NAVAL SURFACE WARFARE CENTER
INDIAN HEAD EXPLOSIVE ORDNANCE DISPOSAL TECHNOLOGY DIVISION

# Dynamic Characterization of Shock Mitigating Materials for Electronics Assemblies Subjected to High Acceleration

61st NDIA Fuze Conference, May 15-17, 2018, San Diego, CA

Presented by

---

Dr. Vasant Joshi
NSWC Indian Head, MD vasant.joshi@navy.mil, (301)744-6769

# Outline

- Introduction and Background
- Objective
- Approach
- Results
- Discussions
- Summary

# Introduction

Electronic circuit boards used in high impact application are subjected to:

- High deceleration -10kG to 50kG
- Multiple reverberations leading to bending and flexing of printed circuit board
- Complex loading on electronic components, based on shape/size

Conventional solution for survivability of the printed circuit board assembly as well as for individual components is to encapsulate board using potting materials, wherein the high G levels in multiple frequency ranges are attenuated.

# Background

Limitations of potting materials:

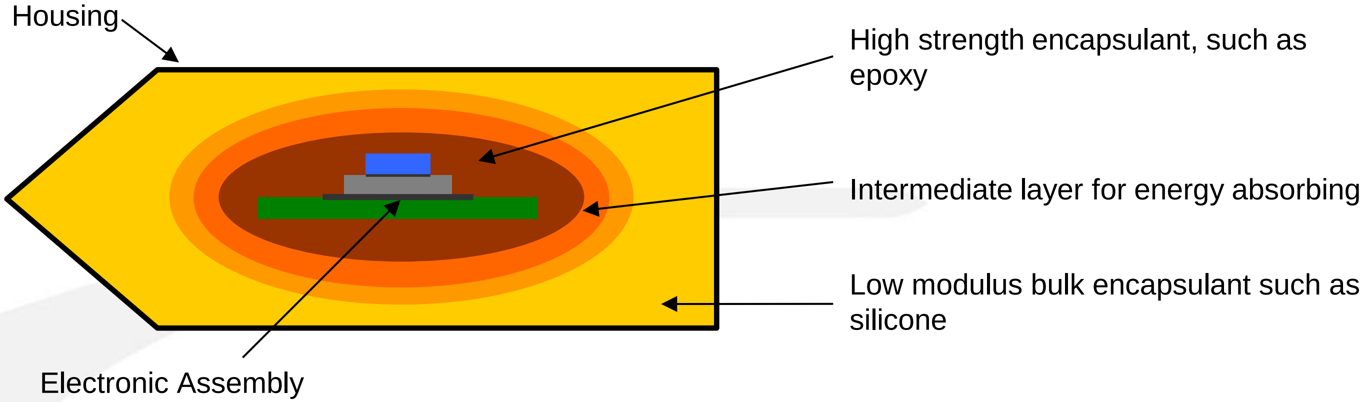
- Soft potting materials may not be strong enough to secure the components
- Hard potting materials may transmit damaging vibration to components
- Combination of hard and soft potting is required, however, response of individual material must be characterized before optimum solution can be implemented

# Objectives

- Characterize potting materials for dynamic environment
- Analyze loss in material during impact (damping) which form basis for providing improved material models for potting compounds
- Compare low and high strain rate response from different test methods
- Seek alternative ways of evaluating damping characteristics for developing optimum damping to be used for improving circuit board survivability
- This presentation focuses on frequency response analysis of potting material

# Approach

- Typical damping scheme may have multiple materials as shown schematically

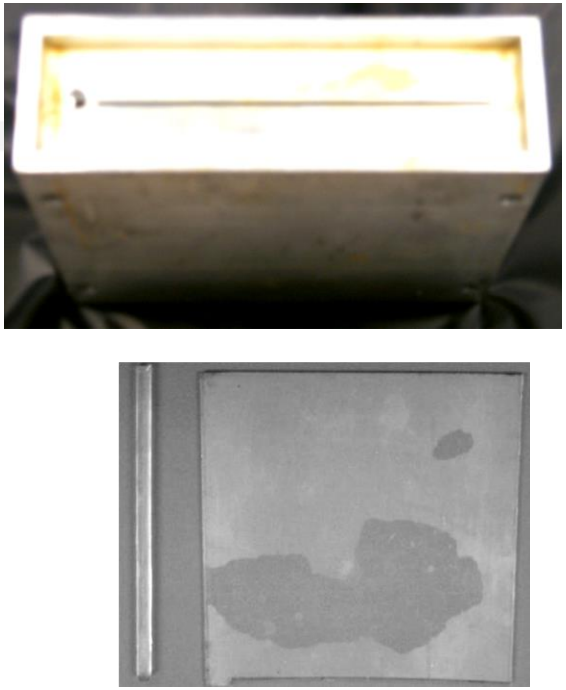


- Current material focuses on a low modulus material Sylgard 184, also known as PDMS
- Use identical material for characterization under different methods
- Conduct DMA test on standard machine, accelerometer based spectrum analysis for high frequency resonant modes to get loss factors and high rate Hopkinson Bar experiments to obtain data

# Approach

Material test data is very sensitive to sample processing and preparation, so best way is to avoid machining of soft materials, use dies and molds, cast samples of Sylgard 184 in place for all tests

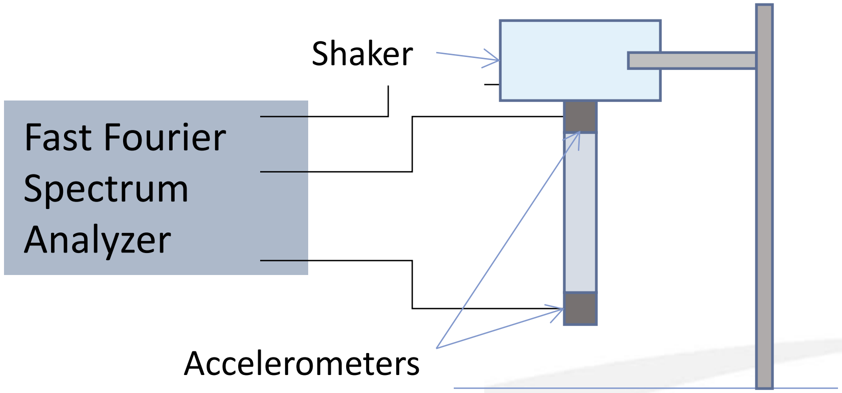
Mold and samples- Cylindrical



Mold and samples-Sheet

# Characterization Methods

## Resonance Scheme



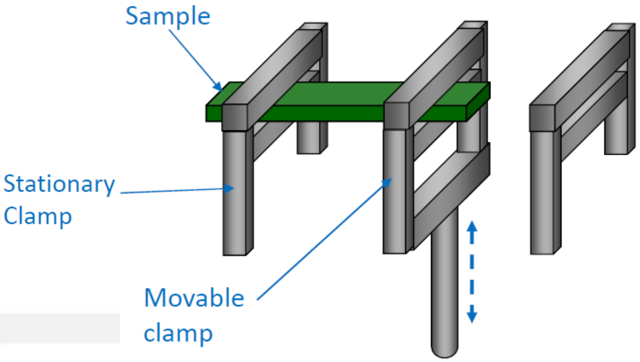
Shaker

Fast Fourier Spectrum Analyzer

Accelerometers

Broadband signal from shaker is transmitted into the sample. Signal input vs. output is recorded for amplitude and phase shift for 10Hz-25Khz

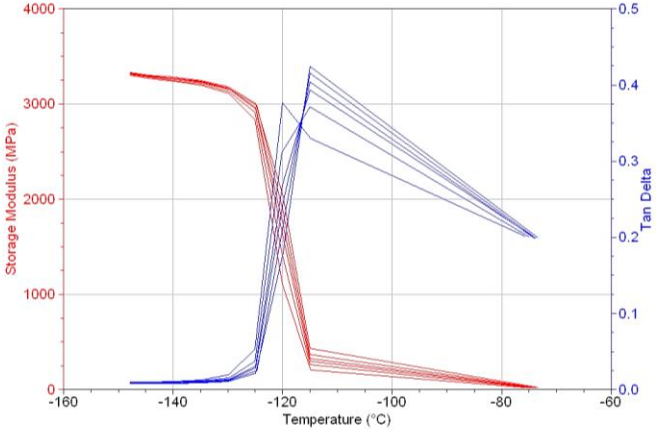
## DMA Scheme



Sample

Stationary Clamp

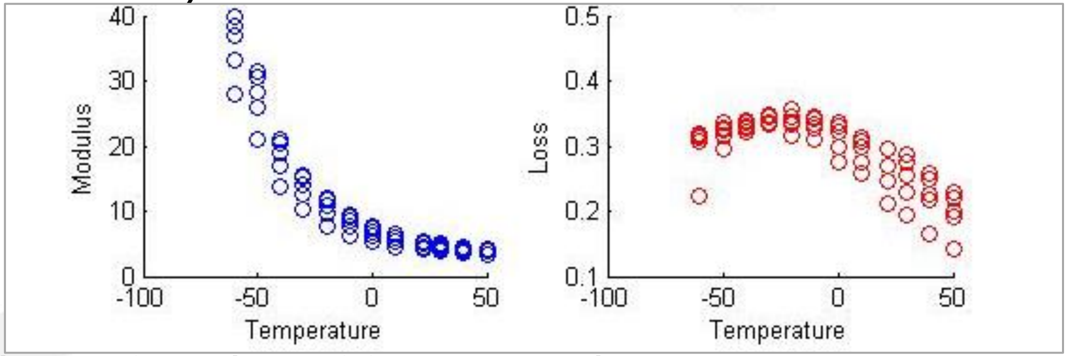
Movable clamp



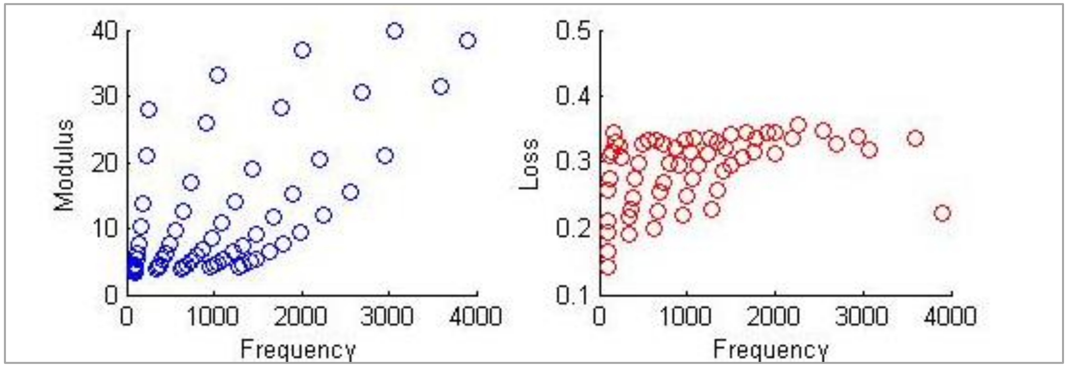
Movable clamp provides predetermined amplitude . Signal input vs. output is recorded for amplitude and loss for 0-10hz

# Resonance

- Results from tests conducted at different temperatures show that even when modulus (MPa) changes are large, losses are still low (5 modes for each temperature are shown).



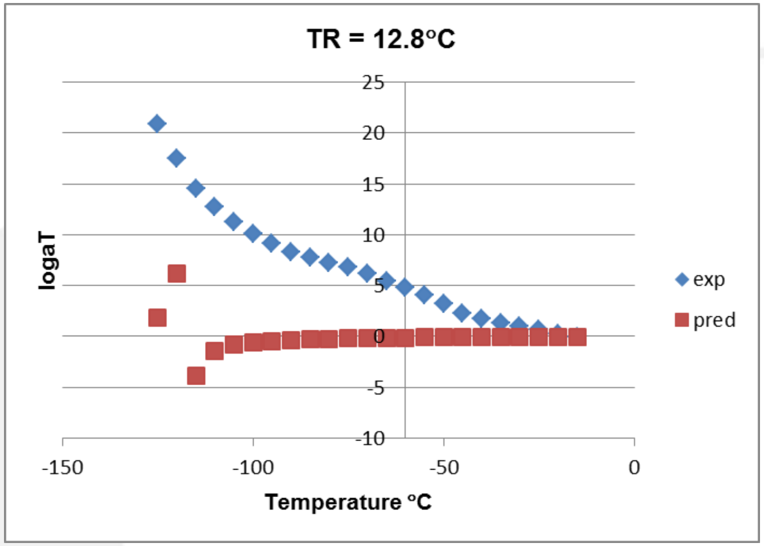
- Results plotted as a function of frequency (lowest temperature correspond to highest modulus and high frequency) also show low loss for high frequency.

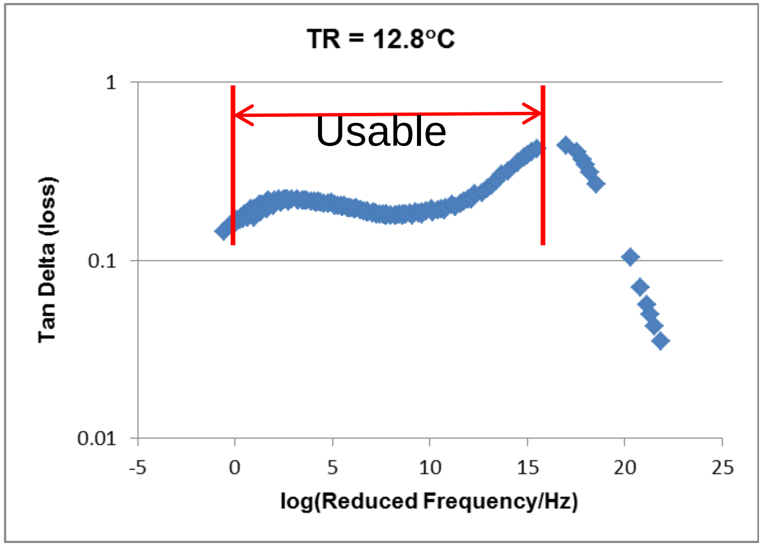


- This leads to interpretation that higher frequencies may have higher attenuation.

# DMA

- Data from DMA was analyzed using Temperature-Time Shift (TTS) program and compared to Williams-Landel-Ferry (WLF) model to obtain shift factor from a reference of 12.8°C to enable extrapolation for high frequencies.
- WLF predictions matched the experimental data only in a small regime, indicating that Sylgard 184 does not behave as an ideal viscoelastic material. However, there is a range of usable data as shown below.

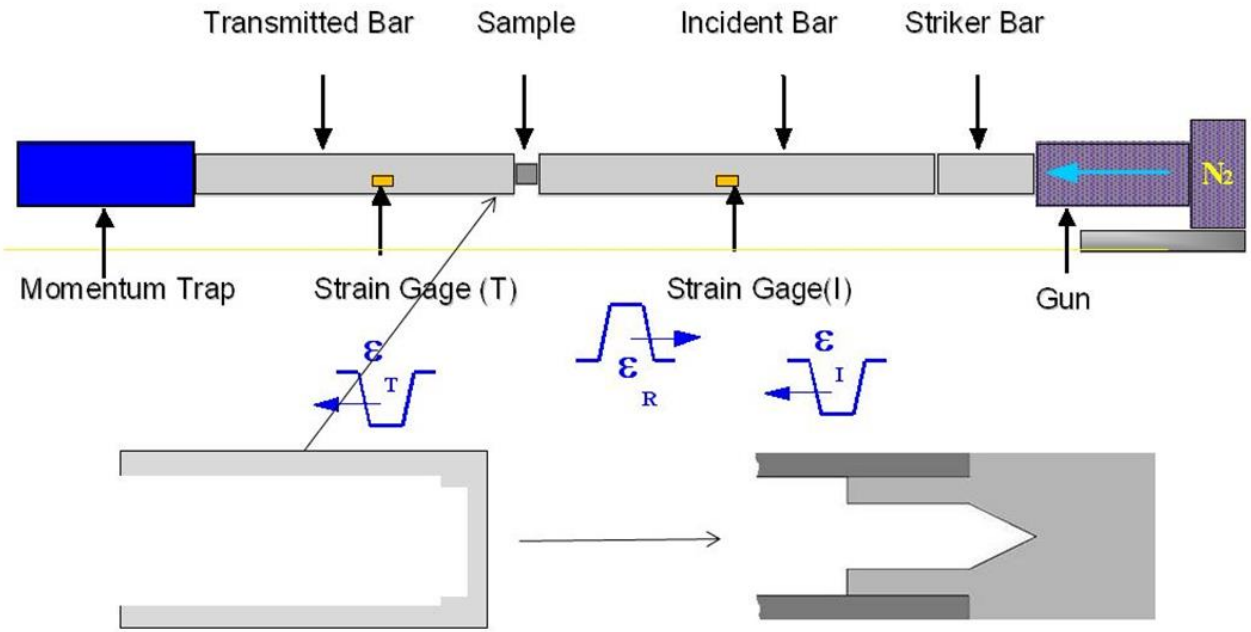




- Extrapolation is not recommended beyond this range, limiting assessment of frequency response to ~3KHz. Also, upper limit of loss factor seems to be about 0.3 (30%) for a calculated strain rate of 140/s.

# Hopkinson Bar

Use Improved Hopkinson Bar (hollow aluminum bar) for high strain rate properties of soft samples (typical strain rate~ 500-5000/s).



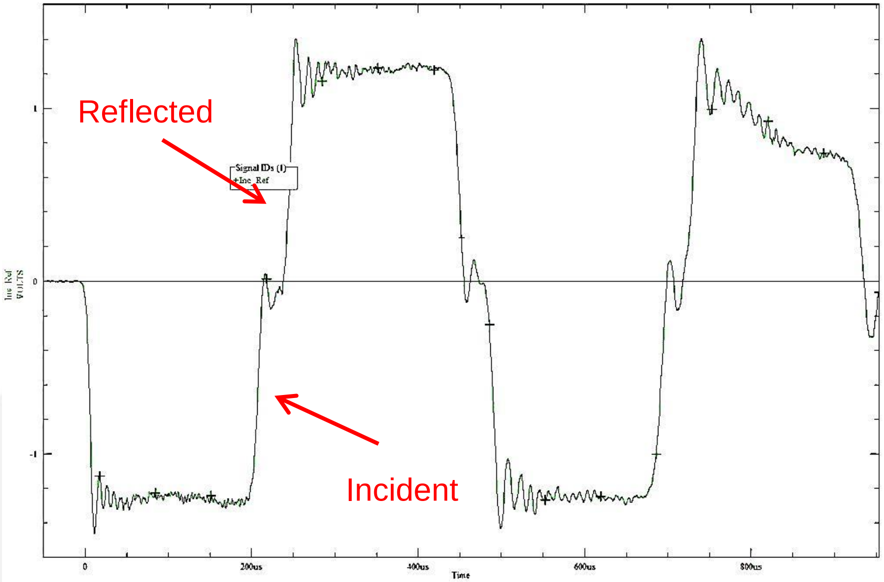
W. Chen Design
Exp. Mech. 39, 1999

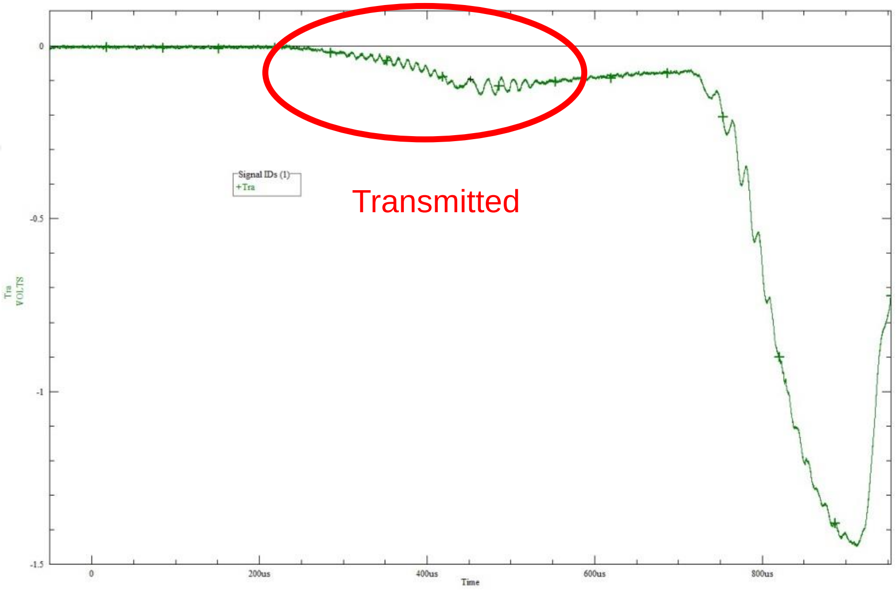
NSWC Design, 2010
APS SCCM 2011

Equivalent Bar Diameter ratio =.59, Area ratio = .39
Reduces dispersion and associated correction issues

# Hopkinson Bar

Typical data acquired is in time domain, whereas generation of a frequency response function (ratio of output to input) requires analysis to be done in frequency domain.





Raw waveforms for incident, reflected and transmitted are isolated and used in calculation of Frequency Response Function (FRF), analysis scheme suggested by Vesta Bateman (Sandia TR 1437).

# Frequency Response Function

Procedure for FRF

- Isolate incident, reflected, and transmitted signals of the three trials.
- Calculate FFT of incident, transmitted, and reflected signals.
- Use low-pass filter to cut off higher frequencies (above 50kHz).
- Dispersion correction.
- Determine conjugate of filtered FFT.
- Find auto-spectrums and cross-spectrums of signals.

Auto-spectrums

$$G_{ii} = G_i G_i^*$$
$$G_{tt} = G_t G_t^*$$
$$G_{rr} = G_r G_r^*$$

Cross-spectrums

$$G_{it} = G_i \, G_t^*$$
$$G_{ti} = G_t G_i^*$$
$$G_{ir} = G_i G_r^*$$
$$G_{ri} = G_r G_i^*$$

# Frequency Response Function

- Use equations to determine H-values
- $H_1$ minimizes noise at input while $H_2$ minimizes noise at output

Transmitted

$$H_1 = \frac{\Sigma G_{it}}{\Sigma G_{ii}}$$

$$H_2 = \frac{\Sigma G_{tt}}{\Sigma G_{ti}}$$

Reflected

$$H_1 = \frac{\Sigma G_{ir}}{\Sigma G_{ii}}$$

$$H_2 = \frac{\Sigma G_{rr}}{\Sigma G_{ri}}$$

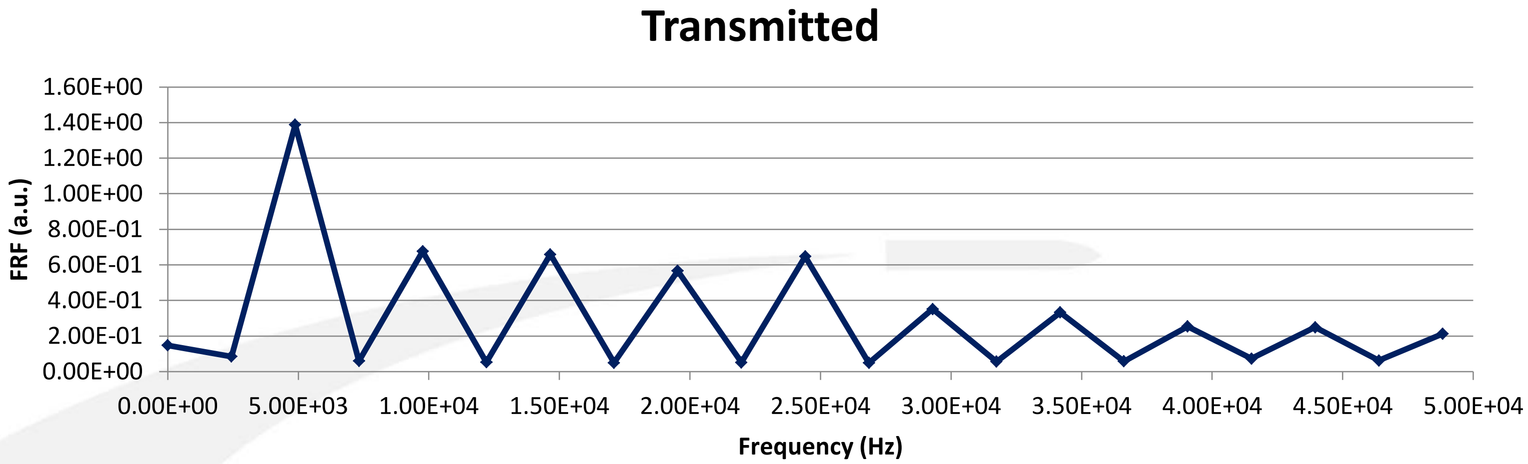
- Obtain H-value by averaging

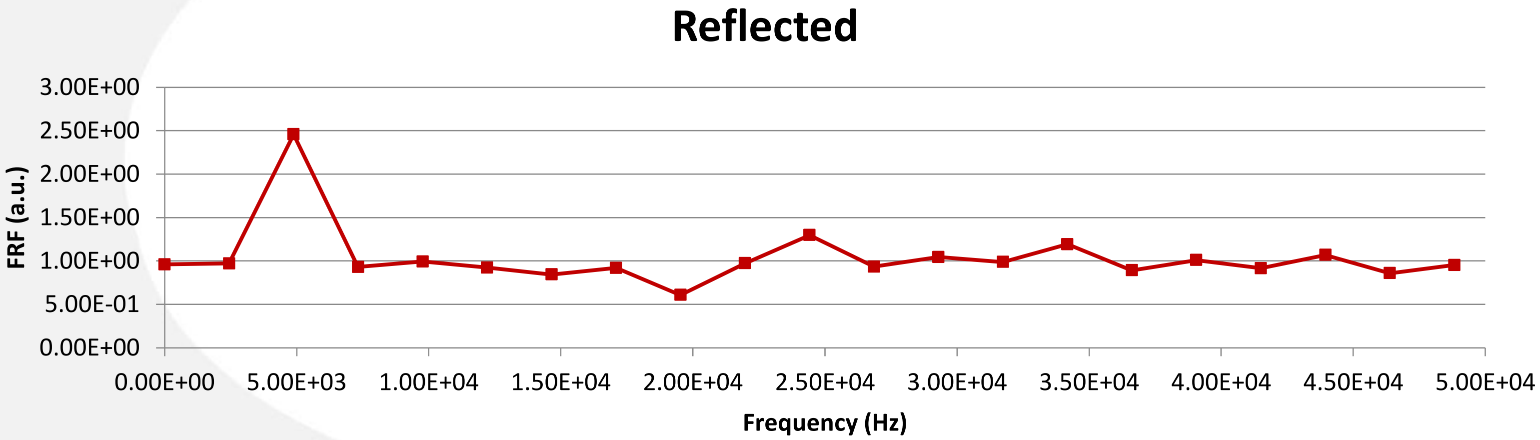
$$H = \frac{H_1 + H_2}{2}$$

- The analysis procedure was developed using 1) SIGNO and 2) MATLAB (both are commercial software).

# FRF in SIGNO

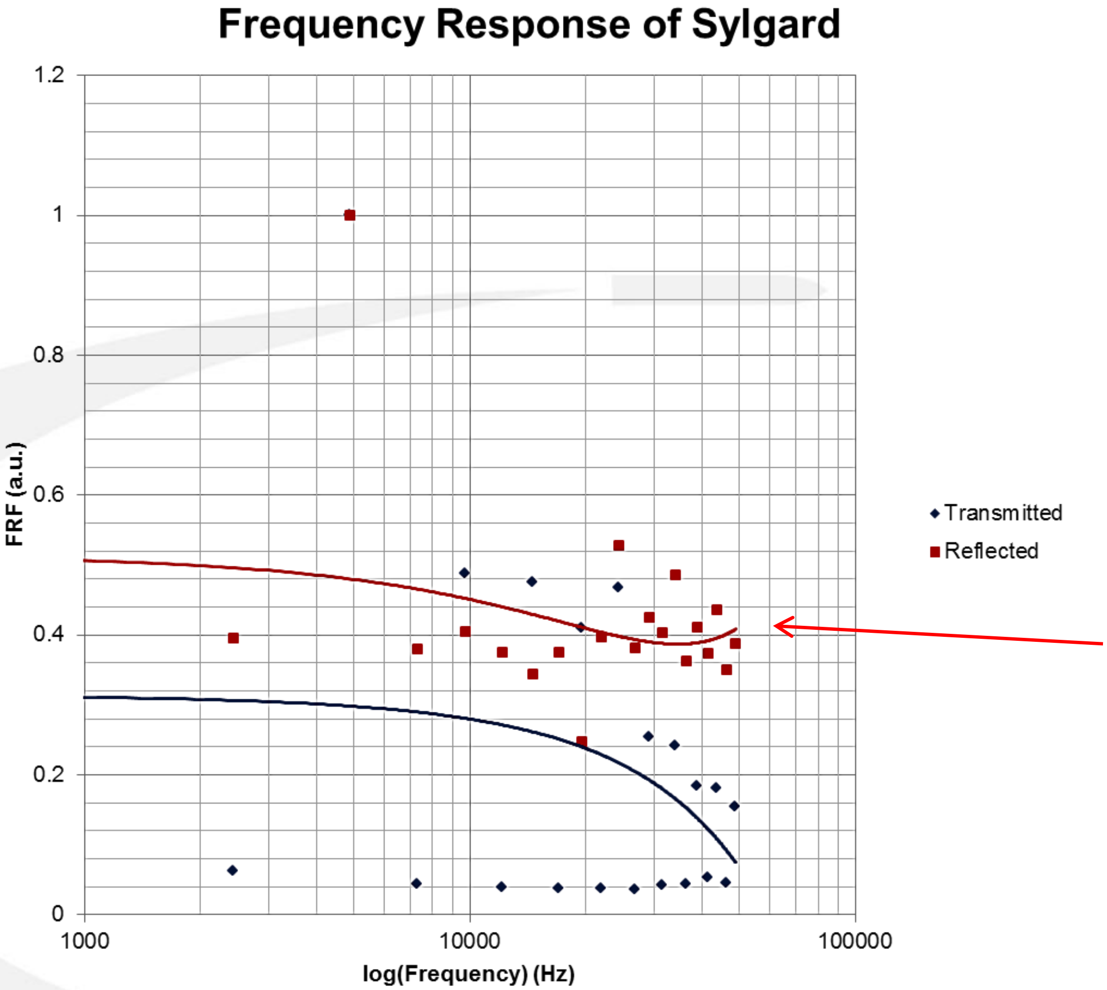
## FFT from waveforms





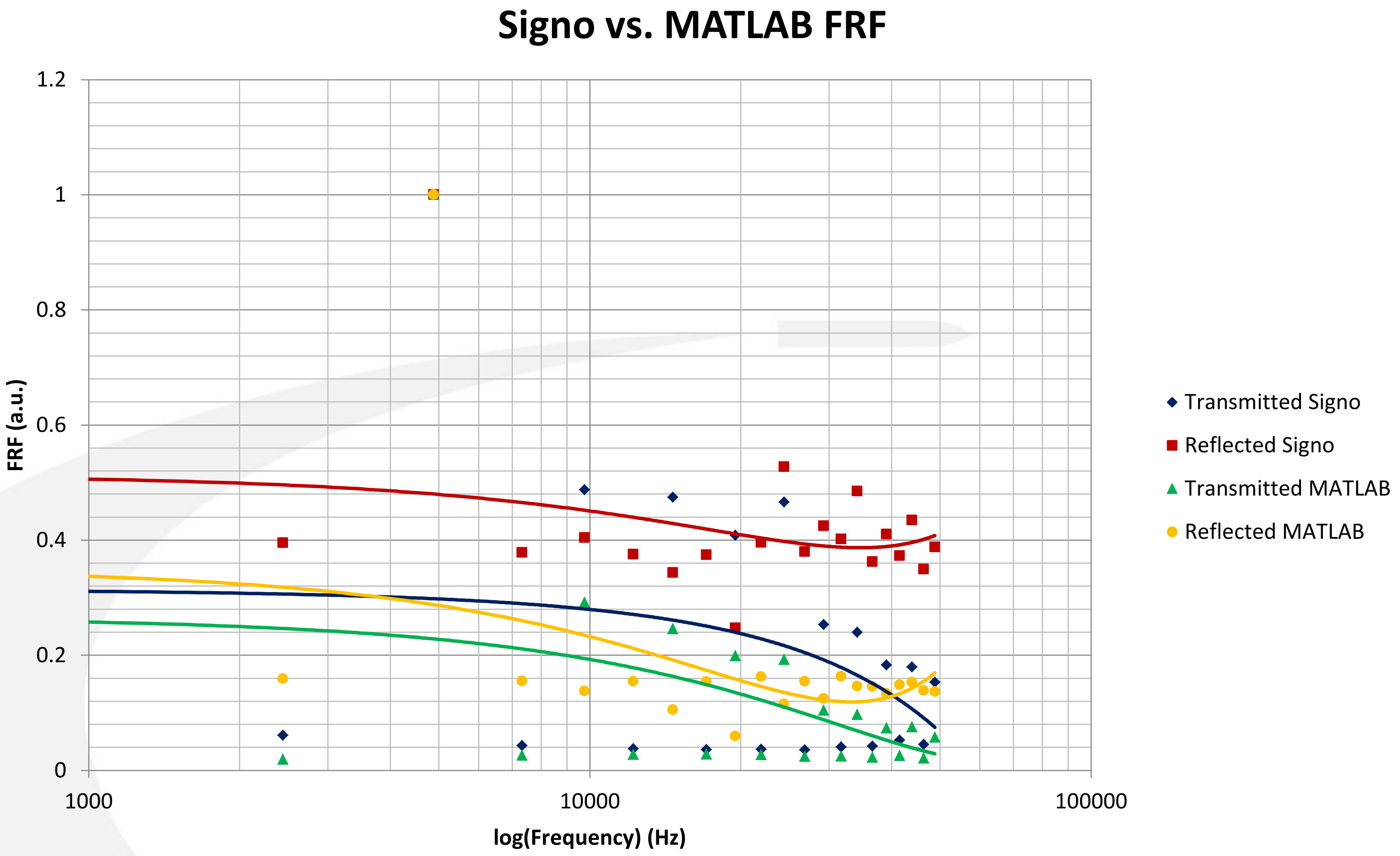
# FRF in Signo

FRF trend results were normalized and fitted with a polynomial fit



Loss/damping values are slightly higher than those observed in DMA or Resonance

# FRF- SIGNO vs MATLAB



Shapes of trend lines consistent, actual and relative magnitudes differ

# Discussions

FRF differences observed due to:

- Algorithms in computing Fast Fourier Transform (FFT)
- Implementation of individual subroutines not standardized
- Automatic generation of number of padding data in Matlab, logic is inaccessible in MATLAB, but well defined in SIGNO
- SIGNO provides more control of individual steps and requires more time
- Dispersion correction routine is built into SIGNO, not in MATLAB

# Summary

- Process for calculating FRF formulated in SIGNO and subroutine written in MATLAB for convenient and quicker processing
- Damping factor as a function of frequency obtained for higher frequencies than DMA analysis for Sylgard 184 using this FRF analysis
- Comparing the two processes (MATLAB/ SIGNO) indicate minor differences (based on intrinsic calculations within software)
- Further refinements for minimizing differences due to procedures are being explored

# Acknowledgements

- This work was supported by DOD Joint Fuze Technology Program at Research and Technology Department at Indian Head, MD. Austin Biaggne, summer intern from Washington State University , WA, contributed to the programming in MATLAB.
- Efforts of Colin Qualters and Ezra Chen at NSWCIHEODTD, Jaime Santiago at NSWC Bethesda, Summer Intern Kaelyn O’Neill are highly appreciated.

# Questions

?

Contact

Dr. Vasant Joshi, NSWC Indian Head, MD
vasant.joshi@navy.mil, (301)744-6769