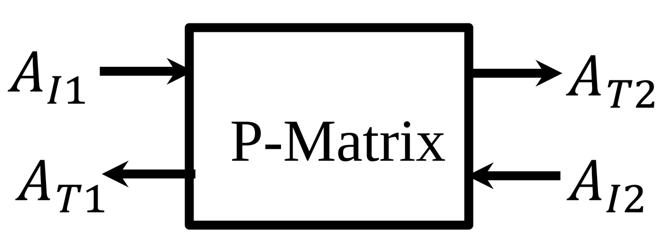
# The FEM Simulation of the Surface Acoustic Wave Delay Line based on the P-Matrix Model for Sensor Application

B. Panchal[1,2], A. Bhadauria[2] & S. Varghese[1]
1. School of Material Science and Engineering, NIT Calicut, Kerala, India 673601
2. Flexible and Non-Silicon Electronics Group, CSIR-CEERI, Rajasthan, India 333031

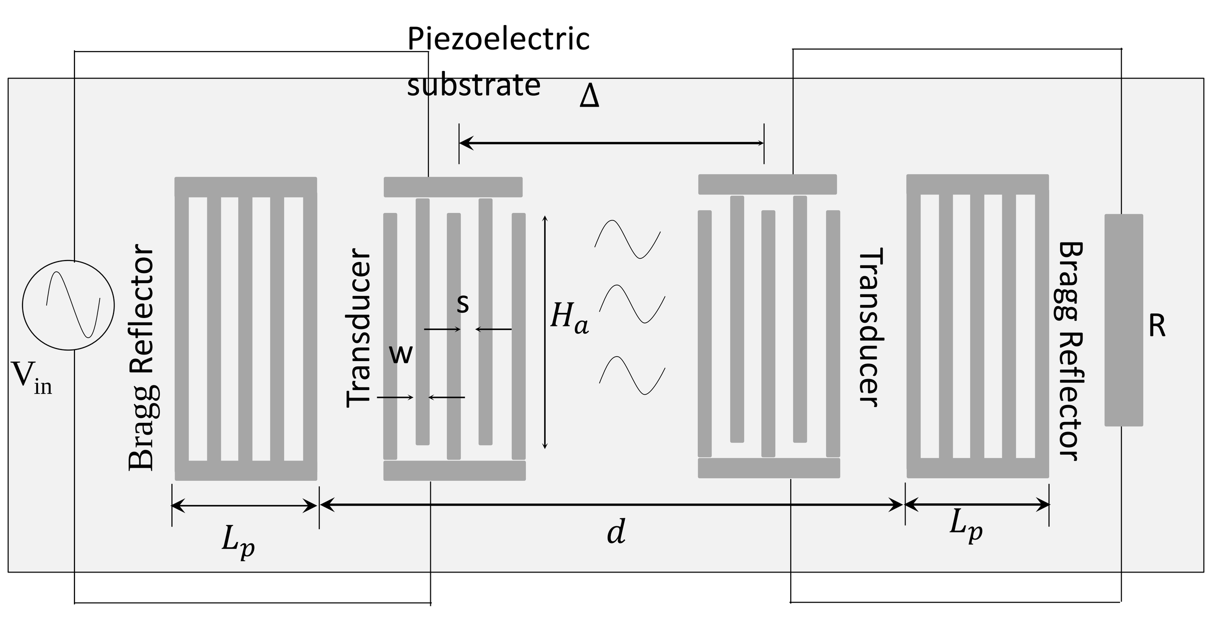
## INTRODUCTION:

Today various technologies are available but SAW sensors are preferable because of its characteristics such as low cost, low power, lightweight, rugged, simple fabrication and handling, small size, portability, wireless detection etc. In this paper 2D FEM Simulation of SAW delay line on Lithium Niobate is presented of 16MHz and 20MHz.




$$\begin{bmatrix} A_{T1} \\ A_{T2} \\ I \end{bmatrix} = \begin{bmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{bmatrix} \begin{bmatrix} A_{I1} \\ A_{I2} \\ V \end{bmatrix}$$

(a) (b)




(c)

**Figure 1**. (a) P-matrix schematic (b) P-matrix (c) Schematic of SAW delay line

## COMPUTATIONAL METHODS:

$$P_{11} = P_{22} = \Gamma = |\Gamma| e^{j\emptyset_g} \quad (2)$$

$$P_{12} = P_{21} = e^{-jkL} \quad (3)$$

$$P_{13} = -P_{31}/2 = j\bar{\rho}_e(k)\sqrt{\omega W \Gamma_s/2}\, e^{-jkL/2} \quad (4)$$

$$P_{23} = -P_{32}/2 = j\bar{\rho}_e(k)\sqrt{\omega W \Gamma_s/2}\, e^{-jkL/2} (5)$$

$$P_{33} = Y_T(\omega) = G_a(\omega) + j(B_a(\omega) + \omega C_T) \quad (6)$$

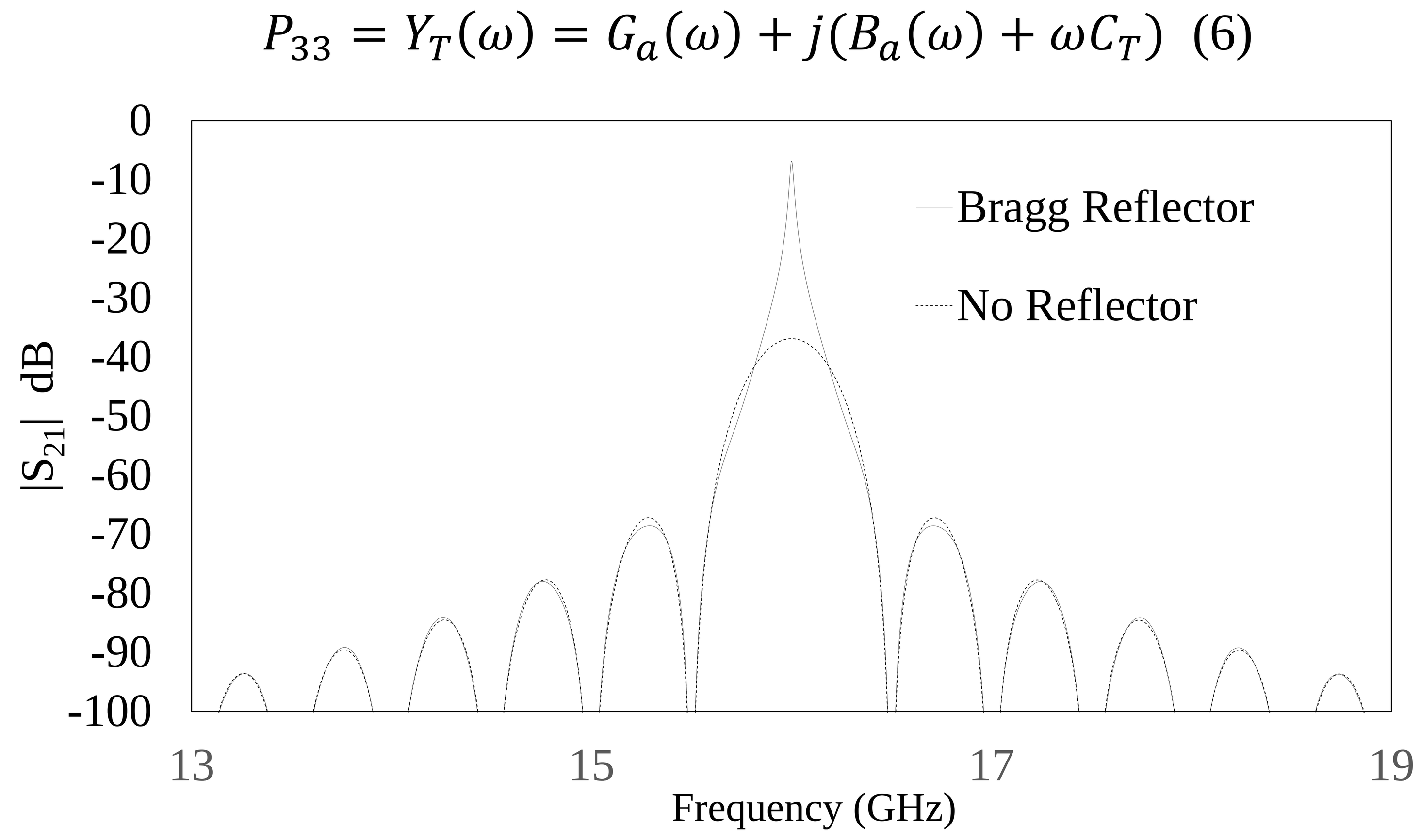



**Figure 2**. Numerical simulation of SAW delay line with reflector and without reflector

| **Parameter** | **SAW1 (16MHz)** | **SAW2 (20MHz)** |
|---|---|---|
| No of IDT (Pair) | 25 | 31 |
| Width of finger (µm)(w) | 60.75 | 48.60 |
| Length of finger(µm) (Ha) | 4860 | 3888 |
| Distance between transducer (µm) | 5589 | 5832 |
| Distance between reflector and IDT (µm) (d) | 637.875 | 510.3 |
| Resonance Frequency (MHz) ($f_0$) | 16.125 | 19.99 |
| Anti-resonance frequency (MHz) (fa) | 16.725 | 20.85 |
| Quality factor at Resonance | 1011.7 | 1056.6 |
| Quality factor at Anti-resonance | 1013.1 | 1007.6 |
| Coupling Coefficient ($K_t^2$) | 0.08534 | 0.09757 |

## RESULTS:

The following 2D simulation is presented in the paper for displacement and von-misses stress. The graph are also presented for admittance and displacement of the waves along the thickness. The image shows the meshing approach implemented during simulation.

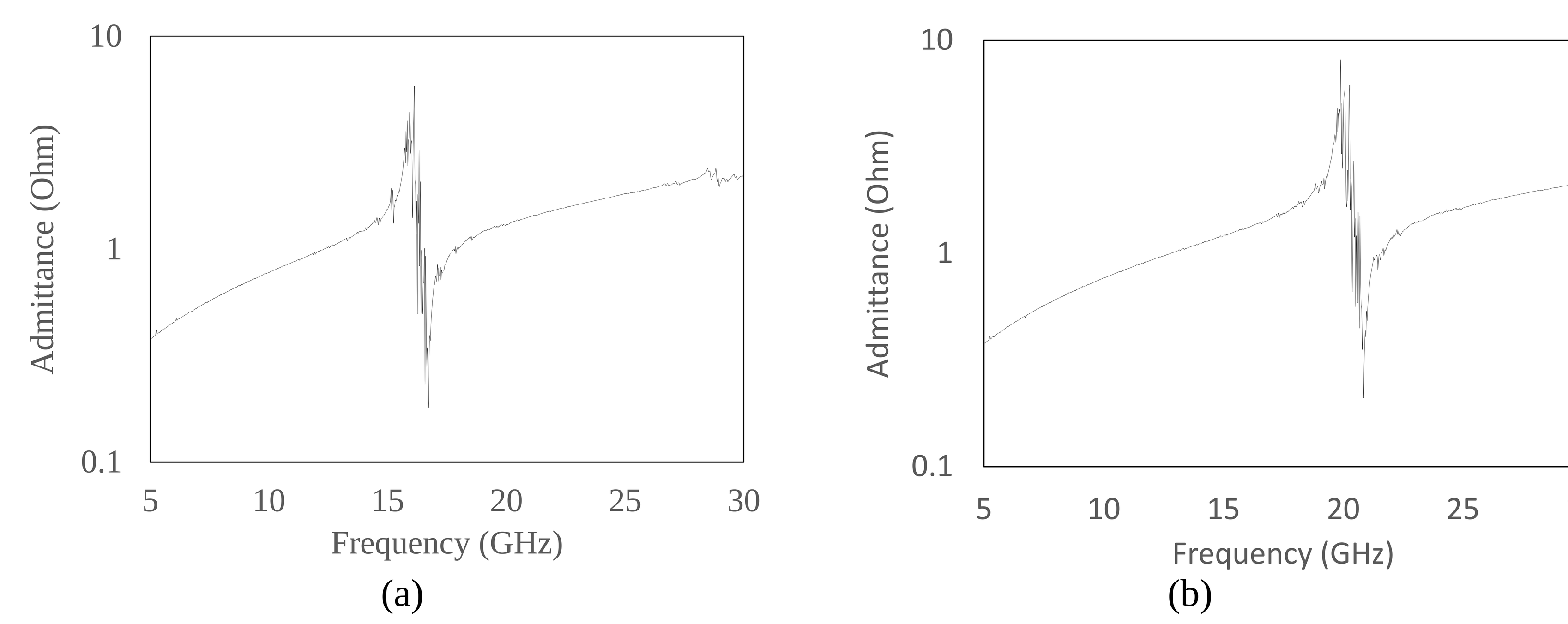



Figure 3. Admittance of SAW devices (1) 16 MHz (2) 20MHz

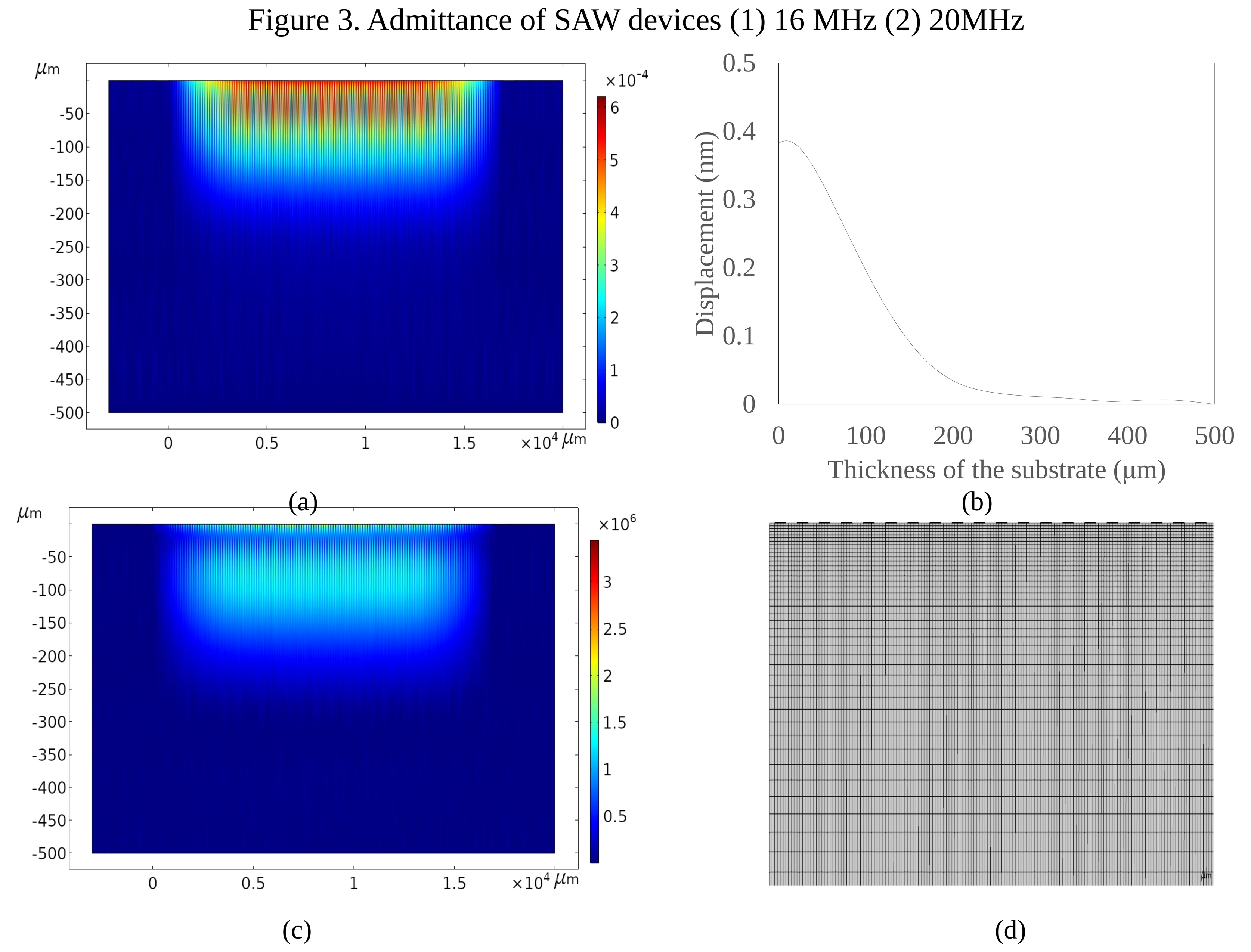



Figure 4. Simulation result of SAW delay line (a) Displacement (b) Displacement of waves along thickness (c) Von-misses stress (d) The meshing approach of SAW delay line

## CONCLUSIONS:

The presented approach shows good agreement between numerical simulation using MATLAB®, FEM simulation using COMSOL Multiphysics® and equivalent circuit simulated in Quite Universal Circuit. The paper has also discussed the meshing approach, S parameter and Admittance characteristics of the SAW sensors.

## Acknowledgement

The author thanks to Director, CSIR-CEERI, Pilani and the Director, NIT Calicut, Kerala for providing the facility of the simulation work.

## REFERENCES:

[1] Kondoh, Jun, et al. "Enzyme-immobilized SH-SAW biosensor." *Sensors and Actuators B: Chemical* 20.2-3 (1994): 199-203.
[2] Berkenpas, Eric, et al. "Pure shear horizontal SAW biosensor on langasite." *IEEE transactions on ultrasonics, ferroelectrics, and frequency control* 51.11 (2004): 1404-1411
[3] Wilson, William C., and Gary M. Atkinson. "Rapid SAW sensor development tools." (2007).
[4] Campbell, Colin. *Surface acoustic wave devices and their signal processing applications*. Elsevier, 2012.
[5] Sakong, Jungyul, Heesu Roh, and Yongrae Roh. "Surface acoustic wave DNA sensor with micro-fluidic channels." *Japanese Journal of Applied Physics* 46.7S (2007): 4729.
.