Lab number: 3

Lab title: Normal incidence of TEM wave onto media boundary
Date lab was performed: 28.04.2020
Names of lab group members: Krzysztof Rudnicki

Theoretical introduction:

We are gonna work with 2 cases in this laboratory:

Case 1 – TEM wave propagation in parallel-plate waveguide terminated with PEC and PMC, which is filled homogeneously. We will be considering a phenomenon namely totally standing wave phenomenon.

Case 2 – Our focus in this case is a partially standing wave when TEM wave impinges at 90 degree angle onto onto one dielectric boundary

Our goal is to become familiar with reflection coefficient, standing wave ratio and power transmission coefficient – parameters of standing wave.

$$a=7.5+0.5=8$$

Cases:
PEC – Perfect Electric Conductor
PMC – Perfect Magnetic Conductor
1. air filling, terminated with PEC (parplat_PEC):
a) $f=a[GHz], \varepsilon_r=1, \mu_r=1, tg(\delta)=0$
b) $f=a[GHz], \varepsilon_r=1, \mu_r=1, tg(\delta)=0.1$

2. air filling, terminated with PMC (parplat_PMC):
a) $f=a[GHz], \varepsilon_r=1, \mu_r=1, tg(\delta)=0$
b) $f=a[GHz], \varepsilon_r=1, \mu_r=1, tg(\delta)=0.1$

3. wave impinges from air to dielectric (parplat_diel):
a) $f=a[GHz], \varepsilon_r=4, \mu_r=1, tg(\delta)=0$
b) $f=a[GHz], \varepsilon_r=1, \mu_r=4, tg(\delta)=0$

4. wave impinges from dielectric to air (parplat_diel):

a) $f=a[GHz], \varepsilon_r=4, \mu_r=1, tg(\delta)=0$

b) $f=a[GHz], \varepsilon_r=1, \mu_r=4, tg(\delta)=0$

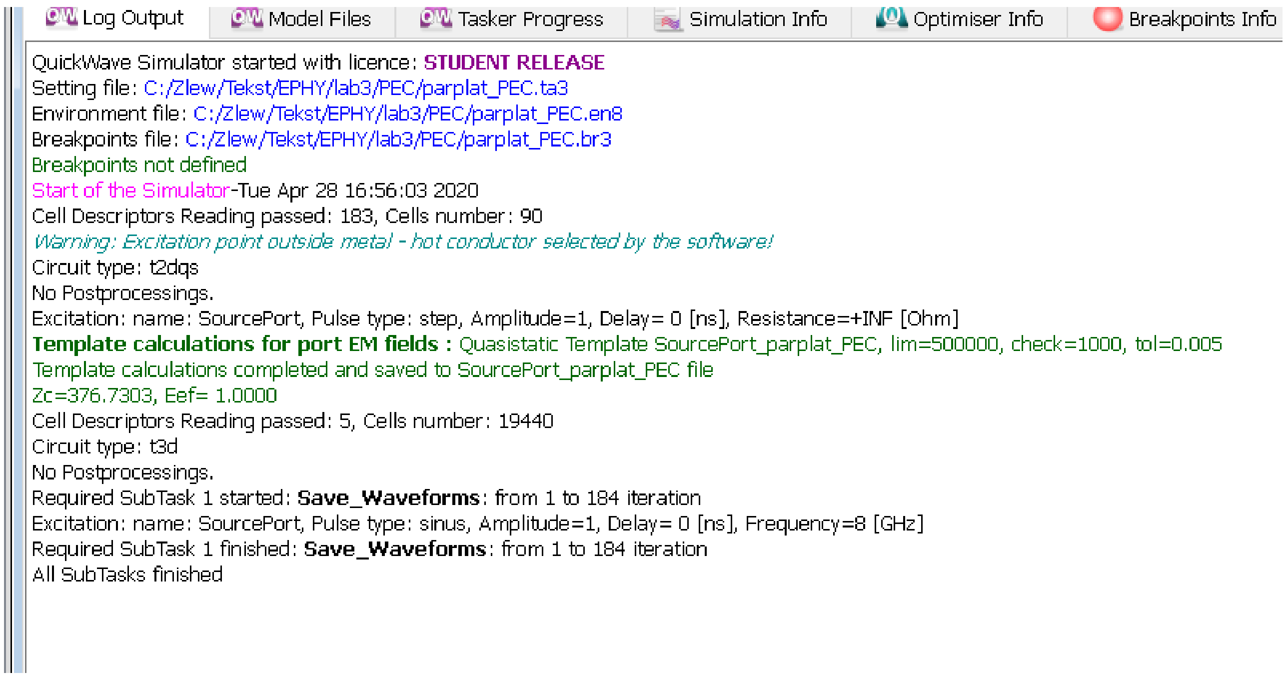
1a)

3.4

Electrical conductivity value:

$$\sigma[S/m] \approx \epsilon_r \frac{f[GHz]}{18} \tan(\delta) = 0 (lossles\, medium)$$

3.6



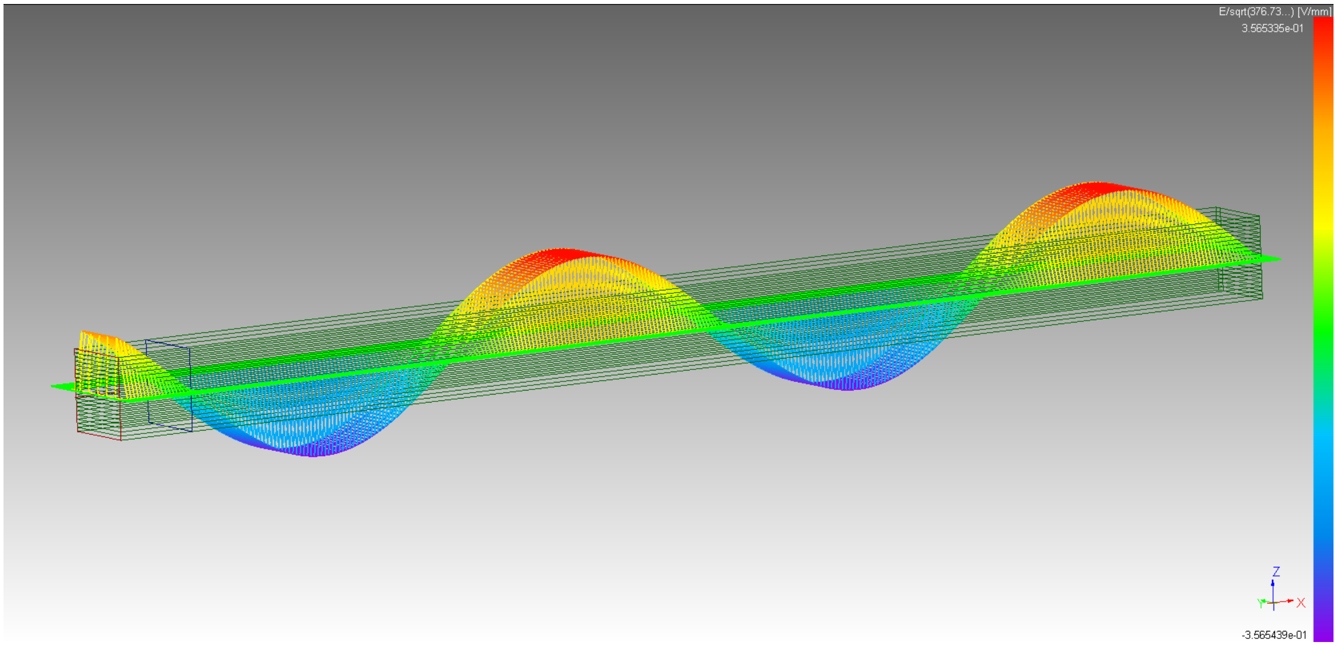
Log Output | Model Files | Tasker Progress | Simulation Info | Optimiser Info | Breakpoints Info

QuickWave Simulator started with licence: **STUDENT RELEASE**
Setting file: C:/Zlew/Tekst/EPHY/lab3/PEC/parplat_PEC.ta3
Environment file: C:/Zlew/Tekst/EPHY/lab3/PEC/parplat_PEC.en8
Breakpoints file: C:/Zlew/Tekst/EPHY/lab3/PEC/parplat_PEC.br3
Breakpoints not defined
Start of the Simulator-Tue Apr 28 16:56:03 2020
Cell Descriptors Reading passed: 183, Cells number: 90
Warning: Excitation point outside metal - hot conductor selected by the software!
Circuit type: t2dqs
No Postprocessings.
Excitation: name: SourcePort, Pulse type: step, Amplitude=1, Delay= 0 [ns], Resistance=+INF [Ohm]
Template calculations for port EM fields : Quasistatic Template SourcePort_parplat_PEC, lim=500000, check=1000, tol=0.005
Template calculations completed and saved to SourcePort_parplat_PEC file
Zc=376.7303, Eef= 1.0000
Cell Descriptors Reading passed: 5, Cells number: 19440
Circuit type: t3d
No Postprocessings.
Required SubTask 1 started: **Save_Waveforms**: from 1 to 184 iteration
Excitation: name: SourcePort, Pulse type: sinus, Amplitude=1, Delay= 0 [ns], Frequency=8 [GHz]
Required SubTask 1 finished: **Save_Waveforms**: from 1 to 184 iteration
All SubTasks finished

Z_c $of\ input = 376.7303 [\Omega]$

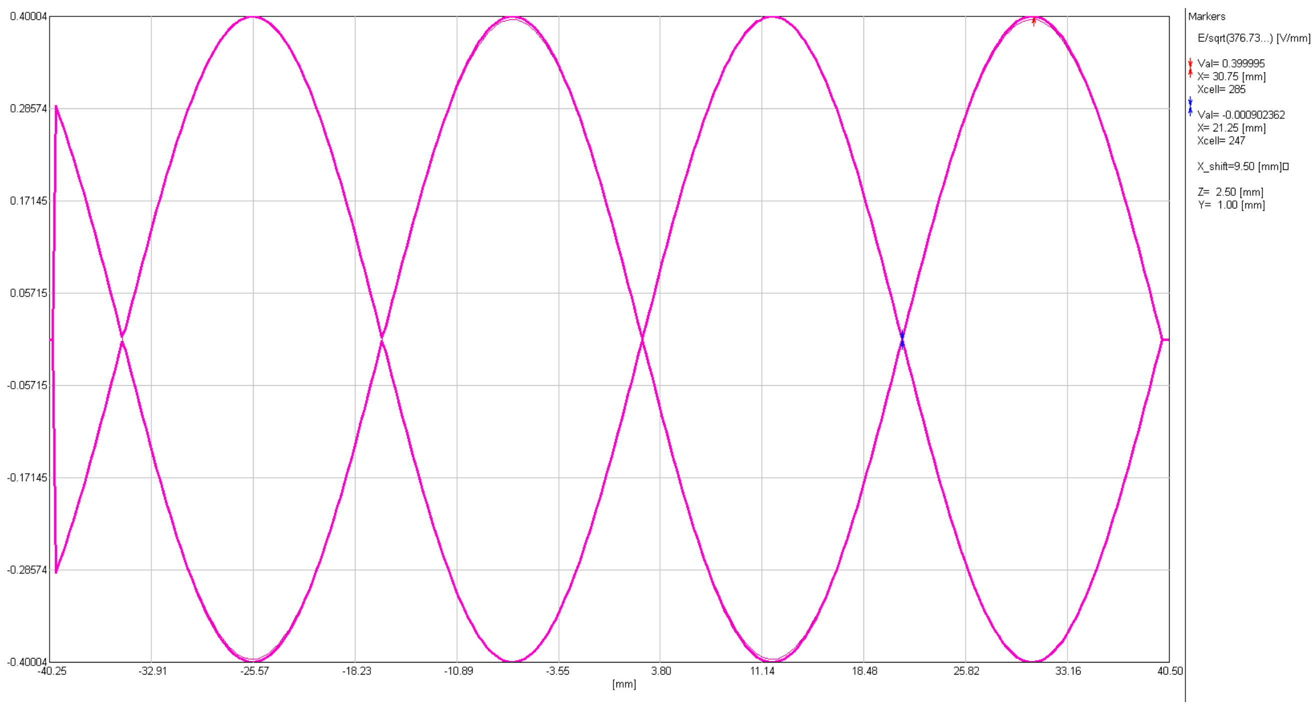
$Z_c - impedance$

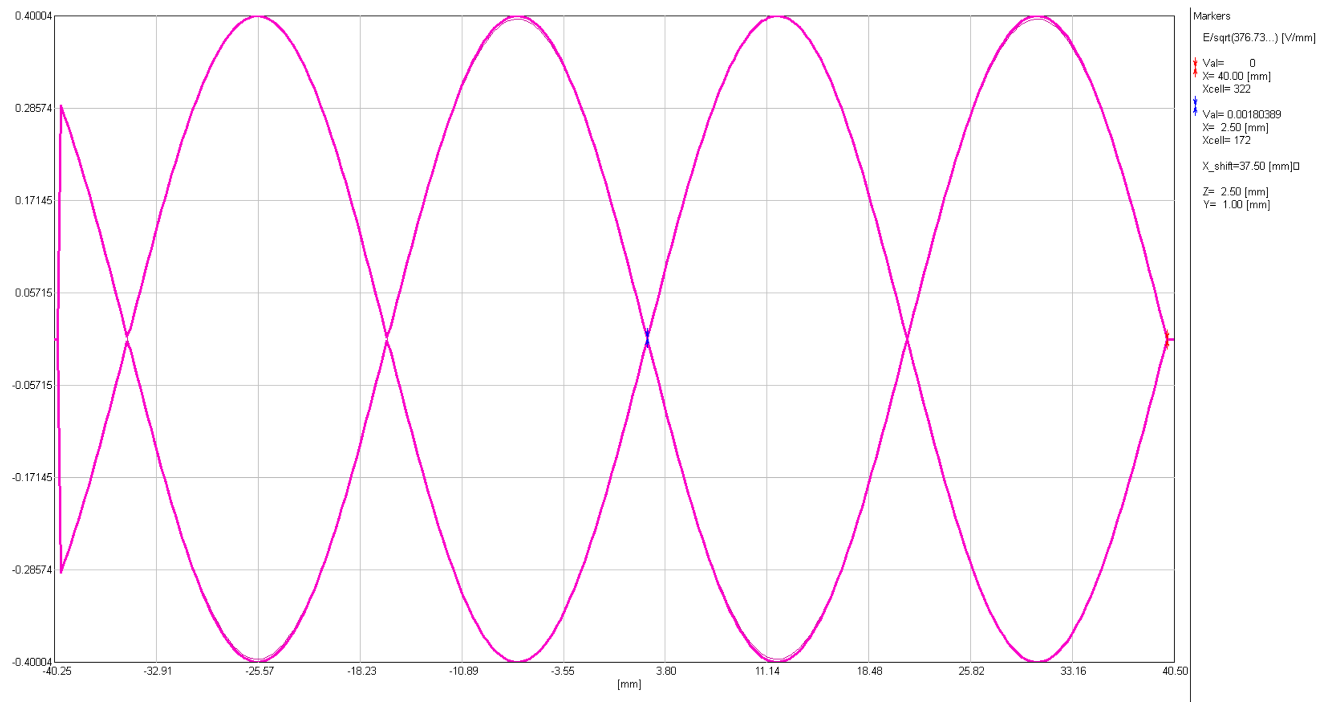
3.7



Direction of EM wave propagation is z. It is the only direction in which the wave is visible.

3.8





$$wavelength\ \lambda = 37{,}5\,[mm]$$

$$SWR = \frac{E_{max}}{E_{min}} = -44{,}44$$

if Gamma > 0:

$$\Gamma(derived\ from\ SWR) = \frac{1+SWR}{1-SWR} = -1{,}04$$

$$Power\ transmission\ coefficient\ T_p = 1-\Gamma^2 = -0{,}09$$

$$Wave\ impedance\ |Z_\perp|\ at\ 0 = 0\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda/8 = 354{,}37\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda/4 = 377{,}00\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ 3\lambda/4 = 376{,}94\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda = -301{,}686138235021\,[\Omega]$$

1b)

3.4

Electrical conductivity value:

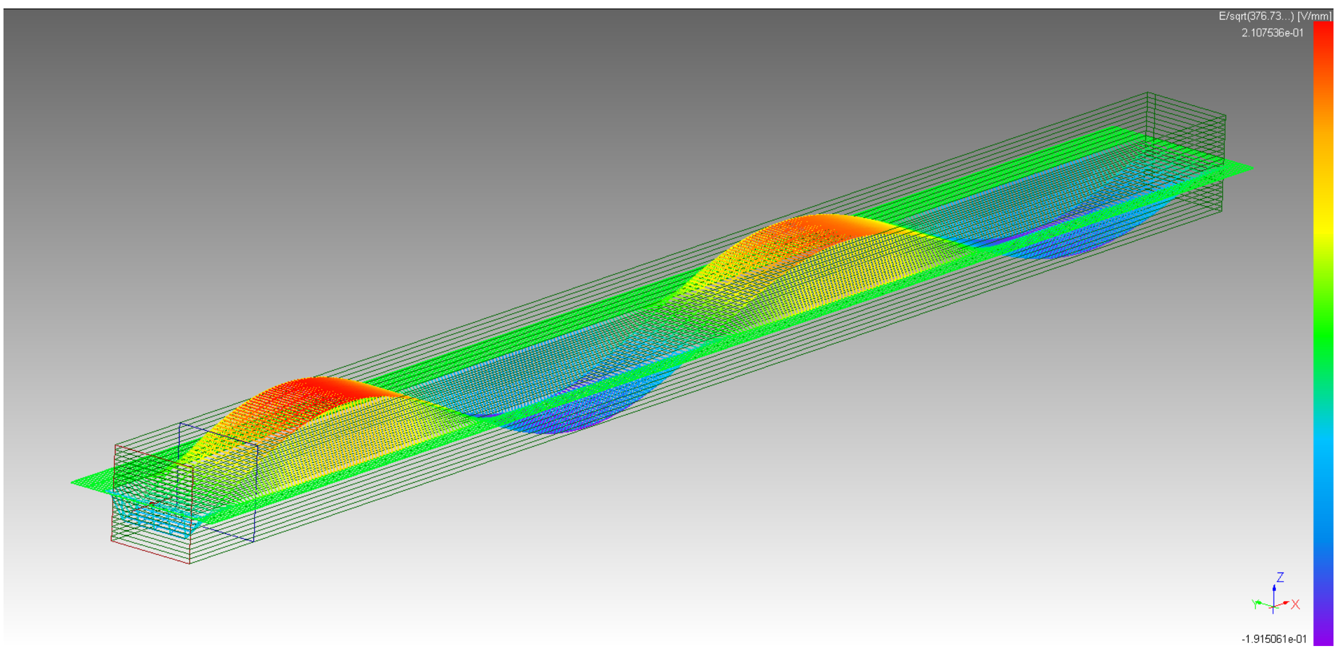
$$\sigma[S/m] \approx \epsilon_r \frac{f[GHz]}{18} \tan(\delta) = 0{,}047\ (lossy\ medium)$$

3.6

$Z_c \, of \, input = 376,7303 [\Omega]$

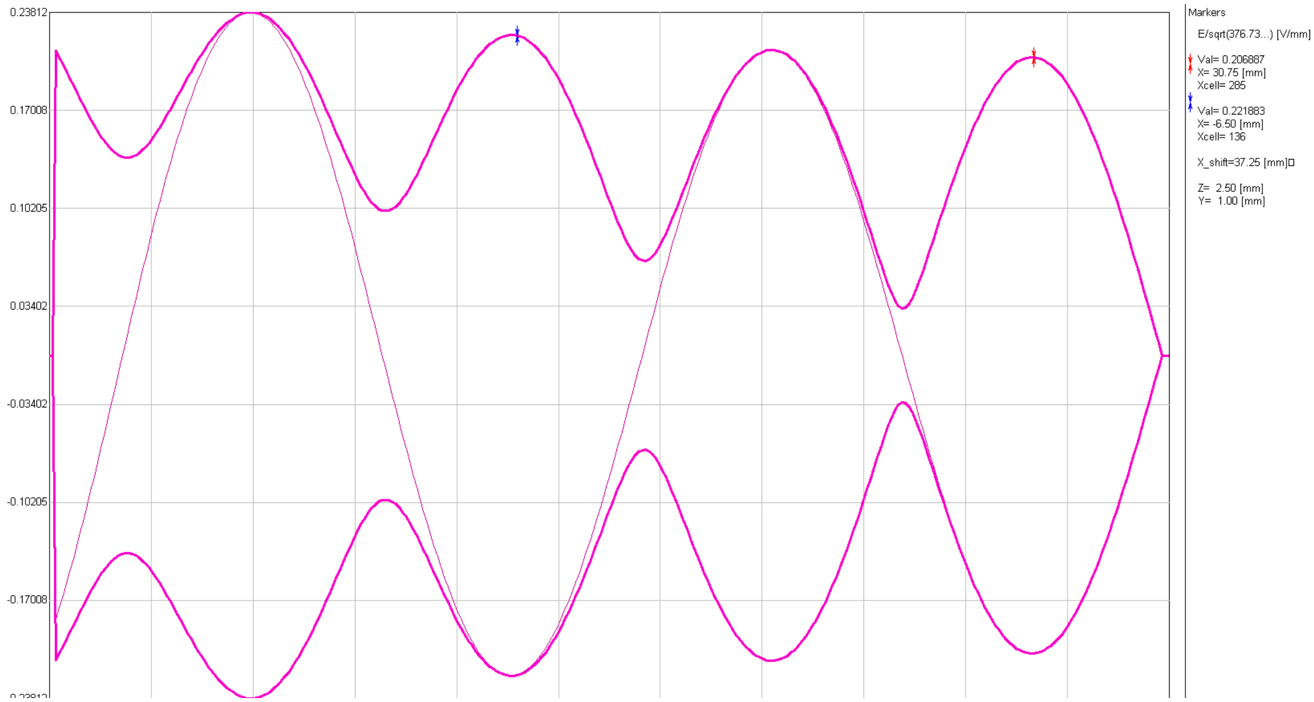
$Z_c - impedance$

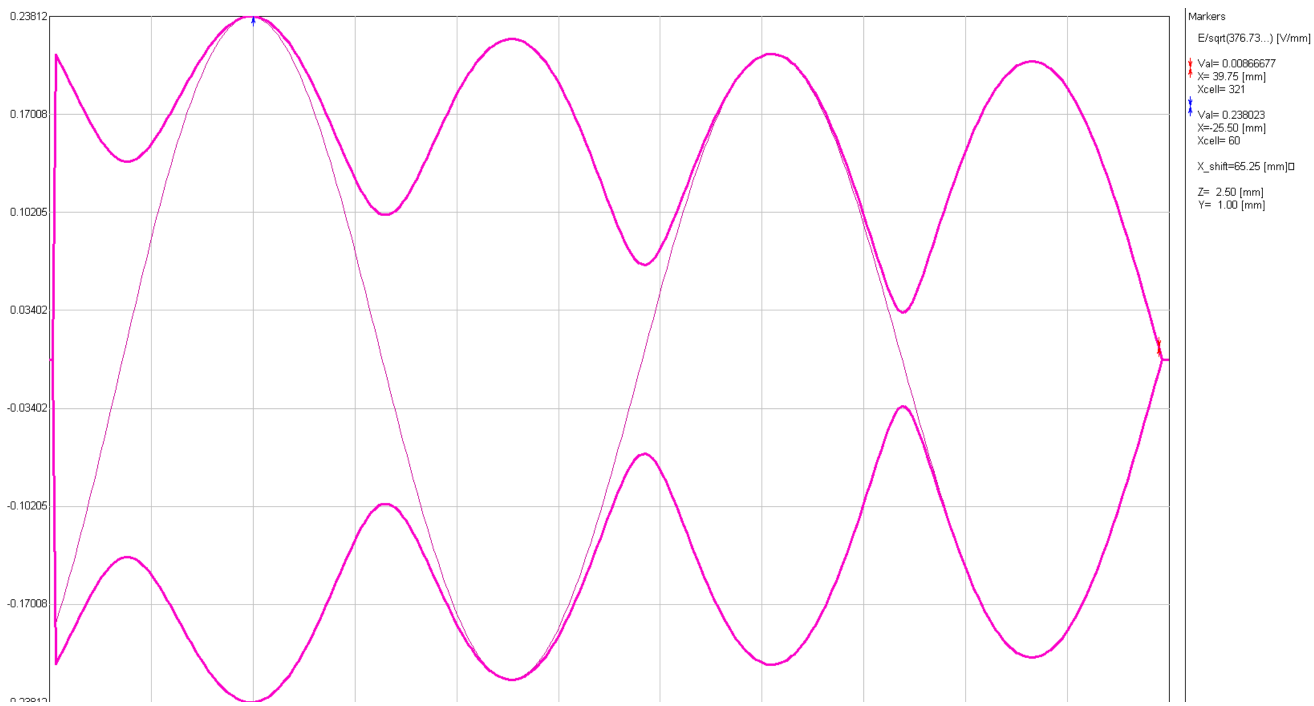
3.7



Direction of EM wave propagation is z, it is the only direction which is visible.

3.8





$$wavelength\ \lambda = 37{,}25\,[mm]$$

$$SWR = \frac{E_{max}}{E_{min}} = 27{,}46$$

$$\Gamma(derived\ from\ SWR) = \frac{1+SWR}{1-SWR} = -1{,}07557475111969$$

if SWR < 0:

$Power\ transmission\ coefficient\ T_p = 1 - \Gamma^2 = -0{,}16$

$Wave\ impedance\ |Z_{\perp}|\ at\ 0 = 754{,}43[\Omega]$

$Wave\ impedance\ |Z_{\perp}|\ at\ \lambda/8 = 369{,}79[\Omega]$

$Wave\ impedance\ |Z_{\perp}|\ at\ \lambda/4 = 381{,}79[\Omega]$

$Wave\ impedance\ |Z_{\perp}|\ at\ 3\lambda/4 = 385{,}49[\Omega]$

$Wave\ impedance\ |Z_{\perp}|\ at\ \lambda = 456{,}31[\Omega]$

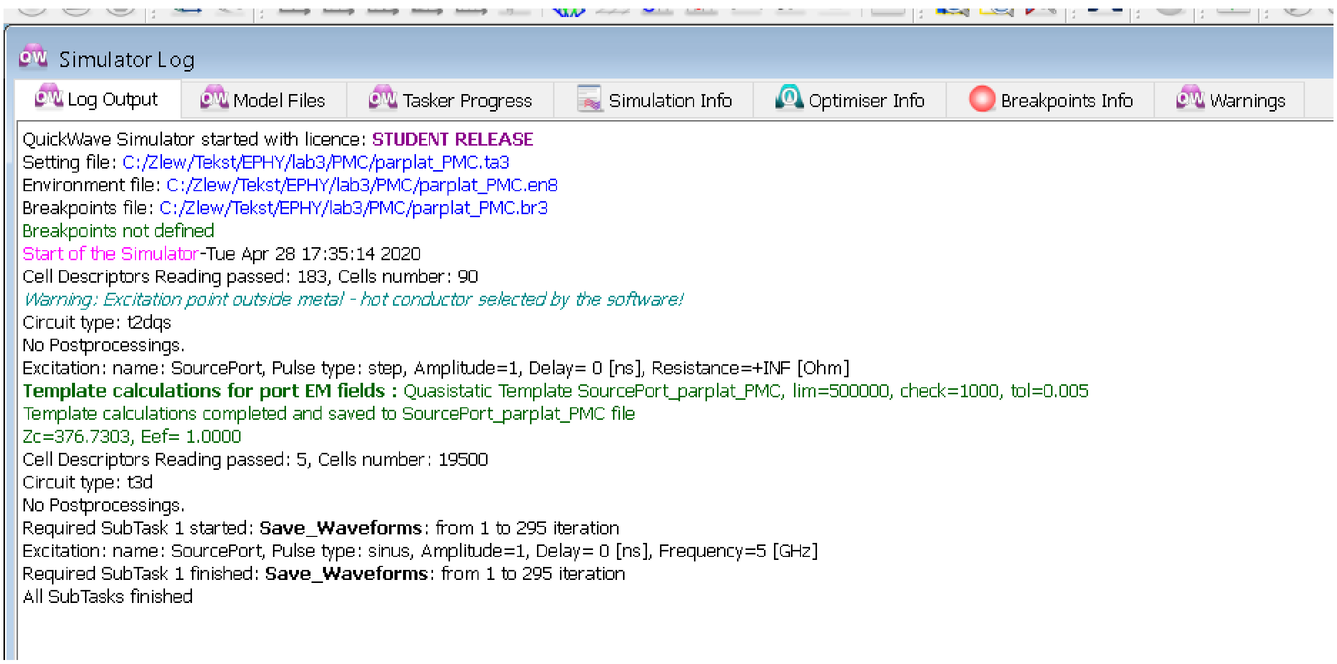
2a)

3.4

Electrical conductivity value:

$$\sigma[S/m] \approx \epsilon_r \frac{f[GHz]}{18} \tan(\delta) = 0\ (lossless\ medium)$$

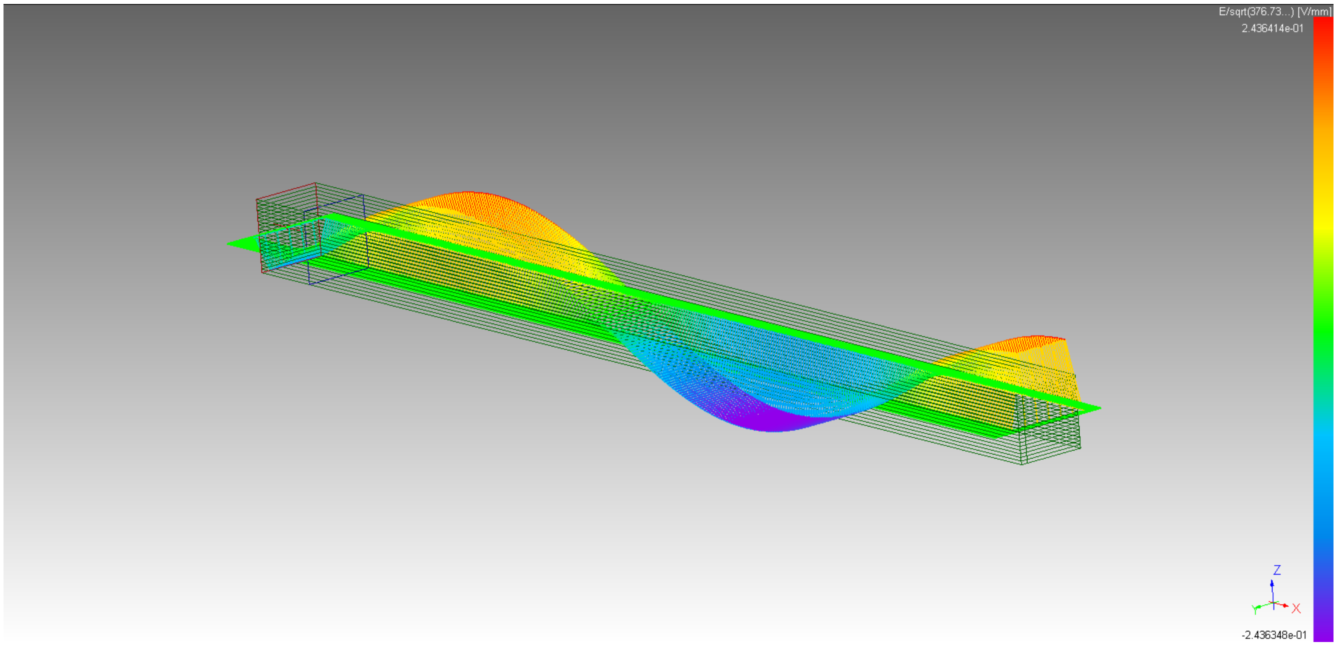
3.6



$Z_c\ of\ input = 376{,}7303[\Omega]$

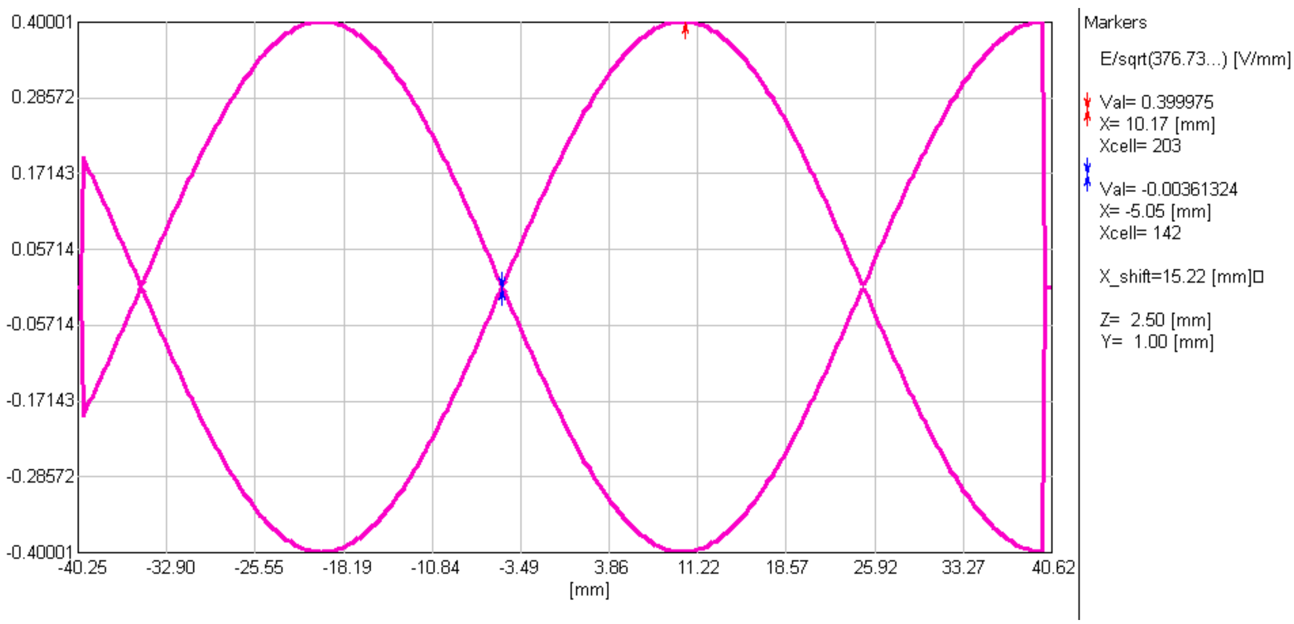
$Z_c - impedance$

3.7



Direction of EM wave propagation is z, it is the only direction visible.

3.8



$wavelength\ \lambda = 60{,}16\,[mm]$

$SWR = -110{,}7$

$\Gamma(derived\ from\ SWR) = \dfrac{1-SWR}{1+SWR} = -0{,}98$

$Power\ transmission\ coefficient\ T_p = 1-\Gamma^2 = 0{,}018$

$Wave\ impedance\ |Z_\perp|\ at\ 0 = 208\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/8 = 471{,}9\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/4 = 377{,}9\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ 3\lambda/4 = 377\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda = 377\,[\Omega]$

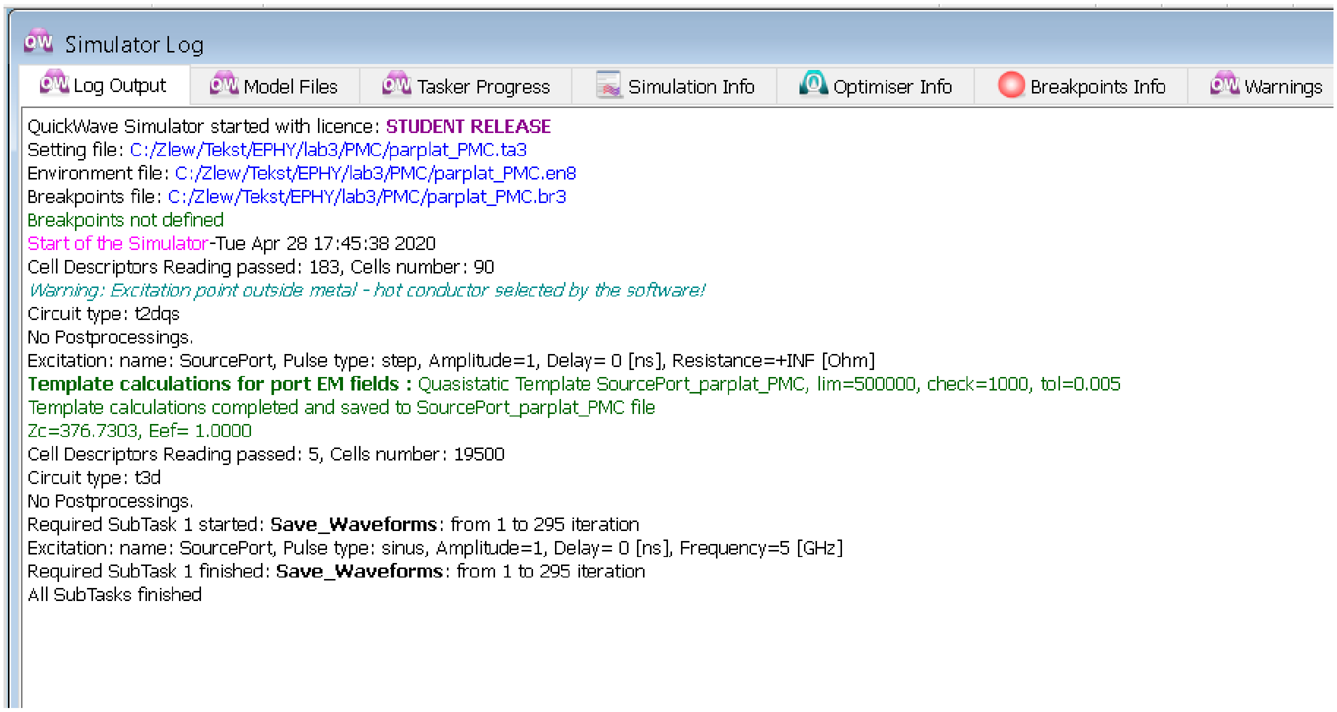
2b)

3.4

Electrical conductivity value:

$\sigma\,[S/m] \approx \epsilon_r \dfrac{f\,[GHz]}{18} \tan(\delta) = 0{,}047\,(lossless\ medium)$

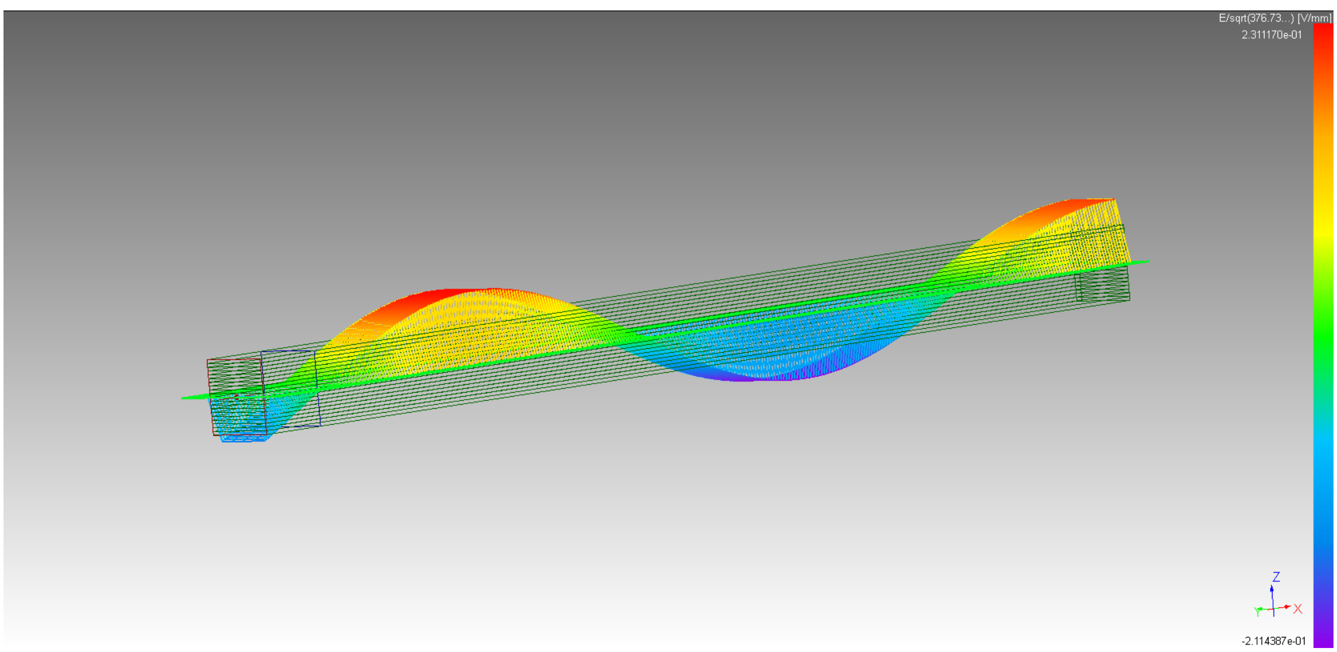
3.6



$Z_c \, of \, input = 376{,}7303 \, [\Omega]$

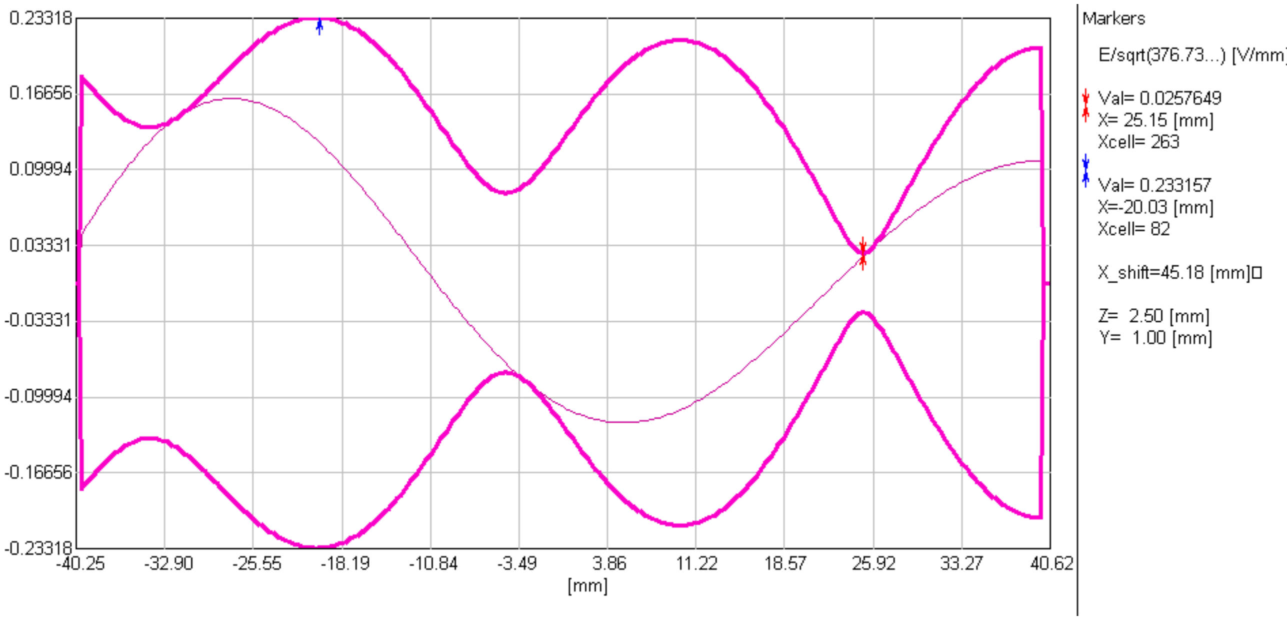
$Z_c - impedance$

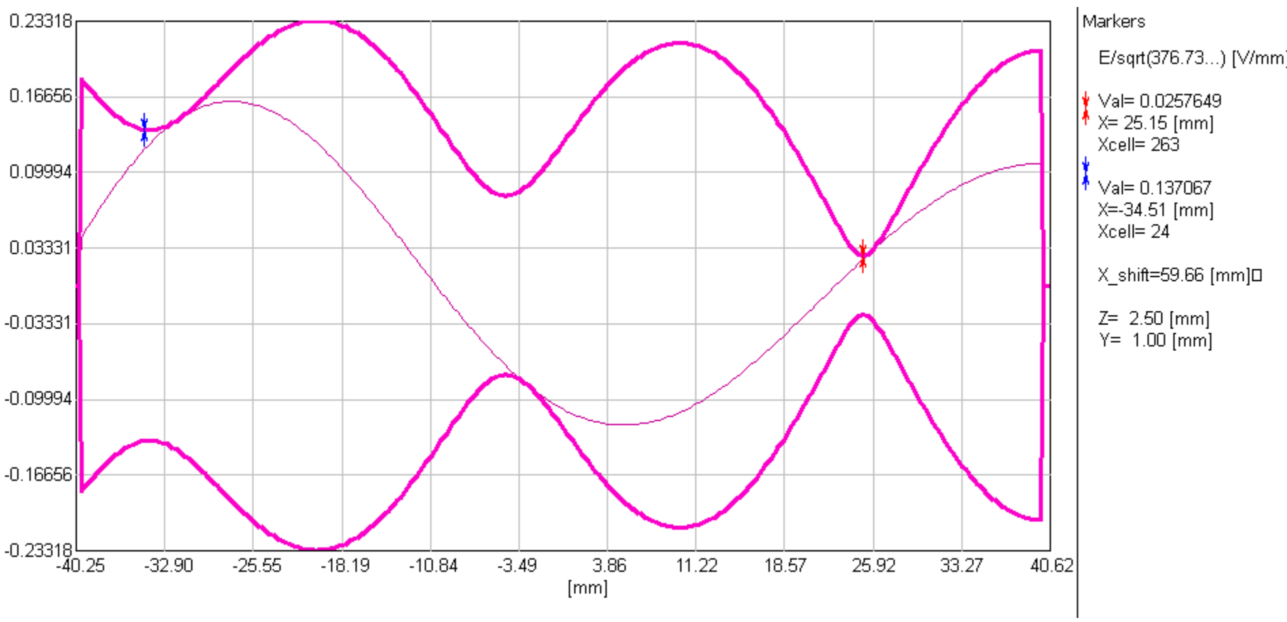
3.7



Direction of EM wave propagation is z, it is the only direction visible.

3.8





$wavelength\ \lambda = 59{,}41\,[mm]$

$SWR = 9{,}05$

$$\Gamma(derived\ from\ SWR) = \frac{1 - SWR}{1 + SWR} = -0{,}8$$

$Power\ transmission\ coefficient\ T_p = 1 - \Gamma^2 = 0{,}36$

$Wave\ impedance\ |Z_\perp|\ at\ 0 = \infty\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/8 = 455{,}7\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/4 = 47{,}5\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ 3\lambda/4 = 1354{,}63\,[\Omega]$

$$Wave\,impedance\,|Z_{\perp}|\,at\,\lambda = 816{,}04\,[\Omega]$$

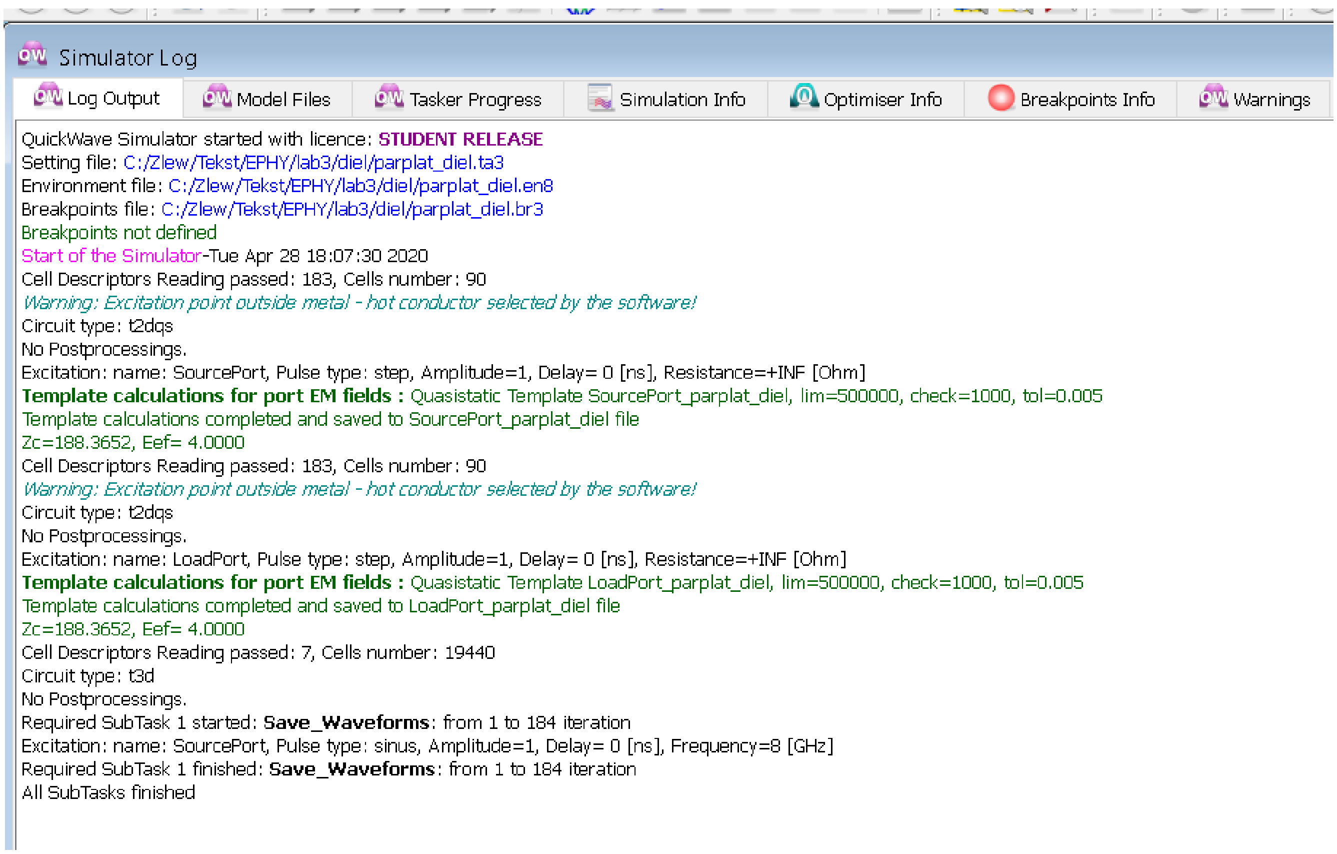
3a)

3.4

Electrical conductivity value:

$$\sigma[S/m] \approx \epsilon_r \frac{f\,[GHz]}{18} \tan(\delta) = 0\,(lossless\,medium)$$

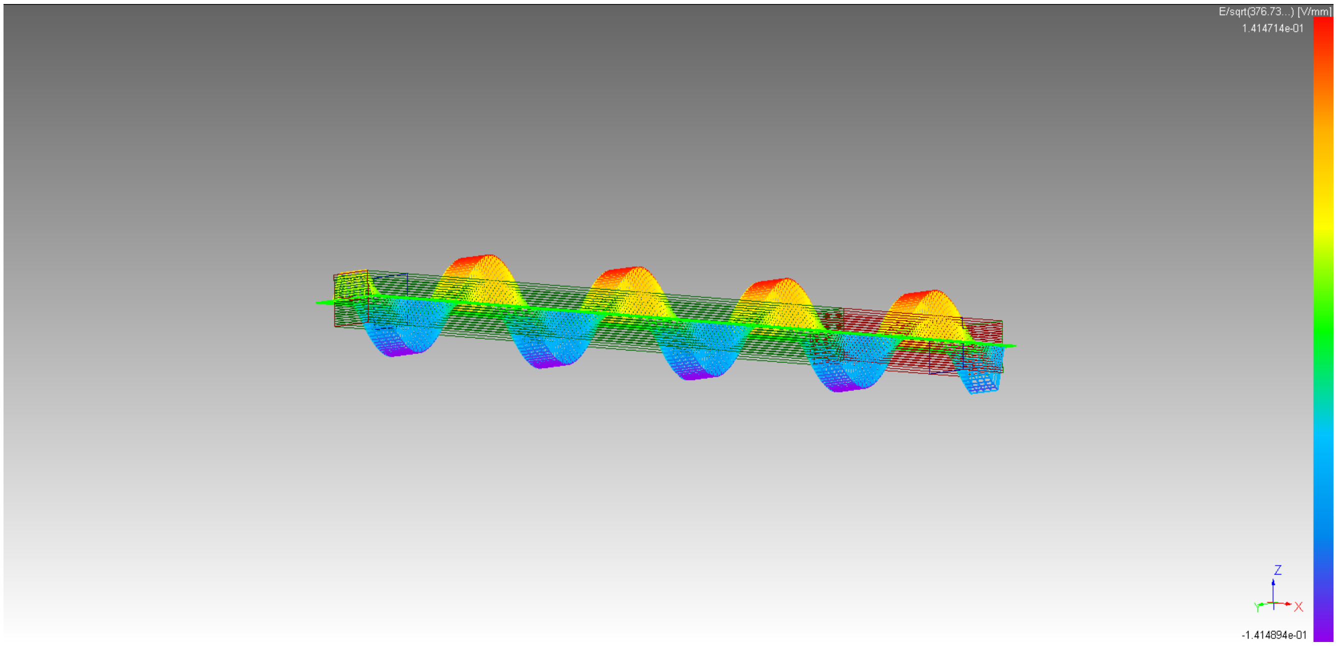
3.6



$$Z_c\,of\,input = 188{,}3652\,[\Omega]$$

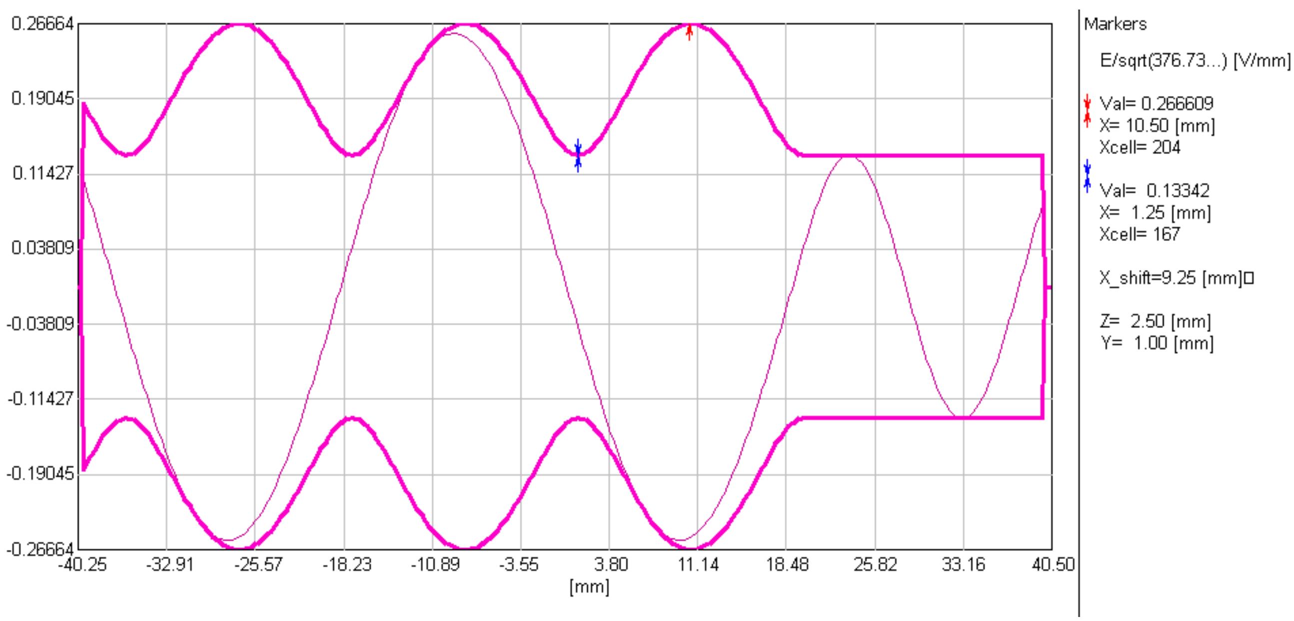
$$Z_c - impedance$$

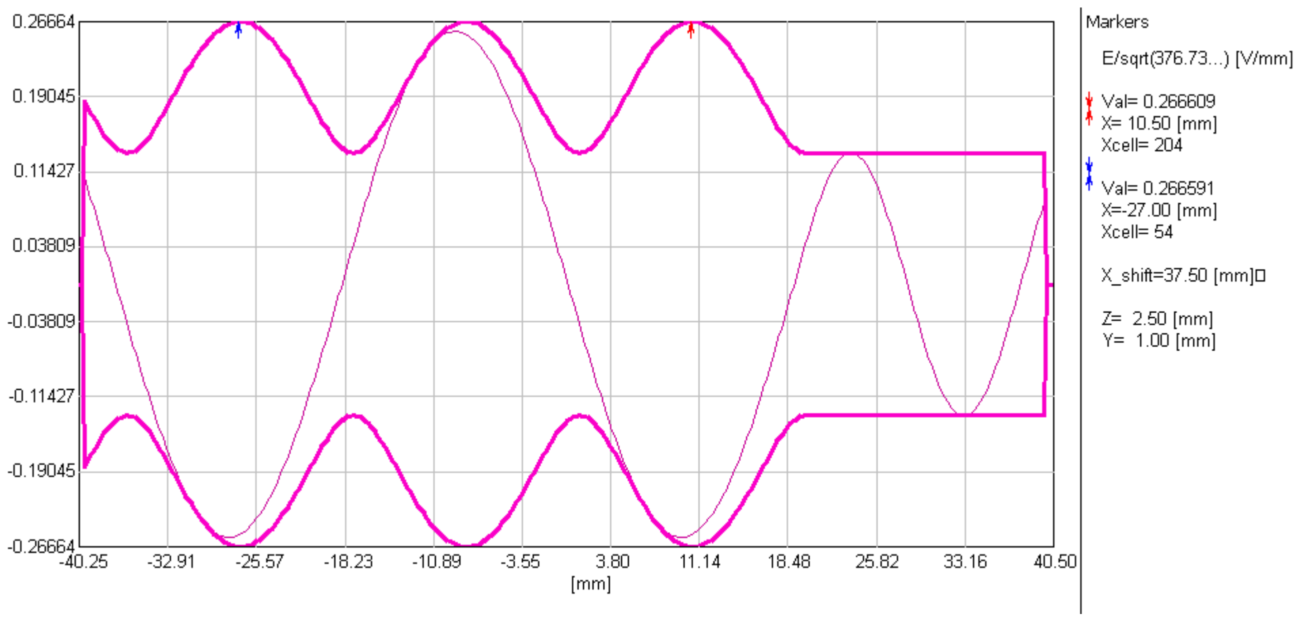
3.7



Direction of EM wave propagation is z, it is the only direction visible

3.8





$wavelength\ \lambda = 37{,}5\,[mm]$

$SWR = 1{,}98$

if SWR > 0:

$\Gamma\,(derived\ from\ SWR) = \frac{1+SWR}{1-SWR} = -3{,}05$

$Power\ transmission\ coefficient\ T_p = 1 - \Gamma^2 = -8{,}3$

$Wave\ impedance\,|Z_\perp|\,at\ 0 = 0$

$Wave\ impedance\,|Z_\perp|\,at\ \lambda/8 = 192{,}14\,[\Omega]$

$Wave\ impedance\,|Z_\perp|\,at\ \lambda/4 = 397{,}82\,[\Omega]$

$Wave\ impedance\,|Z_\perp|\,at\ 3\lambda/4 = 377\,[\Omega]$

$Wave\ impedance\,|Z_\perp|\,at\ \lambda = 376{,}97\,[\Omega]$

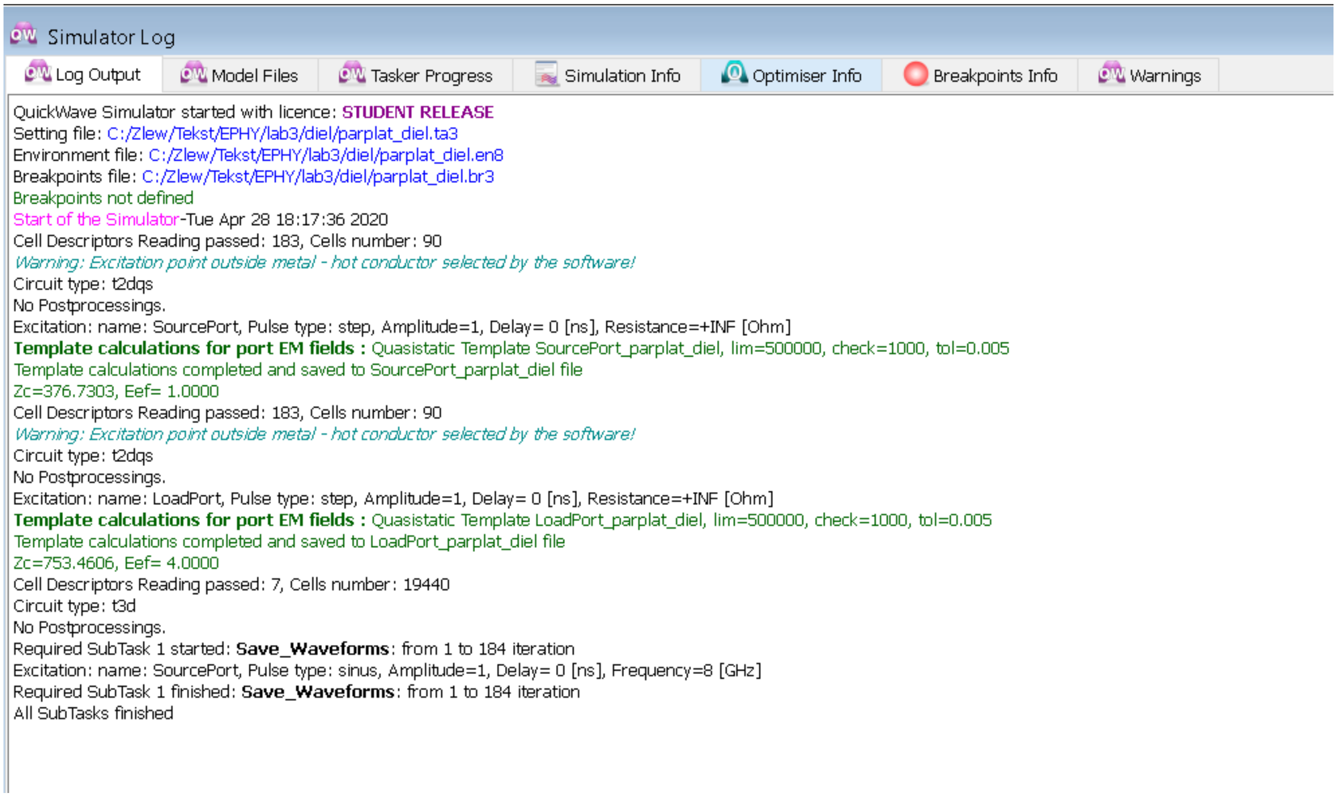
3b)

3.4

Electrical conductivity value:

$\sigma\,[S/m] \approx \epsilon_r \frac{f\,[GHz]}{18} \tan(\delta) = 0\,(lossless\ medium)$

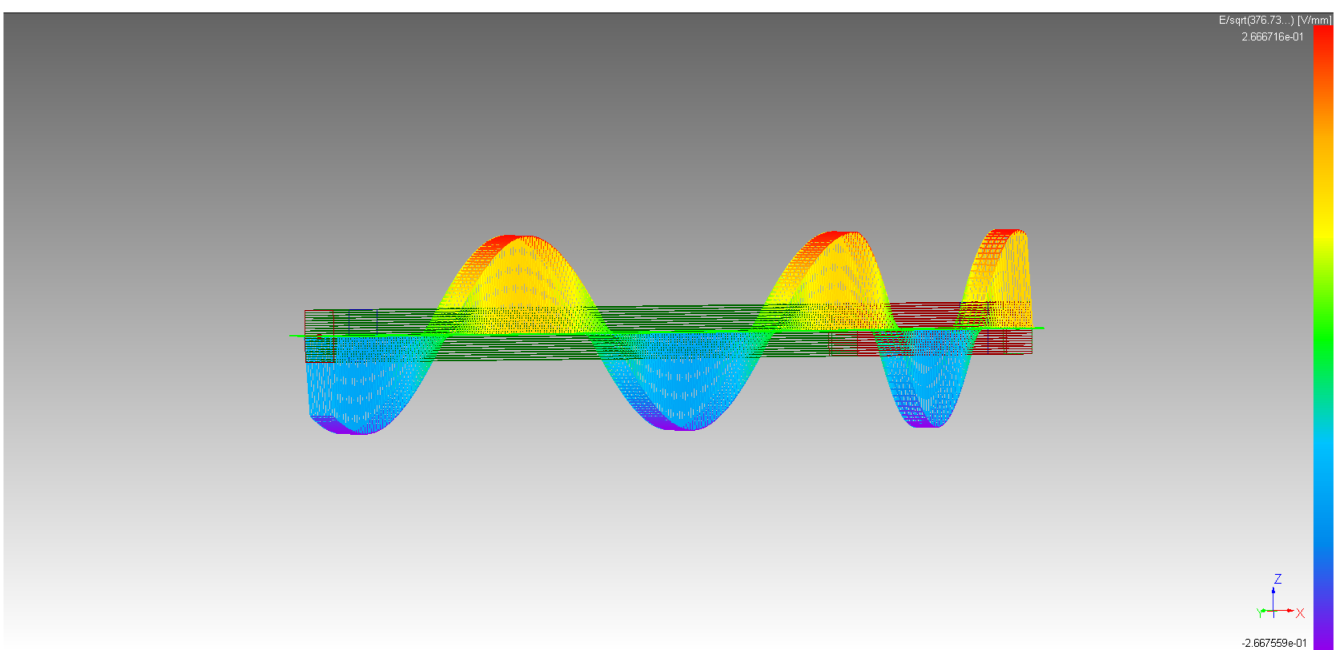
3.6



$Z_c\, of\ input = 753{,}4606\, [\Omega]$

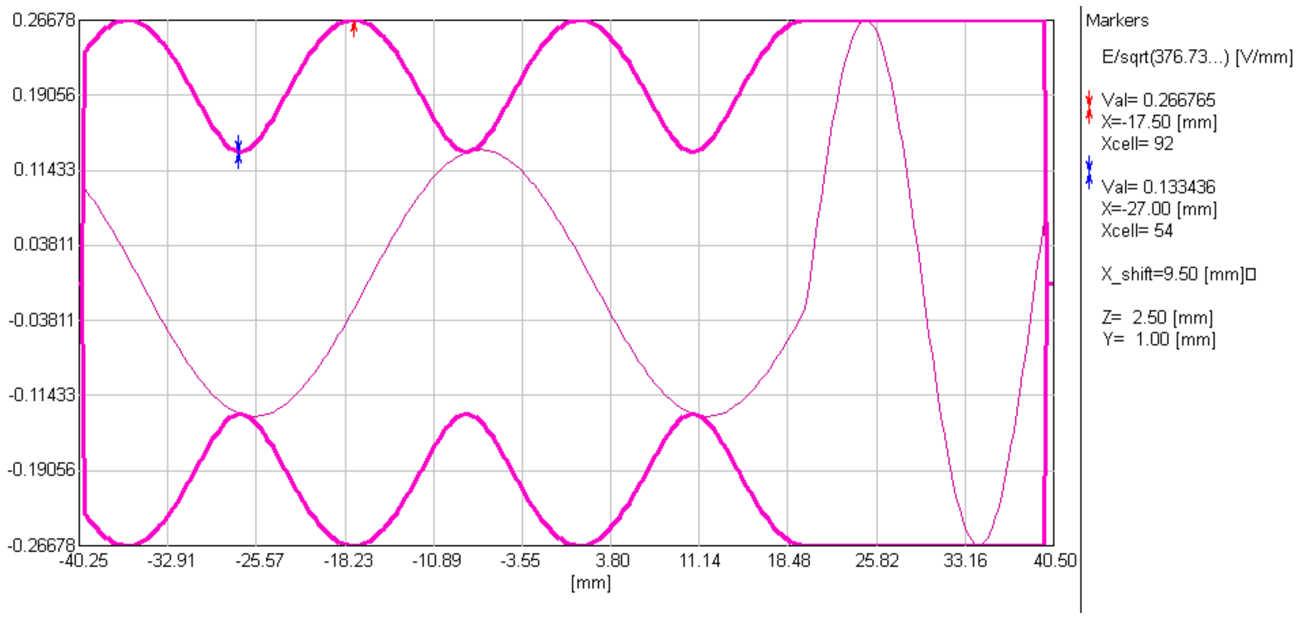
$Z_c - impedance$

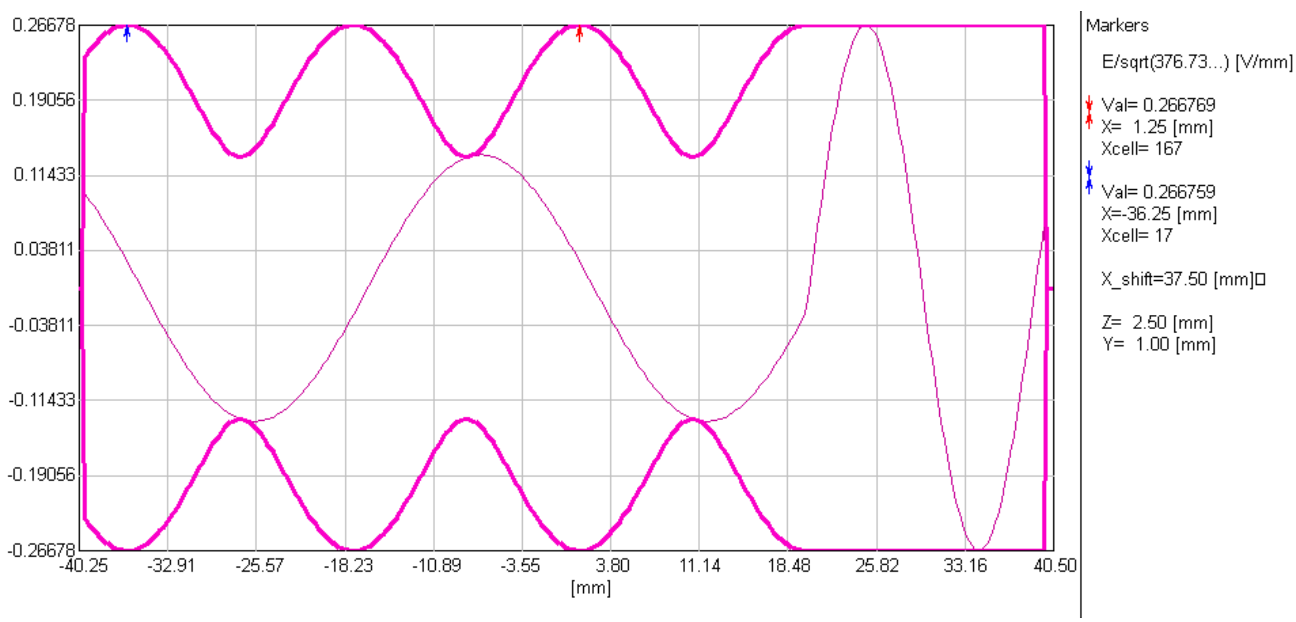
3.7



Direction of EM wave propagation is z, as it is the only direction visible.

3.8





$wavelength\ \lambda = 37{,}5\,[mm]$

$SWR = 2$

$$\Gamma\,(derived\ from\ SWR) = \frac{1+SWR}{1-SWR} = -3$$

$$Power\ transmission\ coefficient\ T_p = 1 - \Gamma^2 = -8$$

$$Wave\ impedance\ |Z_\perp|\ at\ 0 = 0$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda/8 = 748\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda/4 = 347\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ 3\lambda/4 = 356{,}4\,[\Omega]$$

$$Wave\ impedance\ |Z_\perp|\ at\ \lambda = 377\,[\Omega]$$

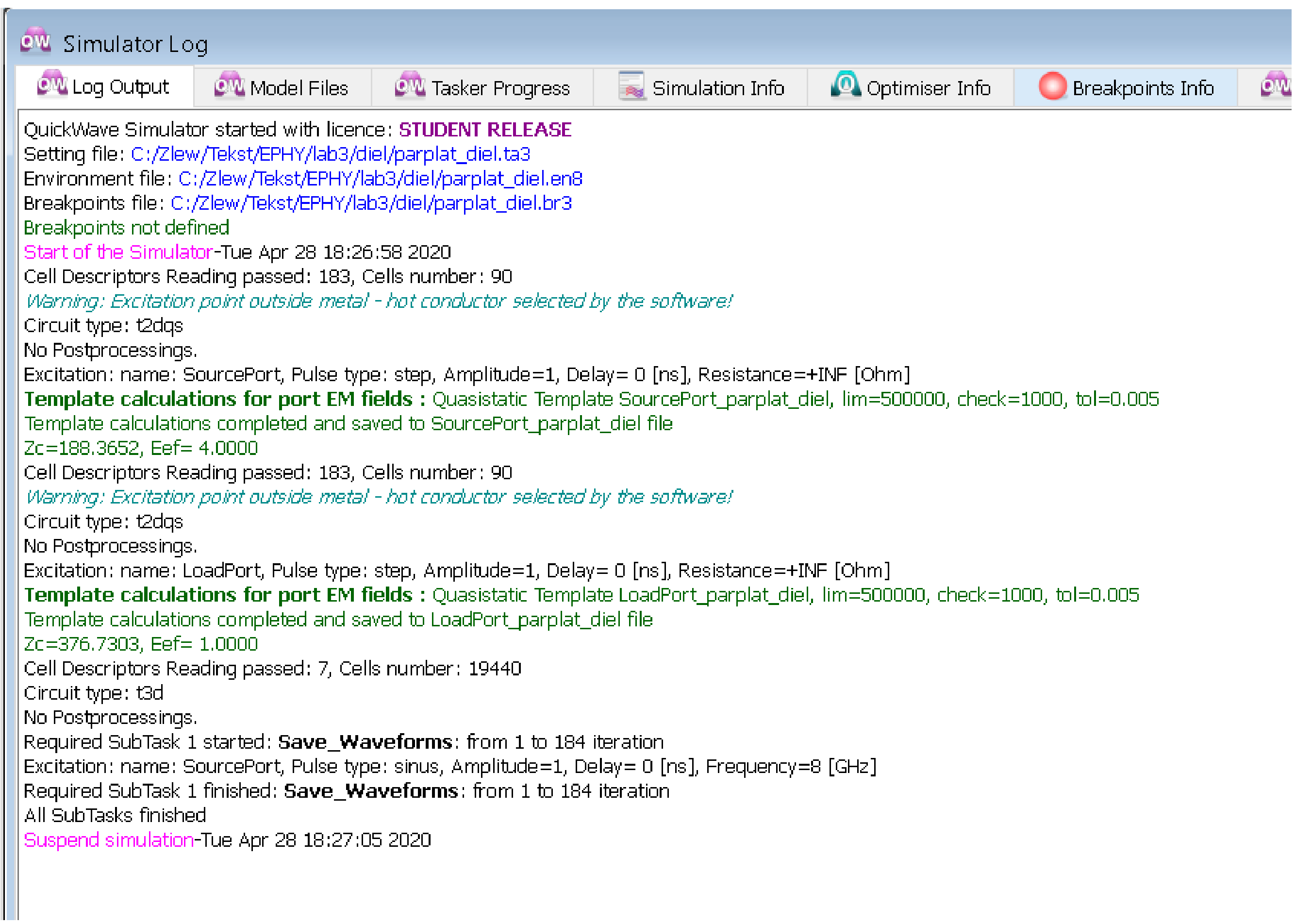
4a)

3.4

Electrical conductivity value:

$$\sigma[S/m] \approx \epsilon_r \frac{f\,[GHz]}{18} \tan(\delta) = 0\,(lossless\ medium)$$

3.6



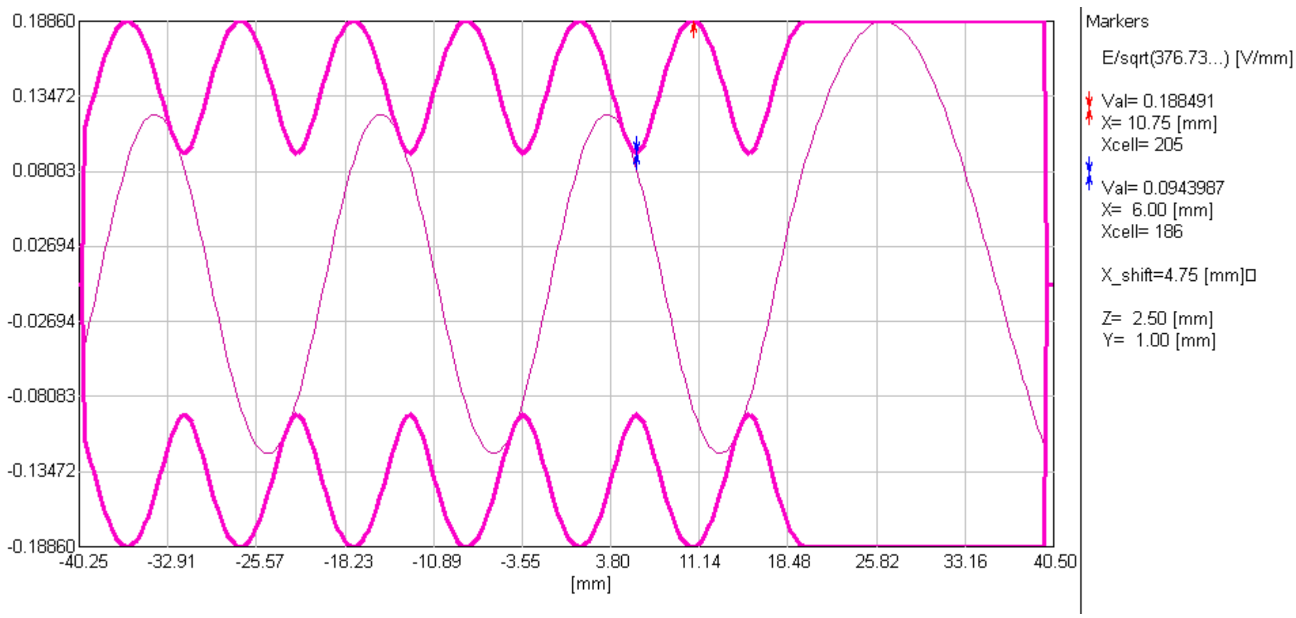
$Z_c \, of \, input = 376{,}7303 [\Omega]$

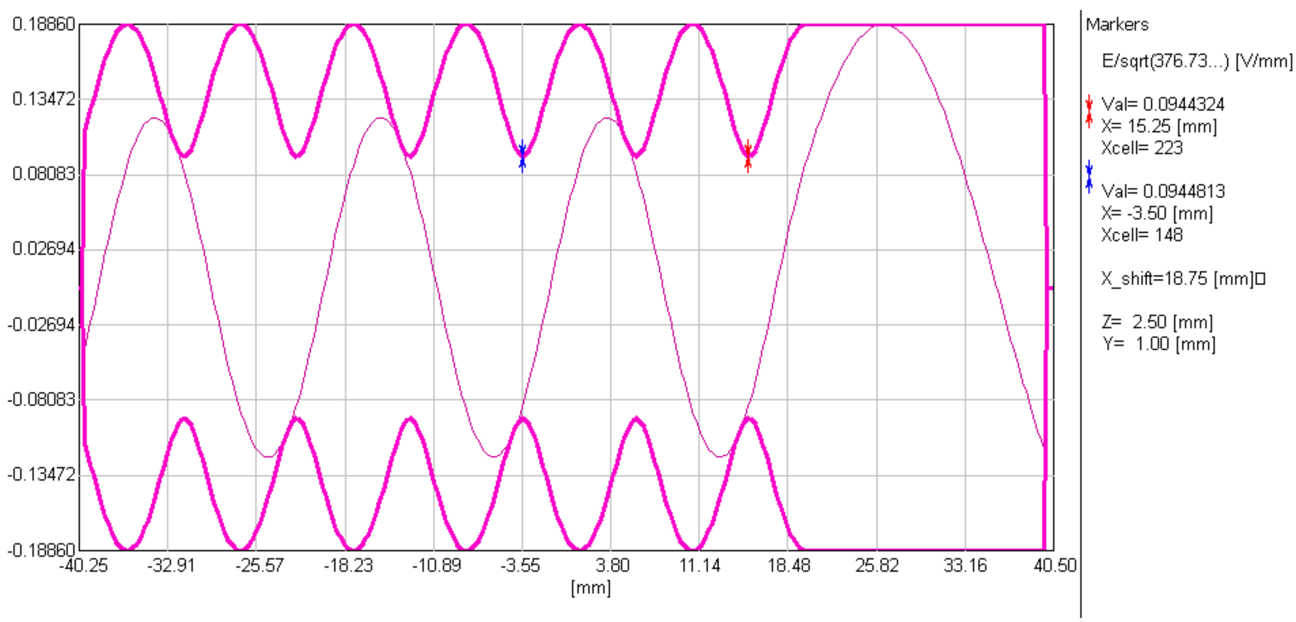
$Z_c - impedance$

3.7

Direction of EM wave propagation is z, it is the only direction visible

3.8





$wavelength\ \lambda=18{,}75\,[mm]$

$SWR=2$

$\Gamma(derived\ from\ SWR)=\frac{1-SWR}{1+SWR}=-0{,}33$

$Power\ transmission\ coefficient\ T_p=1-\Gamma^2=0{,}89$

$Wave\ impedance\ |Z_\perp|\ at\ 0=378{,}43\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/8=112{,}17\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda/4=112{,}028\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ 3\lambda/4=376{,}6\,[\Omega]$

$Wave\ impedance\ |Z_\perp|\ at\ \lambda=94{,}36\,[\Omega]$

Wave impedance is variable because

Boundary conditions for Ez and Hy are

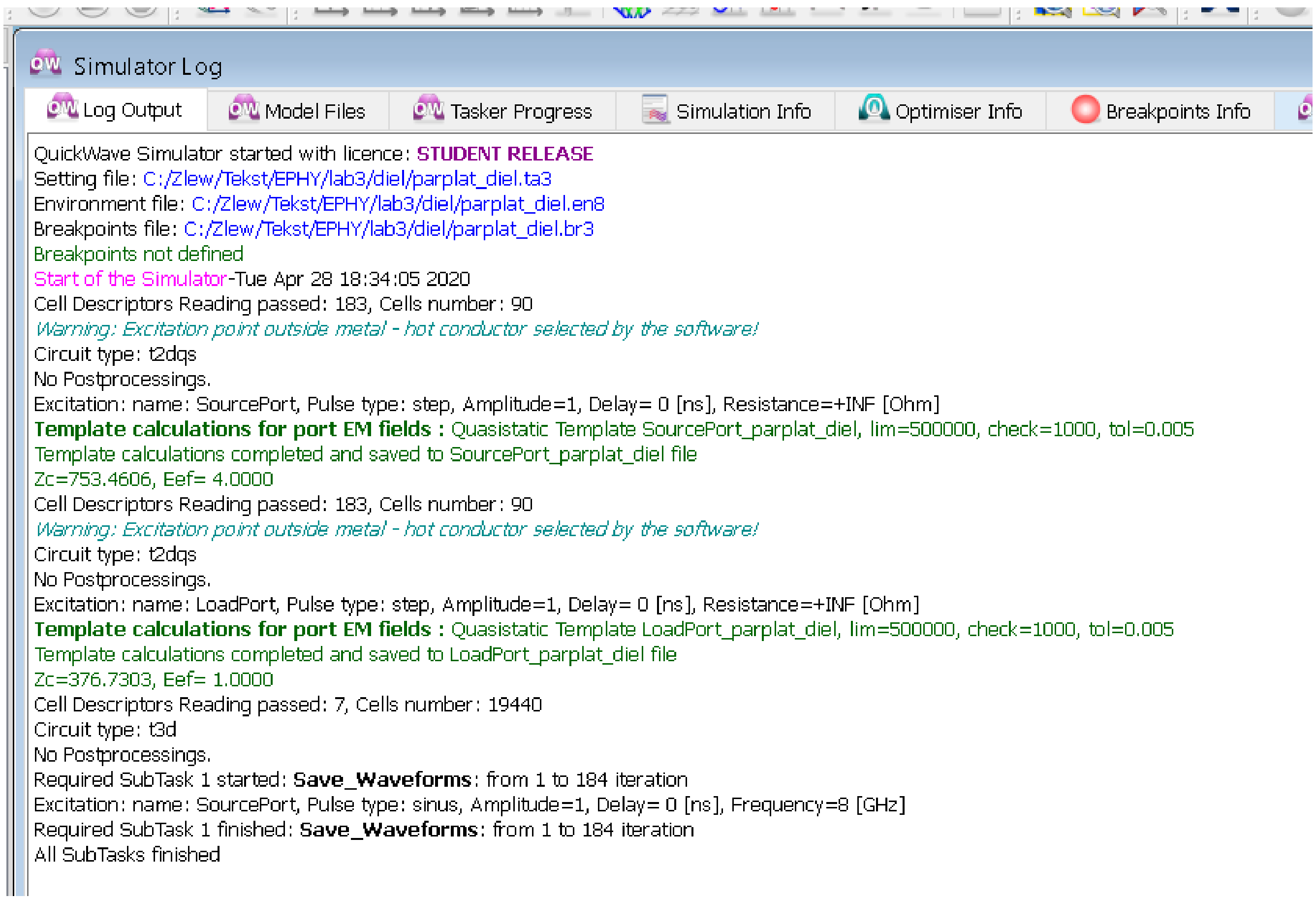
4b)

3.4

Electrical conductivity value:

$\sigma[S/m]\approx\epsilon_r\frac{f\,[GHz]}{18}\tan(\delta)=0\,(lossless\ medium)$

3.6



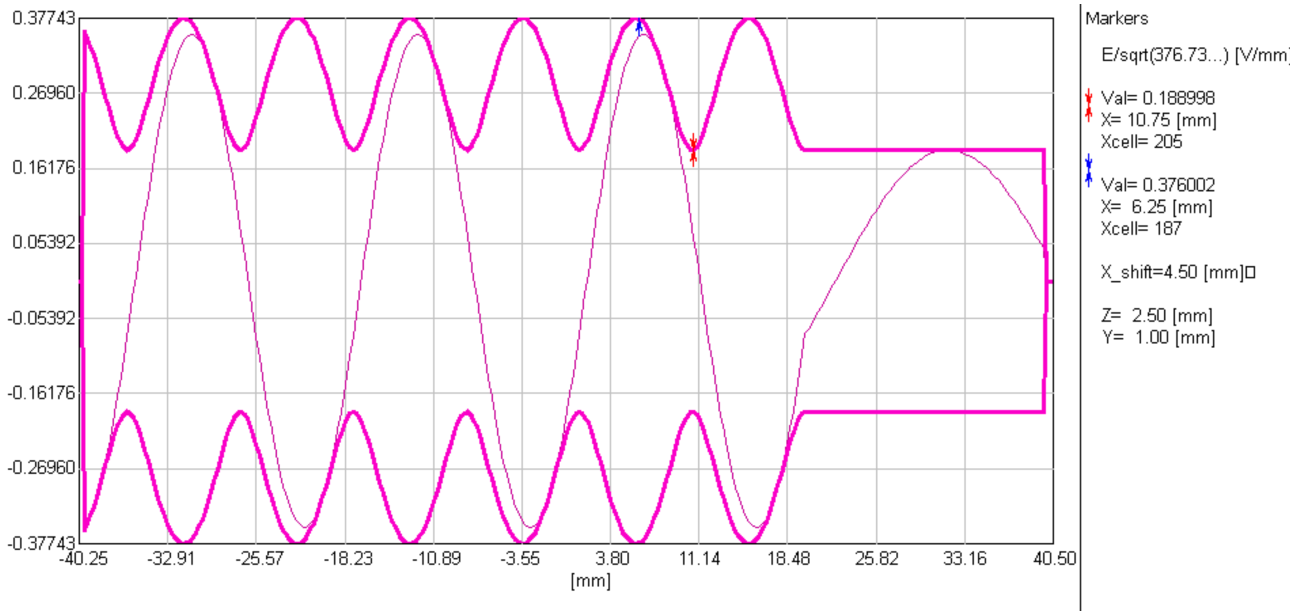
$Z_c \, of \, input = 376{,}7303 \, [\Omega]$

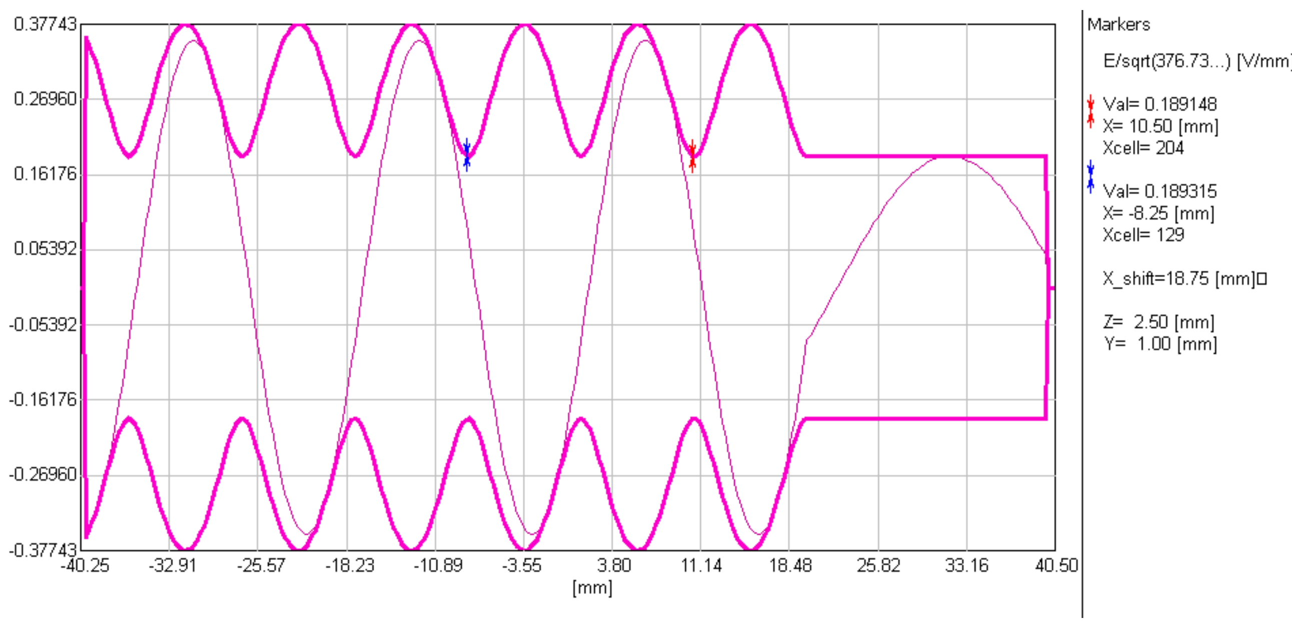
$Z_c - impedance$

3.7

Direction of EM wave propagation is z, it is the only direction visible

3.8





$wavelength\ \lambda = 19\,[mm]$

$SWR = 2$

$$\Gamma\,(derived\ from\ SWR) = \frac{1+SWR}{1-SWR} = -3{,}02$$

$$Power\ transmission\ coefficient\ T_p = 1 - \Gamma^2 = -8{,}13$$

$Wave\,impedance|Z_{\perp}|\,at\,0=352{,}21[\Omega]$

$Wave\,impedance|Z_{\perp}|\,at\,\lambda/8=107{,}21[\Omega]$

$Wave\,impedance|Z_{\perp}|\,at\,\lambda/4=99{,}3[\Omega]$

$Wave\,impedance|Z_{\perp}|\,at\,3\lambda/4=379{,}3[\Omega]$

$Wave\,impedance|Z_{\perp}|\,at\,\lambda=100{,}01[\Omega]$

Wave impedance is variable because it depends on lambda.

Boundary conditions for Ez and Hy are 1 and -1

Questions:

a) Frequency is proportional with standing wave parameters.

b) We asses the sign of Γ by using the equation for Γ.

c) Physically possible range of SWR and Γ is from -1 to 1

d) PEC and PMC would be realized in the easiest way in practical application by

e) SWR and Γ value in illuminated dielectric is negative because the dielectric properties.

f) We cannot obtain a totally standing wave in a lossy medium because there will always be some losses.