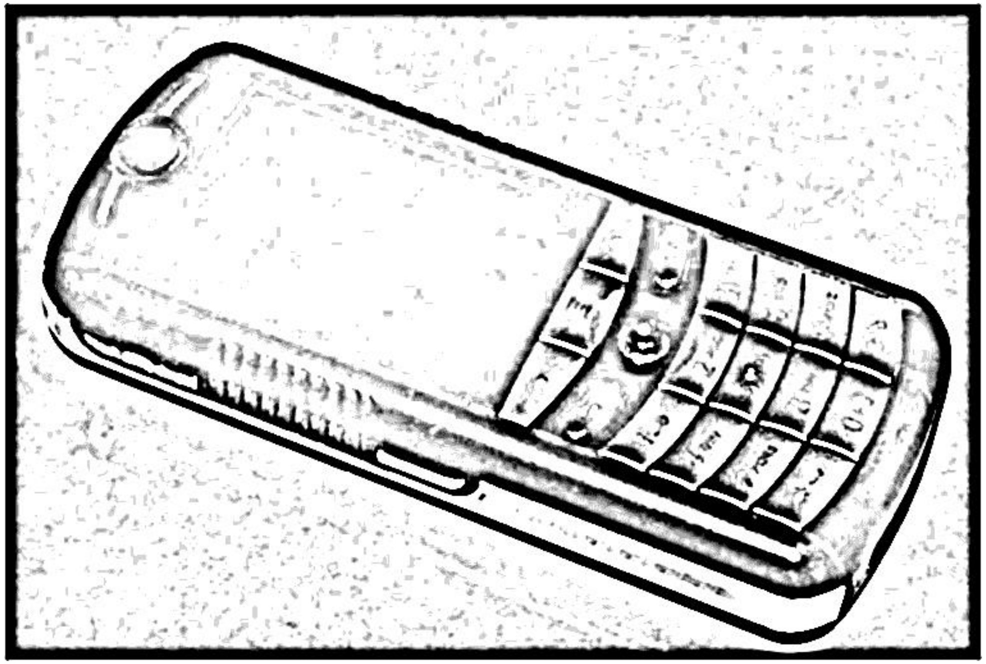
Problem “Resonating modes”

Presented by
Belarusian team

Resonating modes

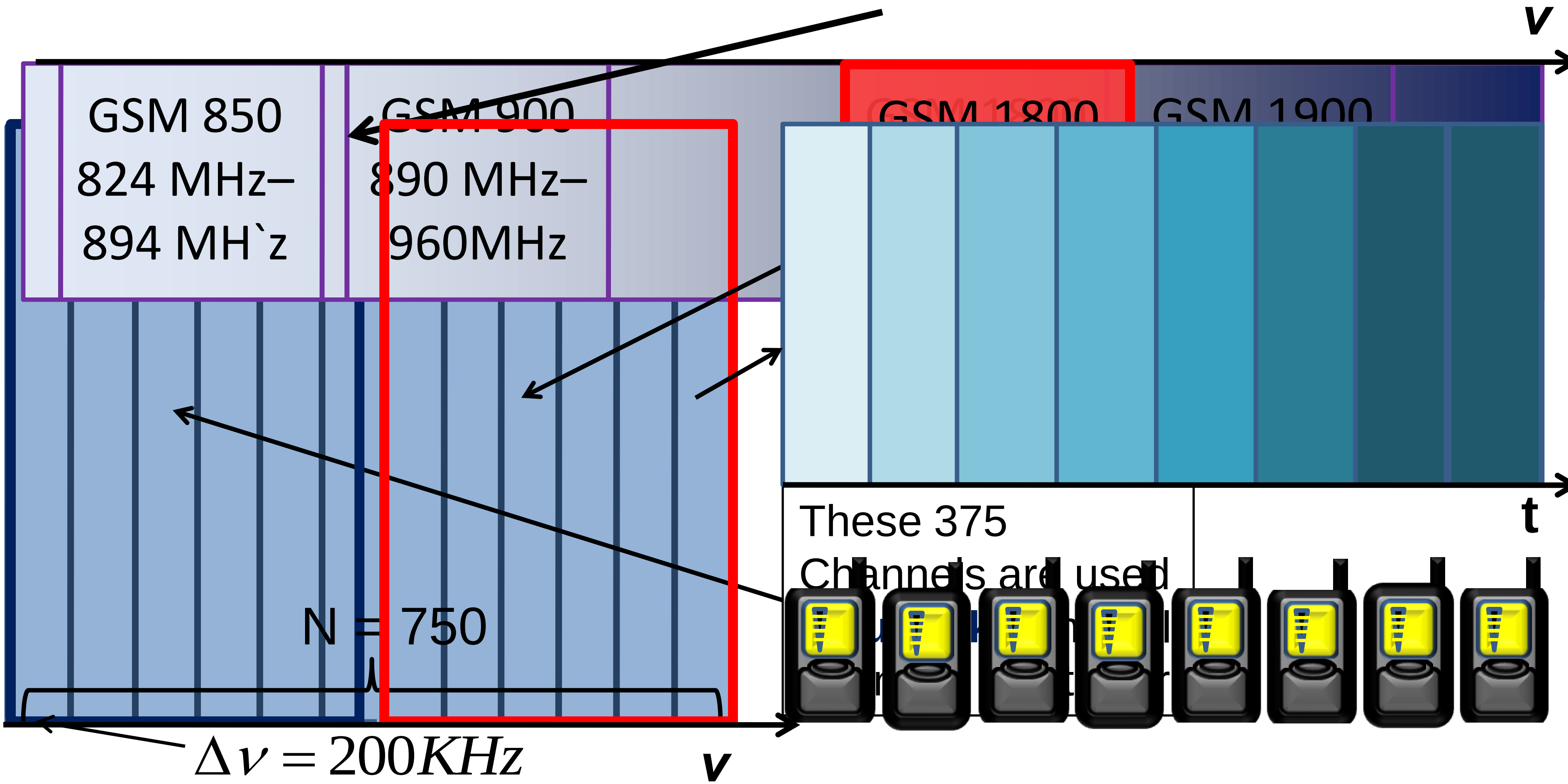
Place a mobile phone inside a metallic container with a hole in it. Investigate under what conditions the mobile phone starts to ring after calling it.



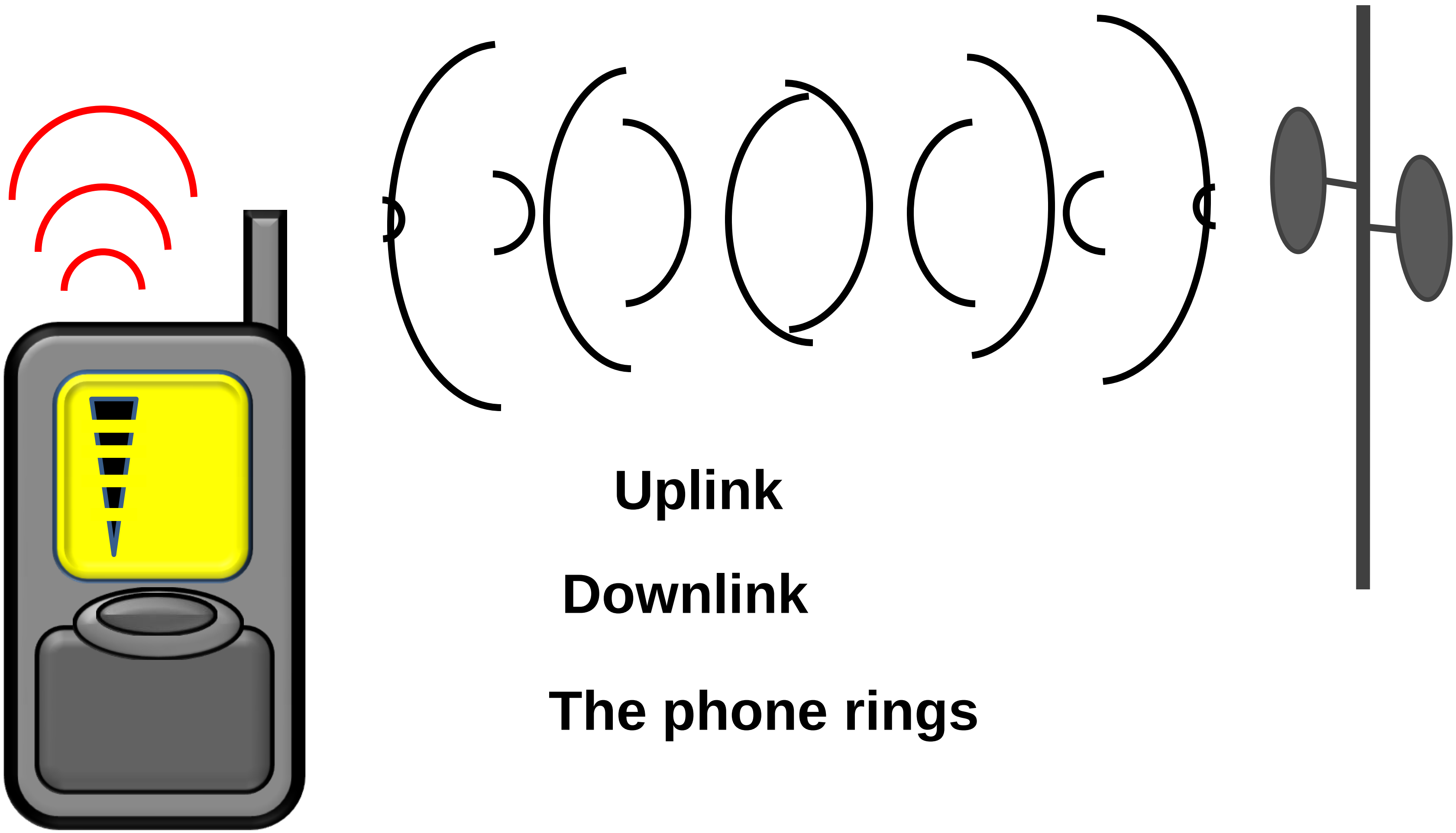
Plan of investigations:

1. To make clear the main principles of the mobile communications;
2. To make sure what the signal is, and what parameters it has.
3. To investigate, how the conducting metal border influences the electromagnetic wave;
4. To research the electromagnetic field in the boxes of some primitive shapes;
5. To find, on which conditions the hole lets the wave pass through.
6. To find the best conditions for the phone to ring.

Frequencies and standards



How does the phone ring?

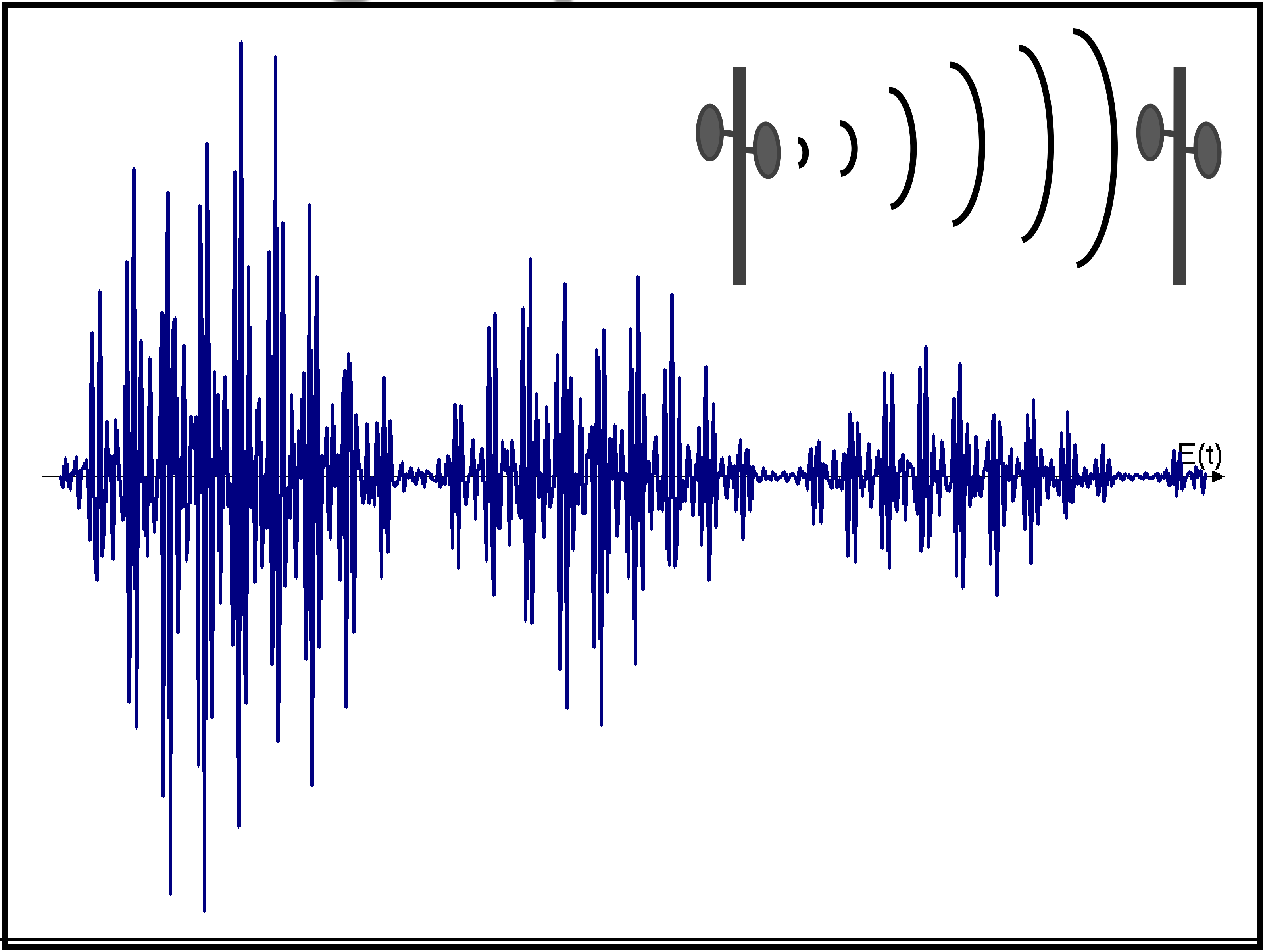


Uplink

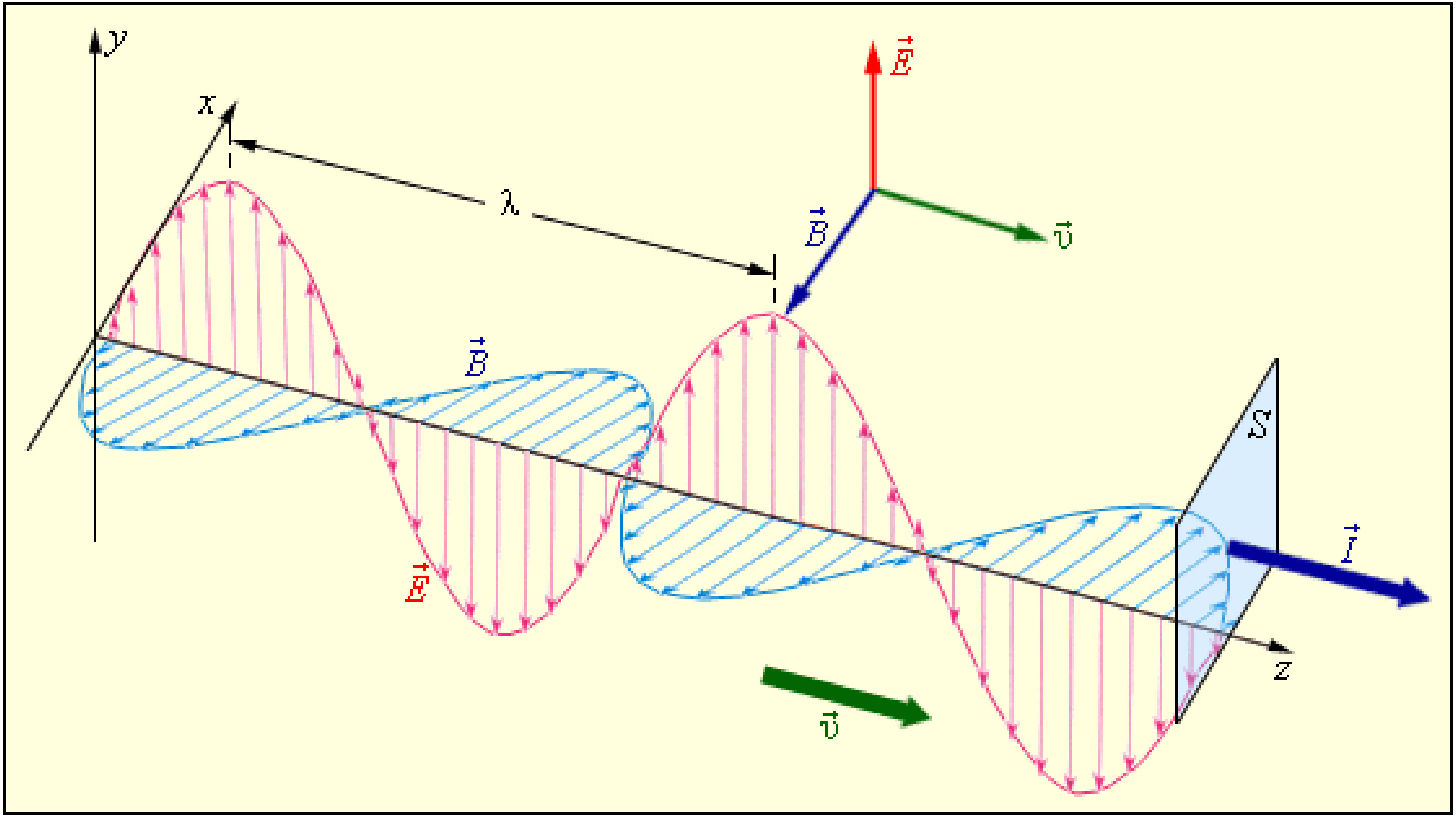
Downlink

The phone rings

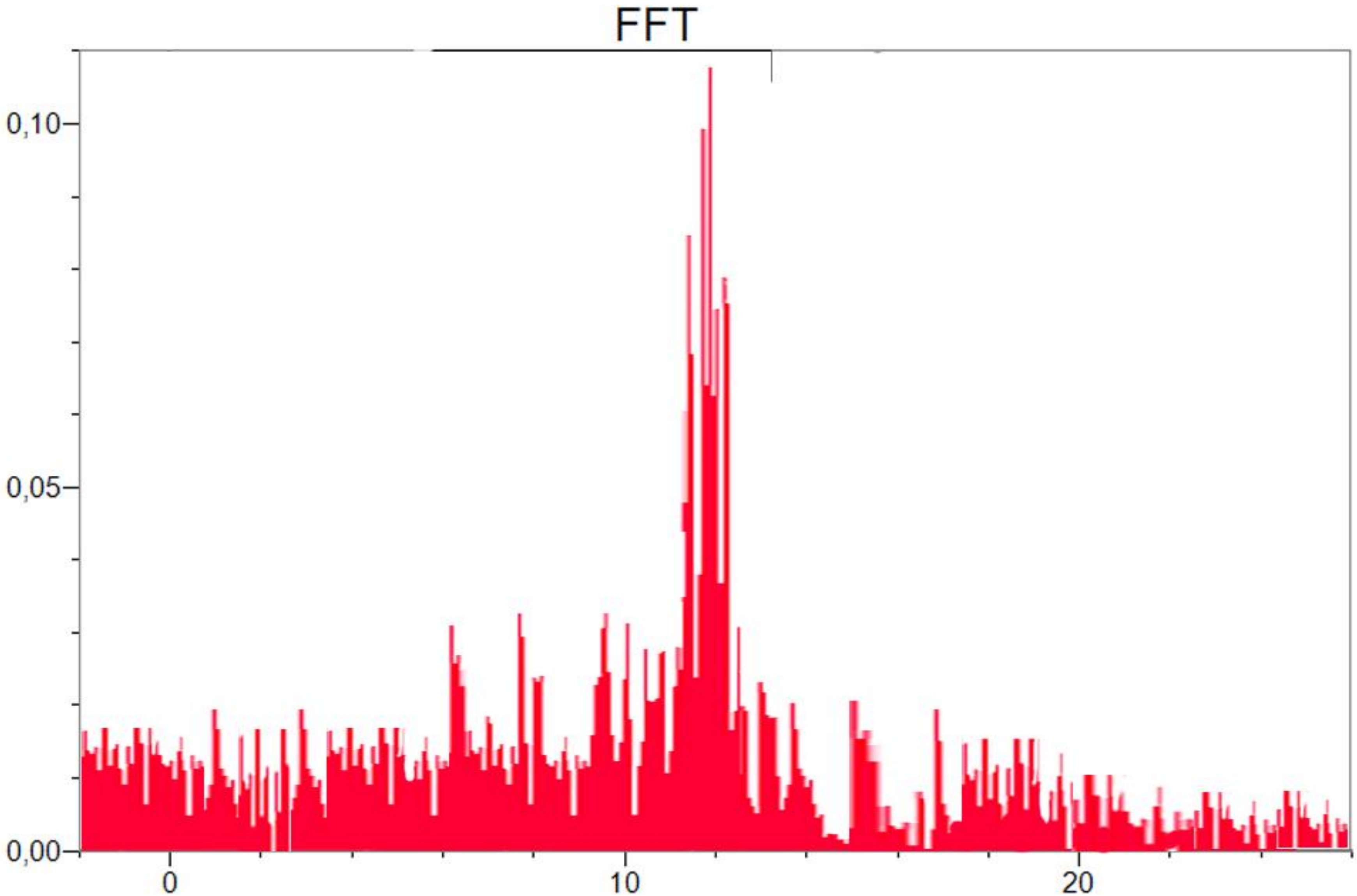
Signal parameters



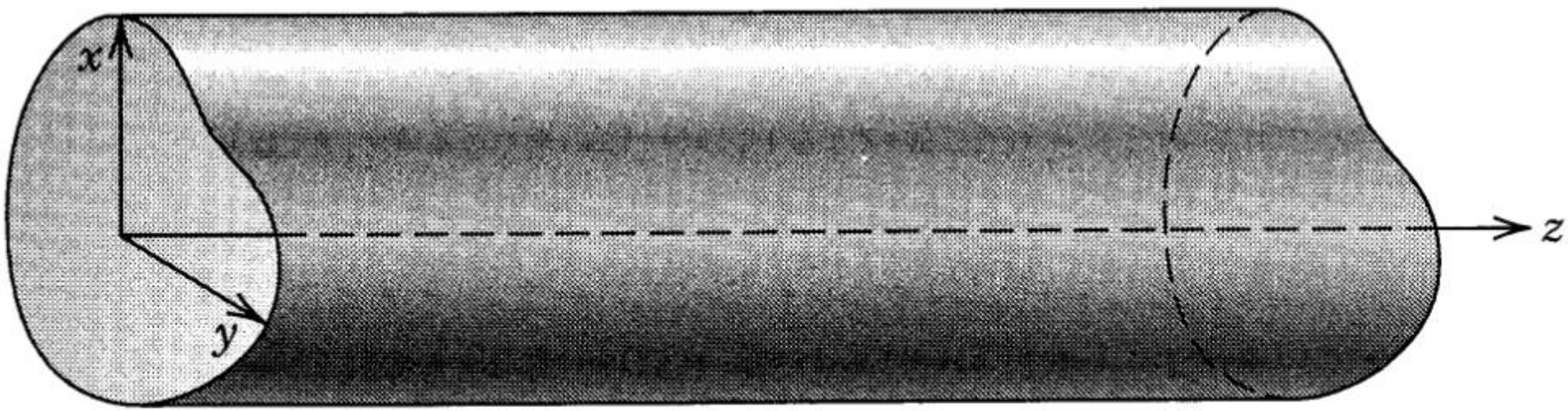
Amplitude, polarization & wavelength (frequency)



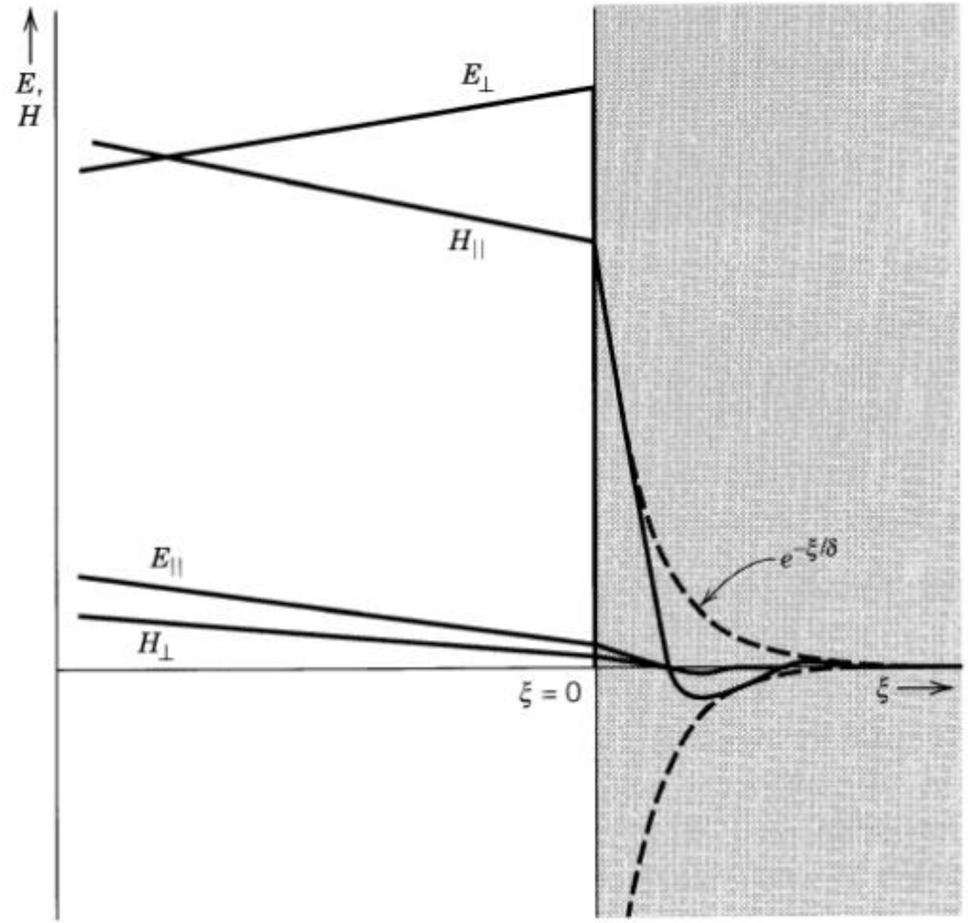
Timbre



Part 1:Electromagnetic wave reflection. Resonant Cavities.

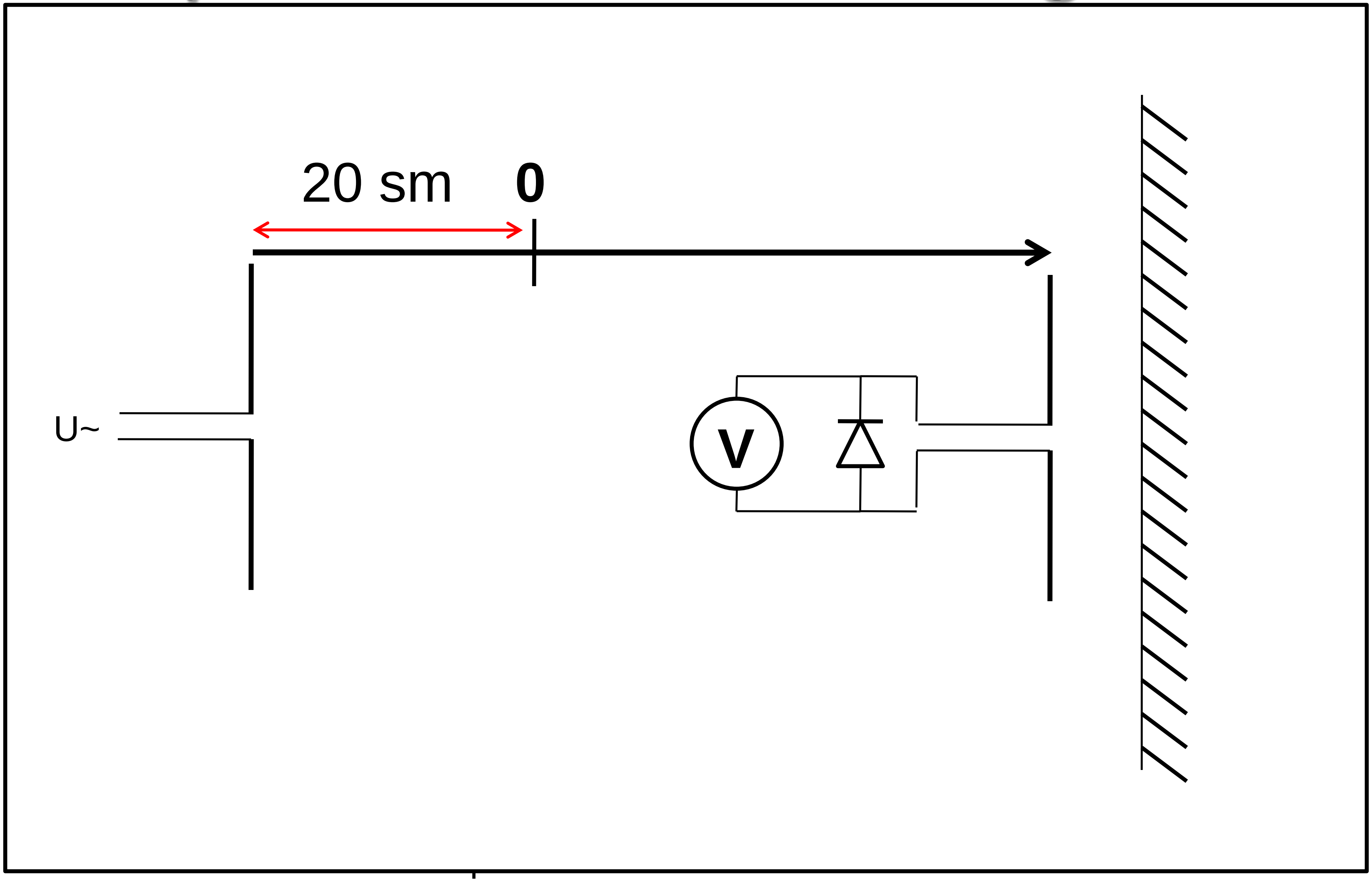


Electromagnetic fields at the Surface and Within a Conductor



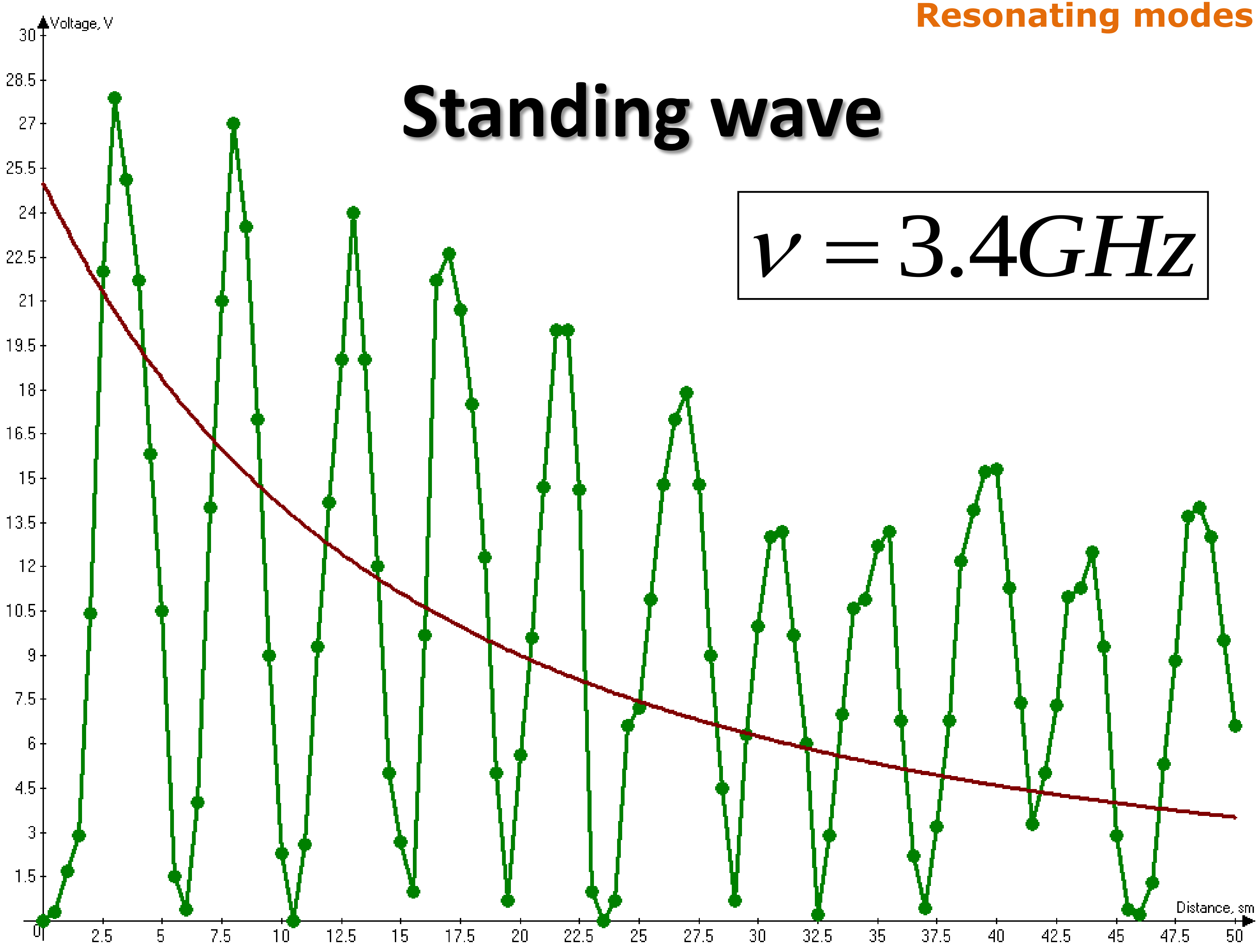
Fields near the surface of a good, but not perfect, conductor. For $\xi > 0$, the dashed curves show the envelope of the damped oscillations of $\mathbf{H}_c$ (8.9).

Experimental Unit 1:Standing wave

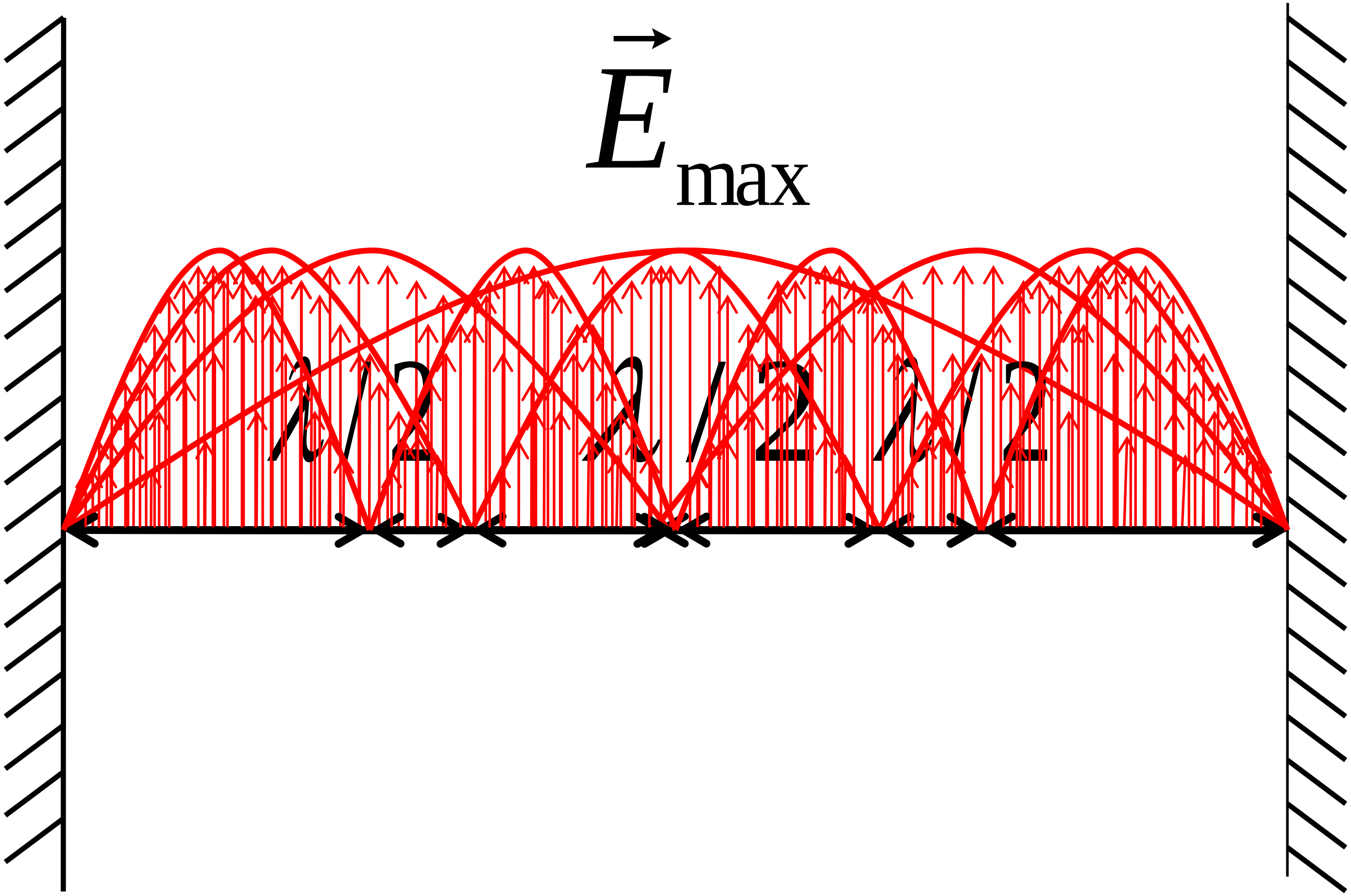


Standing wave

$$\nu = 3.4GHz$$

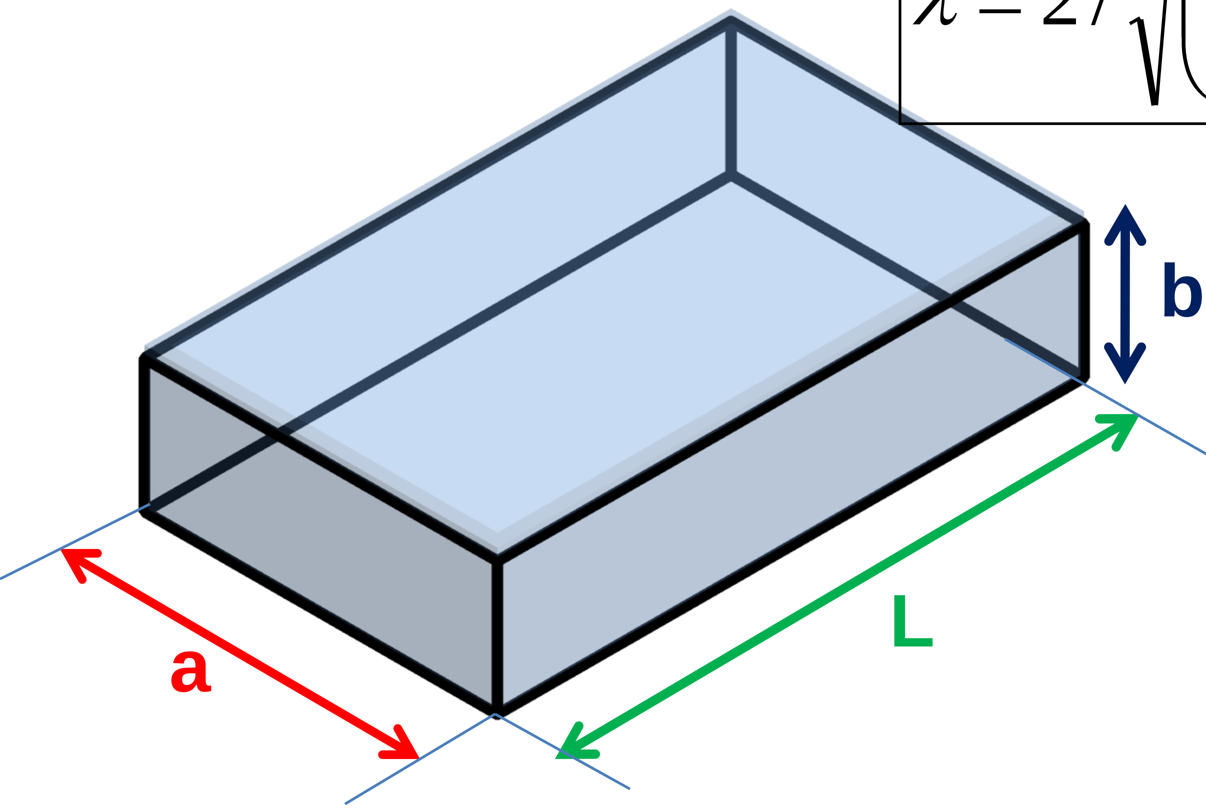


Resonant cavity

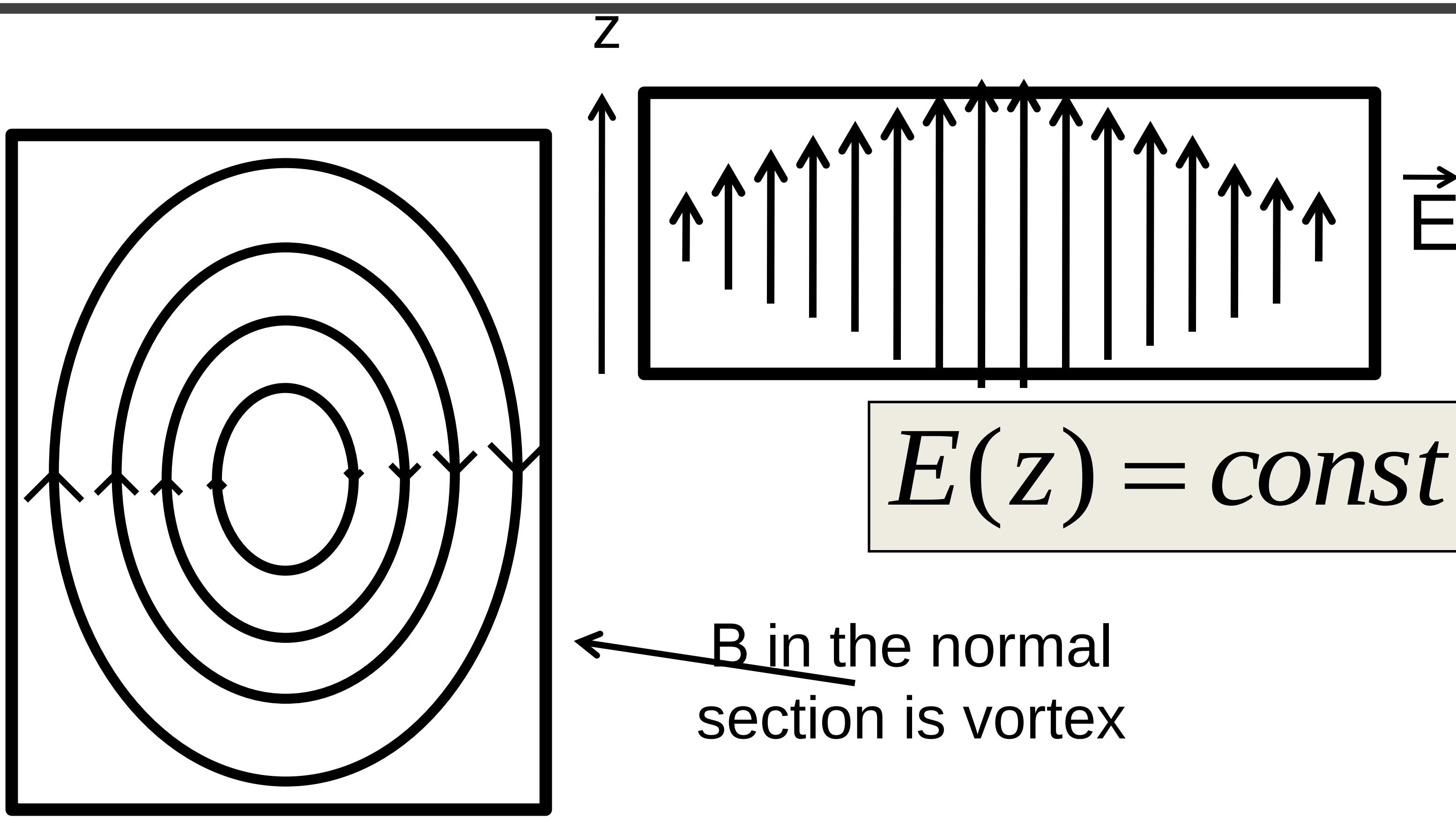


Square resonating cavity

$$\lambda = 2 / \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{L}\right)^2}$$



Field distribution



$$E(z) = const$$

B in the normal section is vortex

Experimental Unit 2. Square cavity

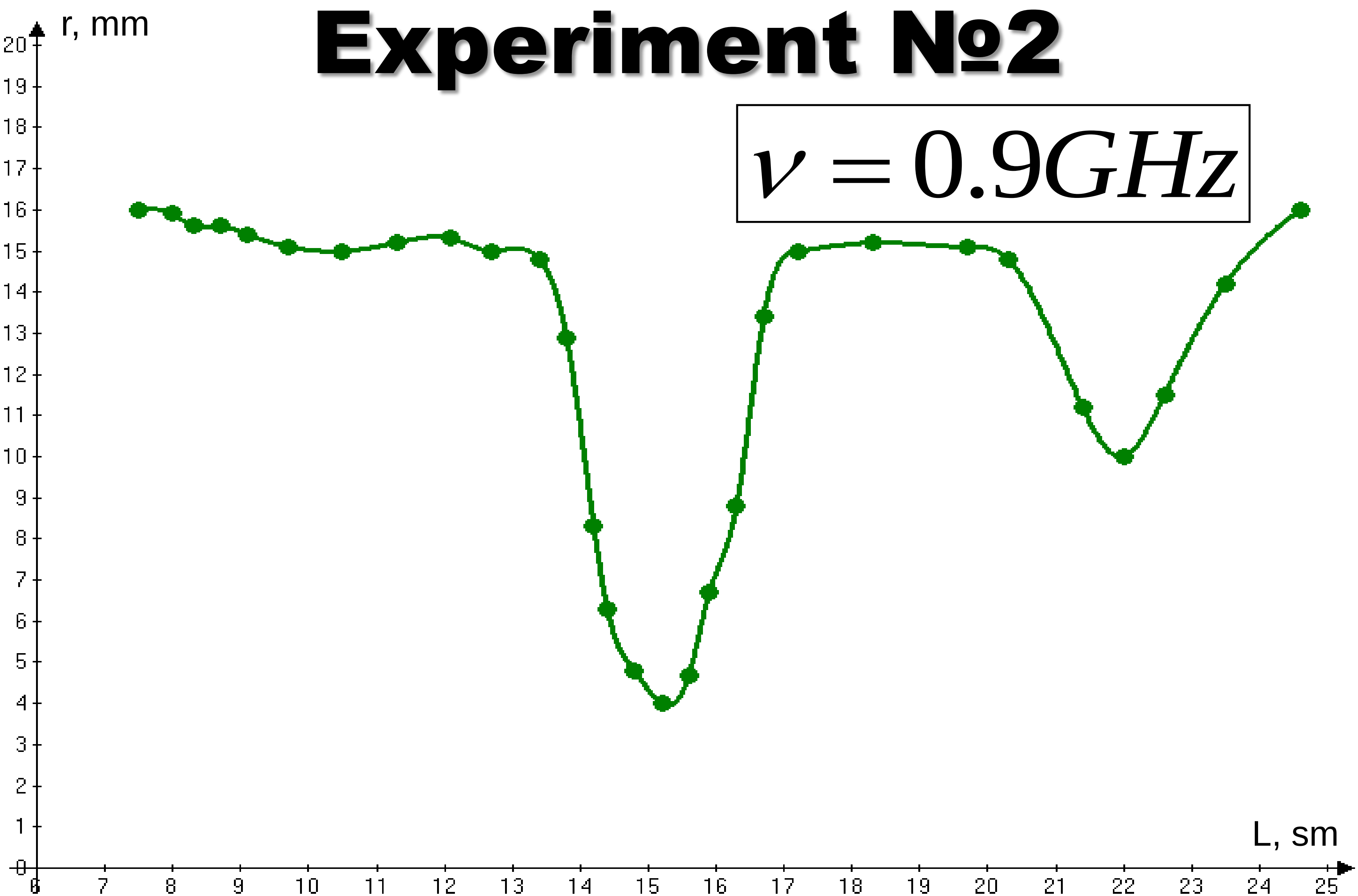
$$a = 6.5sm$$

$$b = 12sm$$

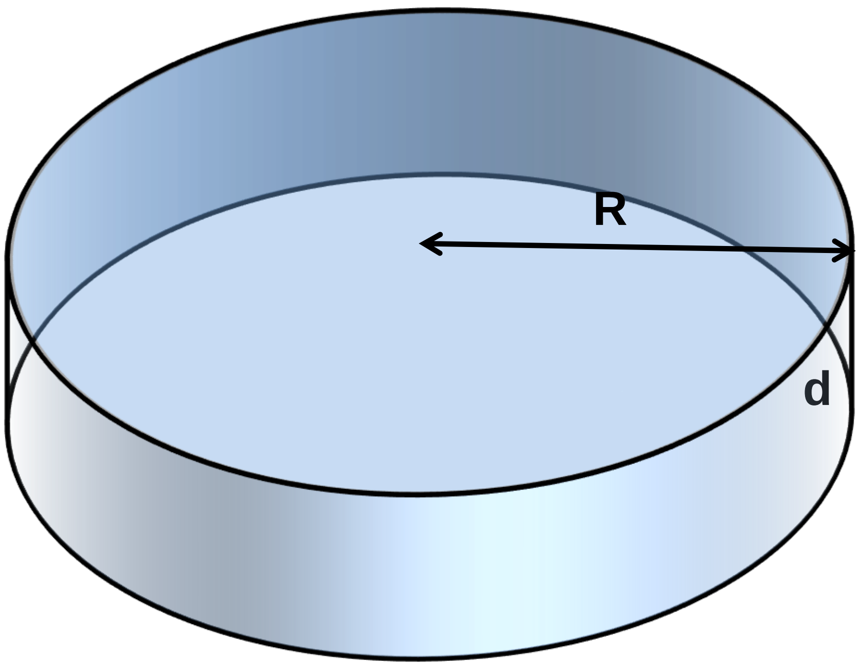
$$L_{\max} = 25sm$$

Experiment №2

$$\nu = 0.9GHz$$



Cylindrical resonating cavity 1



TM oscillations:

$$\omega_{mnp} = \frac{1 \cdot c}{\sqrt{\mu\varepsilon}} \sqrt{\frac{x^2{}_{mn}}{R^2} + \frac{p^2\pi^2}{d^2}}$$

x_{mn} is the nth root of the equation, $J_m(x) = 0$.

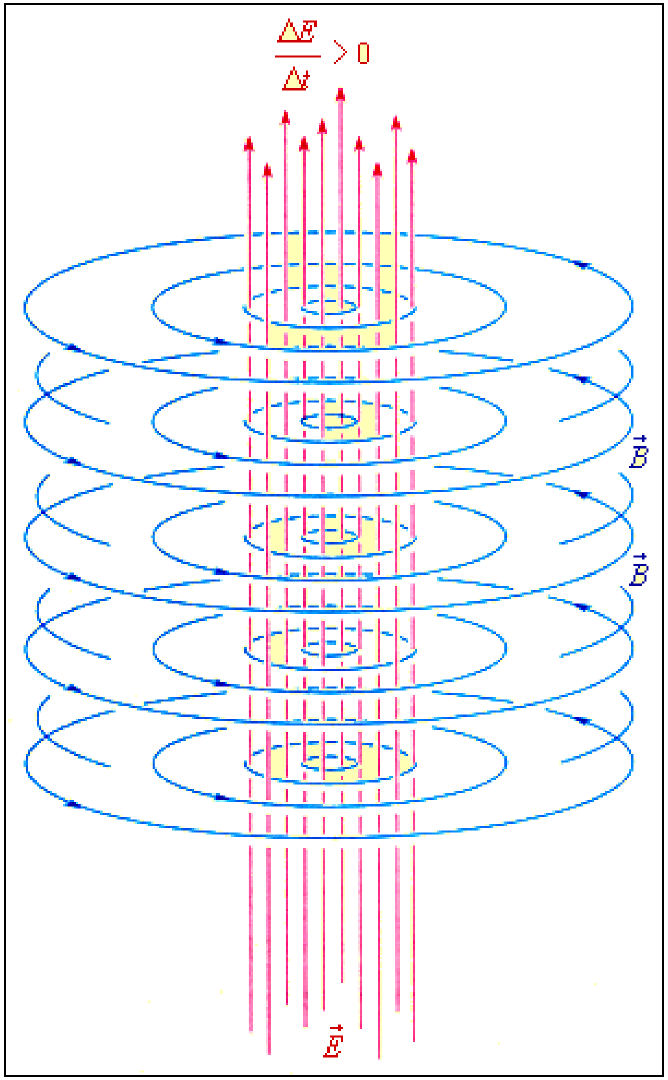
m=0,1,2… n=1,2,3… p=0,1,2…

Lowest mode:

$$m = 0, n = 1, p = 0$$

$$\omega_{010} = \frac{2.405 \cdot c}{\sqrt{\mu\varepsilon} \cdot R}$$

Field in cylindrical cavity



Experimental Unit 3. TM oscillations

h

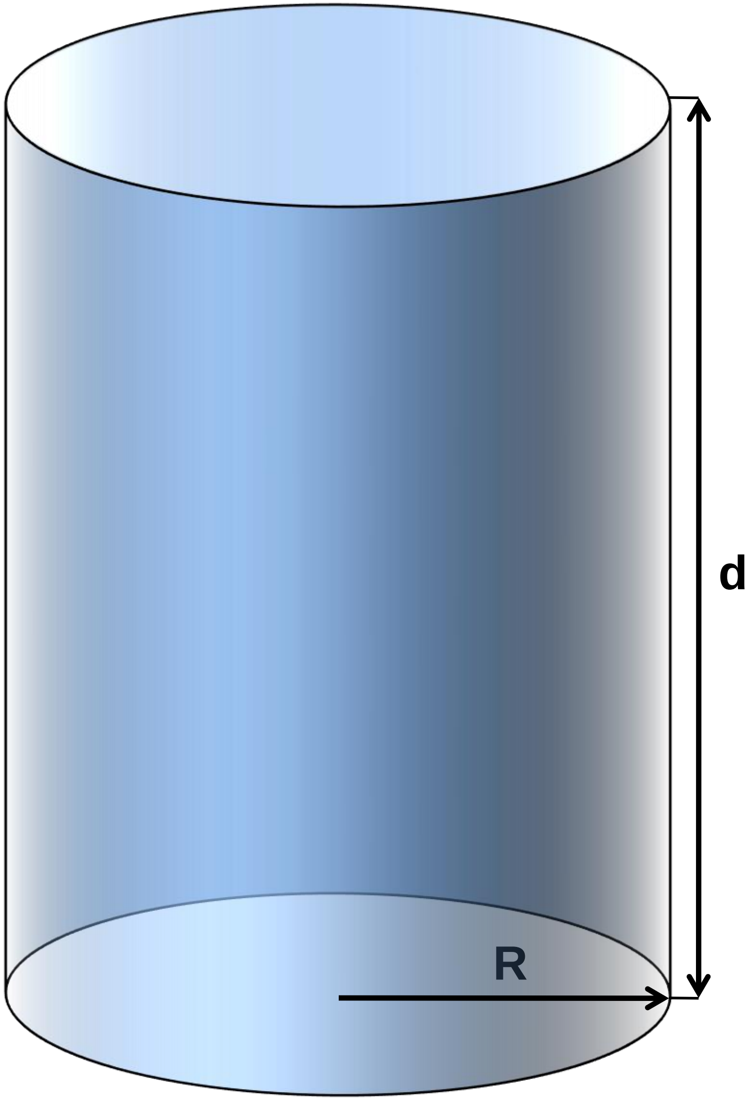
$$R = 6.5sm$$

$$h_{\max} = 20sm$$

We changed height and measured the minimum length of the hole

$$d_{\min} = const = 27mm$$

Cylindrical resonating cavity 2



TE oscillations:

$$\omega_{mnp} = \frac{c}{\sqrt{\mu\epsilon}}\left(\frac{x'^2_{mn}}{R^2} + \frac{p^2\pi^2}{d^2}\right)^{1/2}$$

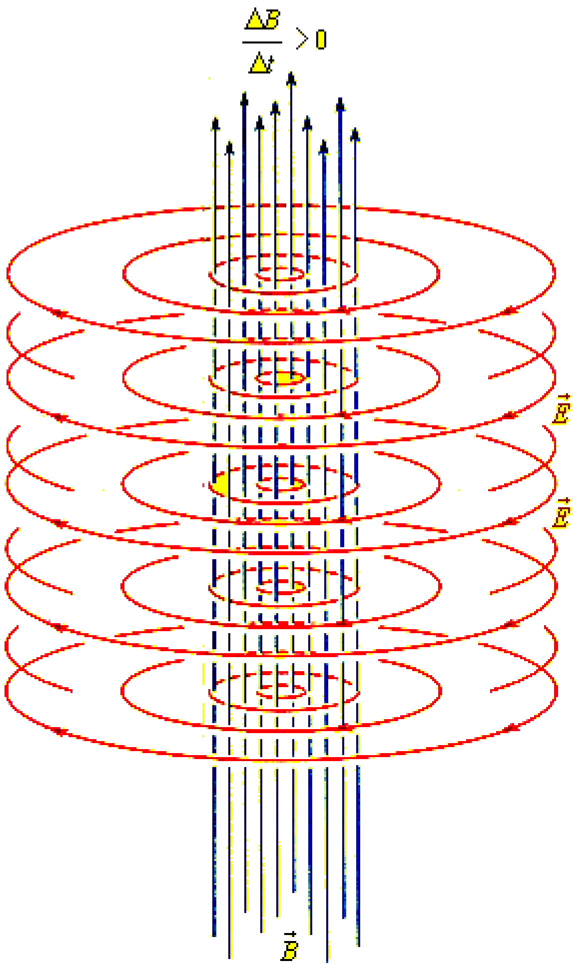
m=0,1,2… n=1,2,3… p=1,2,3…

Lowest mode:

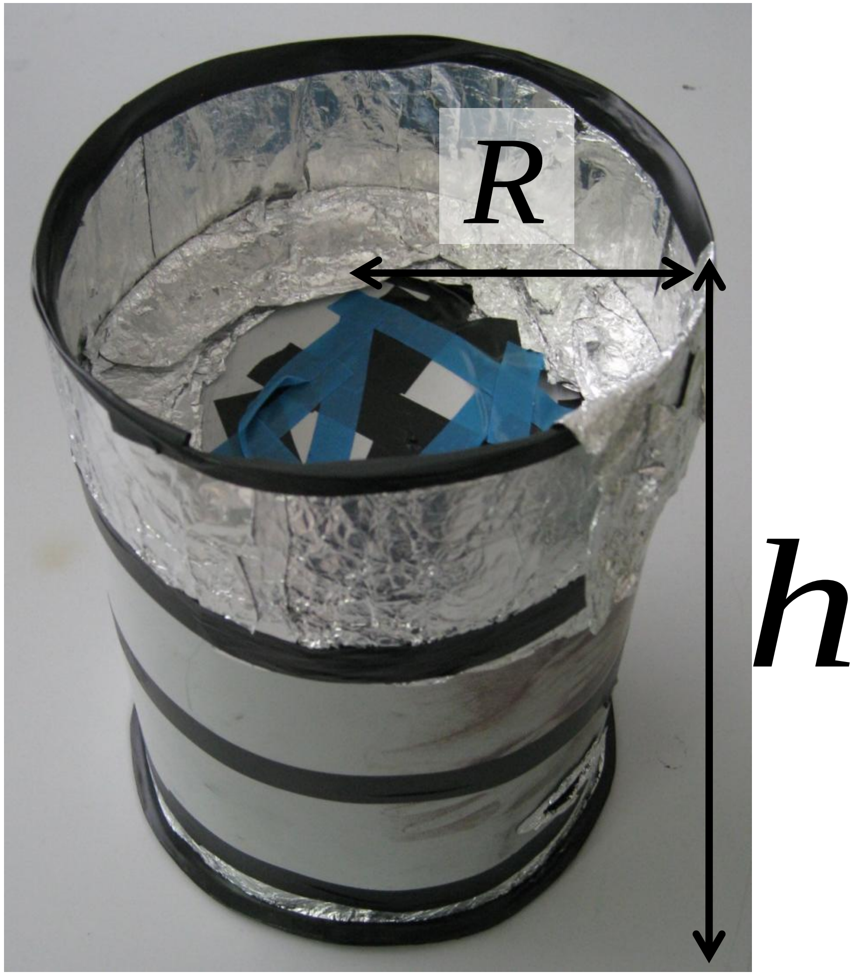
m = 1, n = 1,p = 1

$$\omega_{111} = \frac{1.841c}{\sqrt{\mu\varepsilon R}}\left(1 + 2.912\frac{R^2}{d^2}\right)^{\frac{1}{2}}$$

Field in cylindrical cavity



Experimental Unit 4. TE oscillations

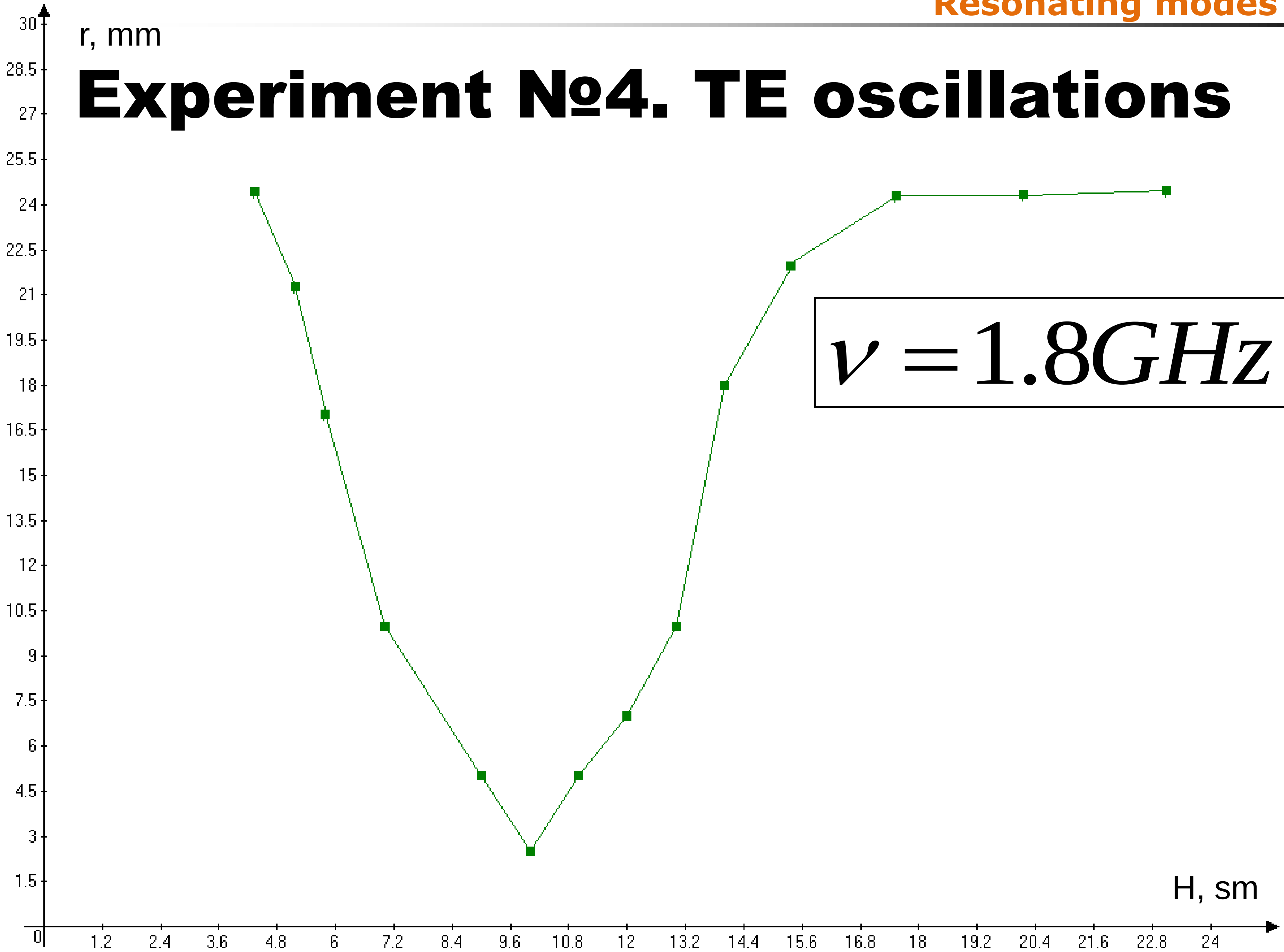


$$R = 9.5sm$$

$$h_{\max} = 25sm$$

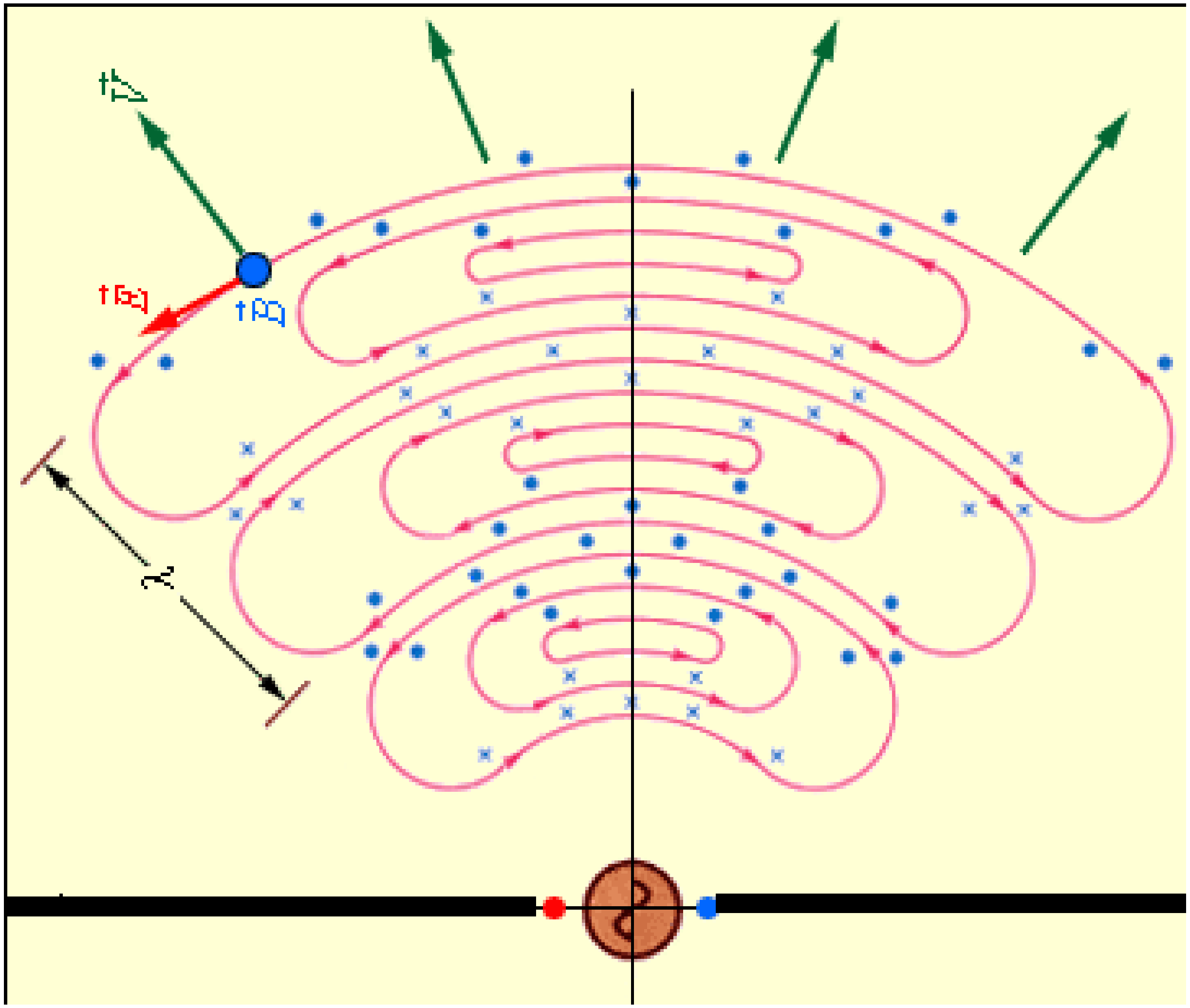
We also changed height and measured the minimum length of the hole

Experiment №4. TE oscillations

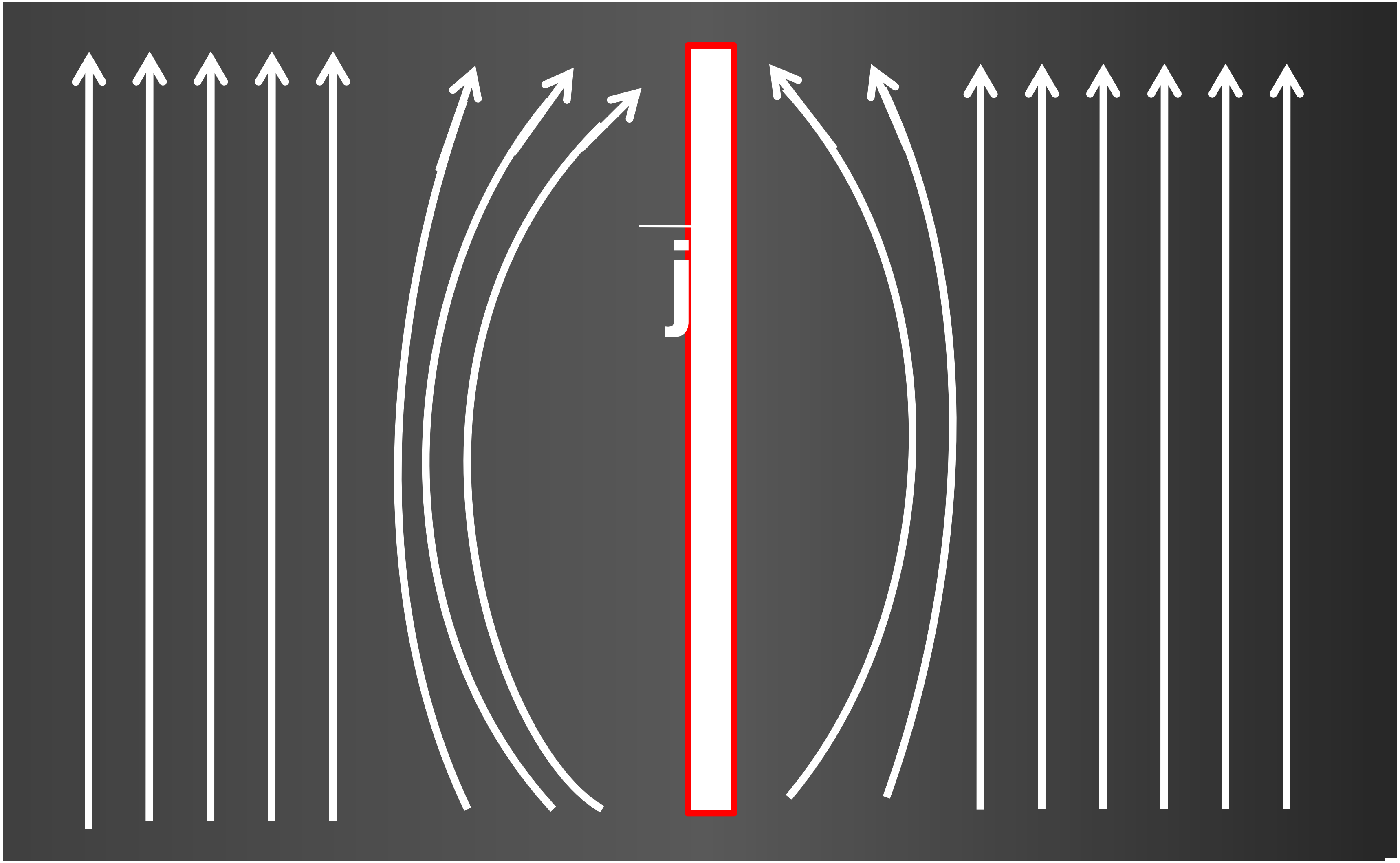


$$\nu = 1.8GHz$$

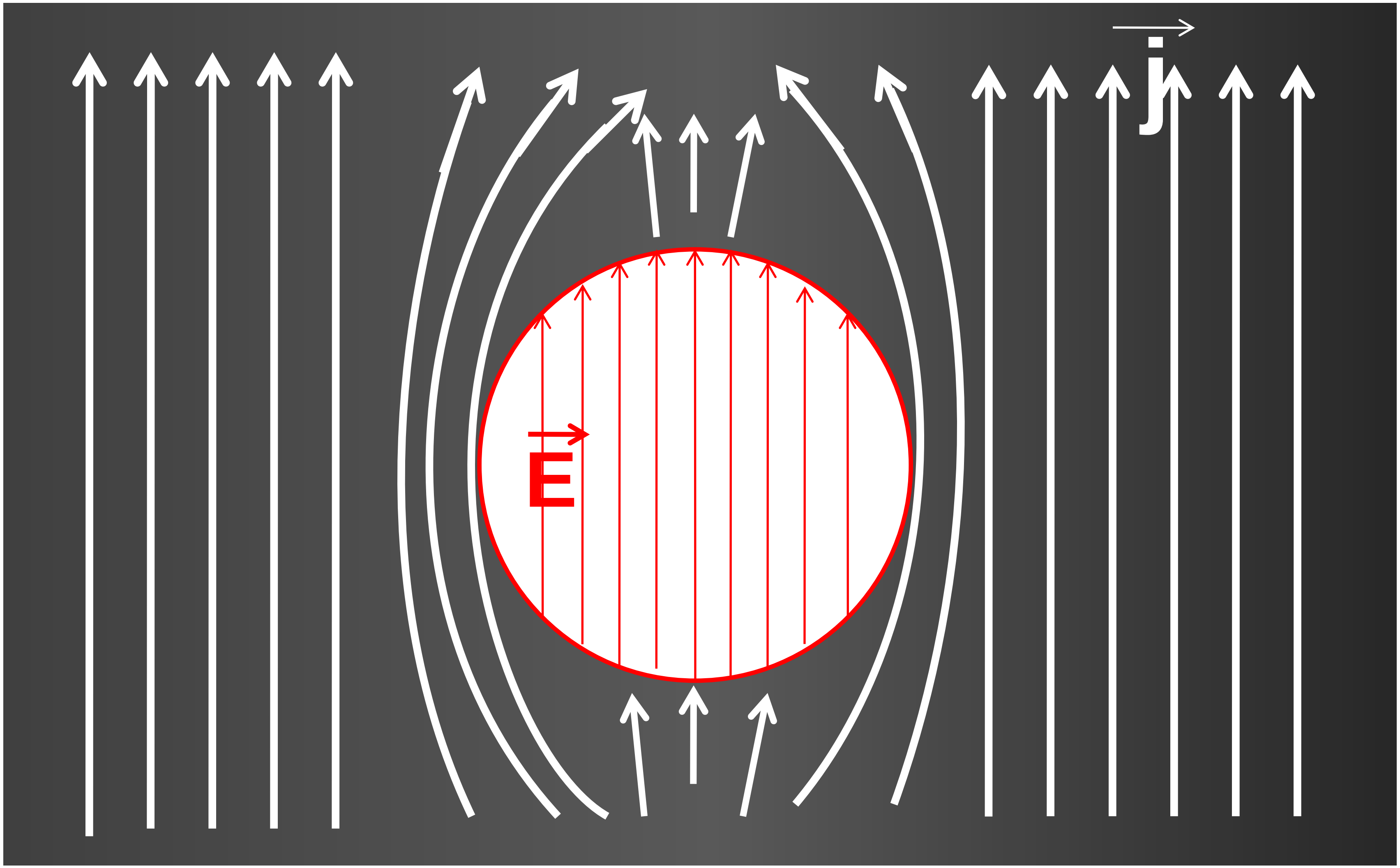
Part 2:Hole radiation



The slot and currents



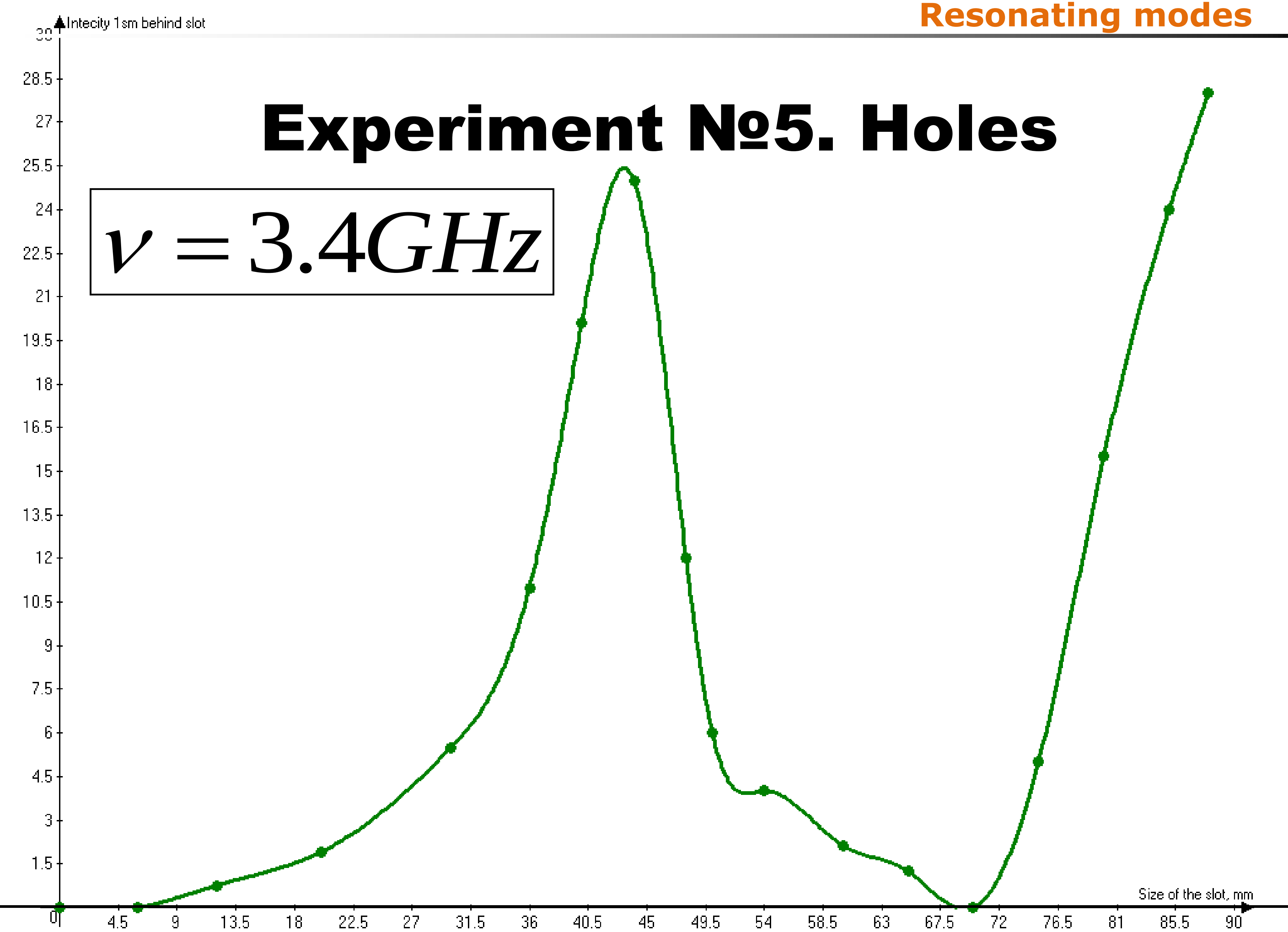
Round hole



Experimental Unit №5. Holes

Experiment №5. Holes

$$\nu = 3.4GHz$$



Part 3:Phone position

Antenna types

Cell phone antennas

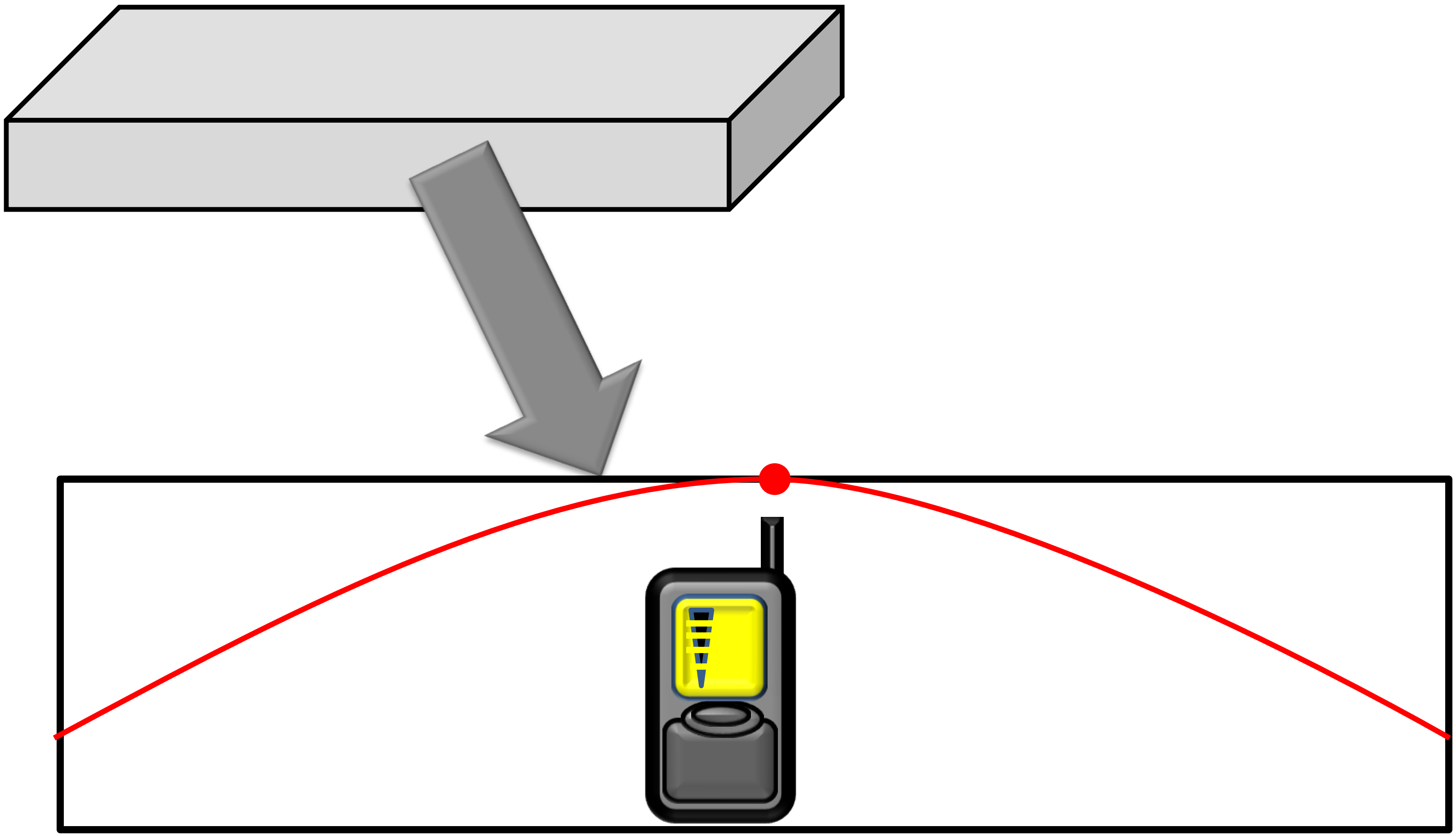
Whip antenna

Planar antenna

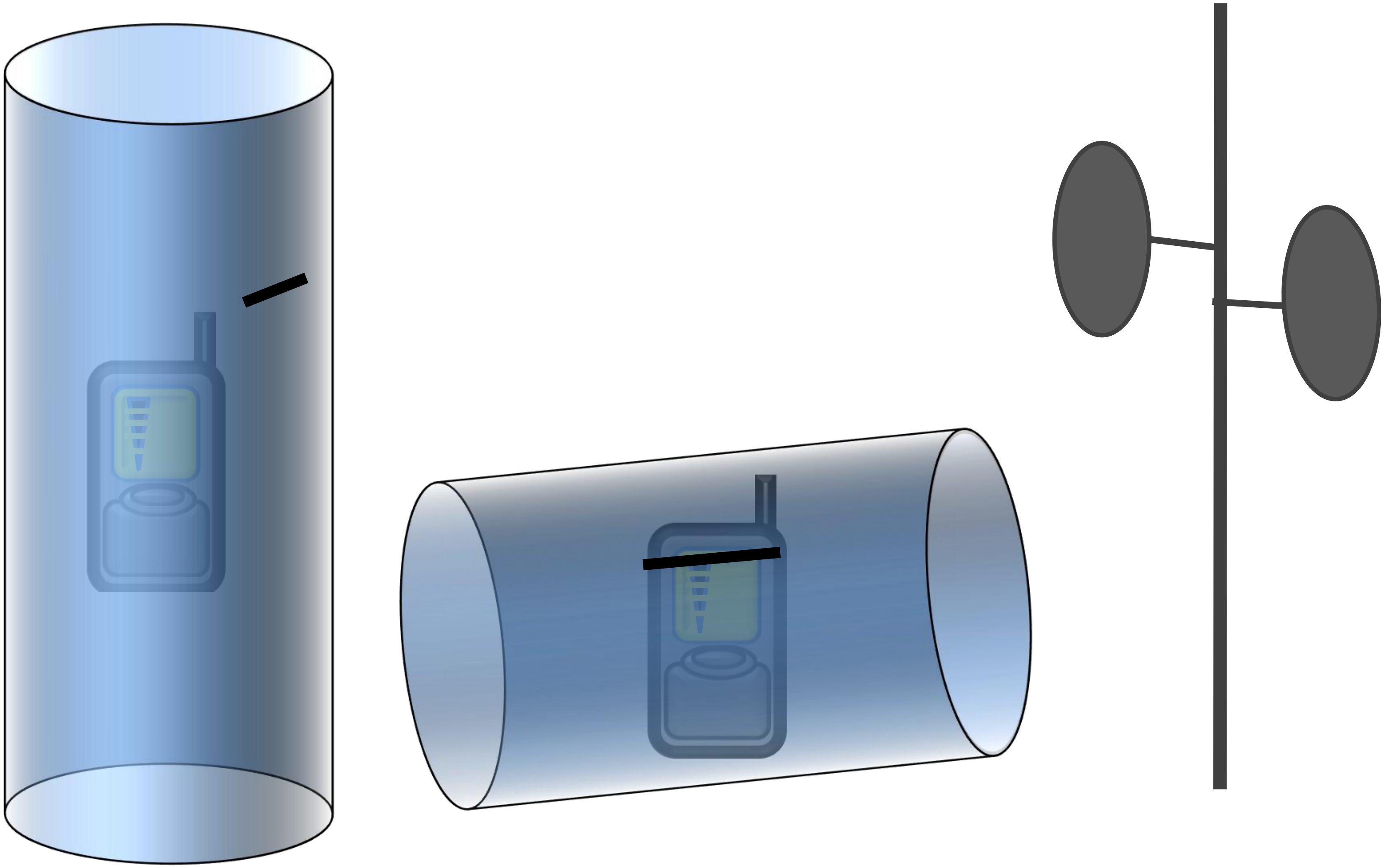
Isn’t tuned quite to resonance

Is tuned to resonance → changes field distribution a lot

Phone position



Box position



Conclusions: What should we do for the phone to ring

- Find a metal box for which the resonance on specified frequency may occur;
- Put the phone into the antinode of standing electromagnetic wave;
- Make a slot near the antinode. Length of the node must be equal to half wave length. It must be normal to vector E;
- Place the box in such way, that the slot will be parallel with the ground and will face the cell tower;

Summary:

The four main factors which the quality of a signal depends on are:

1. The box shape
2. The hole length and position
3. The phone position
4. The box position

We need to keep amplitude as high as possible and all other signal features unchanged for the phone to ring.

Literature:

Wikipedia: Field test mode.
Wikipedia: Timing advance.
Wikipedia: Received signal strength indication.
Wikipedia: Time division multiple access.
Wikipedia: Telecommunications link.
Frequency hopping on GSM networks. CDMA vs. TDMA.
Steve Punter's Southern Ontario Cell Phone Page.
(http://www.arcx.com/)
Jackson J.D. Classical electrodynamics
Feynman's lections 6: Electrodynamics

Thanks for your attention!

$$J_\nu(x_{\nu n}) = 0 \qquad (n = 1, 2, 3, \ldots)$$

$$\begin{aligned}
\nu &= 0, & x_{0n} &= 2.405,\ 5.520,\ \ 8.654, \ldots \\
\nu &= 1, & x_{1n} &= 3.832,\ 7.016,\ 10.173, \ldots \\
\nu &= 2, & x_{2n} &= 5.136,\ 8.417,\ 11.620, \ldots
\end{aligned}$$

Roots of $J'_m(x) = 0$

$m = 0$:	$x'_{0n} = 3.832, 7.016, 10.173, \ldots$
$m = 1$:	$x'_{1n} = 1.841, 5.331, 8.536, \ldots$
$m = 2$:	$x'_{2n} = 3.054, 6.706, 9.970, \ldots$
$m = 3$:	$x'_{3n} = 4.201, 8.015, 11.336, \ldots$

Diffraction

$$\boxed{r_0 = \sqrt{\lambda b}}$$

$$\boxed{r_0 \approx 10 sm}$$