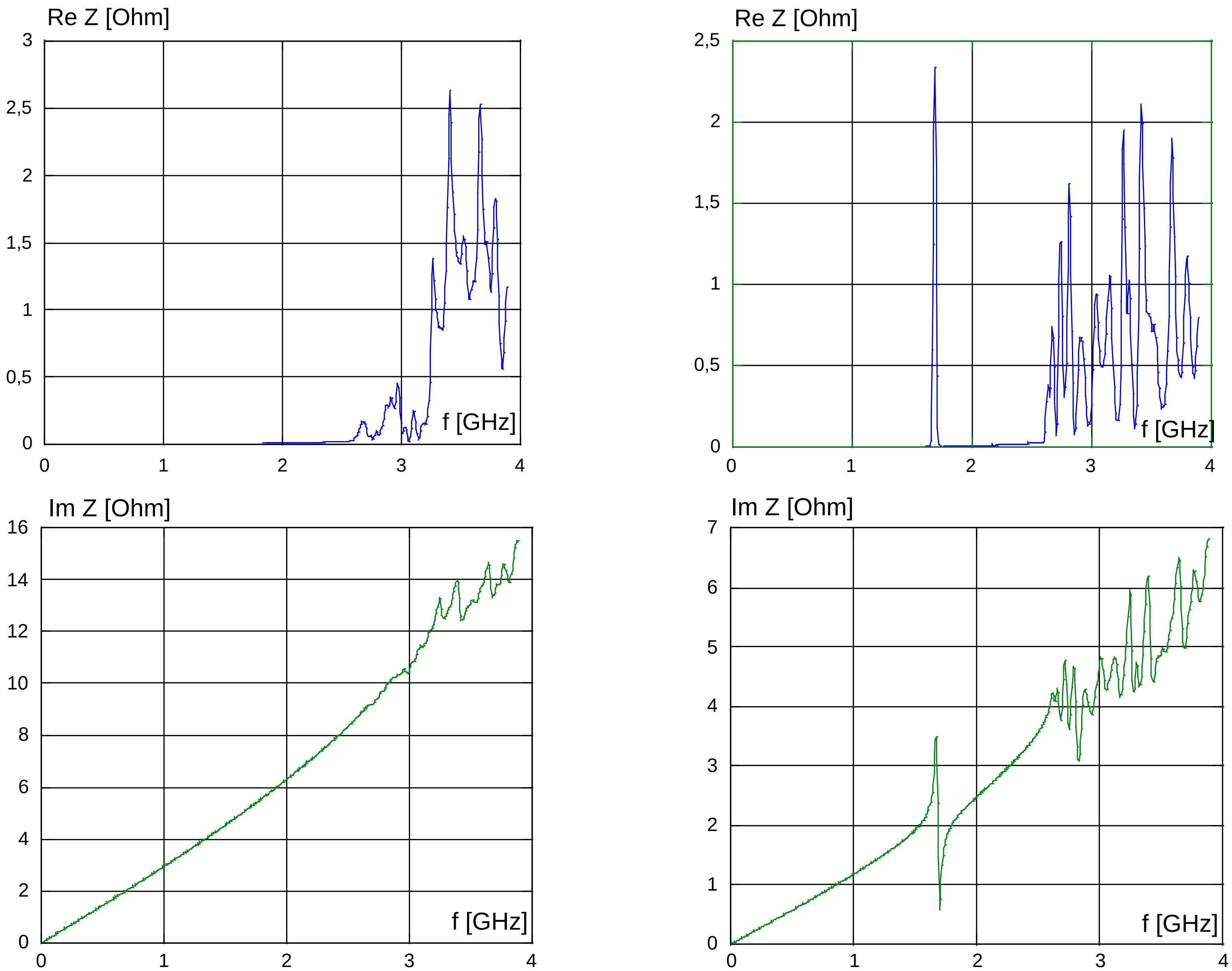




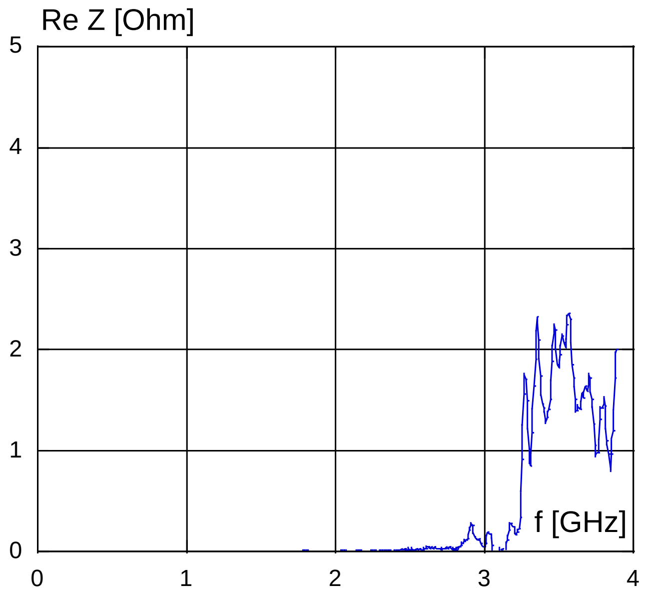


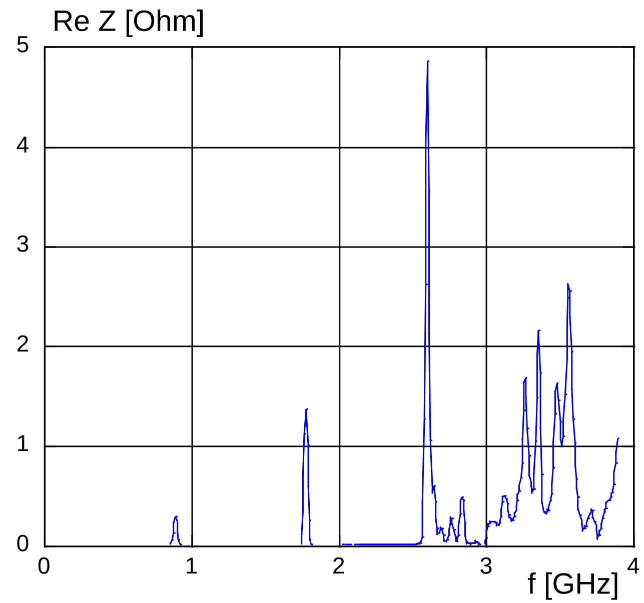


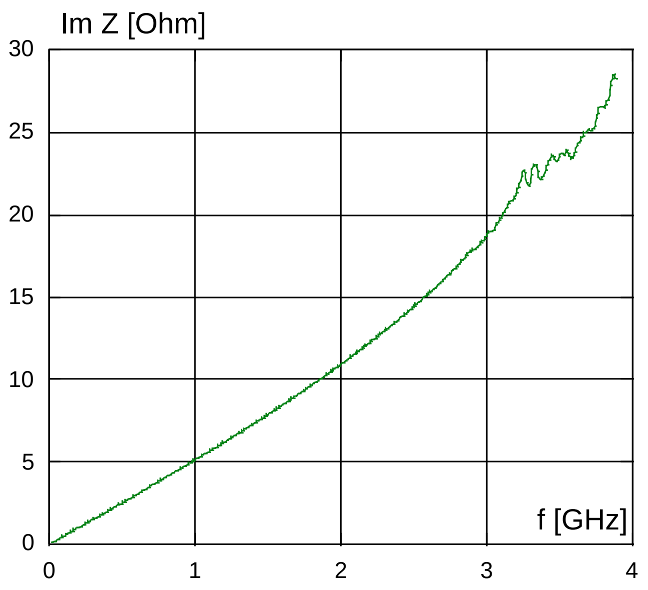
Impedance of Short Electrodes in Straight Sections

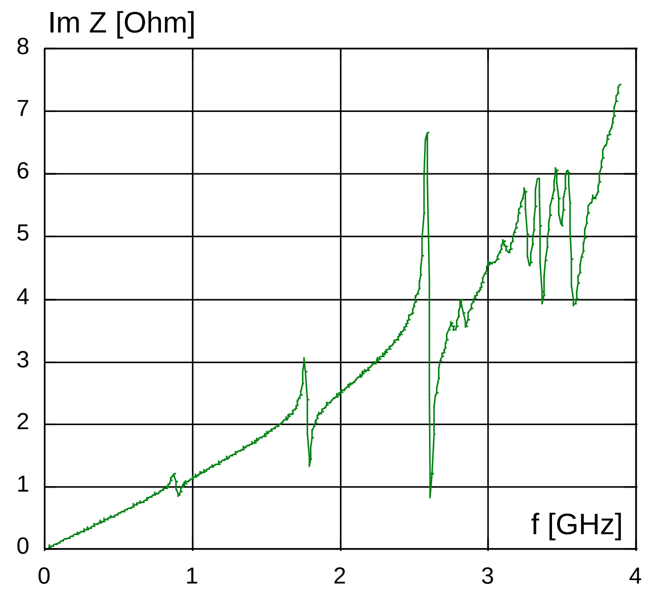


Impedance of Long Electrodes in Straight Sections









ε	W_{min}, V/pC	W_{max}, V/pC	kl, V/pC	L(wake), pH	$\omega_0 L$, Ω
Metal	-1.909e+09	1.990e+09	-7.772e+07	81	1.562e-03
2	-3.794e+09	3.782e+09	-2.809e+06	157	3.027e-03
5	-7.276e+09	7.363e+09	-9.928e+06	302	5.823e-03
9	-9.257e+09	9.472e+09	-1.810e+07	387	7.462e-03
13	-1.050e+10	1.103e+10	-2.914e+07	445	8.580e-03
18	-1.163e+10	1.258e+10	-5.348e+07	500	9.641e-03

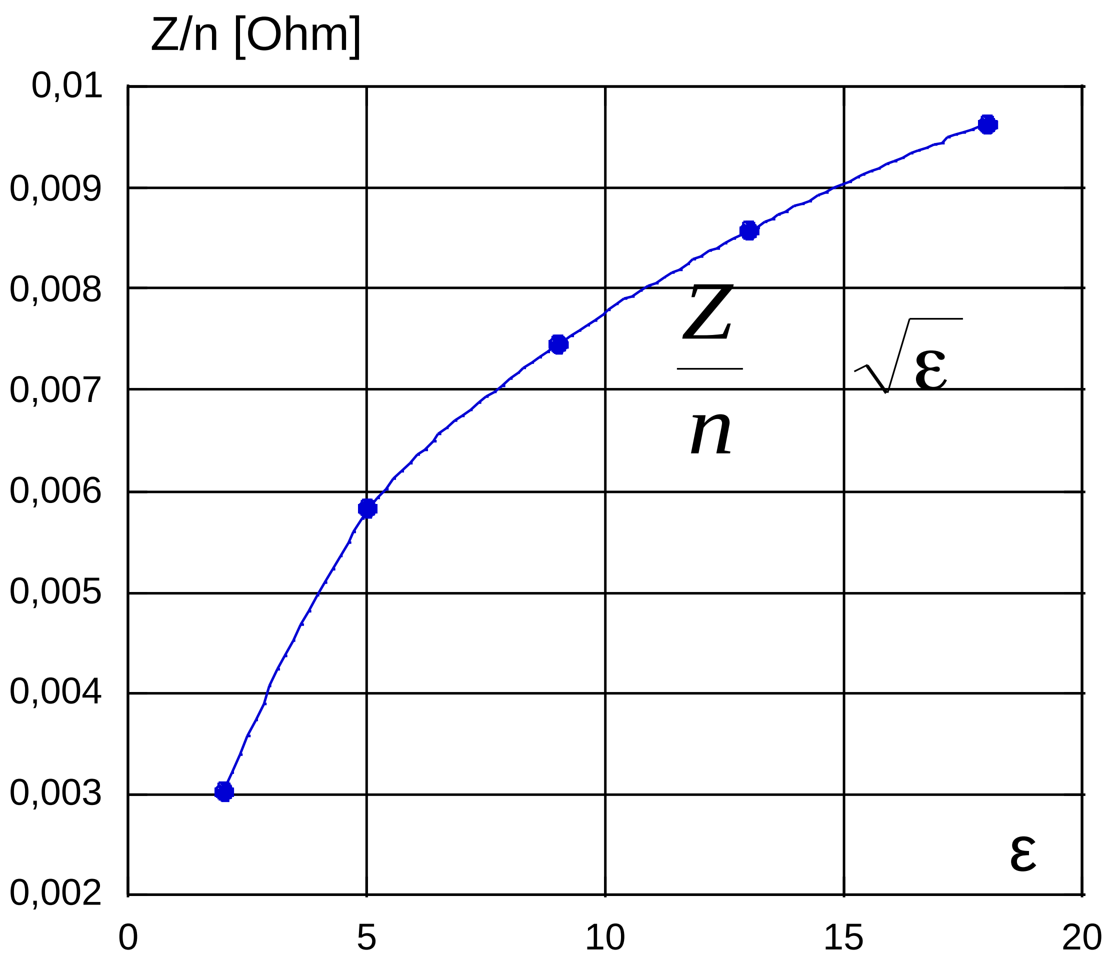
ε	W_{min}, V/pC	W_{max}, V/pC	kl, V/pC	L, pH	$\omega_0 L$, Ω
Metal	-2.802e+10	2.779e+10	-4.679e+09	77	1.485e-03
2	-9.272e+10	9.618e+10	-1.675e+09	153	2.950e-03
5	-2.160e+11	2.010e+11	-9.430e+09	289	5.572e-03
9	-2.024e+11	1.918e+11	-2.169e+10	359	6.922e-03
13	-2.370e+11	1.944e+11	-3.192e+10	399	7.693e-03
18	-2.220e+11	1.898e+11	-4.080e+10	435	8.388e-03

Low Frequency Impedance Scaling

$$Z(\omega) = \sum_n \frac{R_n}{1 + jQ_n\left(\omega/\omega_n - \omega_n/\omega\right)}$$

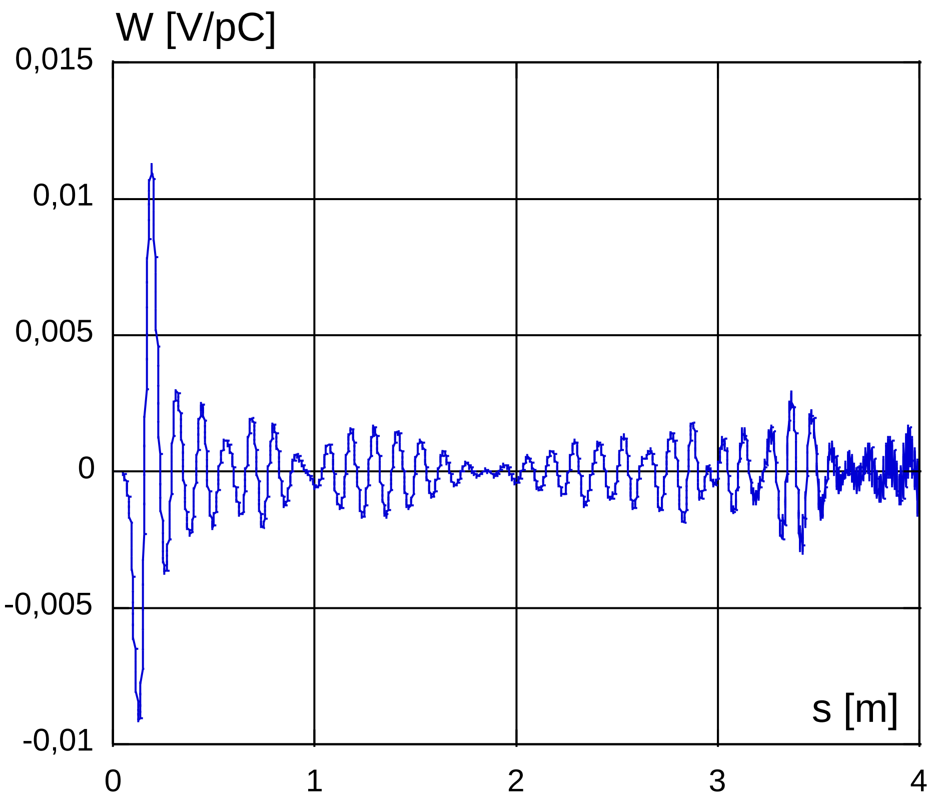
In the low frequency limit $$Z(\omega) \to j\omega L = j\omega \sum_n \left(\frac{R_n}{Q_n}\right)\frac{1}{\omega_n}$$

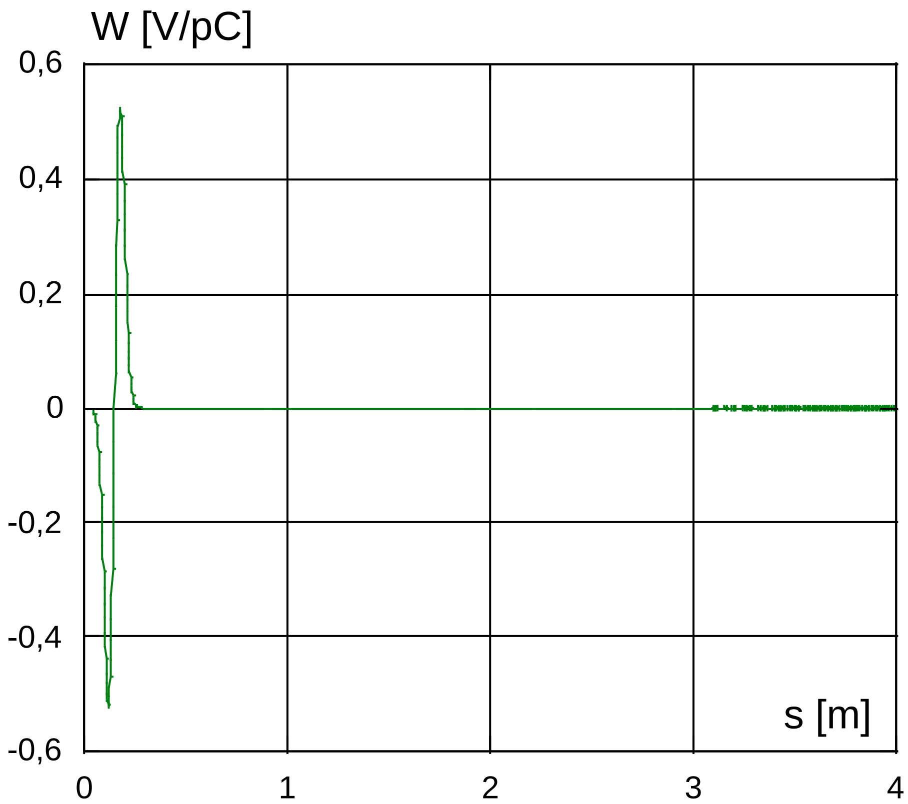
Since the resonant frequencies scale inversely with $\sqrt{\varepsilon}$ one may expect that the low frequency impedance grows proportionally to $\sqrt{\varepsilon}$



Z/n [Ohm]
0,01
0,009
0,008
0,007
0,006
0,005
0,004
0,003
0,002
0
5
10
15
20
Z
n
√ε
ε

Wiggler Electrode Wakes





ε	W_{min} V/C	W_{max} V/C	kl V/C	L(wake) pH	$\omega_0 L$ Ω	Comments
Metal						
2	8.590e+10	8.557e+10	-1.463e+8	3550	68e-3	
5	1.417e+11	1.416e+11	-4.622e+7	5856	113e-3	
9	1.612e+11	1.612e+11	-2.342e+7	6662	129e-3	
13	1.704e+11	1.704e+11	-1.511e+7	7042	136e-3	
18	1.780e+11	1.781e+11	-9.832e+6	7360	142e-3	

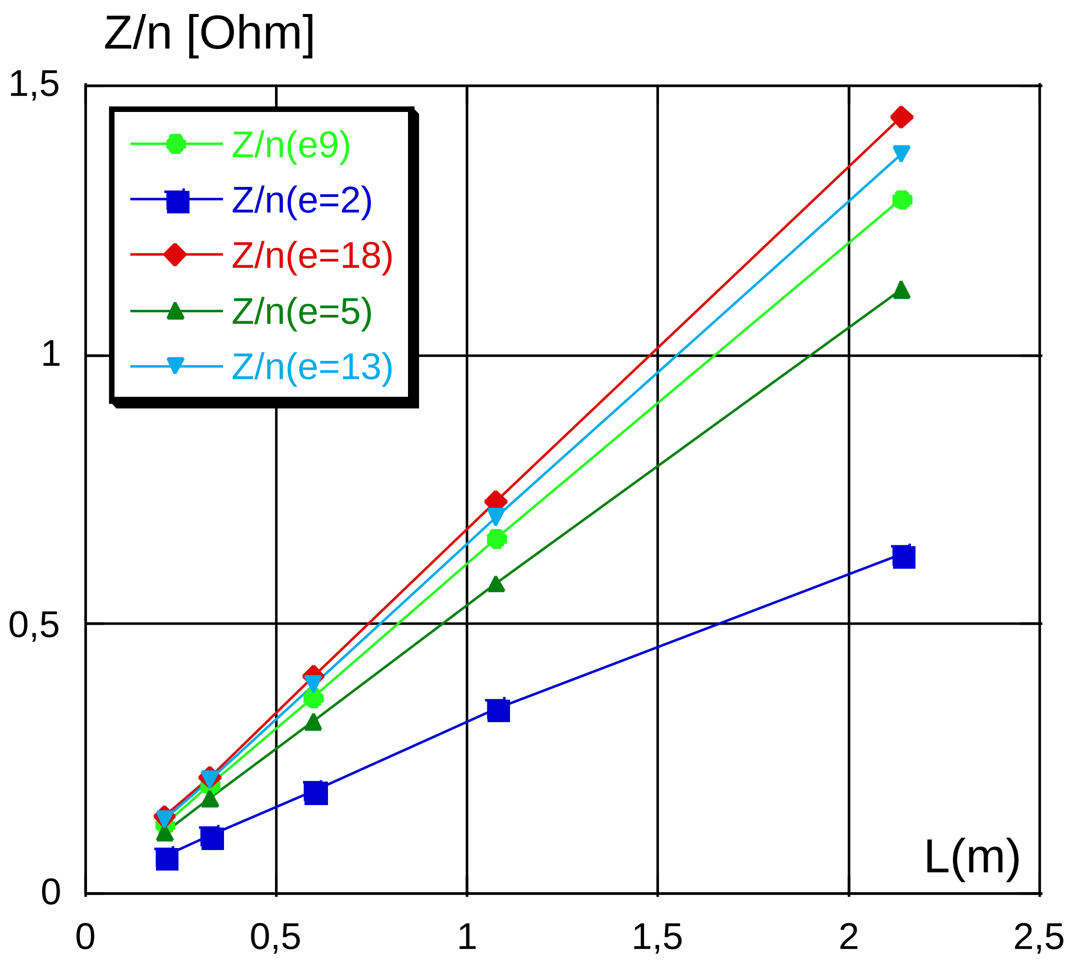
ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	1.335e+11	1.330e+11	-2.300e+8	5517	106e-3	
5	2.221e+11	2.220e+11	-7.268e+7	9179	177e-3	
9	2.529e+11	2.529e+11	-3.679E+7	10452	202e-3	
13	2.675e+11	2.674e+11	-2.371e+7	11055	213e-3	
18	2.794e+11	2.797e+11	-1.538e+7	11361	219e-3	

ε	W_{min} V/C	W_{max} V/C	kl V/C	L(wake) pH	$\omega_0 L$ Ω	Comments
Metal						
2	2.405e+11	2.395e+11	-4.182e+8	9939	192e-3	
5	4.029e+11	4.027e+11	-1.322e+8	16651	321e-3	
9	4.593e+11	4.592e+11	-6.680e+7	18982	366e-3	
13	4.859e+11	4.858e+11	-4.136e+7	20081	387e-3	
18	5.077e+11	5.081e+11	-2.810e+7	20982	405e-3	

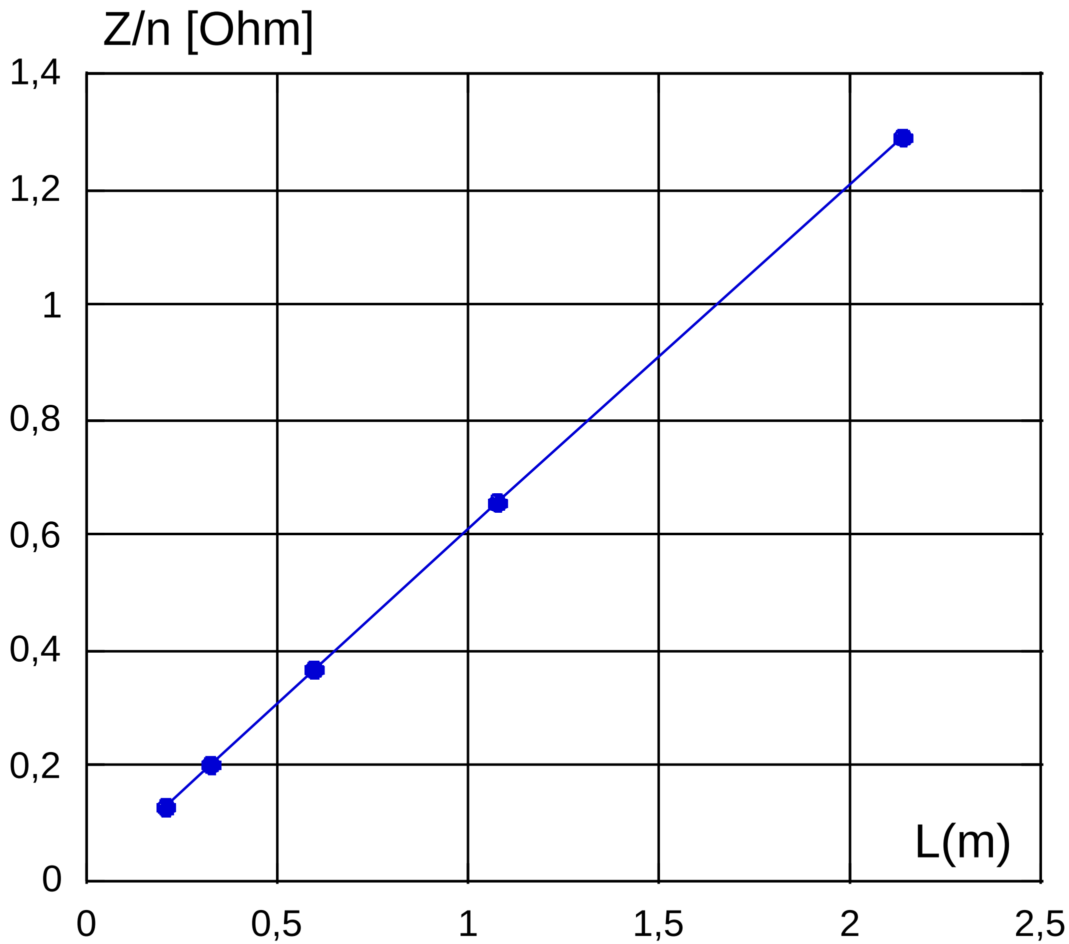
ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	4.307e+11	4.291e+11	-7.526e+8	17800	343e-3	
5	7.243e+11	7.239e+11	-2.381e+8	29933	577e-3	
9	8.262e+11	8.260e+11	-1.200e+8	34145	658e-3	
13	8.741e+11	8.740e+11	-7.778e+7	36124	697e-3	
18	9.135e+11	9.143e+11	-5.061e+7	37753	728e-3	

ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	7.878e+11	7.014e+11	-4.617e+10	32558	0.628	
5	1.404e+12	1.390e+12	-6.299e+09	58024	1.12	
9	1.622e+12	1.610e+12	-5.821e+09	67033	1.29	
13	1.724e+12	1.714e+12	-.506e+09	71248	1.37	
18	1.806e+12	1.800e+12	-3.429e+09	74637	1.44	

ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	8.457e+11	8.559e+11	+6.333e+08	35372	0.682	
5	1.435e+12	1.438e+12	+5.754e+09	59429	1.146	
9	1.630e+12	1.637e+12	+8.555e+08	67658	1.305	
13	1.727e+12	1.732e+12	+3.495e+08	71579	1.380	
18	1.806e+12	1.809e+12	+1.944e+08	74761	1.442	



Z/n [Ohm]
1,5
1
0,5
0
Z/n(e9)
Z/n(e=2)
Z/n(e=18)
Z/n(e=5)
Z/n(e=13)
L(m)
0
0,5
1
1,5
2
2,5


Z/n [Ohm]
1,4
1,2
1
0,8
0,6
0,4
0,2
0
L(m)
0
0,5
1
1,5
2
2,5

ε	W_{min} V/C	W_{max} V/C	kl V/C	L(wake) pH	$\omega_0 L$ Ω	Comments
Metal						
2	2.547e+10	2.694e+10	-7.462e+7	1113	21.5e-3	
5	4.307e+10	4.788e+10	-1.644e+8	1979	38.2e-3	
9	5.098e+10	6.252e+10	-3.400e+8	2584	49.8e-3	
13	5.537e+10	7.498e+10	-6.981e+8	3099	59.8e-3	
18	5.898e+10	8.835e+10	-1.562e+9	3651	70.4e-3	

ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	1.372e+10	1.408e+10	-1.645e+7	582	11.2e-3	
5	2.234e+10	2.304e+10	-2.471e+7	952	18.4e-3	
9	2.551e+10	2.654e+10	-3.167e+7	1097	21.2e-3	
13	2.709e+10	2.851e+10	-3.836e+7	1178	22.72e-3	
18	2.847e+10	3.055e+10	-4.821e+7	1263	24.35e-3	

ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	8.457e+11	8.559e+11	+6.333e+08	35372	0.682	
5	1.435e+12	1.438e+12	+5.754e+09	59429	1.146	
9	1.630e+12	1.637e+12	+8.555e+08	67658	1.305	
13	1.727e+12	1.732e+12	+3.495e+08	71579	1.380	
18	1.806e+12	1.809e+12	+1.944e+08	74761	1.442	

ε	W_{min} V/C	W_{max} V/C	Kl V/C	L pH	$\omega_0 L$ Ω	Comments
Metal						
2	1.487e+12	1.488e+12	+5.238e+08	61495	1.186	
5	2.623e+12	2.627e+12	+5.824e+09	108567	2.093	
9	3.131e+12	3.329e+12	+5.791e+08	137579	2.653	
13	3.431e+12	4.017e+12	-3.580e+09	166012	3.201	
18	3.653e+12	4.902e+12	-2.368+10	202586	3.906	

Conclusions

- The present ICE design helps to eliminate the resonant impedance and excessive power losses. On the other hand, the ICE coupling impedance is highly inductive that makes bunches longer in the e- ring than in the e+ one.
- As it is shown by numerical simulations the low frequency impedance scales as:
  - The square root of the ICE material dielectric ε
  - Proportional to the electrode length L
  - Proportional to the electrode thickness d
- The dominant contribution to the coupling impedance comes from the 4 wiggler ICE, since they are very long (L > 2 m) and are very close to the beam (the width of the wiggler vacuum chamber is 2 cm).