# Numerical Study of the Effect of Beam Skew on Pulse Transmission Measurement in Tilted Transversely Isotropic Media

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## Introduction

The recent growth in the study of tilted transversely isotropic media has motivated efforts in experimentally measure the phase velocity of transversely isotropic media. The most commonly used method is the pulse transmission measurements. In the tilted transversely isotropic media, for example, the foliation of the rock is 45o oblique to the surface, the wave beam skews and the measured phase velocity will be smaller than the theoretical value if the receiver is placed in the straightforward direction of the transmitter. In this study, we numerically studied the effect of beam skew on the pulse transmission measurement in the tilted transversely isotropic media with the tilt angle equaling 45o. The response of the transducer is modeled with distributed point source method (Spies, 1994).

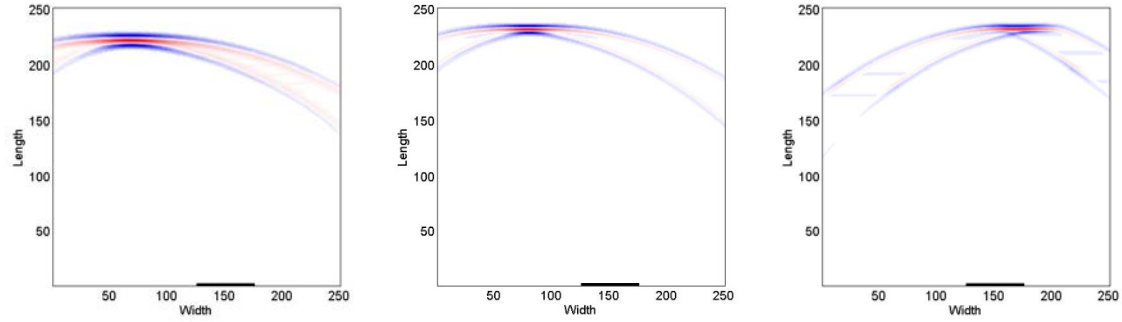
## Methods

In the distributed point source method, the piezoelectric transducer is treated as a line of distributed point sources. The response of each point source is calculated according to the ray tracing theory; the total response of the transducer is calculated by the summation of the response of each point source. The wave fronts of P-wave, SH-wave, and SV-wave were modeled to directly show the beam skew phenomenon. To quantitatively study the effect of beam skew, the transmission time of the receiver in the straightforward direction of the transmitter is modeled and compared to the theoretical value.

## Results

A transversely isotropic shale rock is used as the example and its parameters are density $\rho$ = 2.48 g/cm$^3$, $C_{11}$ = 68.41 GPa, $C_{33}$ = 34.90 GPa, $C_{44}$ = 14.30 GPa, $C_{66}$ = 27.03 GPa, and $C_{13}$ = 12.00 GPa (Ong et al., 2016). The thickness of the model or the vertical distance between the transmitter and the receiver is 10.0 cm. The modeled wave fronts of the P-wave, the SH-wave and the SV-wave in the tilted transversely isotropic media are as shown in Fig. 1. If the propagation time is picked at the first positive peak, the modeled propagation times of the receiver in the straightforward direction for the P-wave, the

SH-wave, and the SV-wave are 23.91 μs, 35.28 μs, and 37.88 μs. The phase velocities calculated from modeled propagation times are 4.182 km/s, 2.834 km/s, and 2.640 km/s. The corresponding theoretical phase velocities are 4.425 km/s, 2.887 km/s, and 2.648 km/s.




*(a) P-wave* *(b) SH-wave* *(c) SV-wave*

*Fig. 1 Wavefronts of waves in the tilted transversely isotropic media with the tilt angle equalling 45$^o$.*

**Discussion**

When the tilt angle equals 45$^o$, three different modes of waves skew with different angles: the P-wave skews 20.76$^o$ to the left; the SH-wave skews 17.12$^o$ to the left; the SV-wave skews 5.46$^o$ to the right. From the comparison of the modeled phase velocity to the theoretical phase velocity, the phase velocity of the P-wave is 5.49 % smaller than the theoretical value; the phase velocity of the SH-wave is 1.81 % smaller than the theoretical value; the phase velocity of the SV-wave is 0.29 % smaller than the theoretical value.

**Conclusions**

The pulse transmission measurement was modeled with the distributed point source method. From the numerical study of the pulse transmission measurement in a shale rock, the beam skew affects the pulse transmission measurement of P-wave phase velocity most. The measured P-wave phase velocity is 5.41% smaller than the theoretical value. The effect of the beam skew on the SV-wave is negligible and the measured phase velocity is only 0.31% smaller than the theoretical value.

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**References**

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