FIRST ANSWERS TO QUESTIONS RAISED ON 23/03/08 BY A. BERTARELLI

F. Caspers, A. Grudiev, T. Kroyer,
E. Métral, F. Roncarolo and B. Salvant

IMPORTANT MESSAGES FROM THE IMPEDANCE TEAM (1/3)

- **1) The choice of the collimator material depends on the stabilization method of the transverse coupled-bunch instability**
  - If one relies on Landau damping (from octupoles) $\Longrightarrow$ One should 1st decrease the imaginary part of the impedance, even if the real part slightly increases $\Longrightarrow$ Go in the direction of the metal jaw (with the best conductivity) or more sophisticated materials
  - If the transverse feedback can be used (let's wait the conclusions from W. Hofle, remembering the issue of the flatness of the real part of the impedance between 8 kHz and 20 MHz) $\Longrightarrow$ One should preferably decrease the real part of the impedance and may be (studies ongoing) go in the direction of ceramics (or more sophisticated materials). Note that if the real part at these frequencies is decreased it will help the feedback but if the impedance increases at high-frequency (in a broad-band manner) then we enter into another type of instability which is the single-bunch one (where there is some margin at the moment)! $\Longrightarrow$ Action: This effect will be evaluated soon

IMPORTANT MESSAGES FROM THE IMPEDANCE TEAM (2/3)

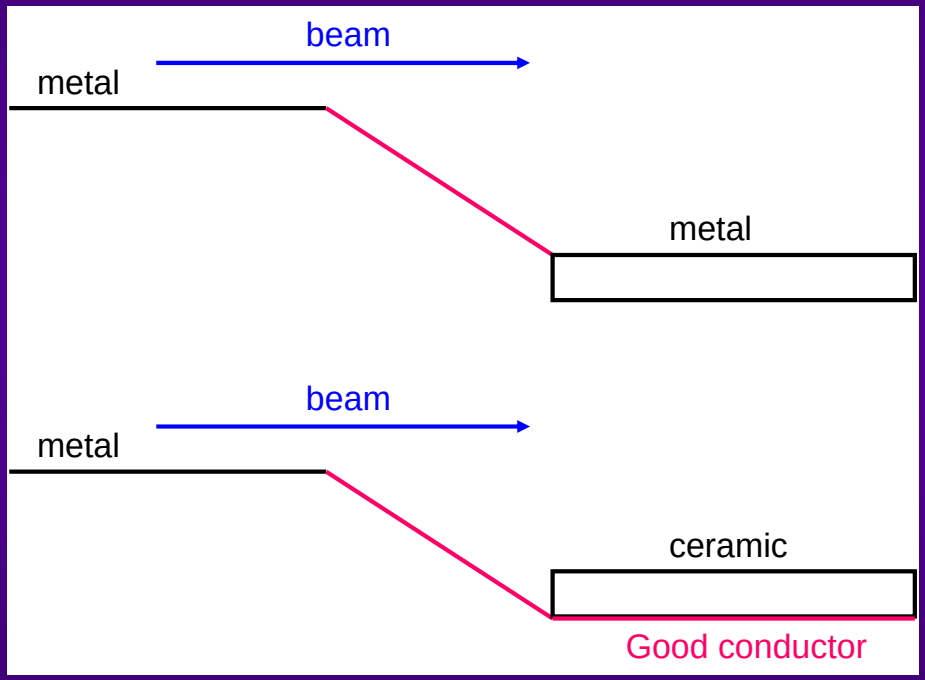
- **2) When using ceramics blocks we do not care about gaps in between as there is no current. This is opposite to the case of metallic blocks!**

- **3) In the case of a ceramic block, the thinner the dielectric the better (we imagine that something like ~ 5-10 mm should be OK) and then one should put the best conductor around (taking into account the mechanical constraints etc.)**

- **4) The heating of a ceramic collimator during operation will change the characteristics of the material (conductivity etc.) and this effect should not be forgotten, as one might enter into a bad regime (see presentation of 27/03/08, or later in this talk)**

IMPORTANT MESSAGES FROM THE IMPEDANCE TEAM (3/3)

- **5) The transition between a ceramic and a metal is different from the transition between 2 metals $\Longrightarrow$ One wants to avoid the step in the induced current (see Figure below)**

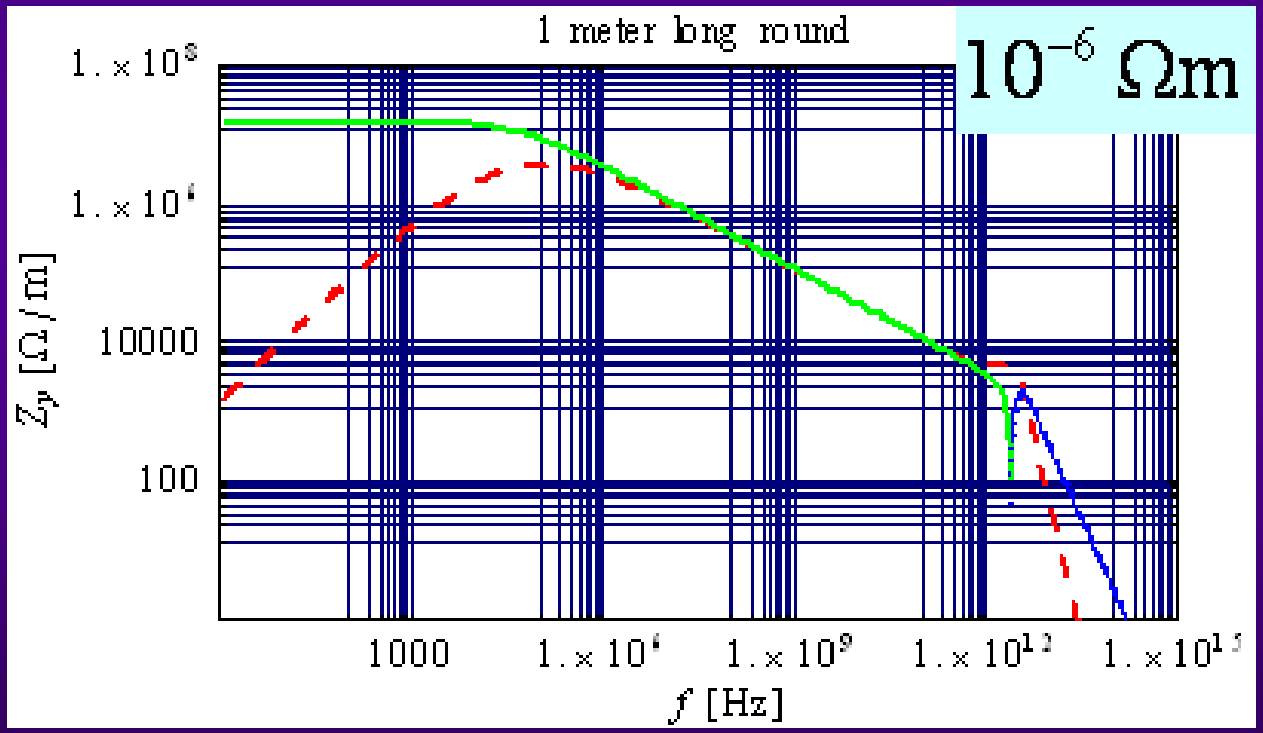


- **6) Once we have the 3D model of the ceramic collimator one needs to make detailed simulations to study the possible resonances etc.**

STUDIES ONGOING FOR A CERAMIC COLLIMATOR (1/10)

ANALYTICAL PREDICTIONS

$\Longrightarrow$ **Scan in resistivity ρ from 10^{-6} to 10^{20} Ωm and** $\varepsilon_r = 5$

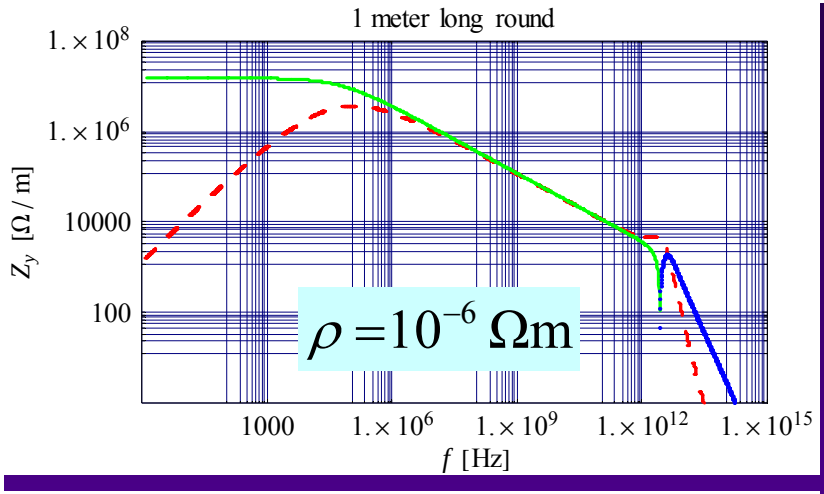


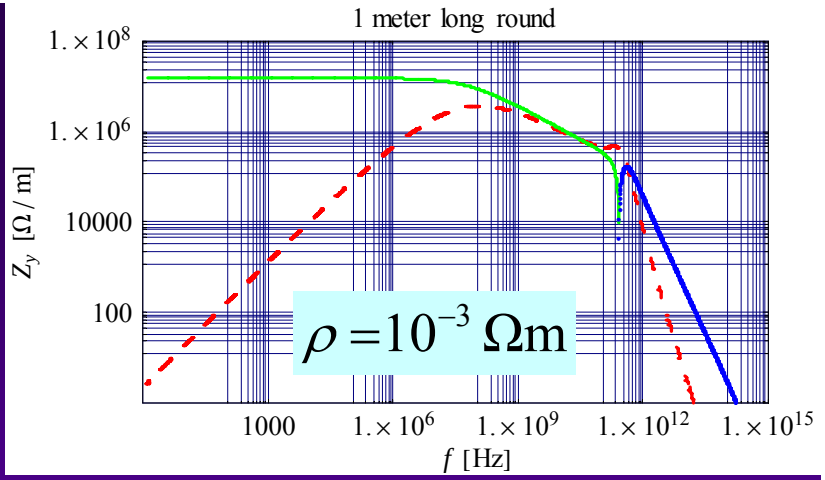
$f_{1\text{st peak}} \propto \rho$

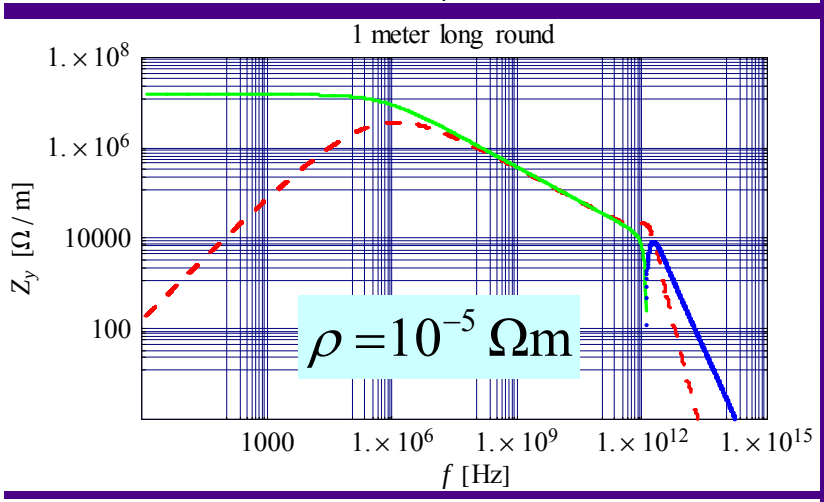
$f_{2\text{nd peak}} \propto 1/\rho$

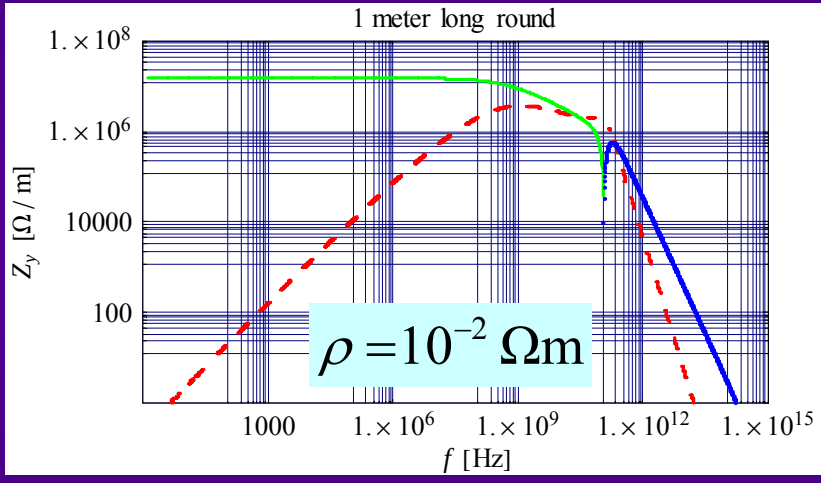
$\varepsilon_r = 5$

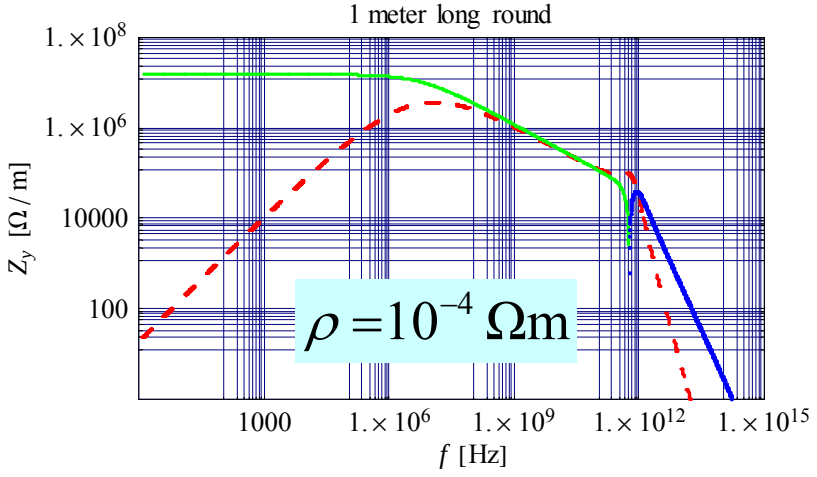
(2/10)

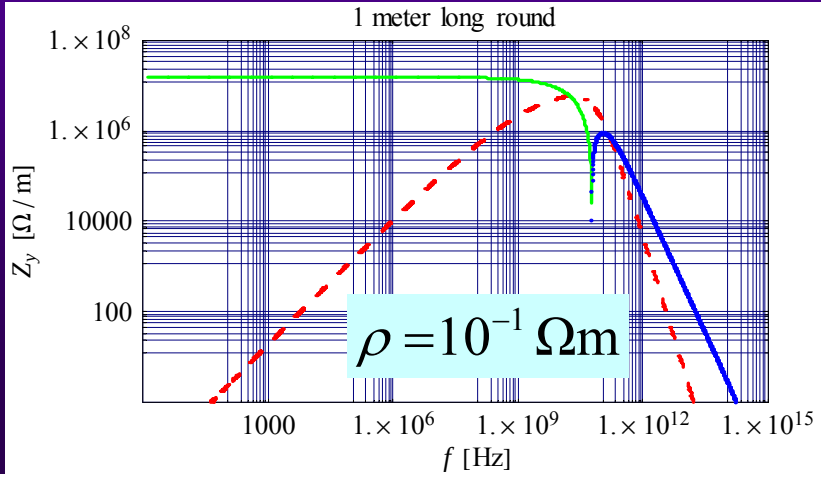


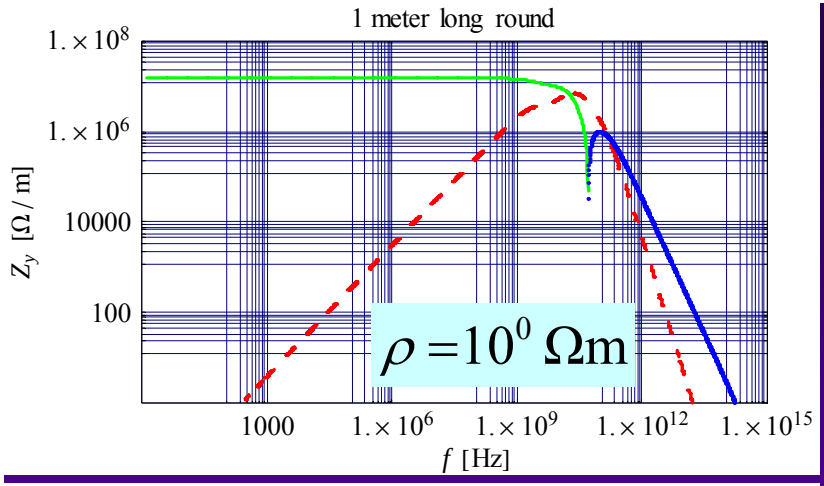








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10000
100
Z_y [Ω / m]
$\rho = 10^{0}$ Ωm
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$1.\times10^{9}$
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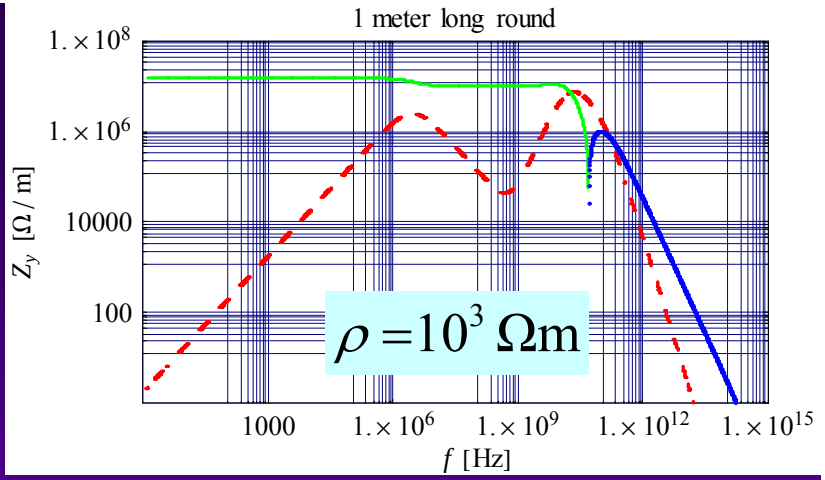
$1.\times10^{15}$
f [Hz]

(3/10)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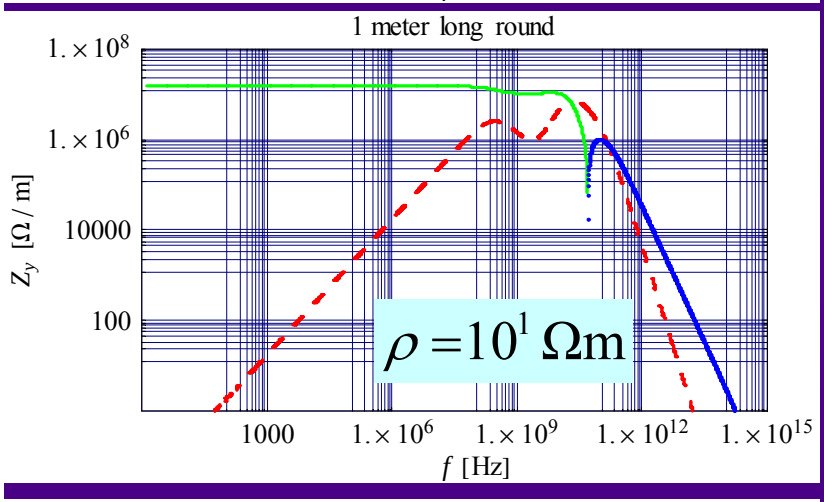
$1.\times10^{15}$
f [Hz]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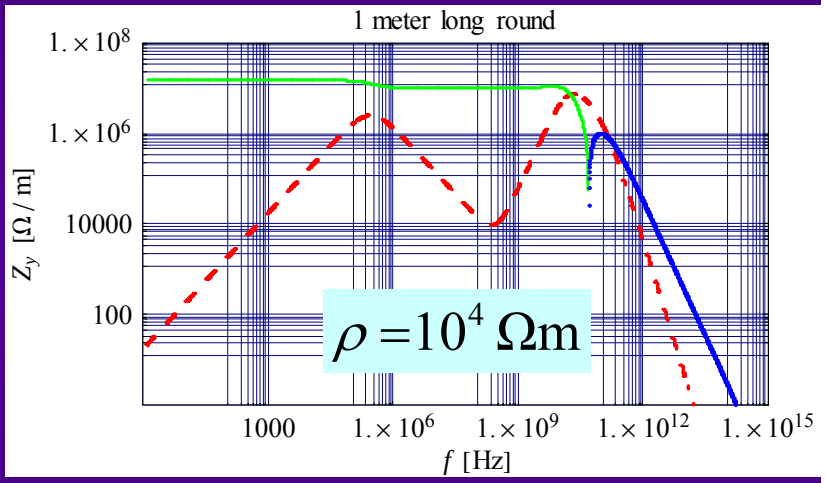
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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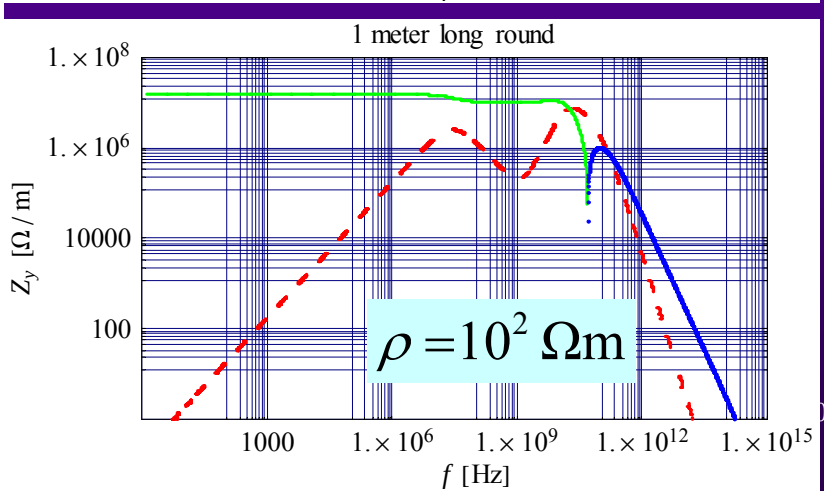
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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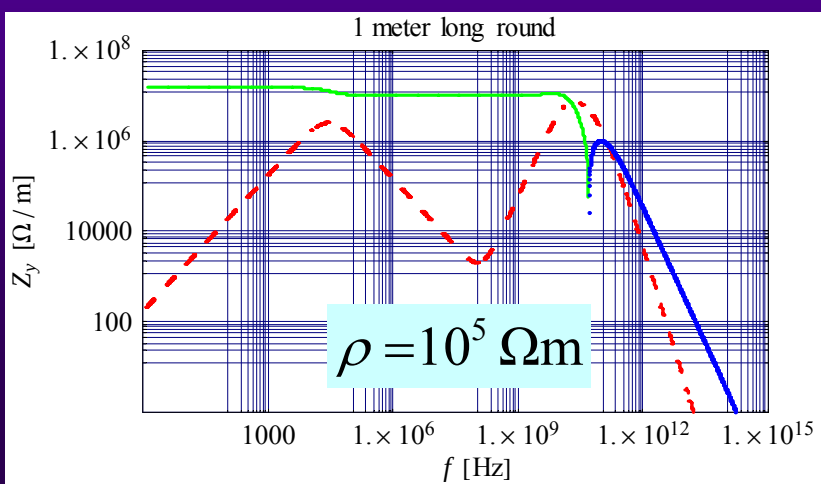
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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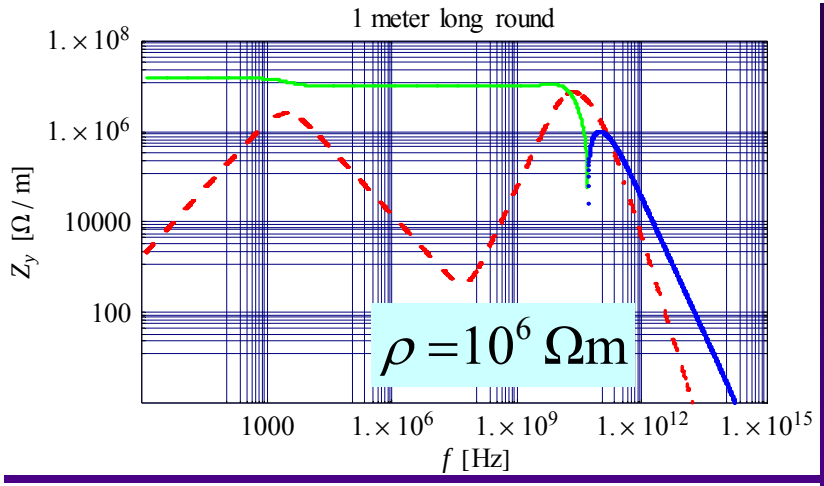
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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Z_y [Ω / m]
$\rho = 10^{6}$ Ωm
1000
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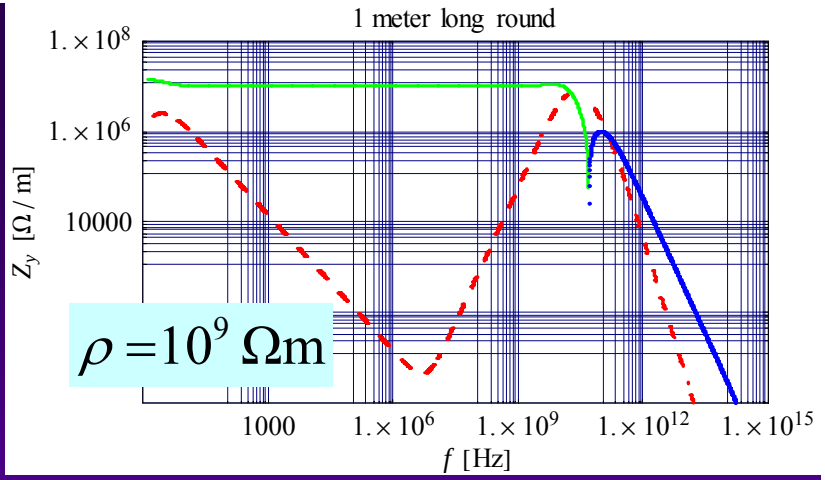
$1.\times10^{15}$
f [Hz]

(4/10)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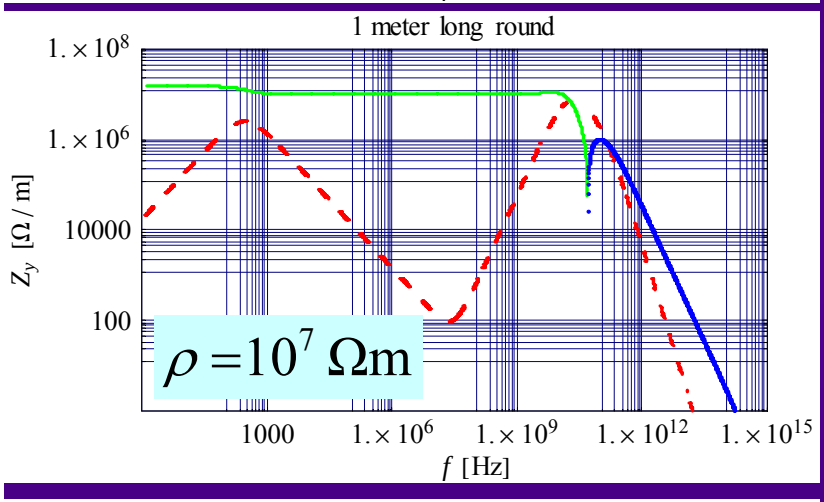
f [Hz]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100
Z_y [Ω / m]
$\rho = 10^{7}$ Ωm
1000
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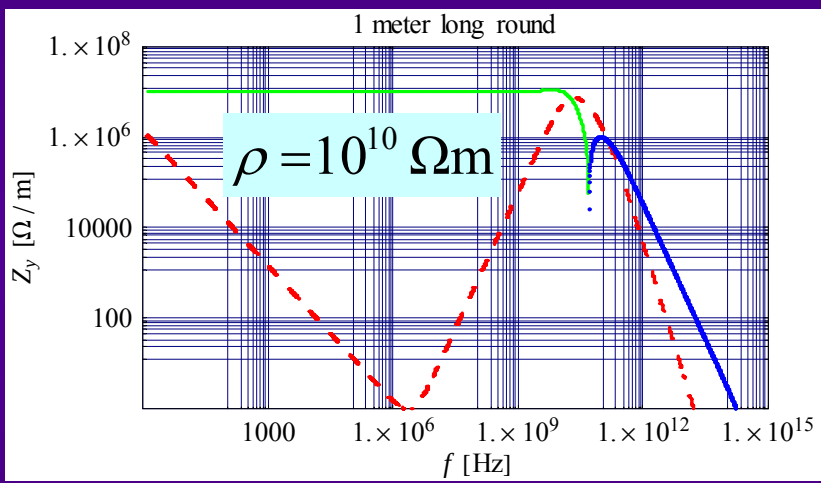
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$1.\times10^{6}$
10000
100
Z_y [Ω / m]
$\rho = 10^{10}$ Ωm
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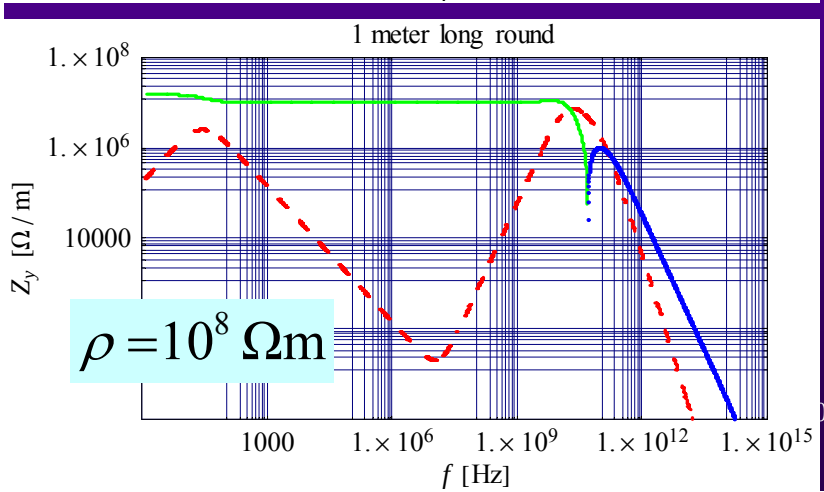
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$1.\times10^{6}$
10000
Z_y [Ω / m]
$\rho = 10^{8}$ Ωm
1000
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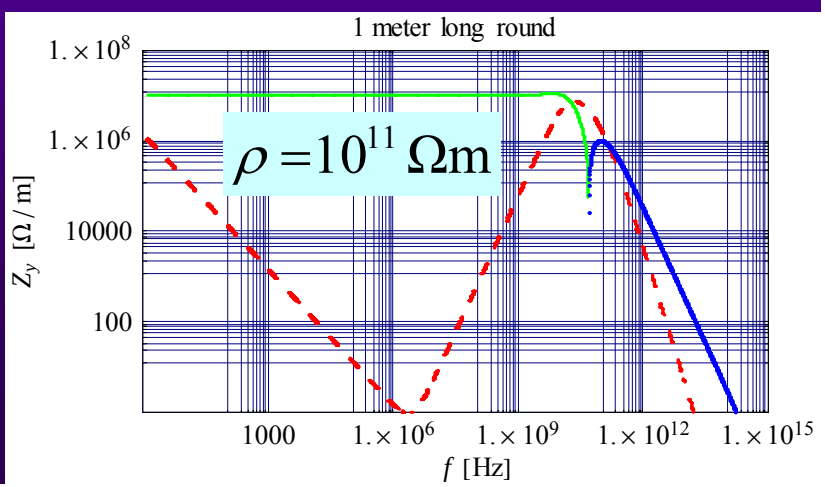
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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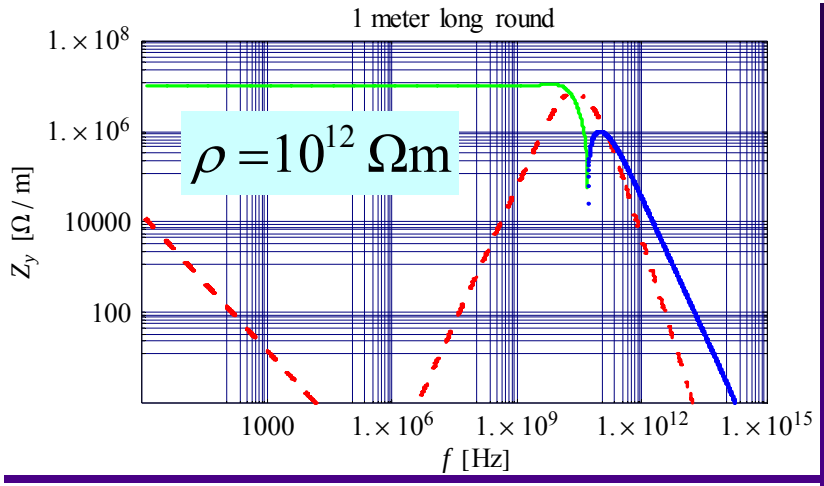
100
Z_y [Ω / m]
$\rho = 10^{11}$ Ωm
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]


1 meter long round
$\rho = 10^{12}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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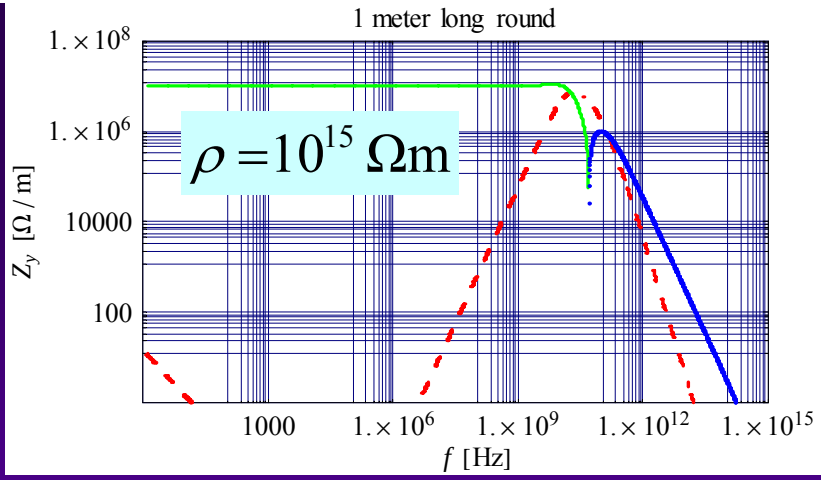
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]


1 meter long round
$\rho = 10^{15}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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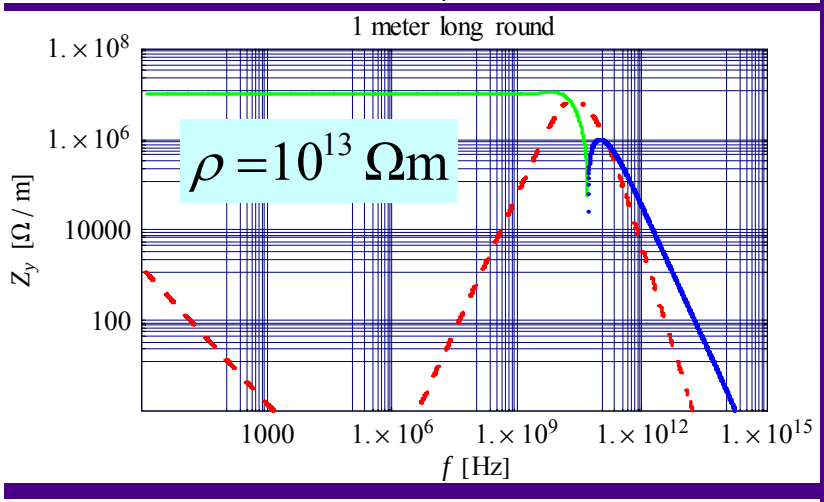
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]


1 meter long round
$\rho = 10^{13}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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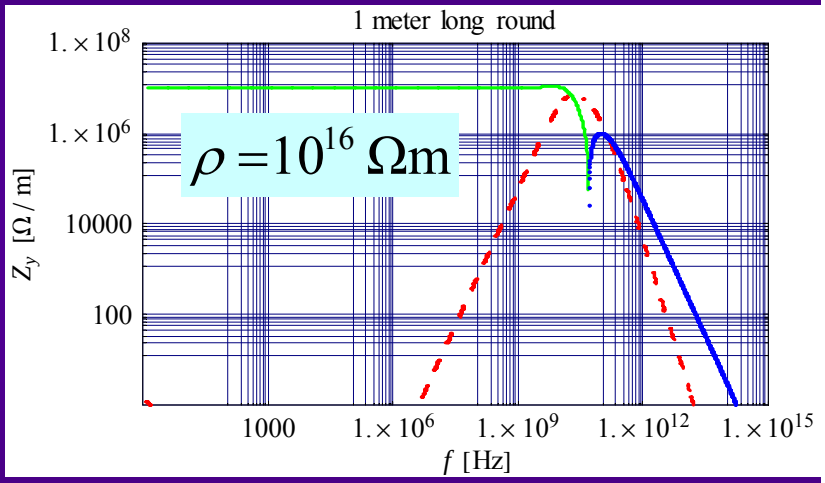
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$\rho = 10^{16}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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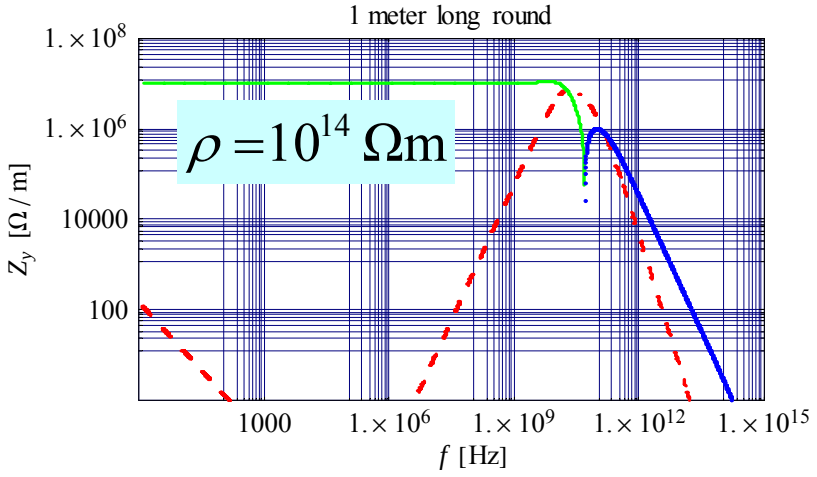
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]


1 meter long round
$\rho = 10^{14}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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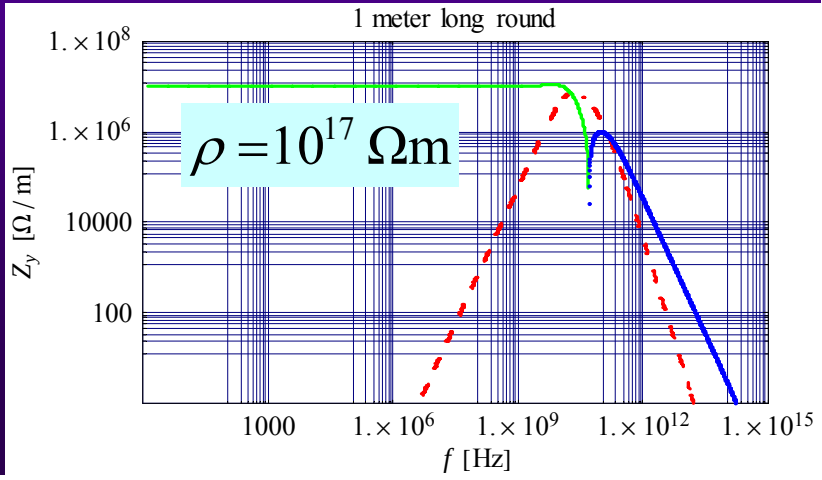
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$\rho = 10^{17}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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$1.\times10^{6}$
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100
1000
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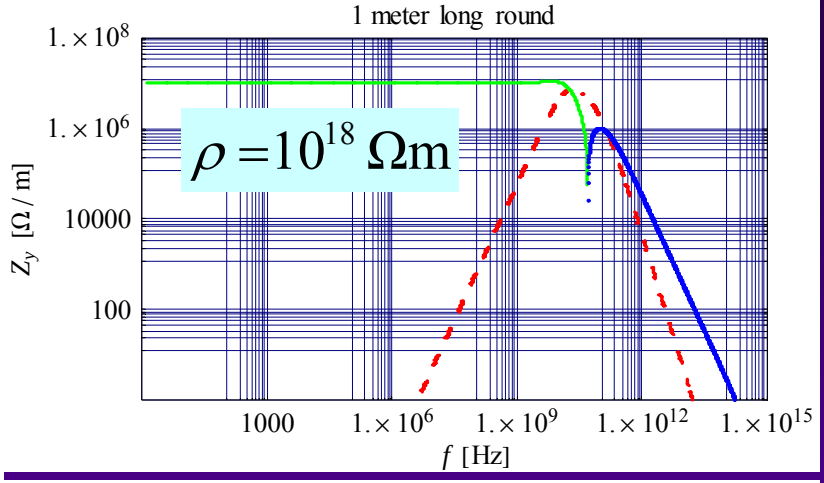
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$\rho = 10^{18}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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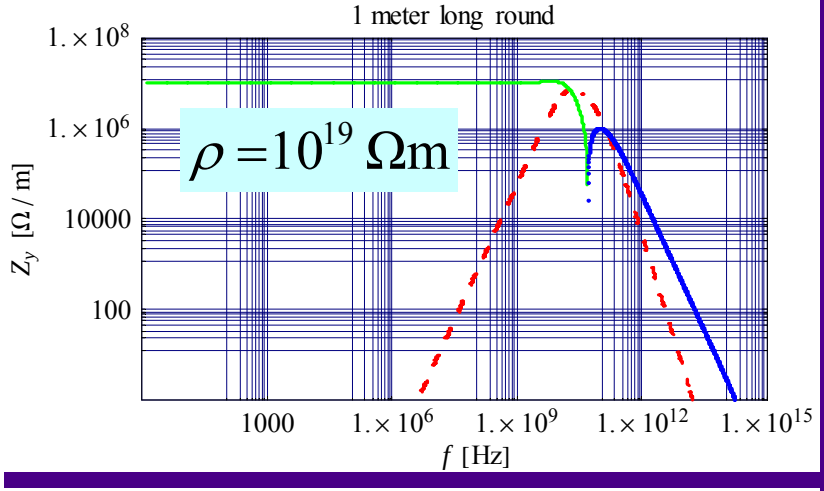
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]


1 meter long round
$\rho = 10^{19}\ \Omega\mathrm{m}$
Z_y [Ω / m]
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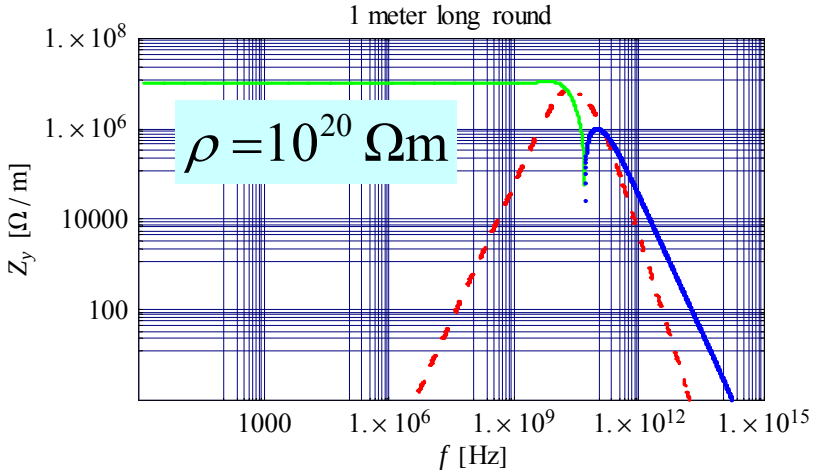
$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]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$1.\times10^{6}$
10000
100
1000
$1.\times10^{6}$
$1.\times10^{9}$
$1.\times10^{12}$
$1.\times10^{15}$
f [Hz]

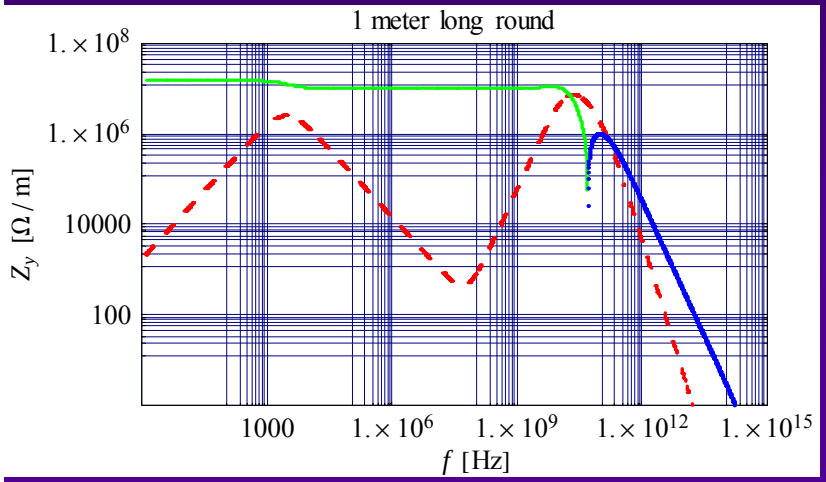
(6/10)

STUDIES ONGOING FOR A CERAMIC COLLIMATOR (7/10)

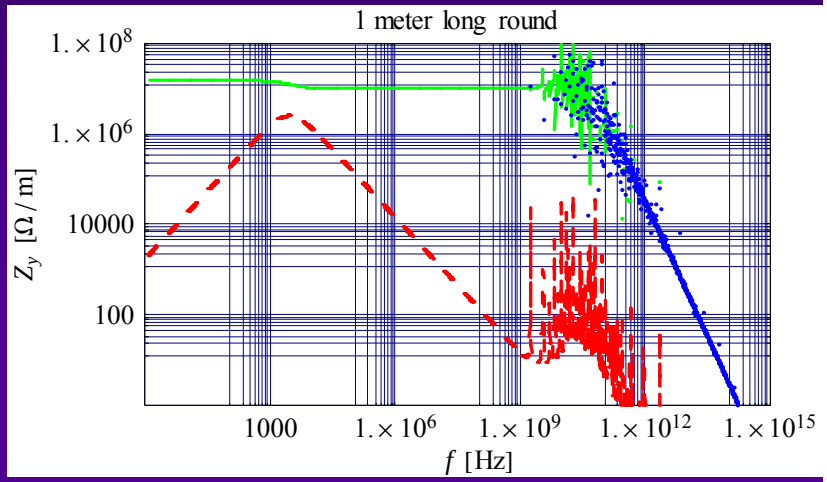
1 layer of infinite thickness

$$\rho = 10^6\ \Omega\text{m}$$

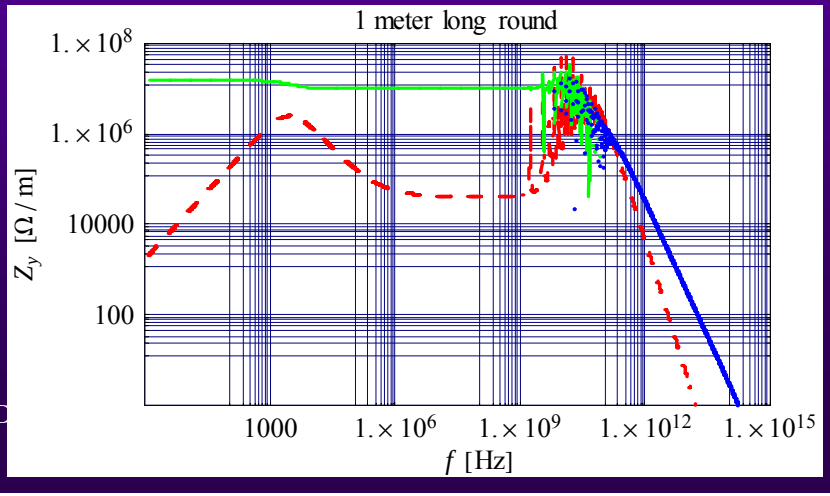
1 layer of thickness 2.5 cm and then Perfect Conductor



$$\varepsilon_r = 5$$



1 layer of thickness 2.5 cm and then Perfect Conductor + $\varepsilon_r = 5\times\left[1 - j\tan\left(0.01\right)\right]$



Lossy dielectric

STUDIES ONGOING FOR A CERAMIC COLLIMATOR (8/10)

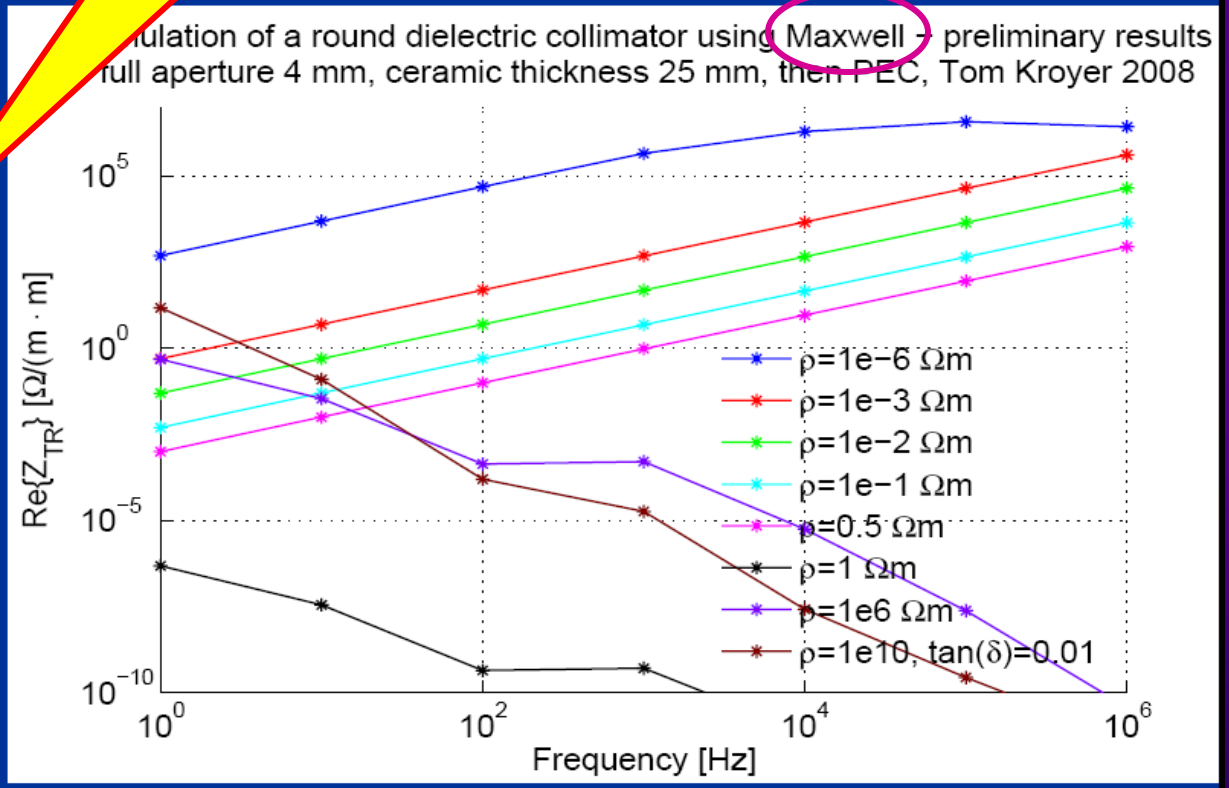
SIMULATIONS

Dielectric collimator - Results

Typo ⟹ "below"

Typo ⟹ "above"

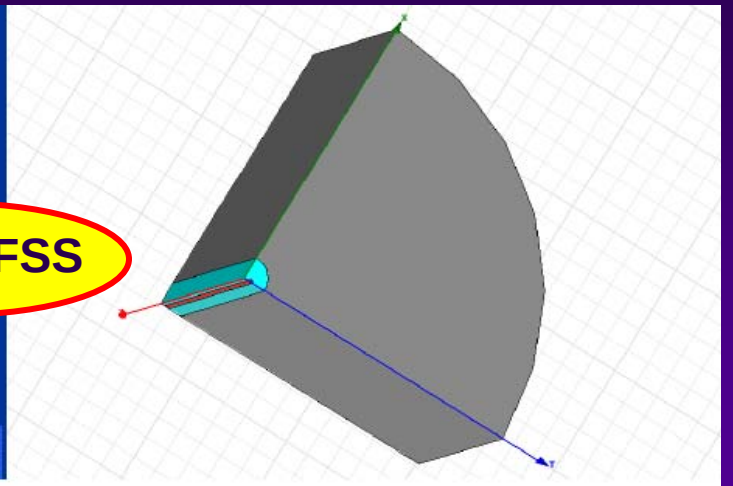
- Data for resistivities above 1 Ohm*m in agreement with Elias' calculations
- For resistivities below 1 Ohm*m no reasonable results obtained so far



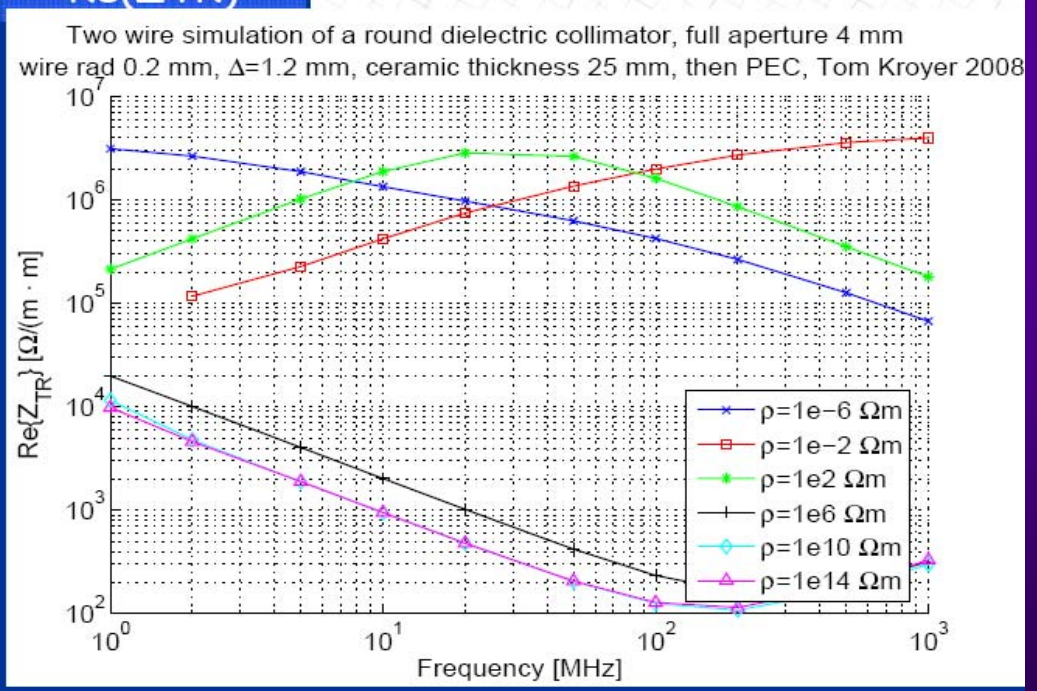
Dielectric collimator – HF Results

- Scan over resistivities rho=1e-6 to 1e14 Ohm*m
- Rotational symmetry, full beam aperture: 4 mm, dielectric thickness 23 mm, then PEC, eps_r=5, two wires with 0.4 mm diameter, spaced by 1.2 mm, structure length 5 mm
- Very good agreement with analytical results from Elias found up to 1e6 Ohm*m
- The peak at ~20 MHz for rho=1e2 Ohm*m was confirmed
- For higher resistivities (rho >= 1e10 Ohm*m) convergence not very good

With HFSS

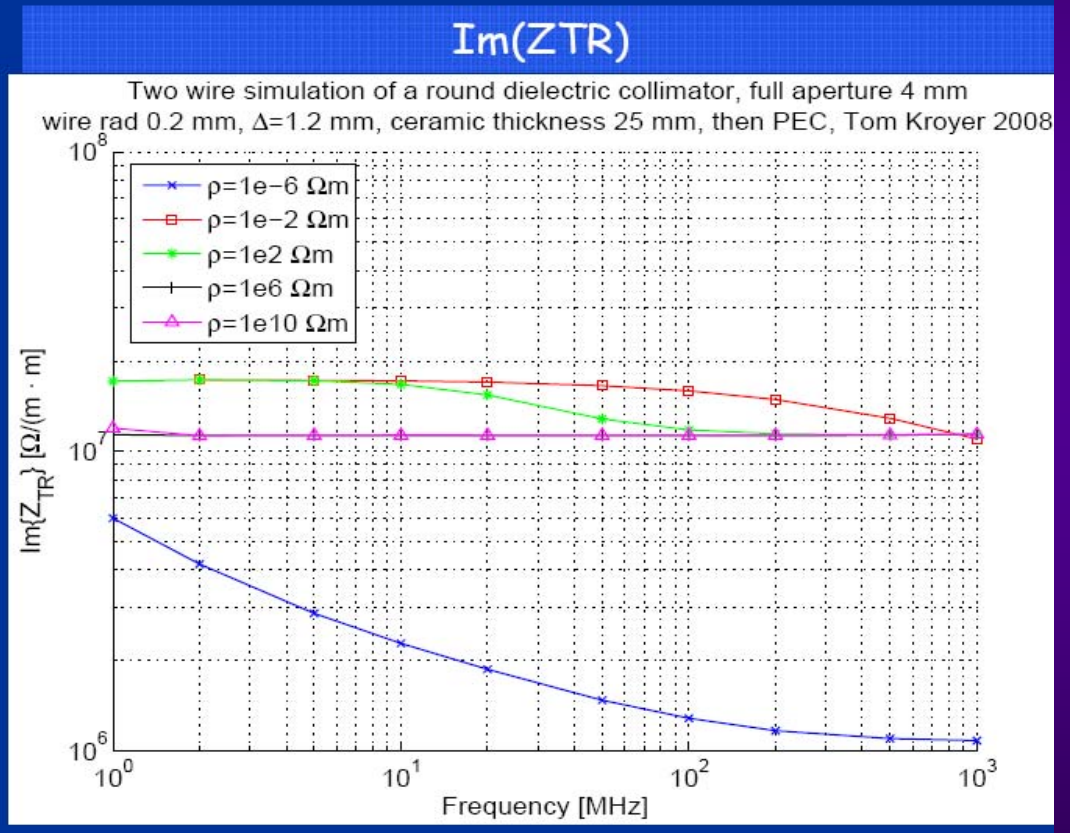


Re(ZTR)

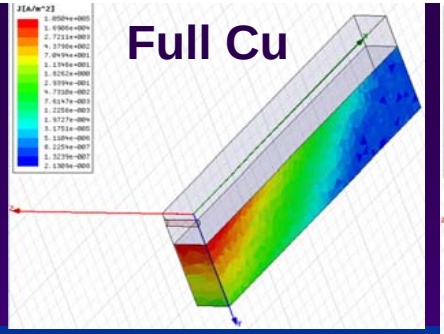


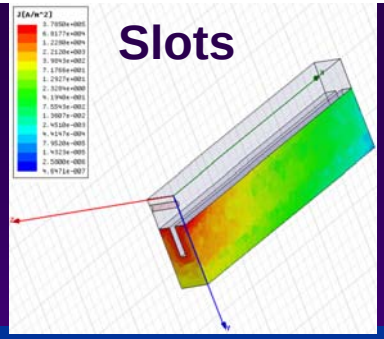
Dielectric collimator – HF Results

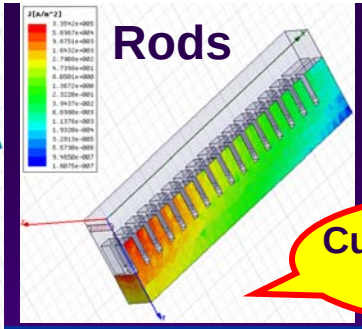
- The imaginary part of the transverse impedance also agrees well with the analytic results, except for rho=1e6 Ohm*m.



NEWS ABOUT COLLIMATOR WITH SLOTS & RODS



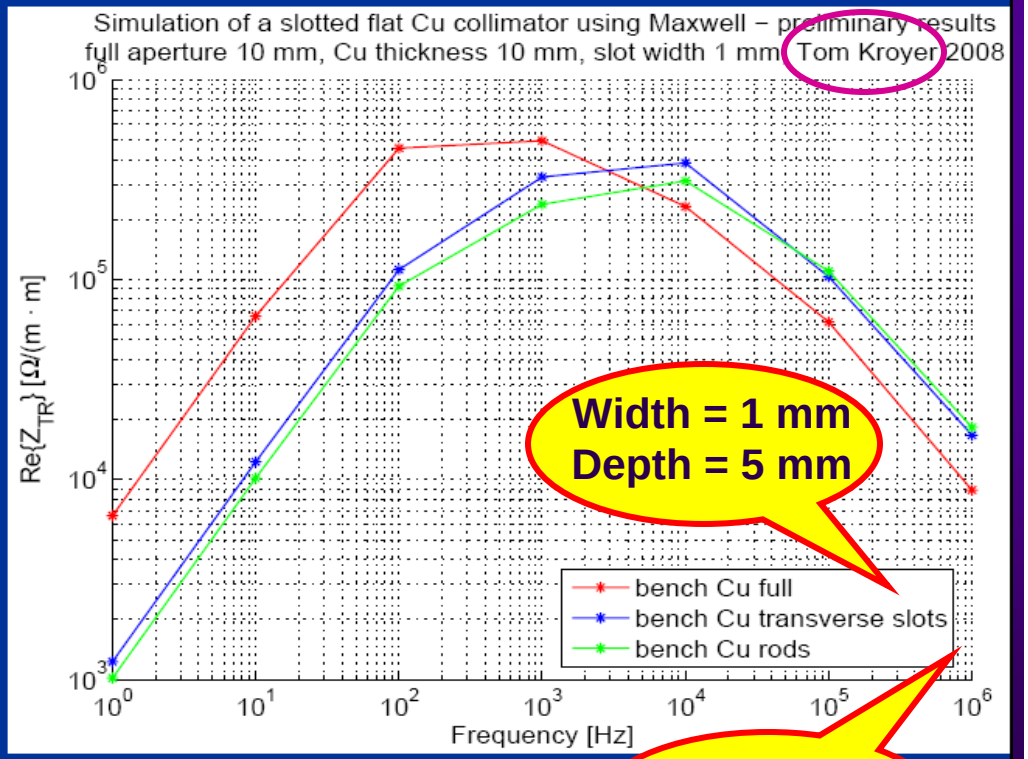




Current density at 10 kHz

Collimator with slots and rods - ZTR

- A full Cu collimator compared to 5 mm deep slots and 5 mm long rods.
- Slots and rods have about the same impedance
- At low frequencies (<3 kHz) Re(ZTR) of rods and slots is smaller than of a full copper jaw, because the currents are forced to flow farther from the surface
- At larger frequencies Re(ZTR) is larger due to the longer path the current have to follow. Im(ZTR) should be increased at all frequencies
- Rods and slots act similar as a material with larger resistivity



MEASUREMENTS (1/2)

- Preliminary measurements with the nail board ("planche a clous") from Fritz were performed by Benoit and Federico but no data are available yet (data stored on some disk only for the moment)

  $\Longrightarrow$ It seems that the nail board behaves as expected by Fritz (and Tom's simulations), i.e. acting as a bad conductor at low frequency and therefore having a smaller impedance at low frequency

MEASUREMENTS (2/2)

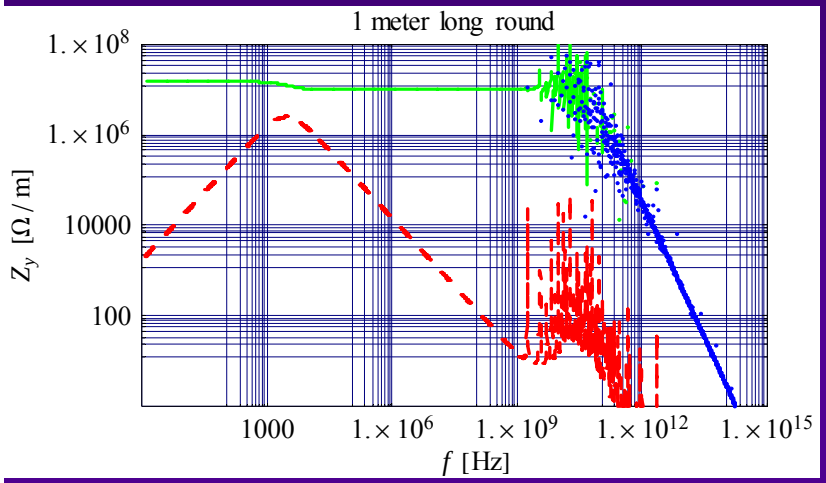
- **Wil Vollenberg brought us on 08/04/08 the following ceramics to be measured:**
  - **1) Silicon Carbide Target SiC**
  - **2) Ti519300 Titanium Diboride Target TiB2**
  - **3) SJ619300 Silicon Nitride Target Si3N4**
  - **4) B4C**

$\Longrightarrow$ We will measure them asap, with the current (coil) setup (even if it is believed that the measurement tool is certainly not the appropriate one… at least one should measure the same thing as predicted by MAXWELL's code!)

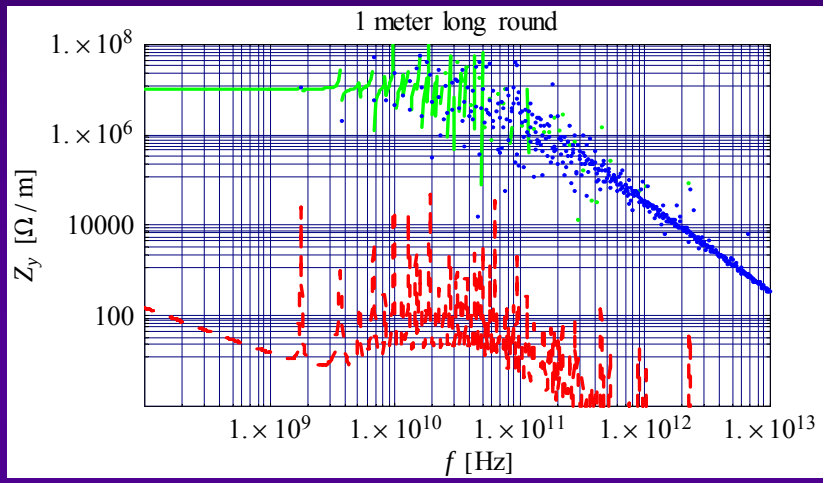
MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (1/6)

1 layer of thickness 2.5 cm and then Perfect Conductor (PC)

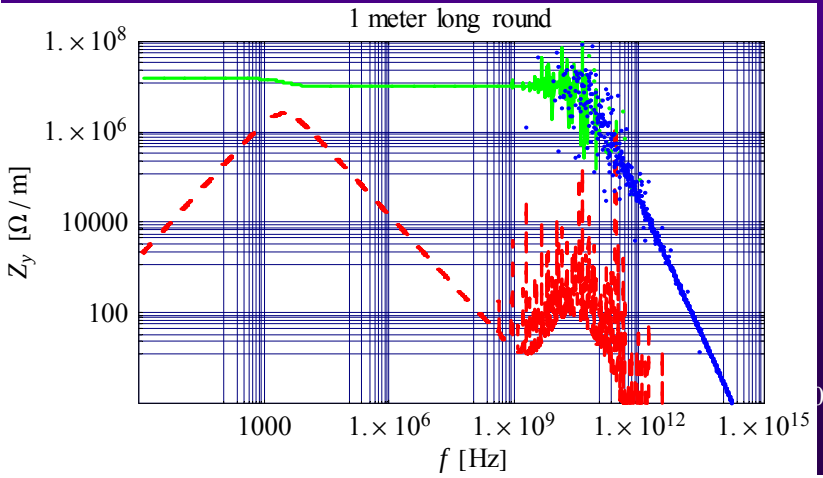
$\rho = 10^6\ \Omega\mathrm{m}$ $\varepsilon_r = 5$



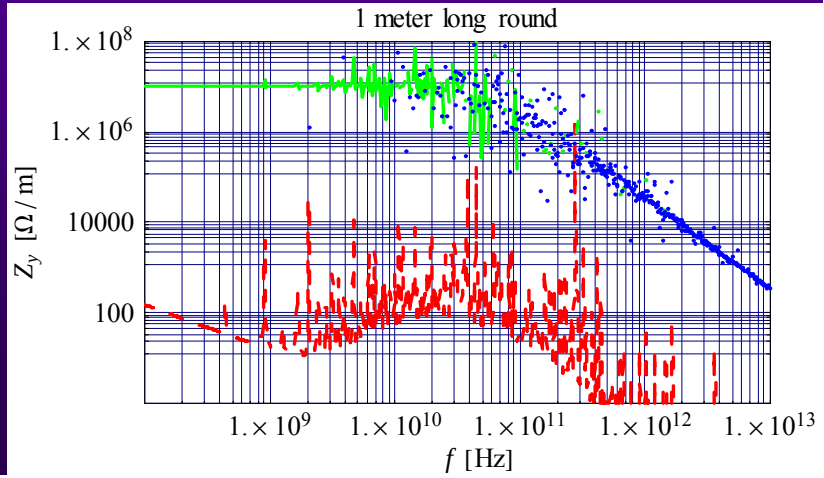
⟹ Zoom



1 layer of thickness 10 cm and then PC

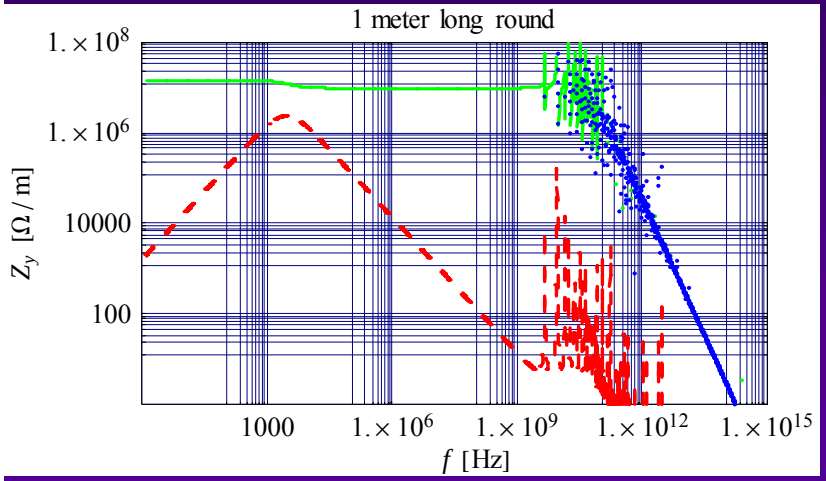


⟹ Zoom

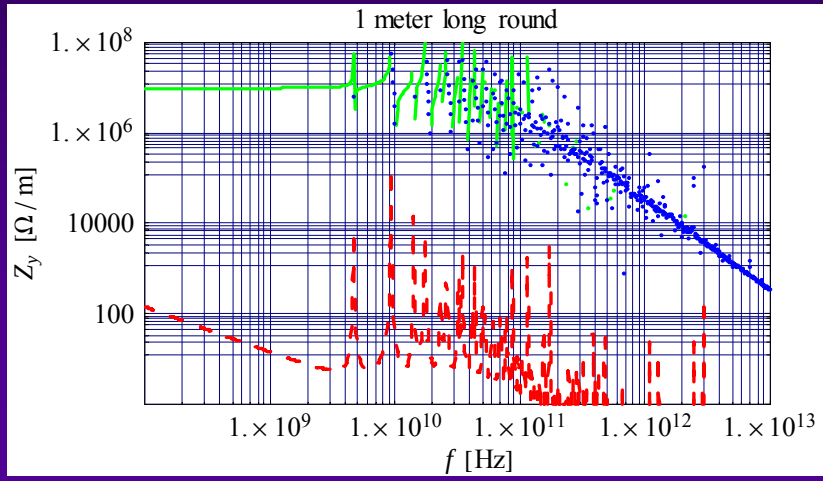


MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (2/6)

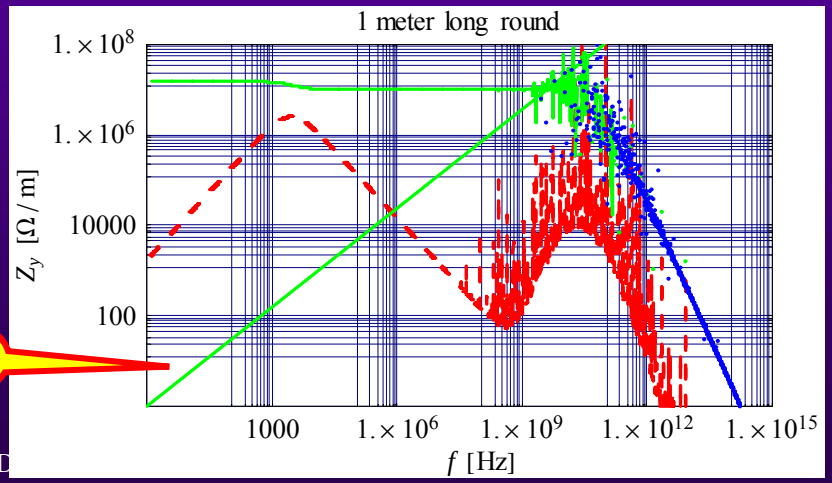
1 layer of thickness 1 cm and then PC



⟹ Zoom



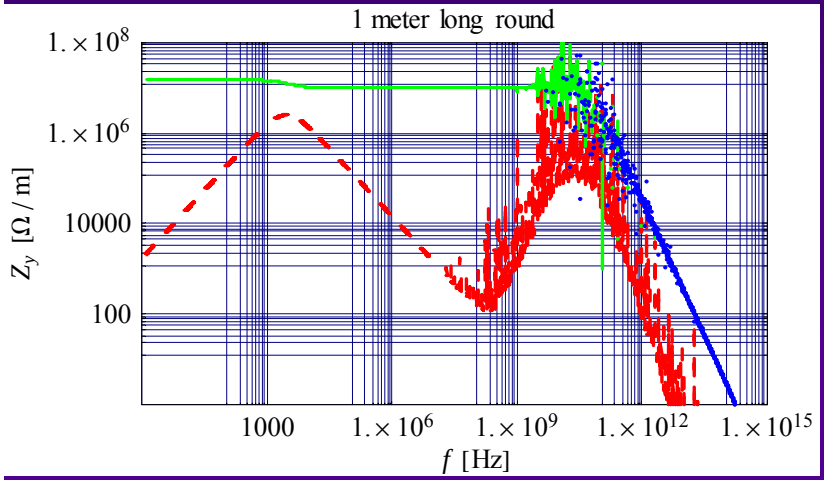
1 layer of thickness 10 m and then PC



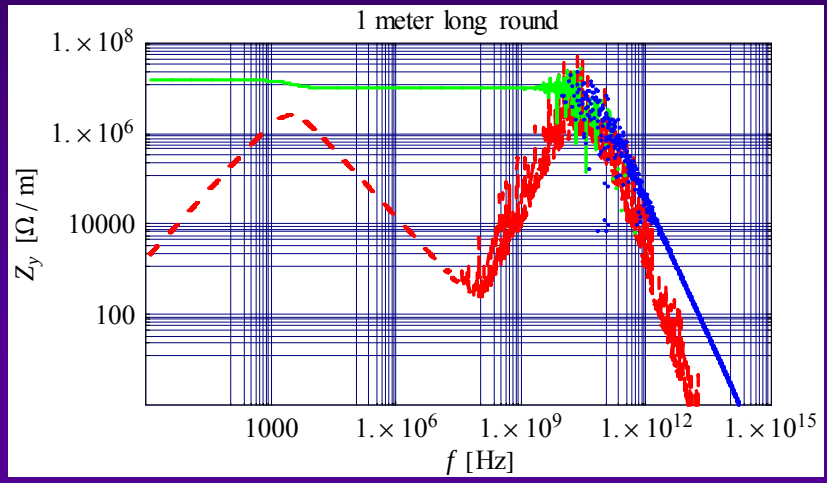
Strange!

MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (3/6)

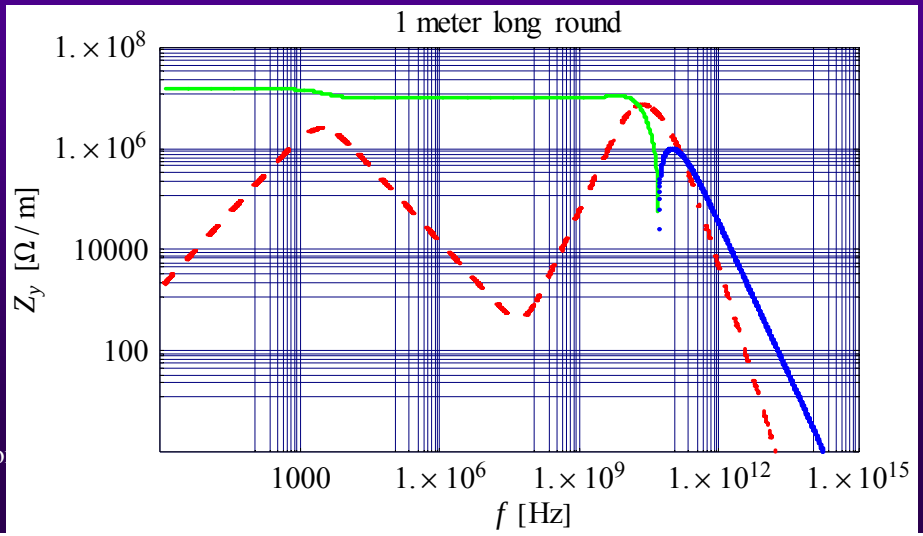
1 layer of thickness 100 m and then PC



1 layer of thickness 1000 m and then PC

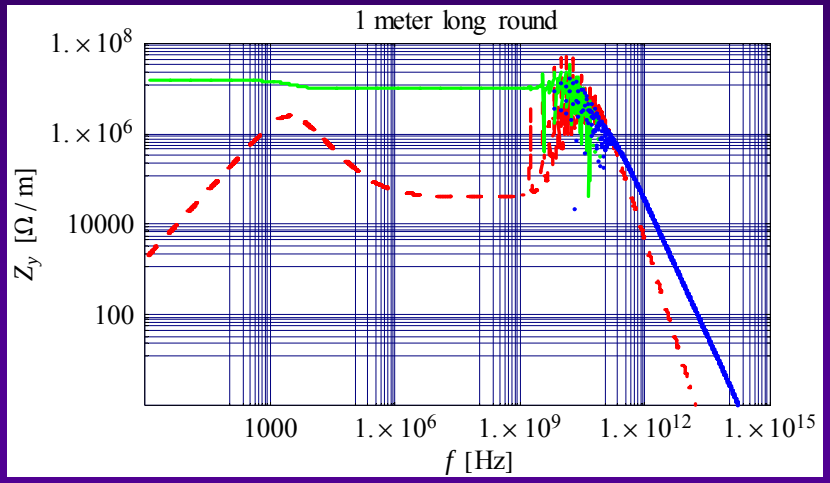


1 layer of thickness infinity



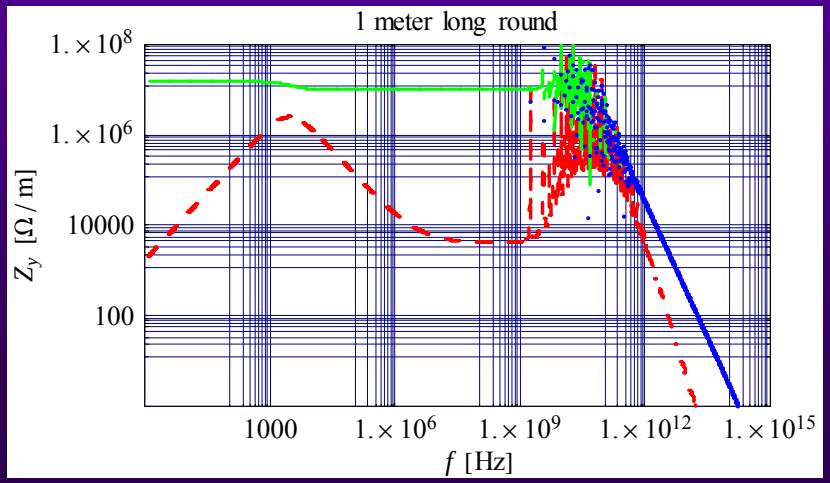
MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (4/6)

1 layer of thickness 2.5 cm and then Perfect Conductor + $\varepsilon_r = 5\times\left[1 - j\tan\left(0.01\right)\right]$

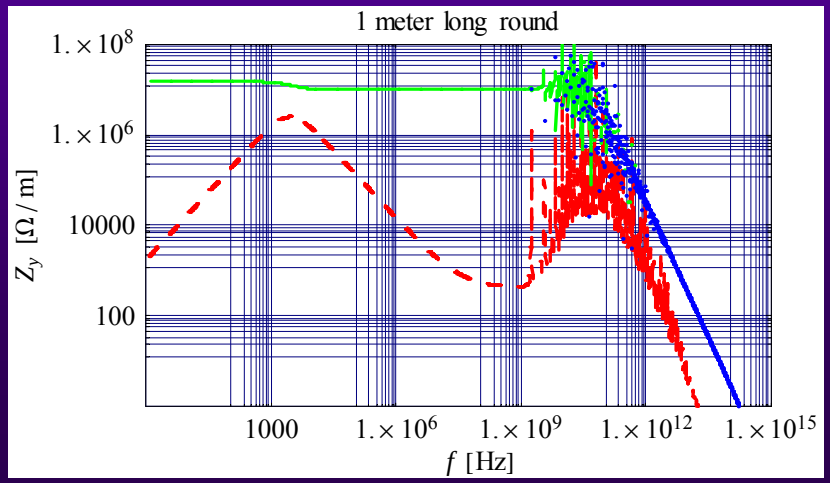


Lossy dielectric

$\varepsilon_r = 5\times\left[1 - j\tan\left(0.001\right)\right]$



$\varepsilon_r = 5\times\left[1 - j\tan\left(0.0001\right)\right]$

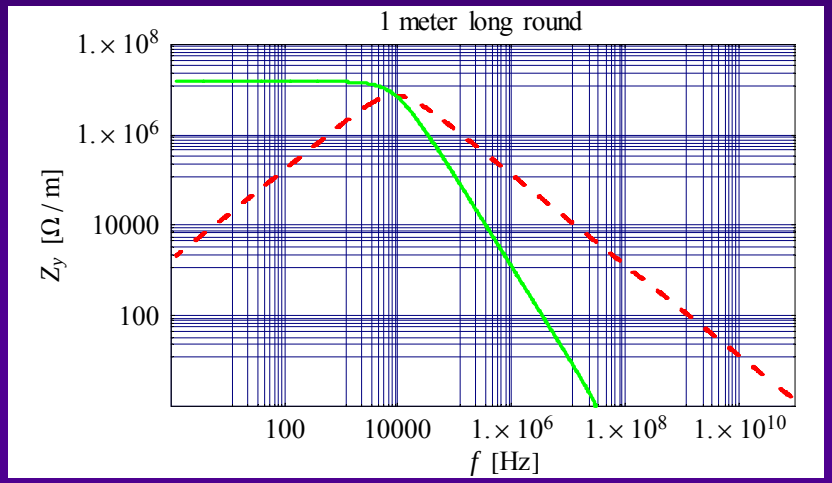


MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (5/6)

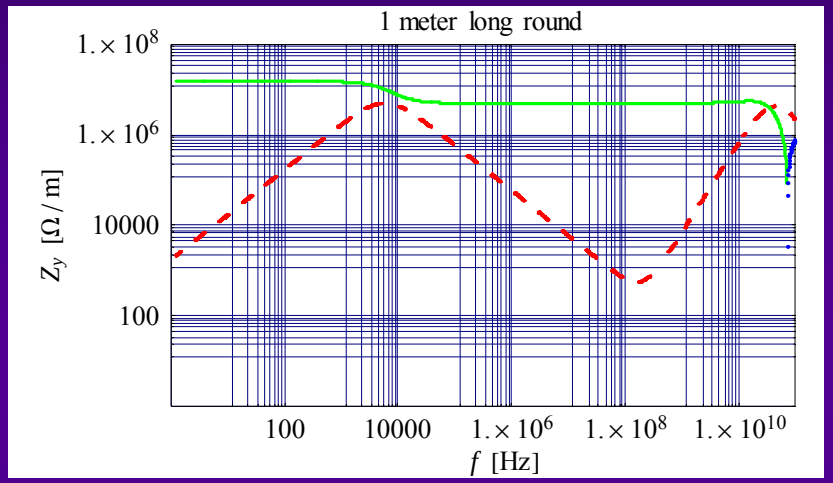
1 layer of thickness infinity

$\rho = 10^6\ \Omega\mathrm{m}$

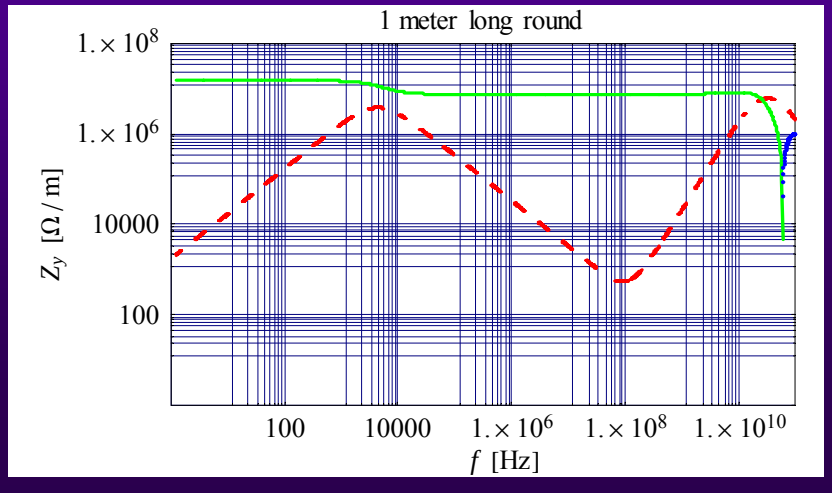
$\varepsilon_r = 1$



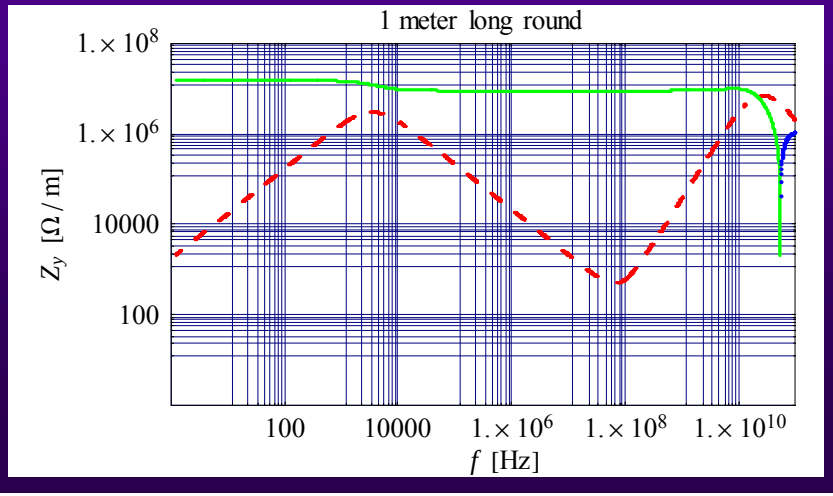
$\varepsilon_r = 2$



$\varepsilon_r = 3$



$\varepsilon_r = 4$

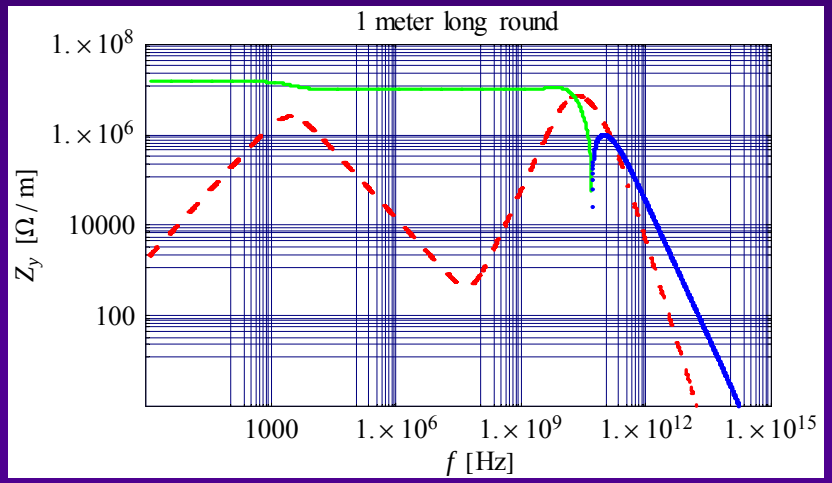


MORE DETAILED ANALYSIS OF THE THEORETICAL PREDICTIONS AT HIGH FREQUENCY (6/6)

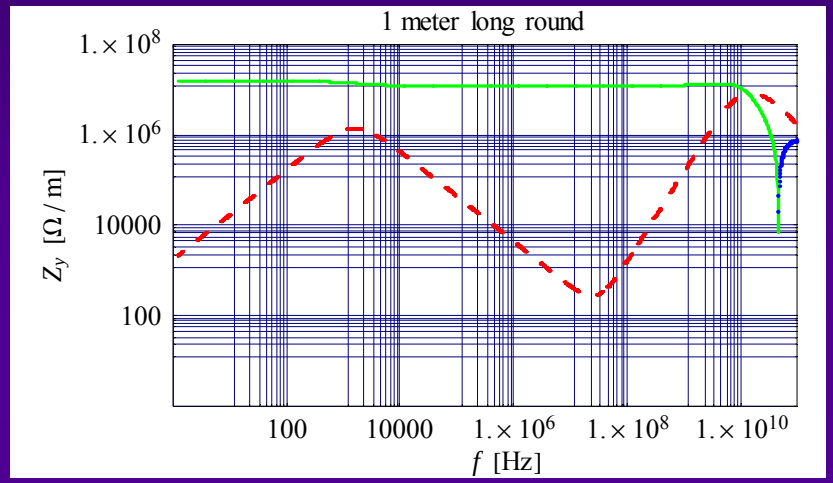
1 layer of thickness infinity

$\rho = 10^6\ \Omega\text{m}$

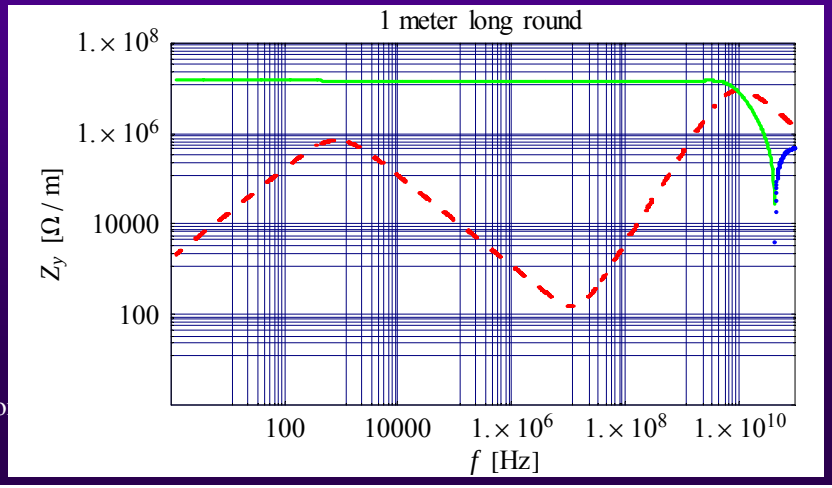
$\varepsilon_r = 5$



$\varepsilon_r = 10$



$\varepsilon_r = 20$



NEXT STEPS

- One will continue to check all these results (GdFidl simulations from Alexej etc.)
- Then, we will draw conclusions for the different materials which Gonzalo Arnau Izquierdo sent to us on 28/03/2008