Ultrasonic System Overview
Learning Objectives

Overview of the UT system components that will be discussed
The ultrasonic system components

- pulser/receiver
- cabling
- transmitting transducer
- receiving transducer
- oscilloscope display
- flaw
voltage versus
time pulse, \( v(t) \)

Fourier
Transforms

magnitude of the
frequency spectrum
of the pulse, \( V(f) \)

(only positive
frequencies shown)

\[ f = \text{frequency} \]
\[ \omega = 2\pi f \]
\[ = \text{frequency} \]
\[ \text{(in cycles/sec or Hz)} \]
\[ \text{(in rad/sec)} \]
The ultrasonic pulser and its equivalent circuit

- Pulser
- Voltage pulse: $v(t)$
- Cable
- Electrical impedance: $(V(\omega), I(\omega))$
- Voltage source: $V_i(\omega)$
- Impedance: $Z_i(\omega)$
- Voltage: $V$
- Current: $I$
cabling and its equivalent transfer matrix

\[
\begin{bmatrix}
V_1 \\ I_1 \\
\end{bmatrix}
= \begin{bmatrix}
T_{11}(\omega) & T_{12}(\omega) \\
T_{21}(\omega) & T_{22}(\omega)
\end{bmatrix}
\begin{bmatrix}
V_2 \\ I_2 \\
\end{bmatrix}
\]
a sending transducer and its equivalent transfer matrix

voltage, current

\[ V_{in} \quad I_{in} \]

force, velocity

\[ F \quad v \]

(a)

\([T^A]\)

(b)
a sending transducer modeled as an impedance and sensitivity

\[ I_{\text{in}} \quad V_{\text{in}} \quad F_t \quad Z_r^{A,a} \]

\[ v_t = S_v^A I_{\text{in}} \]

\[ v_t = F_t / Z_r^{A,a} \]

acoustic radiation impedance

sensitivity

electrical impedance
Putting all the sound generation components together

\[ V_i(\omega) \rightarrow \text{pulser} \rightarrow F_t(\omega) \]

Output:

\[ V_i(\omega) \rightarrow [T] \rightarrow Z_{in}^{A,e} \]

\[ v_t = S_{vl}^A I_{in} \]

\[ F_t = Z_{r,a}^{A,e} v_t \]

\[ V_i(\omega) \rightarrow t_G(\omega) \rightarrow F_t(\omega) \]
the receiving transducer also can be modeled by an impedance and sensitivity

\[ V_s(\omega) = S_{vl}^B(\omega) F_B(\omega) \]

[Diagram of a transducer with incident and scattered waves, and blocked force generated by the waves on the transducer.]

(b)
model of the receiver as an electrical impedance and gain factor
putting all the sound reception components together
Modeling all the wave propagation and scattering components as a transfer function

\[ V_i(\omega) \rightarrow F_t(\omega) \rightarrow t_A(\omega) \rightarrow F_B(\omega) \rightarrow V_R(\omega) \]

acoustic/elastic transfer function
Modeling an entire ultrasonic measurement system

\[ V_i(\omega) \]

\[ F_t(\omega) = t_G(\omega)V_i(\omega) \]

\[ F_B(\omega) = t_A(\omega)F_t(\omega) \]

\[ V_R(\omega) = t_R(\omega)F_B(\omega) \]
In terms of transfer functions the ultrasonic system looks like:

\[ V_i(\omega) \rightarrow t_G(\omega) \rightarrow t_A(\omega) \rightarrow t_R(\omega) \rightarrow V_R(\omega) \]

Can also combine the sound generation and reception transfer functions with the voltage source of the pulser in a single function called the system function:

\[ s(\omega) \rightarrow t_A(\omega) \rightarrow V_R(\omega) \]

acoustic/elastic transfer function