# Graphene interconnect as Coaxial Cable supporting frequencies at Tera Hz range

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# Introduction

- Coaxial carbon nano structure for **THz range** interconnect.
- Rolled Graphene is typically a carbon nano tube (CNT) designed by using **hexagonal Boron Nitride** as dielectric and Graphene layer on outer side of CNT.
- The interconnect bandwidth is measured by Insertion loss of 100 GHz to THz range of graphene cylinder by modelling it analytically using COMSOL Multiphysics software.
- Quantum conductivity and ballistic transport of electrons in graphene make this structure as better substitute for copper interconnects.

# Graphene

- Graphene is a rapidly rising star on the horizon of materials science and condensed-matter physics.
- Graphene can be described as a one- atom thick layer of graphite.
- It is the basic structural element of other allotropes, including graphite, charcoal, carbon nanotubes and fullerenes.
- Zero Band Gap Material
- Graphene is the strongest, thinnest material known to exist.
- Graphene is an atomic-scale honeycomb lattice made of carbon atoms.
- Graphene is a 2D building material for carbon materials of all other dimensionalities.

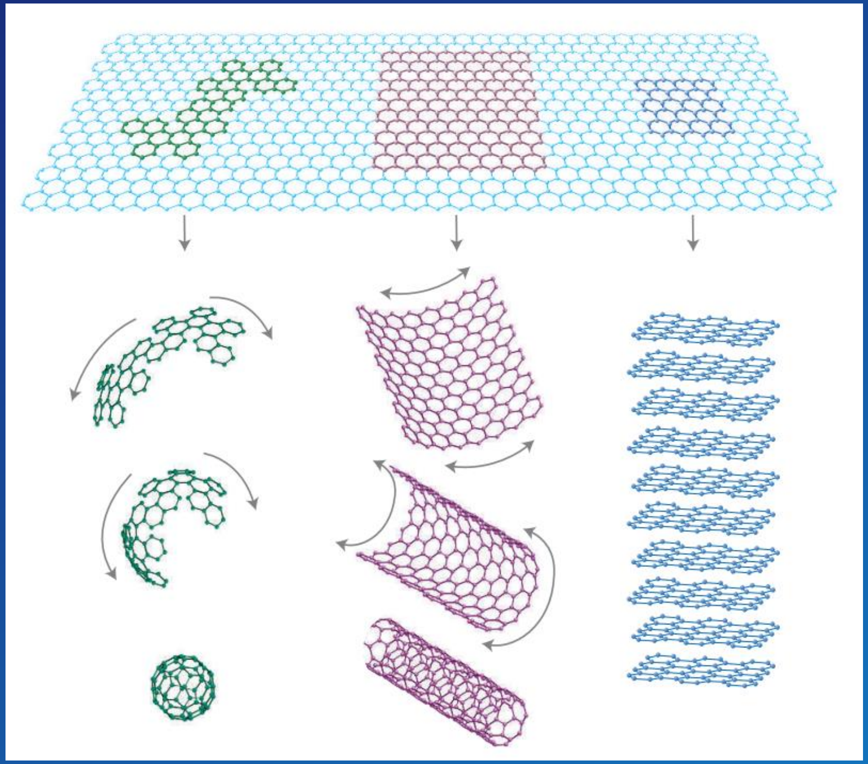
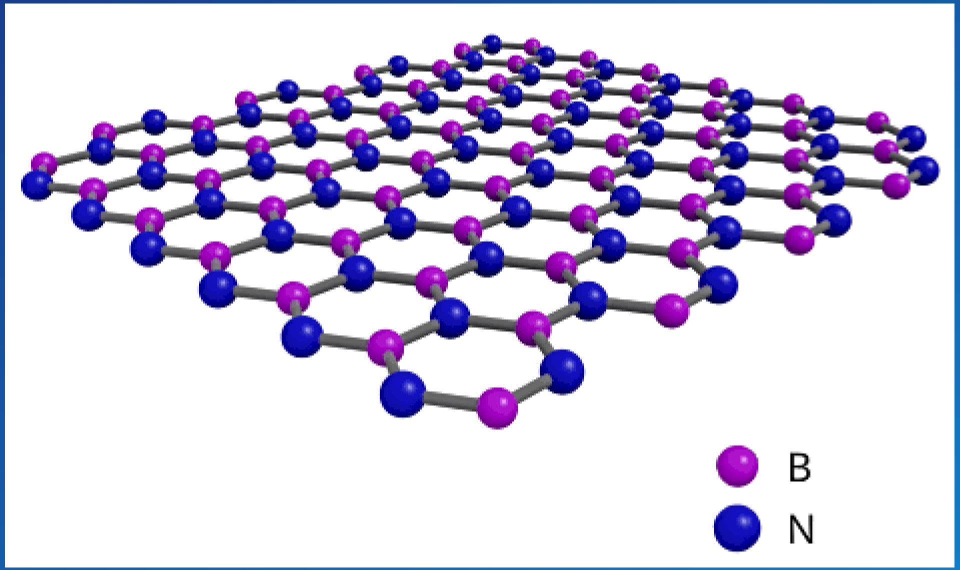


Fig 1: Graphene can be wrapped up into 0D buckyballs, rolled into 1D nanotubes or stacked into 3D graphite.

# Boron Nitride

- Has similar structure that of Graphene.
- Hexagonal boron nitride (h-BN) prove to be efficient dielectric which has relatively smooth surface having dangling bonds giving large electrical bandwidth.
- 5.97 eV bandgap



# Modelling of Graphene Sheet

- Monolayer Graphene sheet is simulated in COMSOL.
- Its mobility, thermal conductivity and electronic conductivity are analyzed.
- Mono- Layer sheet of Graphene is of dimensions 100mm x 100 mm.

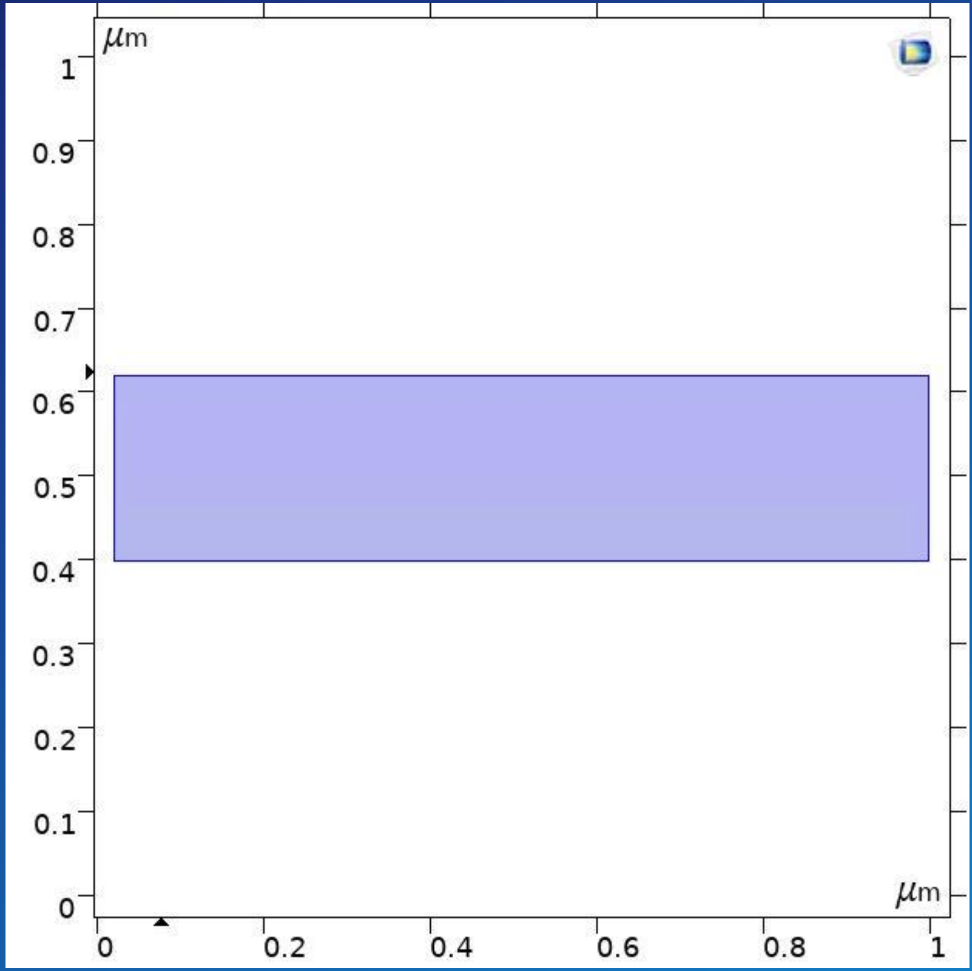



Fig 2: Mono – Layer Graphene Sheet Simulated in COMSOL Multiphysics Tool (5.4 version).

# Mobility of Graphene

Mobility of Graphene:

$$\mu = \frac{4e\hbar\rho v^2{}_f v^2{}_{eff}}{\pi n D^2{}_{eff} K_B T}$$

Where

ħ is effective Planck's constant (h/2π),

$v_{eff}$ is the effective phonon velocity,

n is charge concentration,

$D_{eff}$ is deformation potential

$K_B$ is Boltzmann constant.

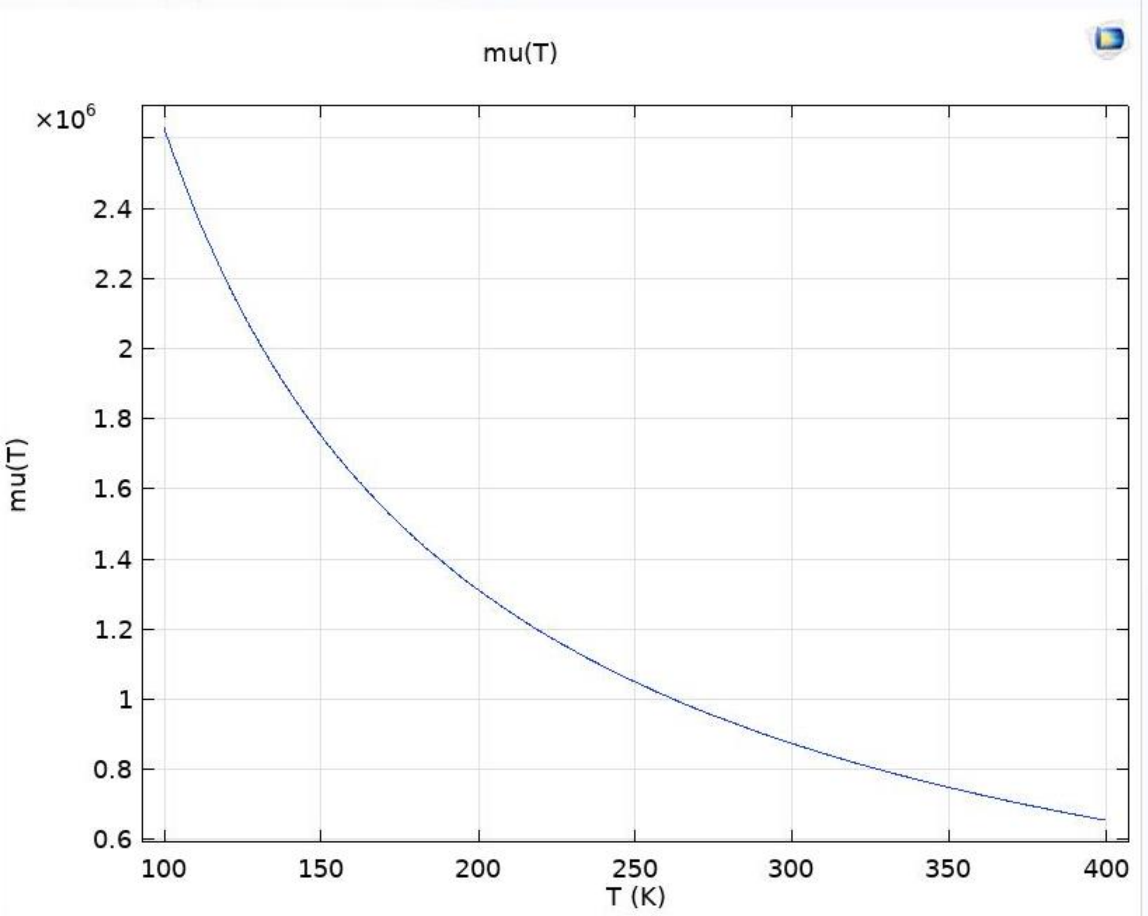



Fig 3: Mobility Curve of Mono-Layer Graphene Sheet simulated in COMSOL Multiphysics.

# Thermal Conductivity

- Thermal conductivity is function of length
- It increases with temperature.

$$k = (2\pi \Upsilon^2)^{-1} \rho \left(\frac{v^4}{f_m T}\right) \ln\left(\frac{f_m}{f_B}\right)$$

$$f_B = \left(\frac{M v^2 f_m}{4\pi \Upsilon^2 K_B T L}\right)^{1/2}$$

Where, ϒ is lattice parameter,
ρ is density of material, v is average velocity of sound,
T is temperature,
fm and fb are upper cut off frequencies, q vector is near to brilluoin zone,
M is mass of carbon atom,
KB is the Boltzmann constant.

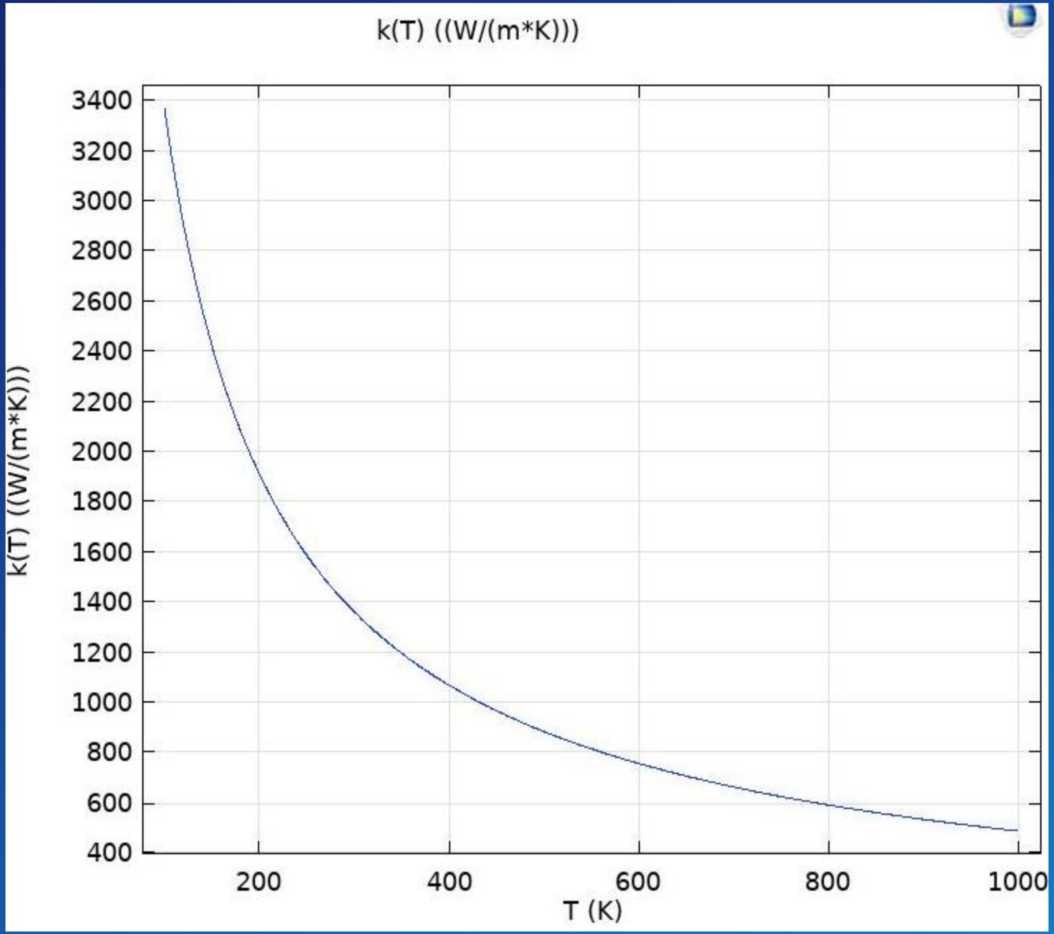
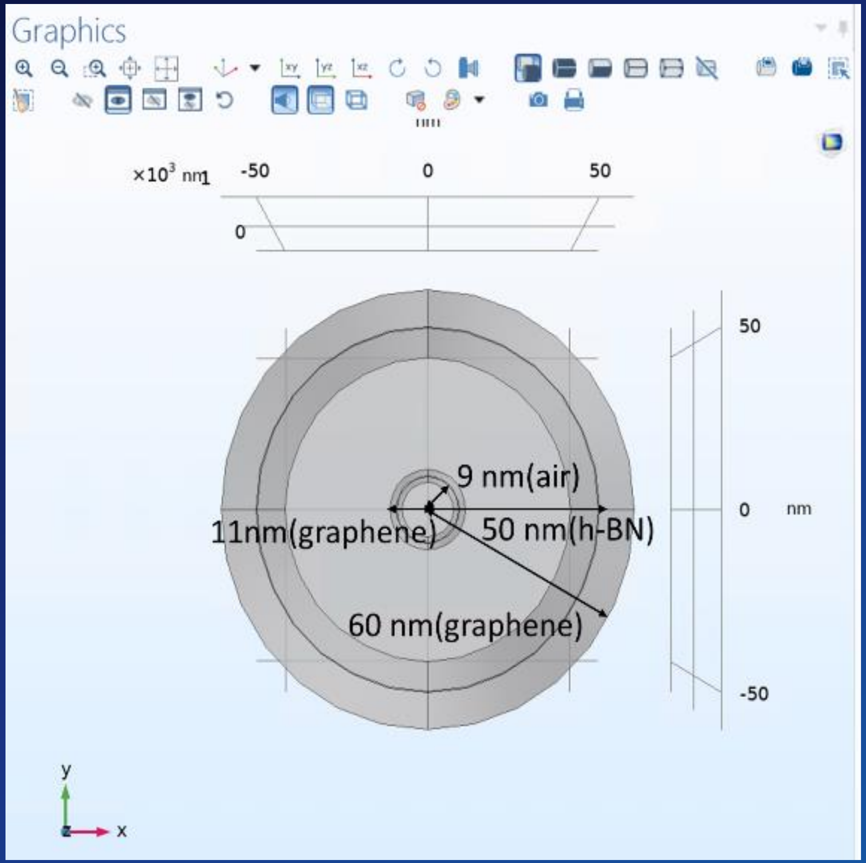



Fig 4: Thermal Conductivity graph of Mono-Layer Graphene Sheet simulated in COMSOL Multiphysics.

# Modeling of Coaxial Cable



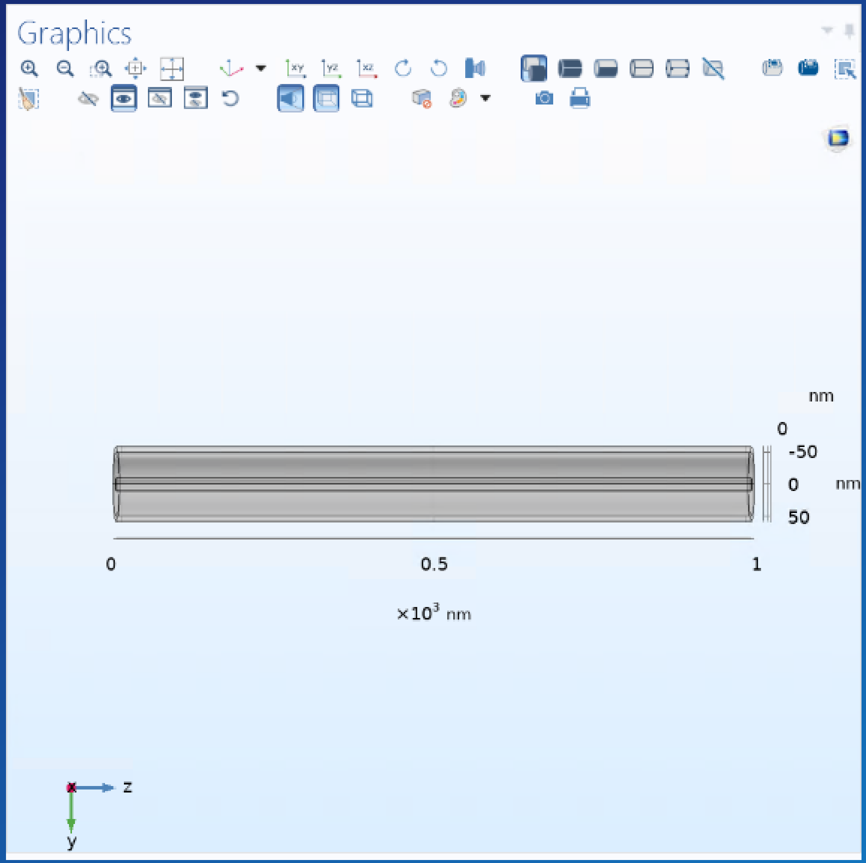




Fig 5: Coaxial cable simulated in COMSOL Multiphysics tool version 5.4 (a) front view, (b) side view.

# Meshing of Coaxial cable

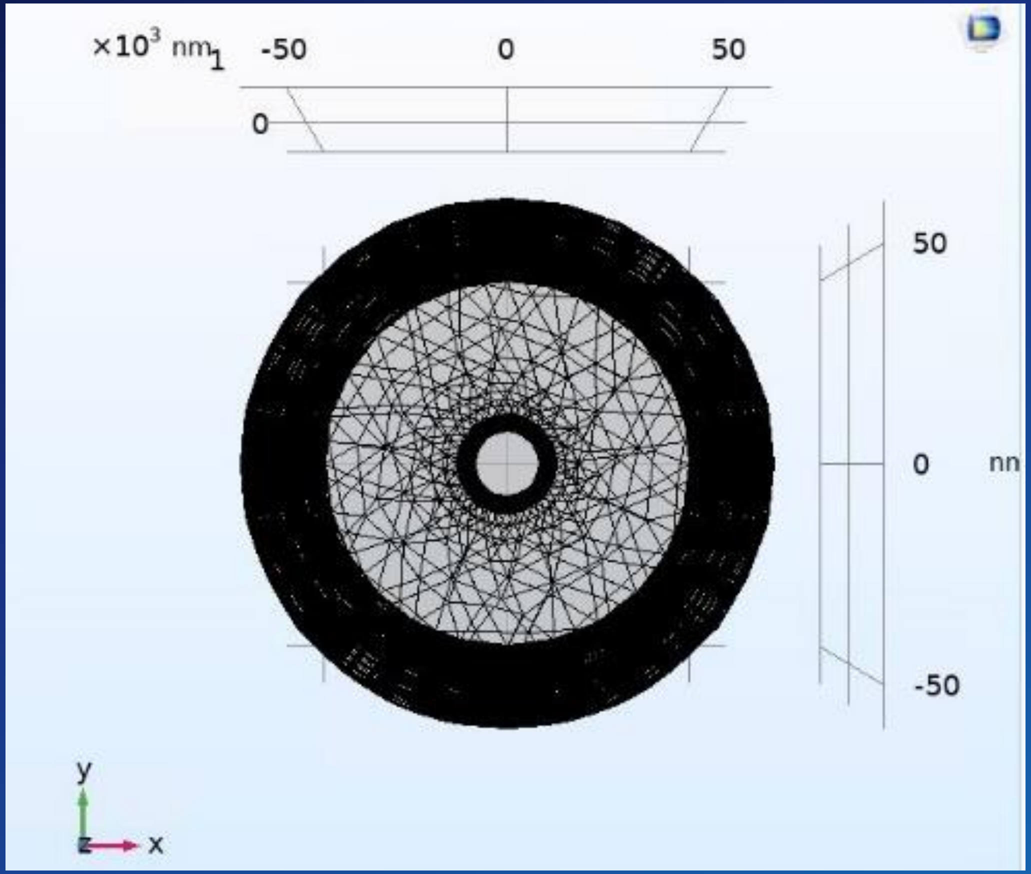



Fig 6: Meshing of Coaxial cable simulated in COMSOL Multiphysics tool.

# Result and Discussion

The S-parameter graph shows

At 100 GHz: S11 -38.7523 dB,
S21 -0.1022 dB

At 1THz: S11 -36.1285 dB,
S21 -0.1204 dB

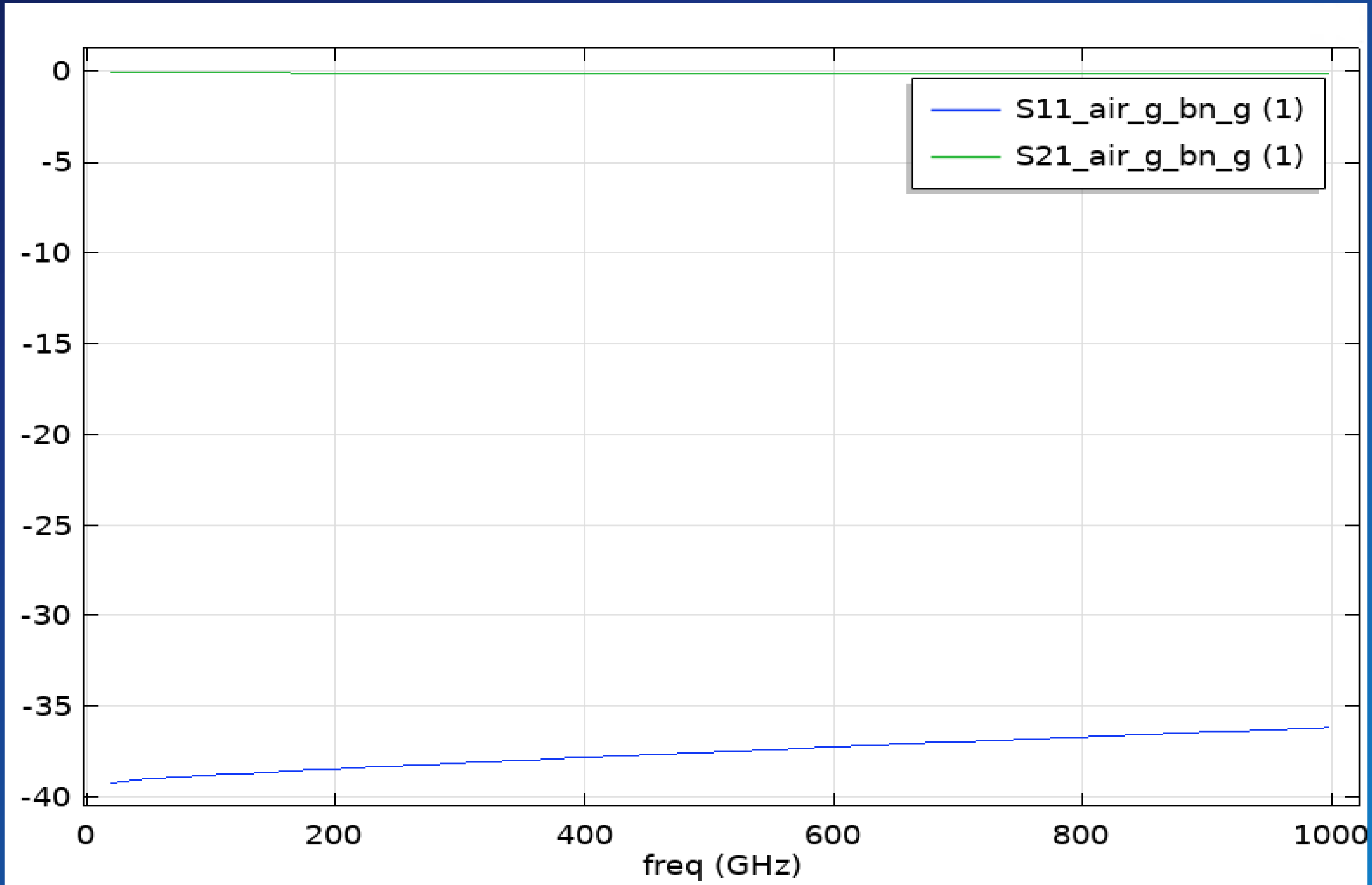



Fig 7: S11 and S12 parameters over frequency graph simulated in COMSOL tool

# Electric Field Distribution

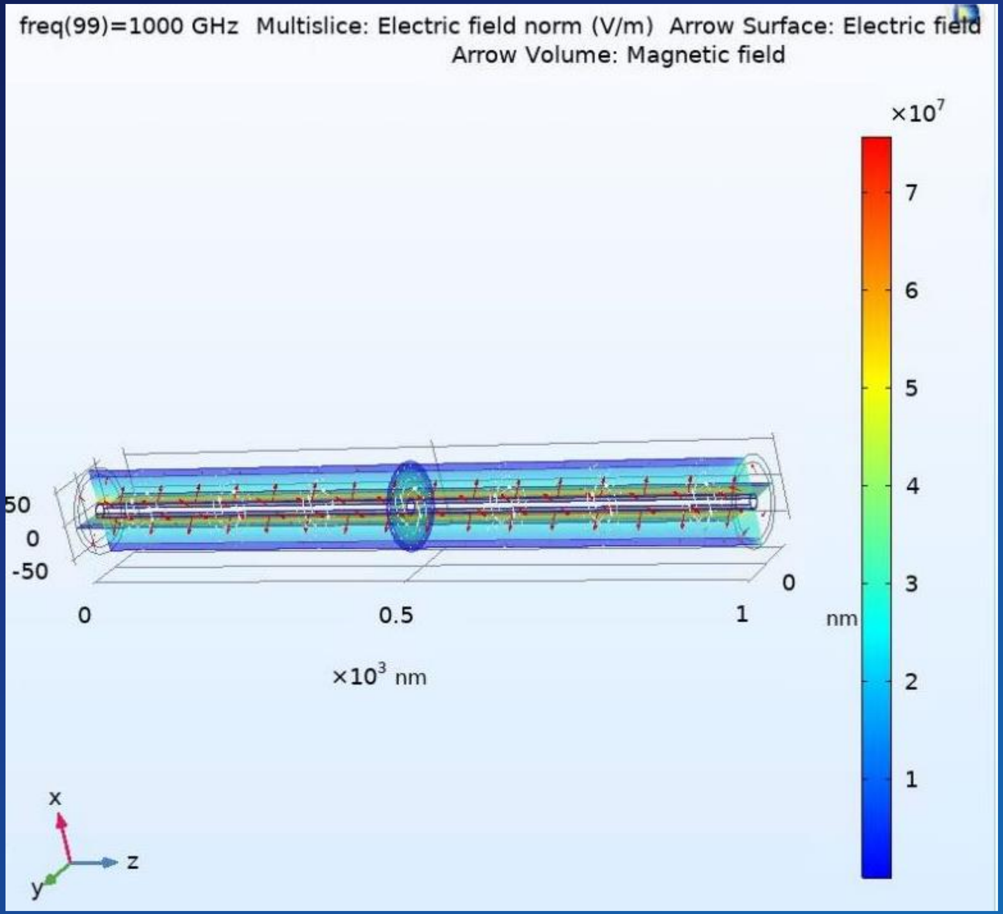



Fig 8: Electric field distribution in graphene coaxial cable simulated in COMSOL 5.4.

# Conclusion

- Hence proposed coaxial structure gives better S - parameter value resulting in efficient transmission medium from 100 GHz to THz range.
- Manufacturing copper coax is challenging due to difficulty of its growth at nanoscale.
- Routing density of copper cannot be as high as Graphene because of its challenging complex design.
- Graphene based coaxial structure proves to be efficient alternative to copper interconnects.

# Thank You

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