ANTENNA COUPLING

LABORATORY SESSION WITH *Wire-MoM*

Objective. Investigate coupling between two wire antennas when different polarizations of the transmitting and receiving antennas are chosen. Study the directive properties of the antennas.

Wire-MoM program

Wire-MoM is a method of moments program for wire structures. The *electric field integral equation* (EFIE) for the current distribution on three-dimensional conducting wire structures in free space is solved in the frequency domain using the method of moments (MoM).

$$\text{EFIE: } \vec{E} = f(\vec{J})$$

where the terms on the left-hand side of this equation is incident field and $\vec{J}$ is the induced current. The electric field integral equation can be derived from the Maxwell's equations.

Lumped voltage sources and impedance elements, such as resistors, inductors and capacitors can be modeled.

The *method of moments* (or moment method) is a technique for solving complex integral equations by reducing them to a system of simpler linear equations. The induced current $\vec{J}$ is expanded as a finite sum of known basis functions, $\vec{b}_i$

$$\vec{J} = \sum_{i=1}^{M} J_i \vec{b}_i$$

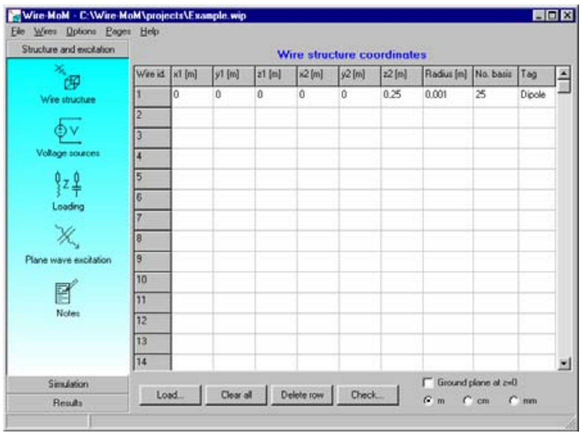
where coefficients J_i are to be determined. The unknown coefficients of the induced current are the terms of the $\vec{J}$ vector, and are related to the conductors (wires).

The moment method realized in Wire-MoM can be applied to configurations of conductors for analyzing a wide variety of important three-dimensional electromagnetic radiation problems. The moment method is particularly efficient at modeling wire antennas or wires attached to large conductive surfaces, e.g. ground planes. This is widely used for antenna and electromagnetic scattering analysis.

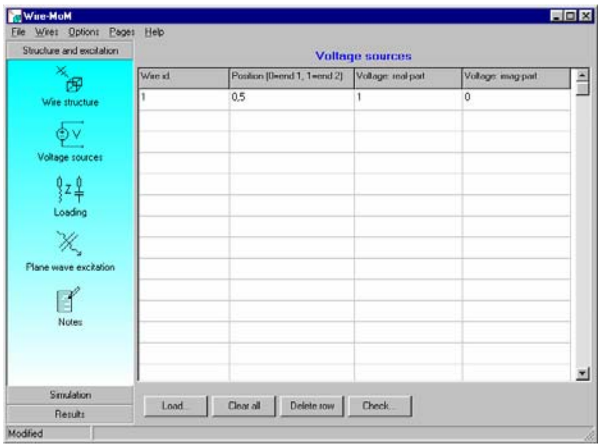
As a result of a Wire-MoM simulation both near- and far-field points can be inspected to give the EM-field intensities as well as the induced currents on the wires are computed as functions of coordinates and frequency.

Example.
For the 25cm dipole antenna made of a perfect conductor with the radius of 1mm, fed with the ideal 1V voltage source at the frequency range 300MHz – 1500MHz. Plot radiation resistance and reactance curves, as well as the total current curve in the frequency domain. Determine the frequency f_0 at which the antenna would radiate most efficiently. Find the current distribution along the antenna at the frequency f_0. Plot 3D antenna pattern, and 2D antenna gain at that frequency.

1. Run the Wire-MoM using the path c:\Wire-MoM\Wire-MoM.exe. *Structure and excitation* window will be activated and the *Wire structure coordinates* panel will appear.
2. By clicking on the *Save project as…* under *File* in the *main menu* save the project as *Example.wip*.
3. Put in the parameters of the quarter-wave dipole, as shown in the Figure. The parameter *Radius* specifies the radius of the wire, the parameter *No. basis* specifies the number of basis functions per length of the wire. In this example the number of the basis functions is 25, meaning that the induced current on the wire will be computed for each 1cm–segment of the wire. The more basis functions (odd number recommendable) the more precise result would be obtained, provided that the radius of the wire is much less than the length of the elemental segment. In fact, by clicking the *Check* button Wire-MoM will check the errors in the wire structure and excitation input.

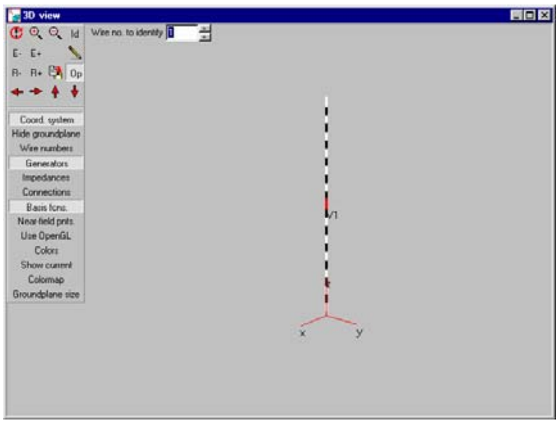


4. Activate *Voltage sources* panel by clicking on  button.
5. Put in the *Voltage source* parameters for the previously defined Wire 1, as follows:

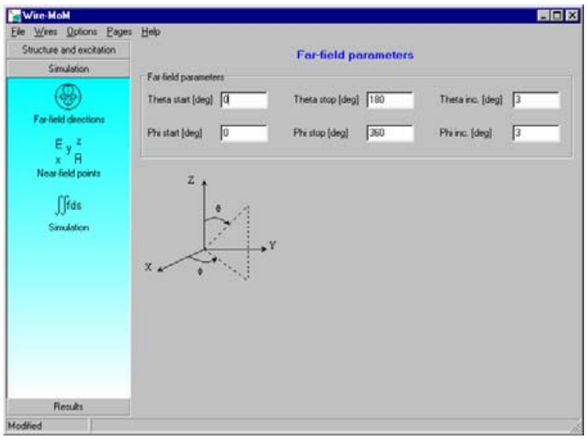


The 1V voltage source has been placed in the middle of the wire (factor 0.5).

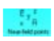
6. Click on the *3D view of structure* under *Wires* in the *main menu* to activate the 3D View window, where you can move, rotate, elevate and copy the view of the structure. Press *Op* button to choose a set of the 3D view options.

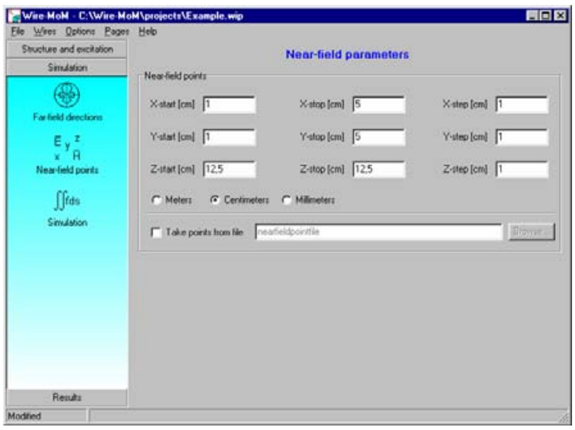


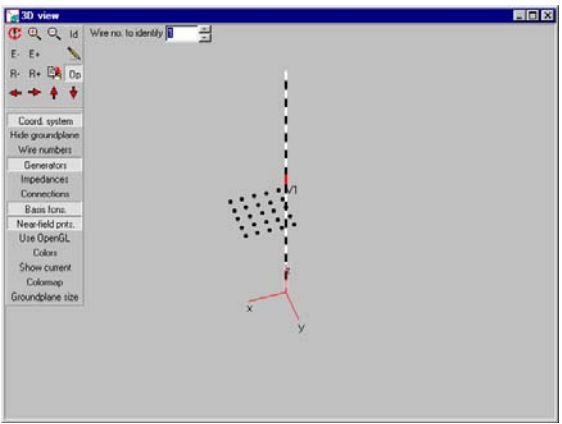
7. Dismiss the 3D View window and click on *Simulation* tab to activate the *Simulation* window.
8. Click on the button *Far-field directions*  to activate *Far-field parameters* panel. These parameters specify the radiation pattern of the antenna and provided in the spherical coordinate system.



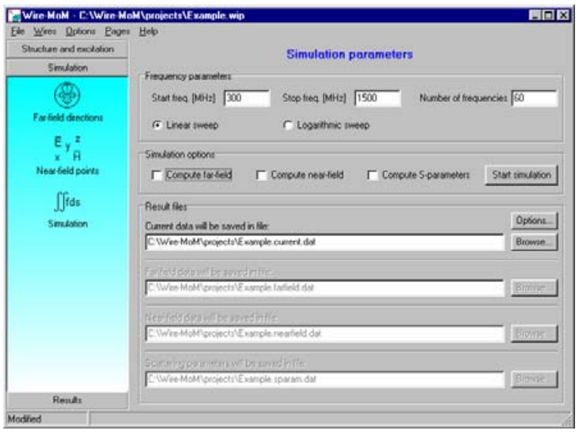
Put in the boxes the values shown in the Figure, so that the far-fields will be calculated in all the directions around the dipole.

9. Click on *Near-field points* button  to put in the near-field points to be inspected.





10. Click on *Simulation* button to activate the *Simulation parameters* panel. Uncheck both the *Compute near-field* and Compute *far-field* boxes, and specify *start* and *stop frequencies* as 300MHz and 1500MHz accordingly, as well as the *Number of frequencies* as 60, giving the frequency stepping about 20MHz.



The results of simulation will be saved in the Result files, which are specified in the corresponding boxes.

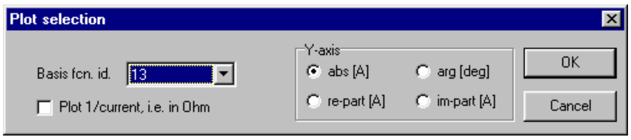
11. Start simulation by clicking on the *Start simulation* button. *Simulation parameters* message window will appear. Click on the *Compute* button to start computation.

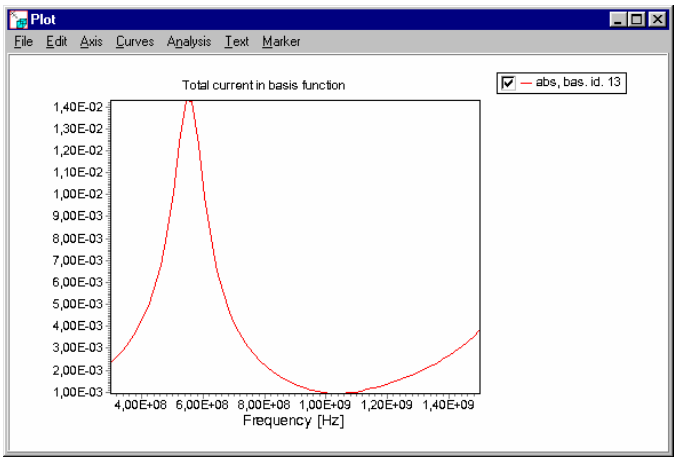
12. The time of computation will depend on the number of basis functions used to represent the structure. When the computation is completed, the *Computation done* message window will appear. Click on Ok.

13. Click on the *Results* tab to activate the *Results* window.

14. *Click* on the Current button and then *Load data* button.

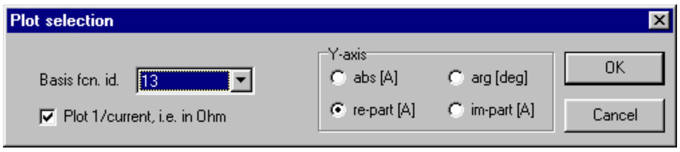
15. *The frequency domain plot can be obtained by clicking on the button Plot I(f)*. The *Plot selection* window will be activated. Put in the 13th basis function corresponding to the feeding point on the antenna. The computed total current can be observed in this point by checking the radio button *abs[A]* and clicking on Ok.

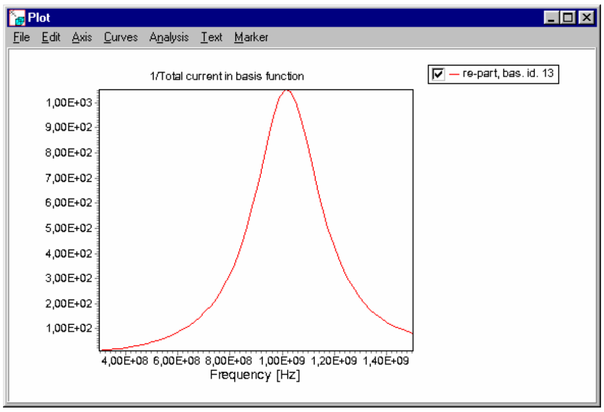




The *Plot* application window will be activated, where a user is enabled to perform a number of operations, such as editing, copying and saving the plot, changing axes and line parameters. Data analyses options are provided as well.

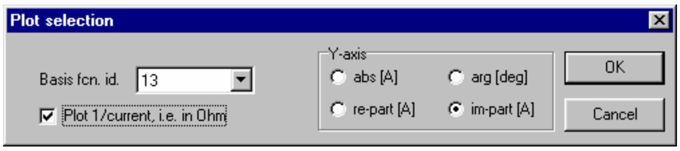
16. The radiation resistance of the antenna can be plotted by checking the *Plot 1/current* box and the *re-part* box in the *Plot selection* window:

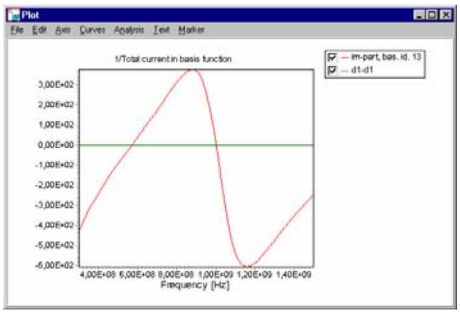




Note! If the voltage magnitude of the voltage source is, say, 10V, in order to obtain the radiation resistance for a particular frequency, one should multiply the appropriate value taken from the plot by 10.

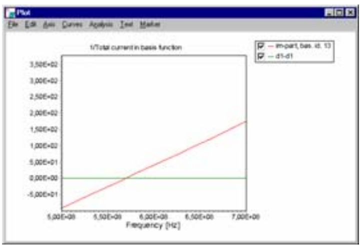
17. The radiation reactance of the antenna can be plotted by checking the *Plot 1/current* box and the *im-part* box in the *Plot selection* window:





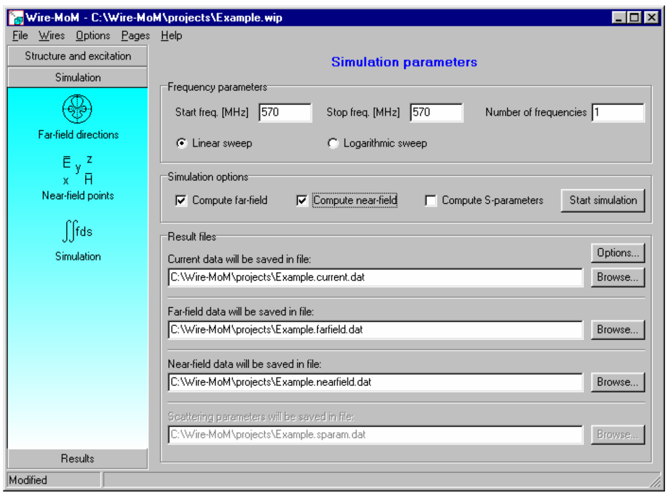
Note! If the voltage magnitude of the voltage source is, say, 10V, in order to obtain the radiation reactance for a particular frequency, one should multiply the appropriate value taken from the plot by 10.

The reactive part of the input impedance is zero at the frequency about f_0=570 MHz, that is when the dipole is slightly shorter than half of the wavelength. This maximizes the total radiated power, due to the minimum radiation reactance.

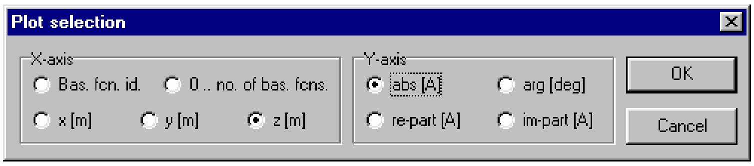


--- Increased

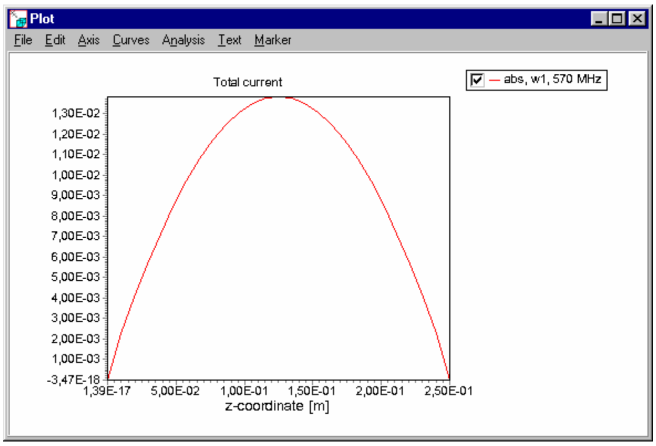
18. Making the simulation for the frequency 570 MHz, with checked *Compute near-field* and *Compute far-field* boxes, as shown in Figure



19. Now the current on each segment of the wire is available at the frequency 570MHz. Click on the *Plot I(x)* button to make a plot of the current as the function of coordinate along the wire. After clicking on *Plot I(x)* button the plot selection dialog window will be activated, allowing a user to assign different parameters to the coordinate axes. Check the radio buttons is shown in the Figure.

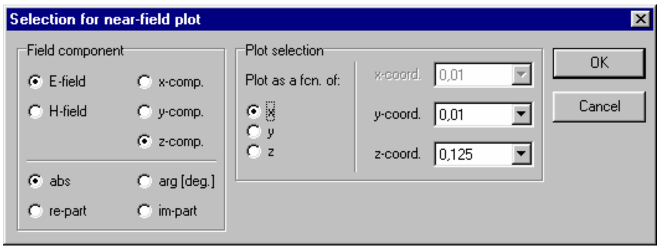


20. Click on Ok. The *Plot* application window will be activated.

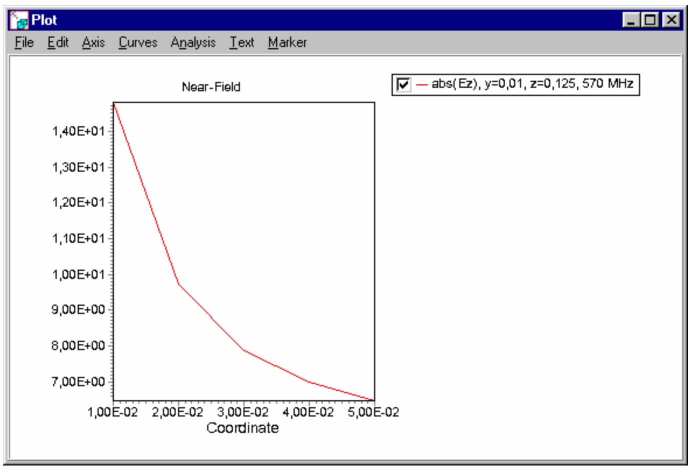


21. Having observed total current distribution along the wire, dismiss the Plot window.

22. Staying in the *Results* window, click on the *Near-field* button  and then *Load data* button in order to load near-field data. Click on *Plot E(x), H(x)* button and select a near field plot as shown in Figure.

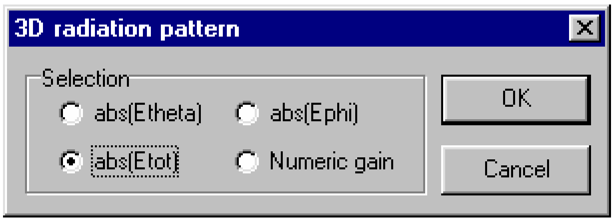


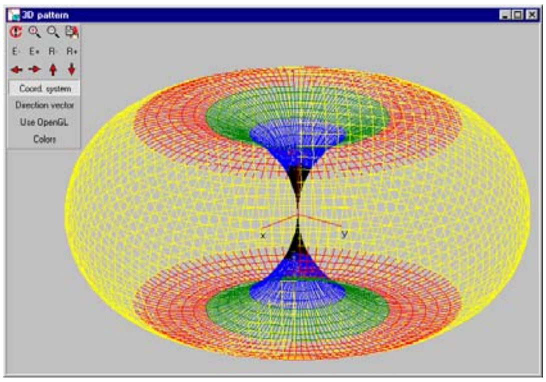
23. Click on Ok to show the near-field plot.



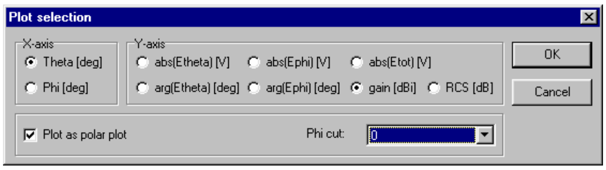
Plot *x* and *y* components of E-field as well. Click on *Y-Axis* under *Axis* item in the *main menu* of the *Plot* window in order to observe, that those components of the E-field are negligible in comparison with the *z* component, which is co-directional with the dipole antenna. Dismiss the window.

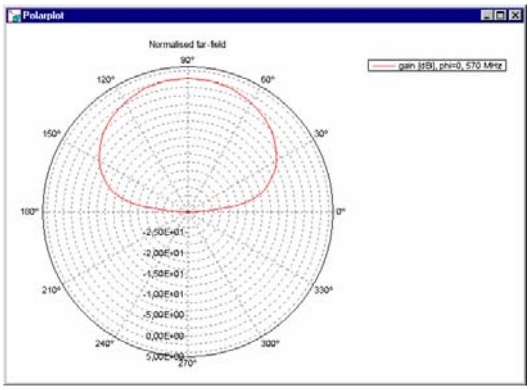
24. Staying in the *Results* window, click on the *Far-field* button and then *Load data* button in order to load far-field data.
25. Click on *3D Plot* button to obtain 3D radiation pattern of the antenna. Dismiss the window.





26. Click on *Plot E(alfa)* button to obtain 2D antenna gain in dBi.





Note. **Gain, dB**i. The gain expressed in decibels relative to an isotropic point radiator: $G(dBi)=10\log_{10}(G)$

27. Save the project.

Exercise

Assume the distance between transmitting and receiving half-wave dipole antennas equal 2m. The transmitting antenna is fed with an ideal voltage source (12V, 600MHz). Assuming that the middle point of the transmitting antenna has coordinates **(0, 0, z_0)** whereas the middle point of the receiving antenna has coordinates **(0, 2m, z_0)**, address the two following cases:

a) The transmitting antenna is directed along the z-axis and the receiving antenna is directed along the x-axis (90° polarization)
b) Both the transmitting and receiving antennas are co-directional with the z-axis.

Note. Antennas are made of perfect electric conductors. Use 25 basis functions for each wire of radius 1mm

For the cases a) and b) determine the maximum induced total currents both in the transmitting and receiving antennas. Fill in the tables below:

Case (a): 90° polarization

Maximum total current in the transmitting antenna [A]	Maximum total current in the receiving antenna [A]

Case (b): co-directional antennas

Maximum total current in the transmitting antenna [A]	Maximum total current in the receiving antenna [A]

Compare the induced currents in the receiving antenna for the cases a) and b). Make a conclusion about polarization effect on the coupling between transmitting and receiving antennas. Plot 3D radiation patterns of the antennas and 2D antennas' gains.

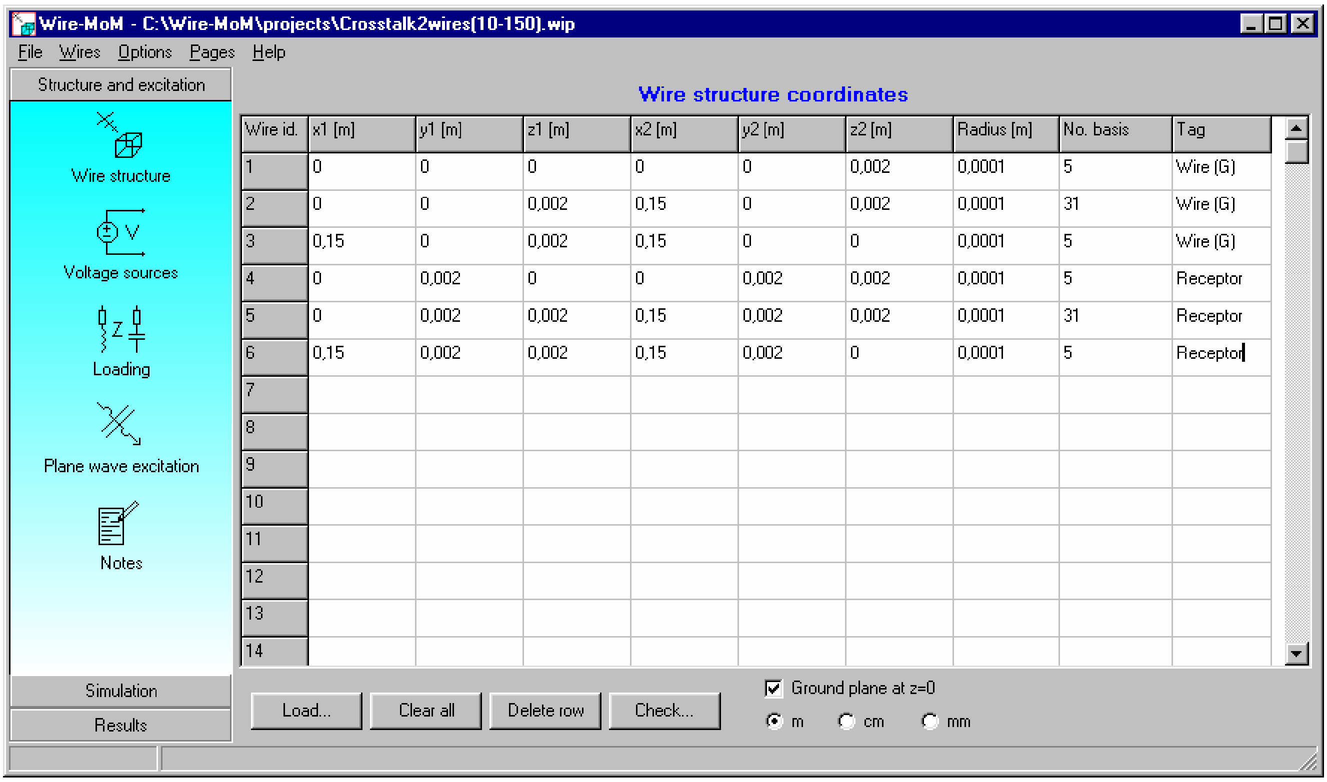
CONCLUSION:

CROSSTALK

LABORATORY SESSION WITH *Wire-MoM*

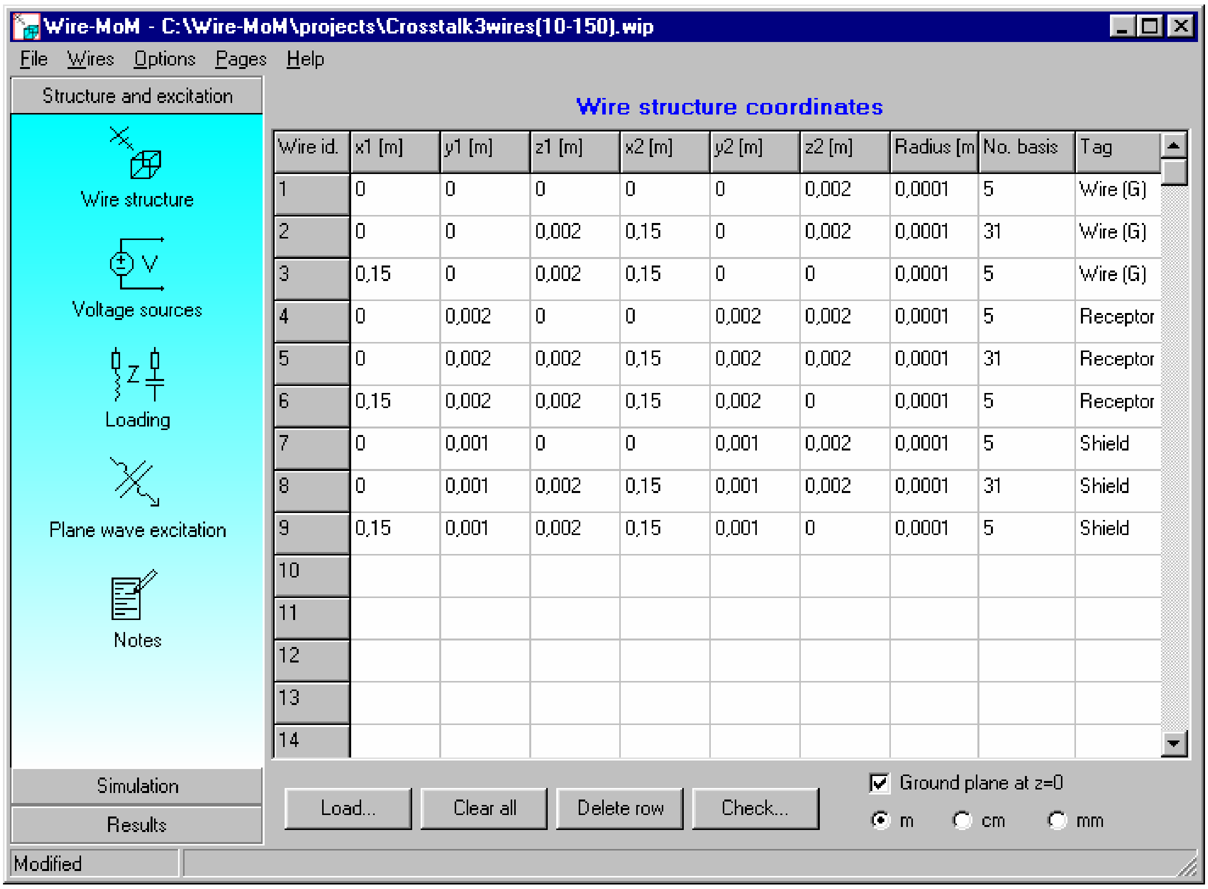
Objective. Investigate and solve the crosstalk problem for three-conductor transmission lines.

Exercise 1. Construct the following three-conductor transmission line, with the perfectly conducting ground plane as the reference conductor. Plot the total current in the receptor conductor for the frequency range 10MHz-150MHz*.



** Save the resulting plot by copying it to the clipboard, and pasting to a MS Word file.*

Exercise 2. Add the shield conductor to the structure from Exercise 1, so that the shield conductor is parallel both to the generator and receptor conductors and is at the equal distance from each of them. Plot the total current in the receptor conductor for the frequency range 10MHz-150MHz.



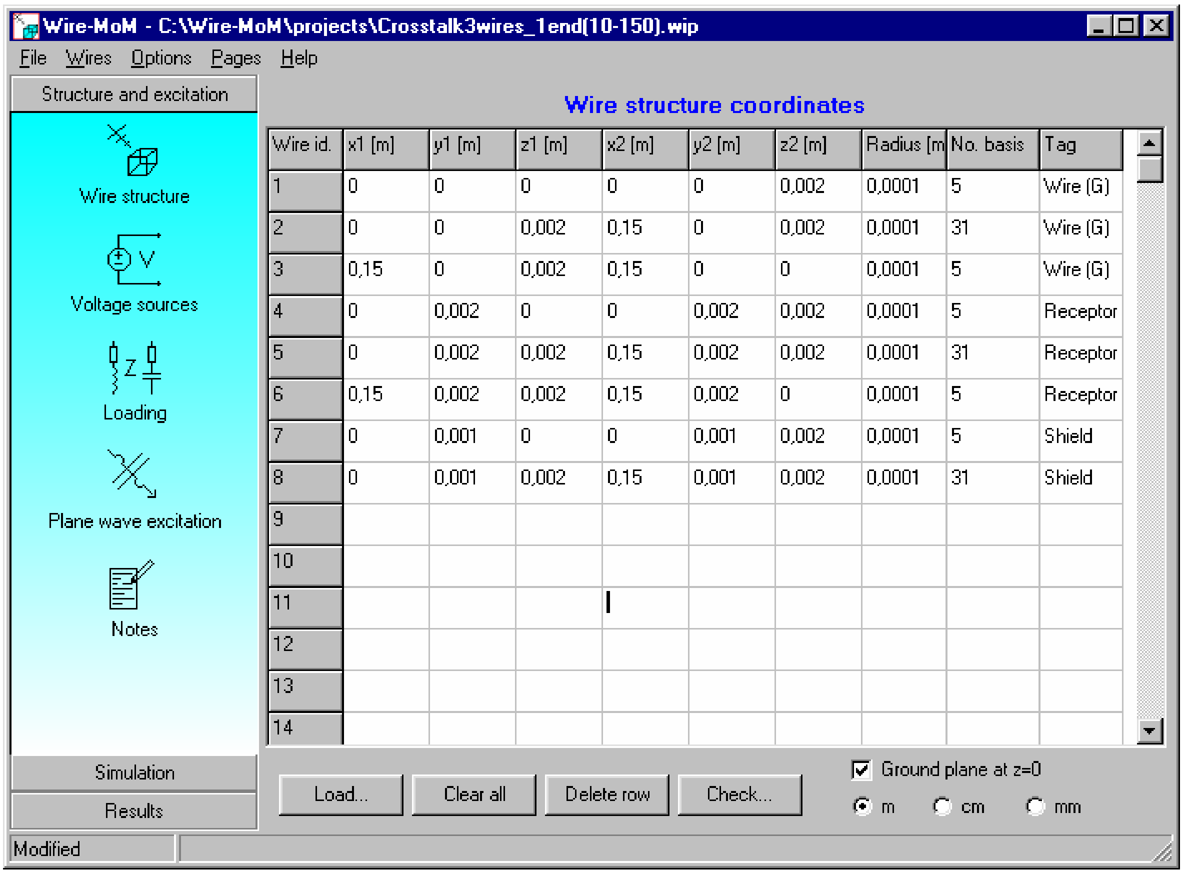
Wire id.	x1 [m]	y1 [m]	z1 [m]	x2 [m]	y2 [m]	z2 [m]	Radius [m	No. basis	Tag
1	0	0	0	0	0	0,002	0,0001	5	Wire (G)
2	0	0	0,002	0,15	0	0,002	0,0001	31	Wire (G)
3	0,15	0	0,002	0,15	0	0	0,0001	5	Wire (G)
4	0	0,002	0	0	0,002	0,002	0,0001	5	Receptor
5	0	0,002	0,002	0,15	0,002	0,002	0,0001	31	Receptor
6	0,15	0,002	0,002	0,15	0,002	0	0,0001	5	Receptor
7	0	0,001	0	0	0,001	0,002	0,0001	5	Shield
8	0	0,001	0,002	0,15	0,001	0,002	0,0001	31	Shield
9	0,15	0,001	0,002	0,15	0,001	0	0,0001	5	Shield
10									
11									
12									
13									
14									

** Save the resulting plot by copying it to the clipboard, and pasting to a MS Word file.*

Compare the results of Exercises 1 and 2.

CONCLUSION (about the shielding effectiveness).

Exercise 3. Remove a grounding wire from the shield conductor, and check the effectiveness of shielding by plotting the total current in the receptor conductor for the frequency range 10MHz-150MHz.



** Save the resulting plot by copying it to the clipboard and pasting to a MS Word file.*

Compare the results of Exercises 2 and 3.

CONCLUSION (about the dominant coupling mechanism).

____

____

____

____

____

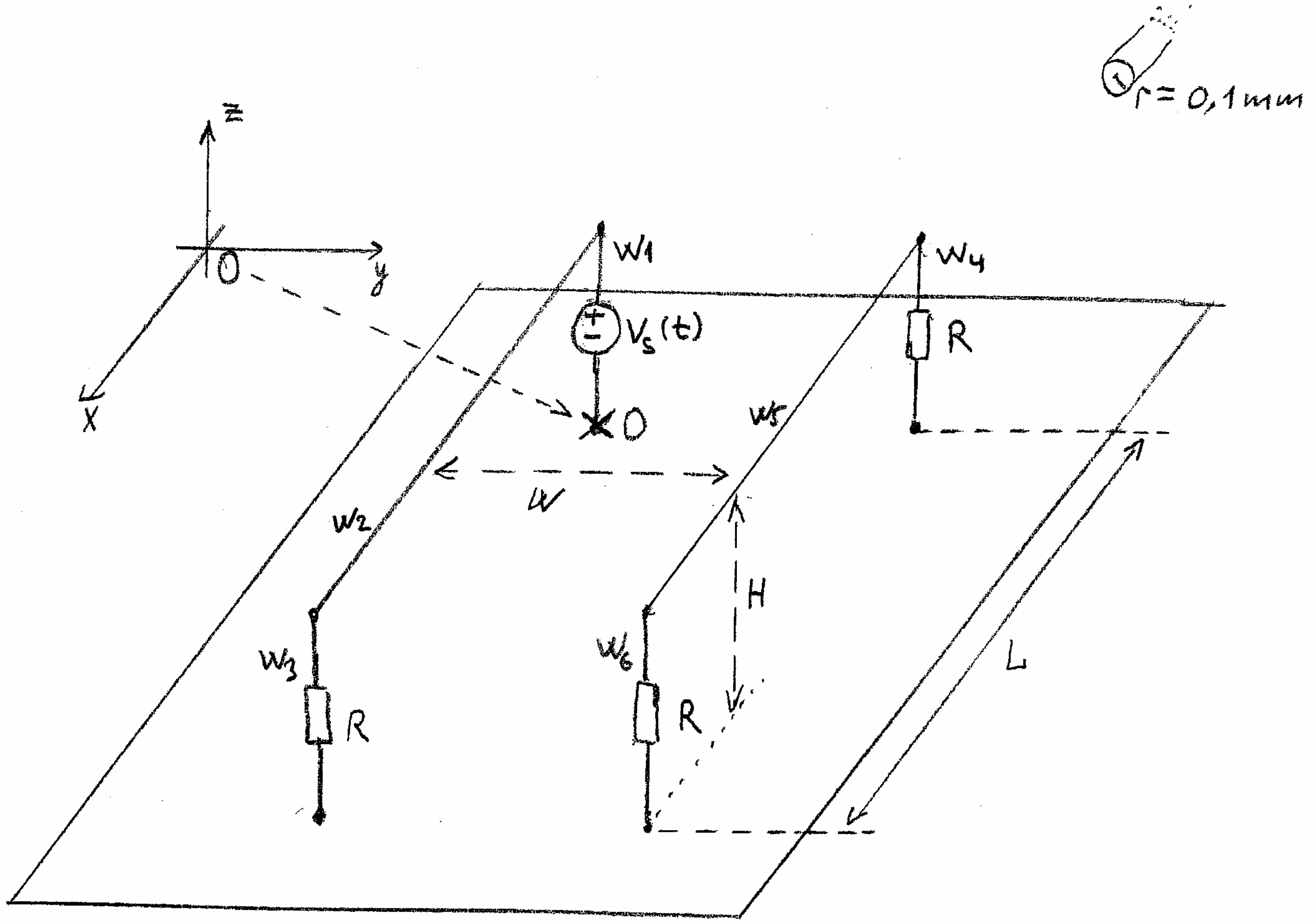
APPENDIX

Illustration for Exercise 1.

Illustration for Exercise 2.

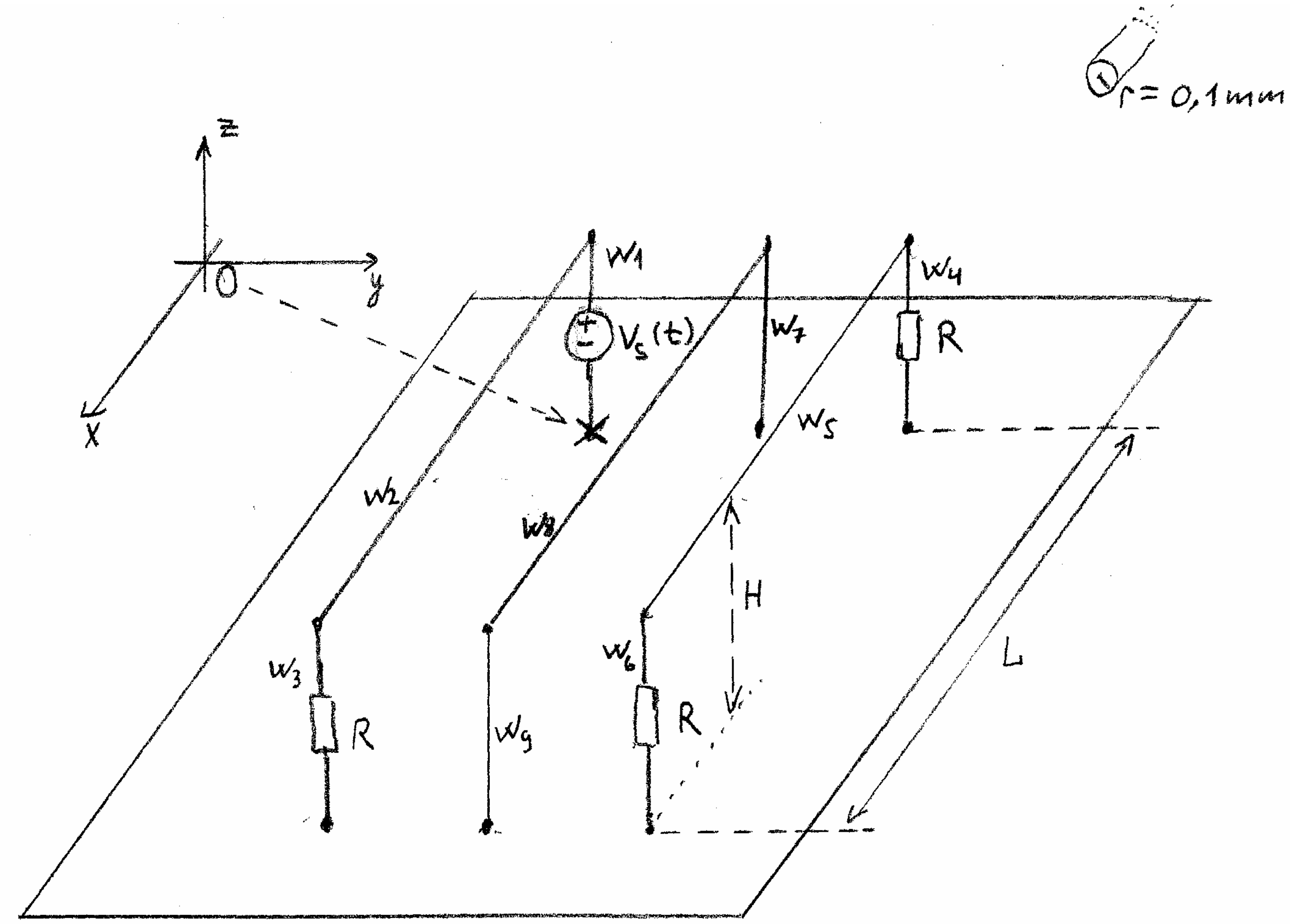
Illustration for Exercise 3.

EXERCISE 1.



$L = 15$ cm	$R = 1$ kΩ
$H = 2$ mm	$V_s(t) = V_0 sin(2\pi ft)$
$W = 2$ mm	$V_0 = 1\ V$

EXERCISE 2.

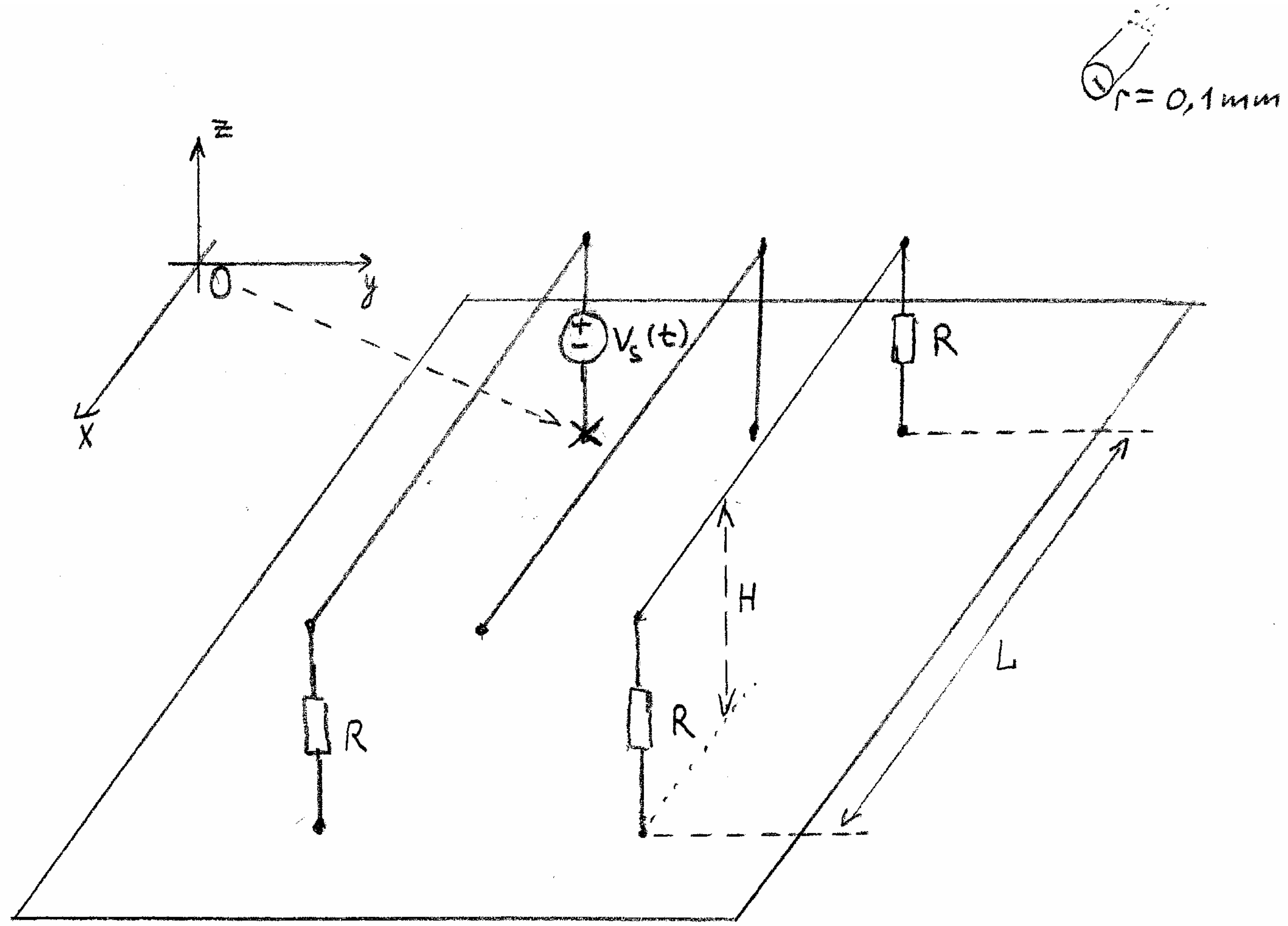


$L = 15$ cm $\quad R = 1$ kΩ

$H = 2$ mm $\quad V_s(t) = V_0 \sin(2\pi f t)$

$W = 2$ mm $\quad V_0 = 1\ V$

EXERCISE 3.



L = 15 cm	R = 1 kΩ
H = 2 mm	$V_s(t) = V_0 sin(2\pi ft)$
W = 2 mm	$V_0 = 1\ V$