Frequency Dependent UEP Signature of Naval Vessels Modeled by a Current Dipole

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1. Abstract

In this poster we present UEP signatures of naval vessels approximated by a current dipole using the FEM simulation software COMSOL Multiphysics [1]. Here, we use the radio frequency (RF) module of the software in a low frequency range from 1Hz up to 10kHz. The electrical conductivity of the seawater has a significant influence on the wavelength. Furthermore, the rotation of the electric field becomes non-zero because of the AC conduction current from the dipole. Thus, the problem can not be described as stationary anymore and so the electric current (EC) module can not be used. The electromagnetic waves (EMW) module with its fullwave equations has to be used. Here the displacement current can be neglected and only the conduction current is required. The following simulation results are a partial work of a research project between the lab of ATE and WTD71 where the simulations of electromangetic fields on naval vessels are a fundamental research part.

2. Module description and underwater wavelength

A comparison between EC module and EMW module:

if $\nabla \times \vec{E} = \vec{0} \rightarrow$ EC module: $\nabla \cdot (\sigma \nabla \varphi) = 0$

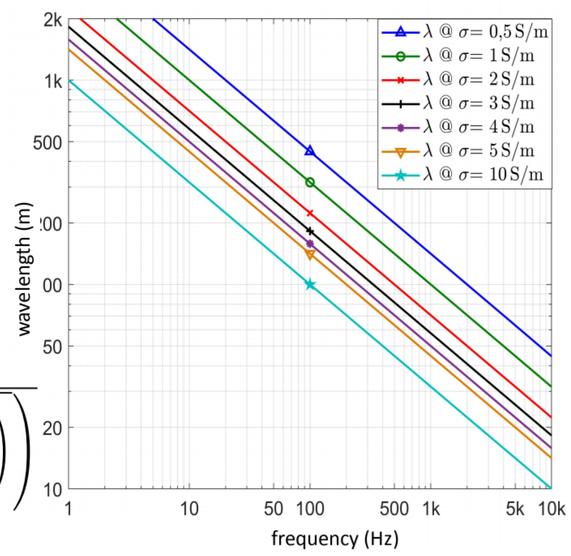
if $\nabla \times \vec{E} \neq \vec{0} \rightarrow$ EMW module:

$$\nabla \times \frac{1}{\mu_r}(\nabla \times \vec{E}) - k_0^2(\varepsilon_r - \frac{\mathrm{j}\sigma}{\omega\varepsilon_0})\vec{E} = \vec{0}$$

for $\sigma \gg \omega\varepsilon_0\varepsilon_r$ we obtain $\nabla \times \nabla \times \vec{E} + \mathrm{j}\omega\mu_0\mu_r\sigma\vec{E} = \vec{0}$

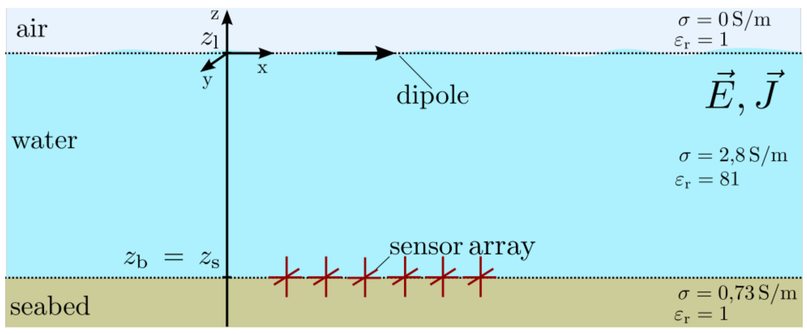
Influence of:
electrical conductivity σ

$$\lambda(f, \varepsilon_r, \sigma) = \frac{c_0}{f\left(\sqrt{\frac{\mu_r\varepsilon_r}{2}\left(\sqrt{1+\left(\frac{\sigma}{2\pi f\varepsilon_0\varepsilon_r}\right)^2}+1\right)}\right)}$$

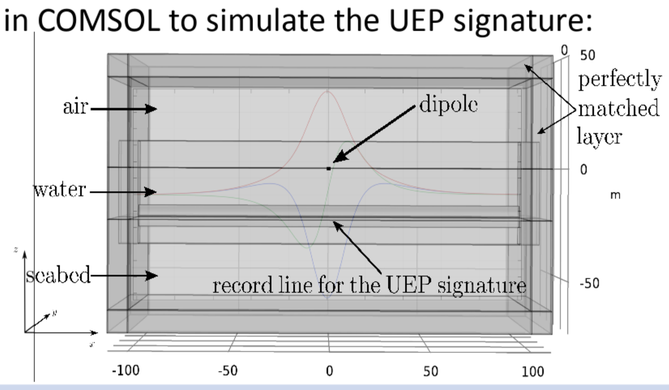


3. COMSOL Model

Model of the simulation setting in COMSOL to simulate the UEP signature:



Simulation area in COMSOL to simulate the UEP signature:



4. Input impedance based on the EC & EMW module

EC module EMW module

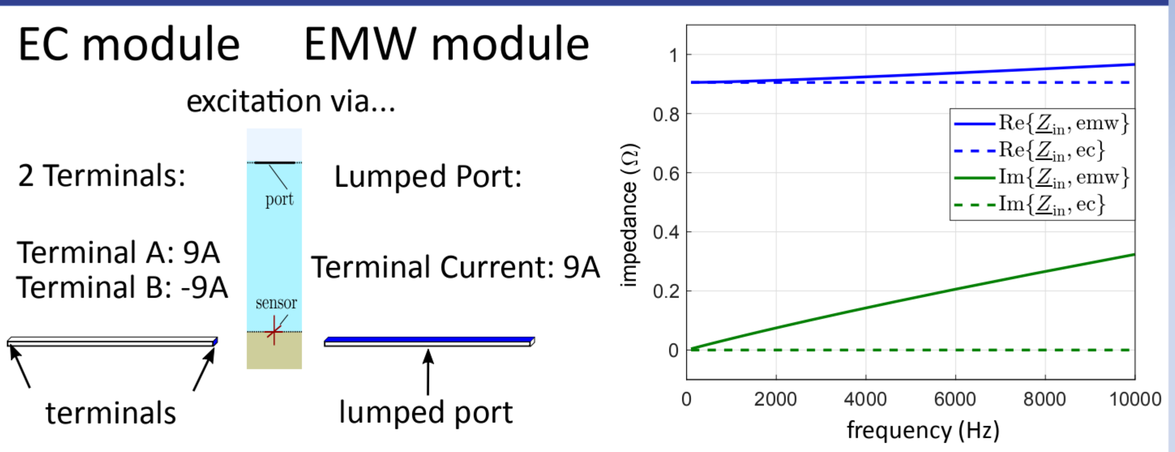
excitation via...

2 Terminals:

Terminal A: 9A
Terminal B: -9A

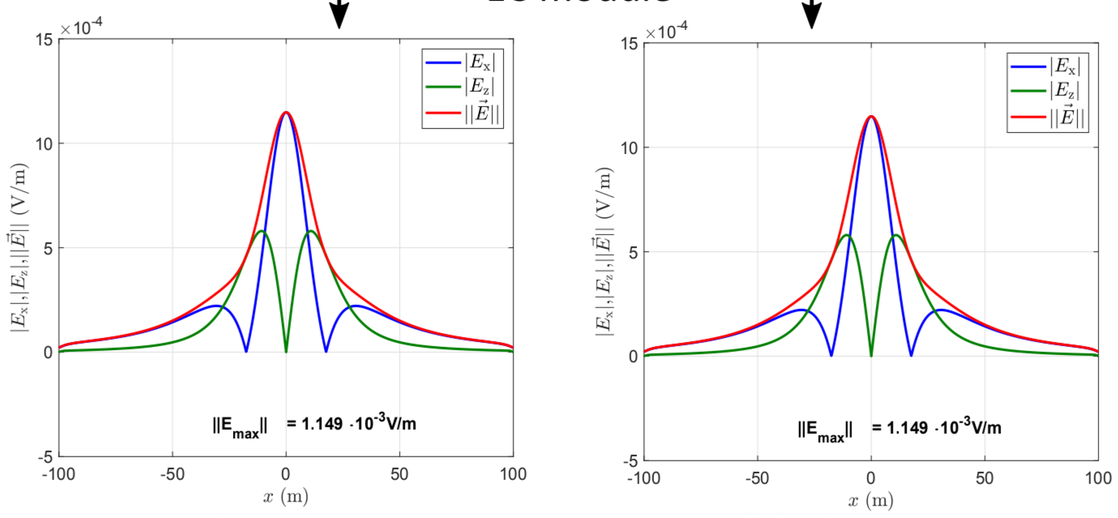
Lumped Port:

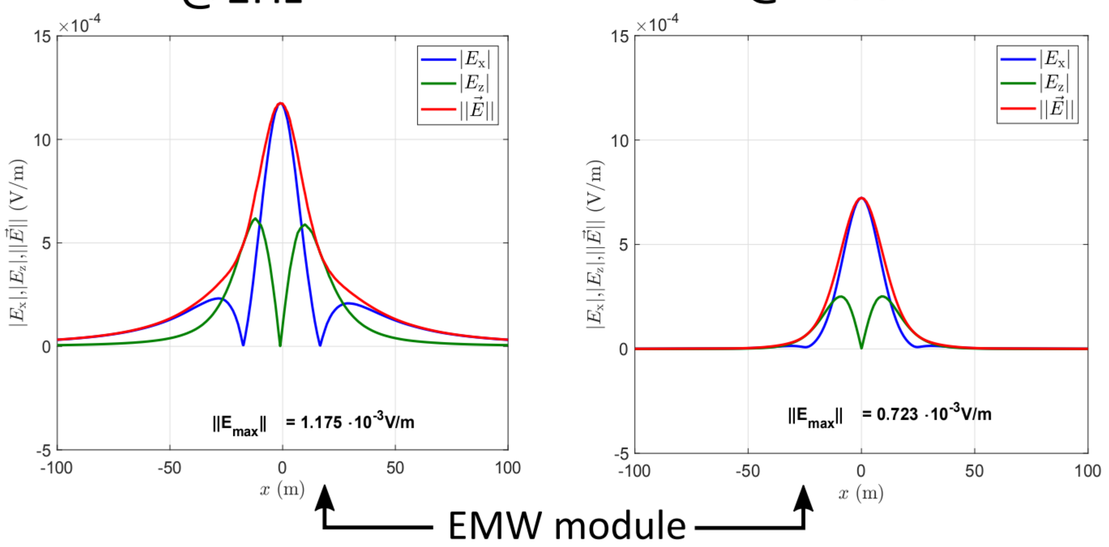
Terminal Current: 9A



5. UEP signatures from the current dipole

EC module





EMW module

6. Conclusions

- the frequency dependence of the EC module does not include the equation which is necessary for the underwater wave propagation
- for underwater frequency dependent signatures it is neccessary to use the EMW module to calculate the wave solution
- both modules have been compared. The difference between them is mainly the imaginary part & different UEP signatures.

7. Literature

[1] COMSOL. (2018, August) COMSOL Multiphysics. [Online] Available: https://www.comsol.com

[2] O.Georg, Electromagntic Waves, Springer 1997

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