

Periodic 3D Leaky SAW Simulations with 42° Y-cut Lithium Tantalate

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Introduction

Leaky Surface Acoustic Wave (LSAW) resonators in rotated Y-X cut Lithium Tantalate (LiTaO₃) are widely used for resonator based ladder filters in telecommunication applications. These devices make use of quasi-shear waves confined to the surface of the piezoelectric layer for resonance. However, they are prone to losses due to some wave radiation to the busbar and coupling of slow shear bulk acoustic waves to the main SAW mode above resonance frequency[1]. Therefore, it is necessary to perform FEM simulations in order to quantify these losses and minimize them for designing low insertion loss devices.

A LSAW finite aperture device with 42° YX-cut LiTaO₃ substrate was simulated in COMSOL Multiphysics®.

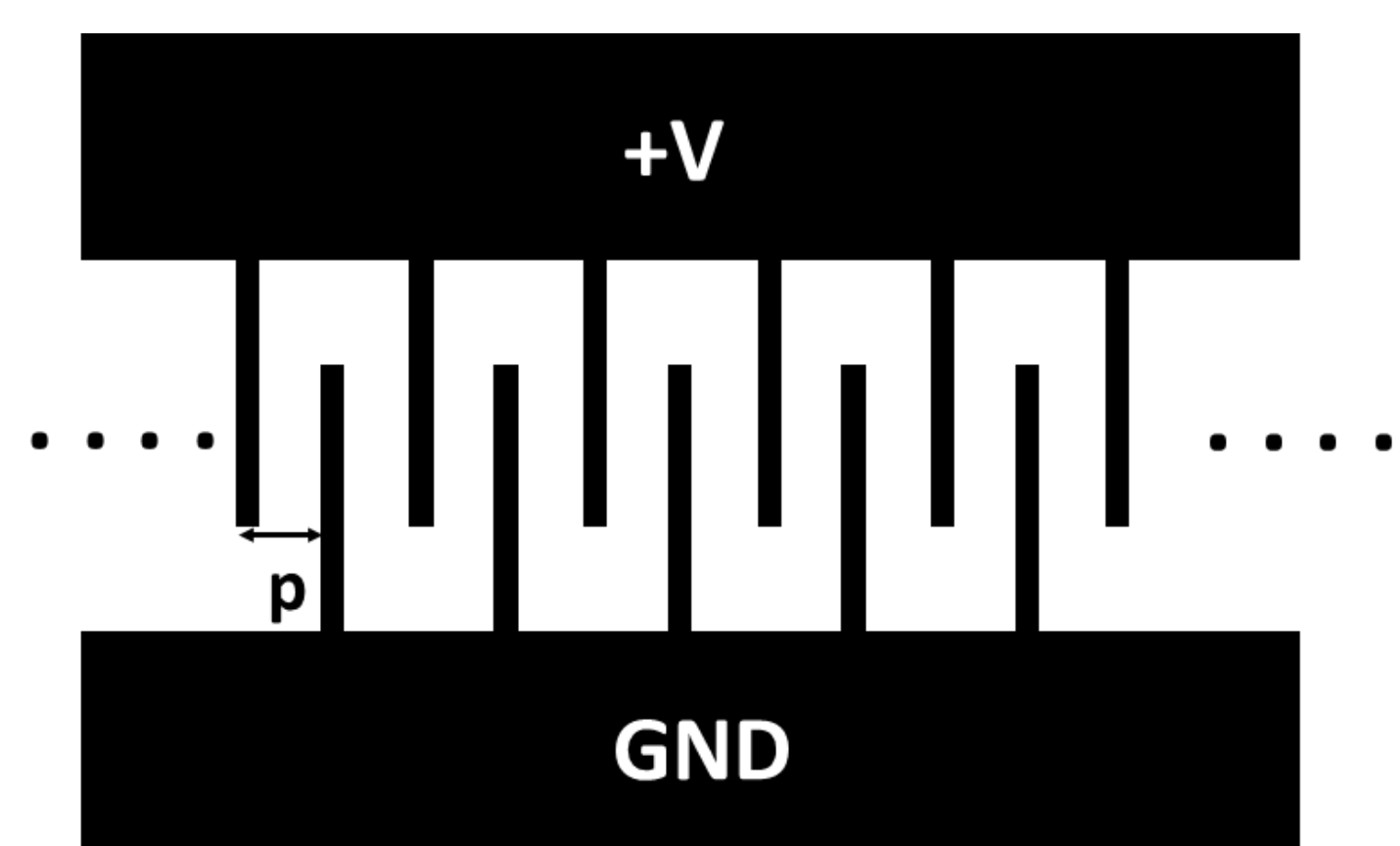


Figure 1. Geometry of periodically repeated electrodes on Lithium Tantalate surface

Simulation methods

The simulations are performed for a periodic resonator on 42° YX-cut LiTaO₃ substrate as shown in Fig.1. The device for modelling has a wavelength $2 * p = \lambda_0 = 2\mu\text{m}$, an aperture of $W = 20\lambda_0 = 40\mu\text{m}$, aluminum electrodes with metallization of 50% and electrode metal thickness of $h/\lambda_0=8\%$ (160nm).

Other features included in the design are busbars $3\lambda_0$ wide and gap between the electrode tips and the busbars equal to $0.25\lambda_0$

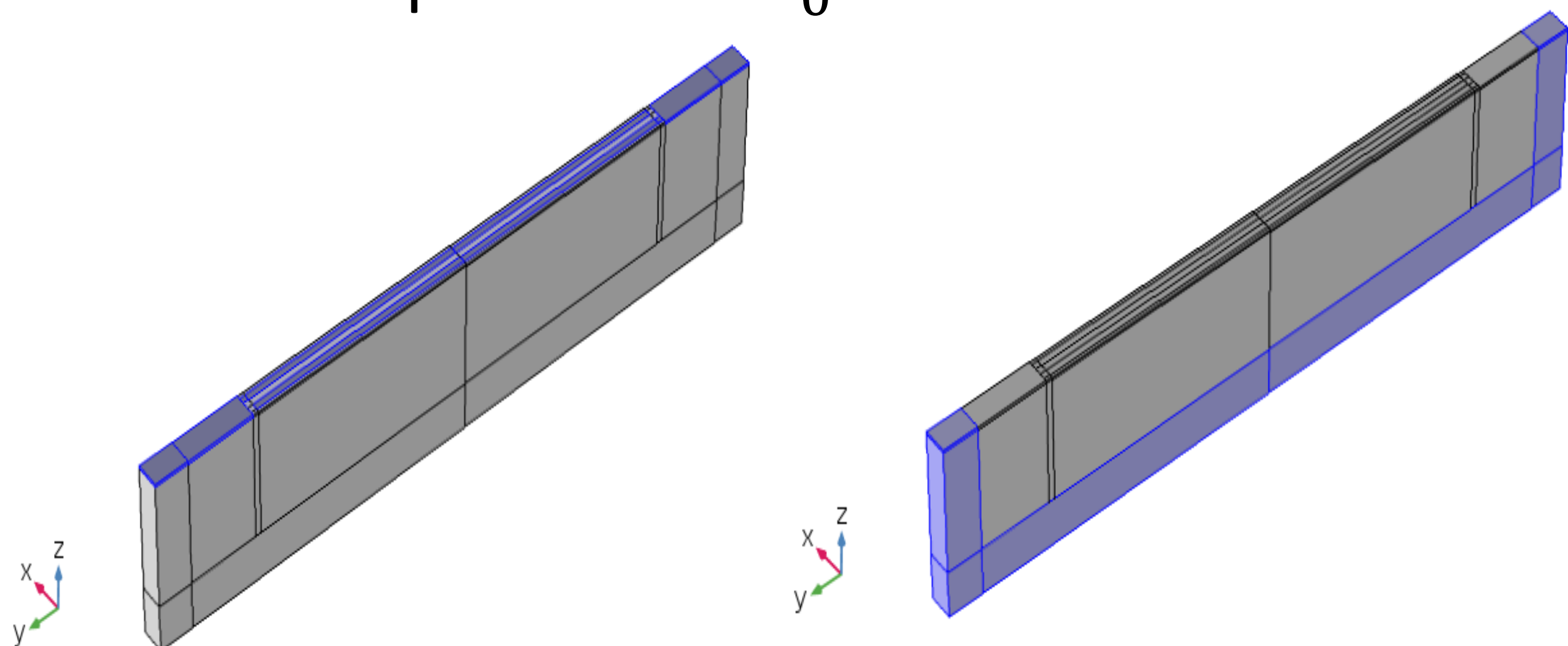


Figure 2. 3D geometry of unit cell of resonator. The Al electrodes are highlighted to the left and PMLs are highlighted to the right.

The model uses piezoelectric Multiphysics with solid mechanics and electrostatics modules. The model consists of a single unit cell of width $2\mu\text{m}$ with LiTaO₃ substrate, two electrodes (+0.5V and -0.5V AC applied).

Vacuum of height $2\lambda_0(4\mu\text{m})$ is present above the piezoelectric surface and solid Perfectly Matched Layer(PML) surrounds the unit cell laterally and at the bottom. The two lateral sides perpendicular to the aperture have periodic BC imposed on them in order to emulate an infinitely long resonator with infinite number of electrodes. The periodic BC used in this case is Floquet where the displacement of the source and destination are equal i.e. $u_l = u_r$ with $k_{x,y,x} = 0$. The periodic BC is applied in structural mechanics, whereas in electrostatics, continuity BC is applied where the potential on both faces are equal i.e. $V_L = V_R$.

Results

The resonance frequency according to simulations is 1.970GHz and wide frequency sweep is as shown in the Real and Absolute Admittance plot normalized for 100 pairs of electrodes in Fig.3. Y-displacement at resonance is shown in Fig. 4.

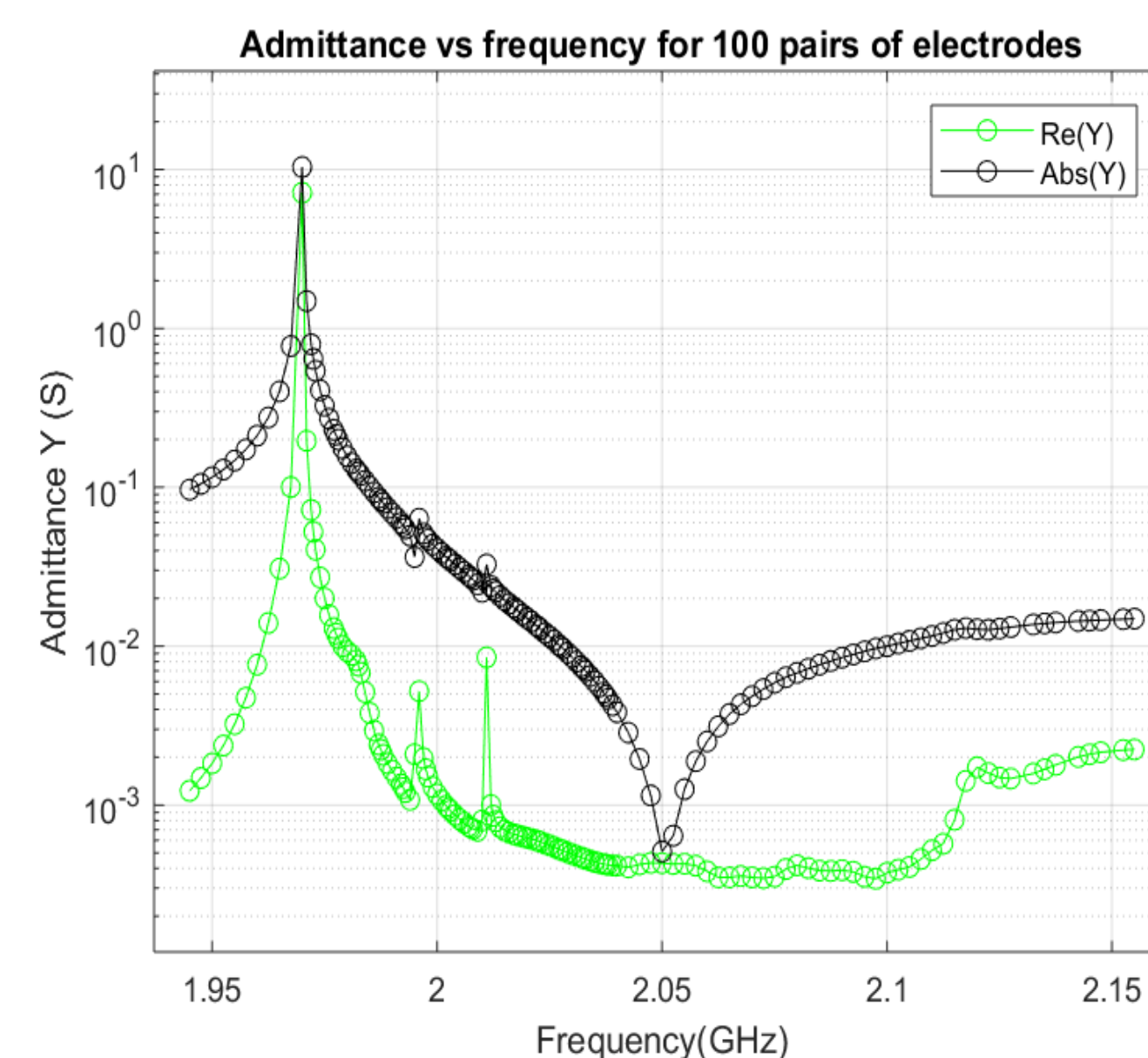


Figure 3. Real and Absolute Admittance plot of periodic LSAW resonator

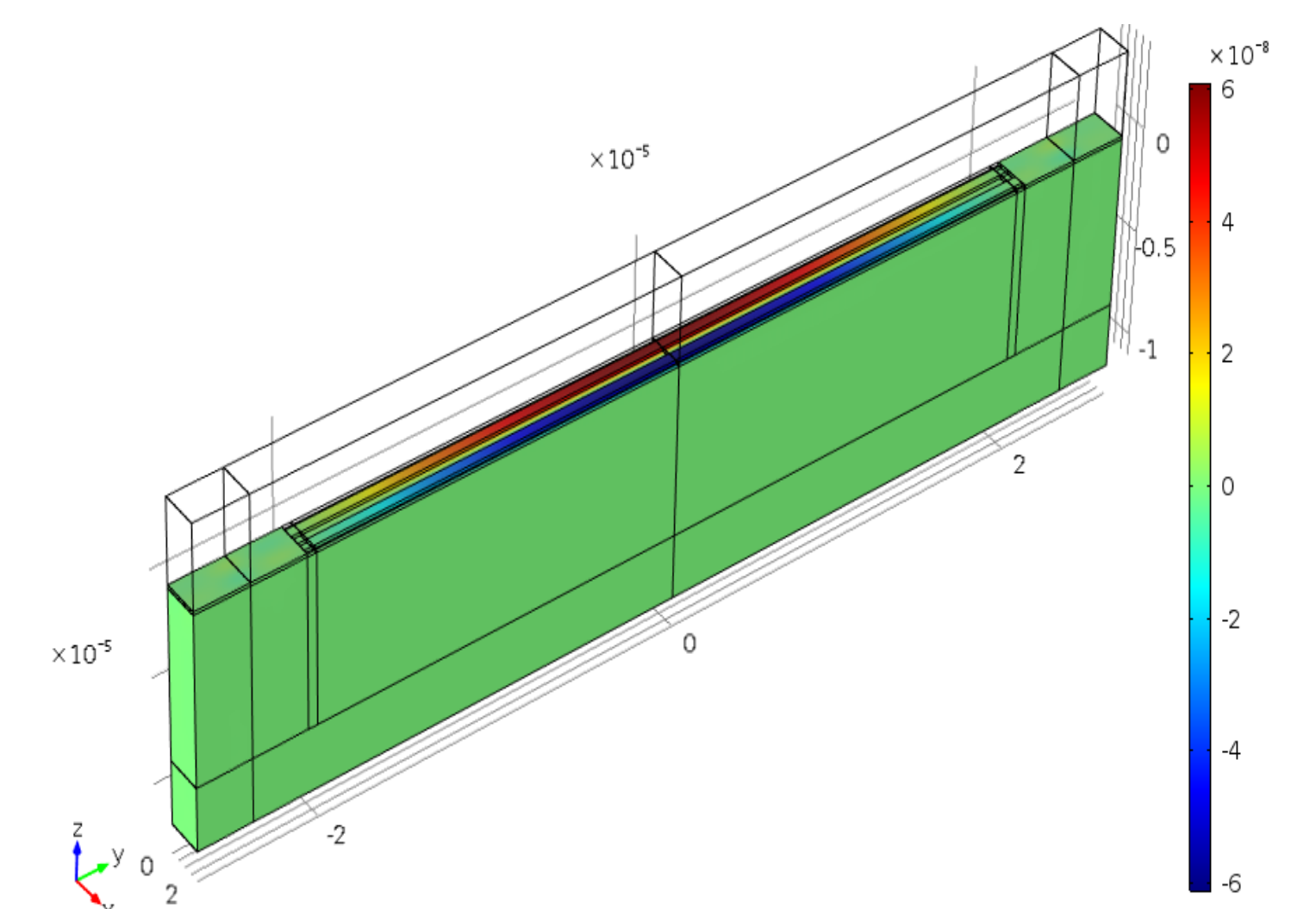


Figure 4. Y-displacement plot at resonance

Conclusions

As predicted from coupling of modes(COM) model, resonance peak is seen at 1.97 GHz. Radiation to the busbar is observed from 1.977GHz and onset of bulk radiation to the substrate from 2.11GHz. PML instabilities such as negative admittance and growth in displacement in PML are observed around busbar radiation frequency range around 1.977GHz which was reduced by increasing mesh density in busbar and PML. However the instability issue is not completely resolved and future work includes applying used defined PML with COMSOL® for tailoring to piezoelectric crystals.

REFERENCES:

1. J. Koskela, J. V. Knuuttila, T. Makkonen, V. P. Plessky, and M. M. Salomaa, "Acoustic loss mechanisms in leaky SAW resonators on lithium tantalate", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Vol. 48, No. 6, pp. 1517–1526, (November 2001).