Validation of the VA-One Periodic Subsystem Module with the Goal to Increase Accuracy of SEA Subsystems in the High Frequency Regime

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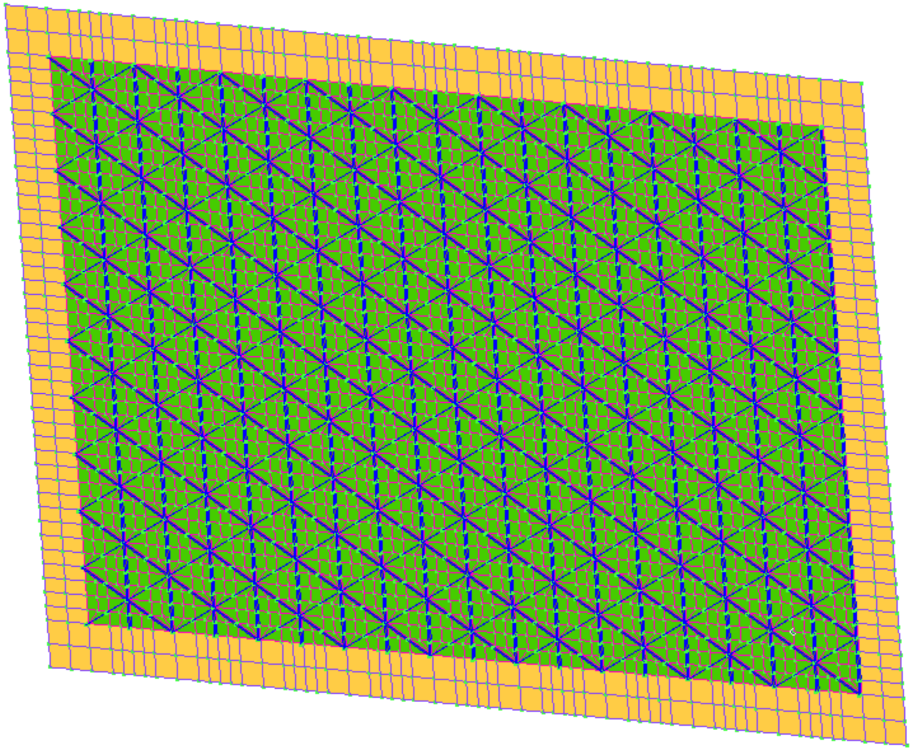


Justin R. Harrison - Alexis Castel, Ph.D.

Agenda

- Authors Background
- Introduction/Motivation
- Hybrid Transmission Loss Results
- Model Setup
- Results
- Conclusions and Forward Work
- References

Authors Background

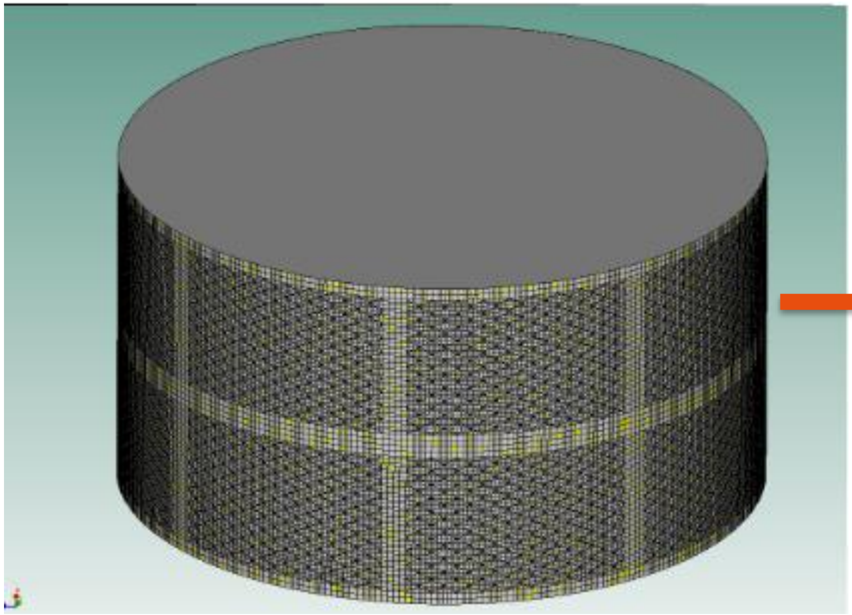
- Justin Harrison
  - CRM Solutions, Inc. in Huntsville, Alabama. www.crmsolutionsinc.com
  - Primary responsibilities are all vibroacoustic and internal acoustic environment predictions for the Launch Vehicle Stage Adapter on the NASA SLS.
  - Bachelors of Mechanical Engineering - Auburn University 2007
  - Masters of Mechanical Engineering - Auburn University 2014

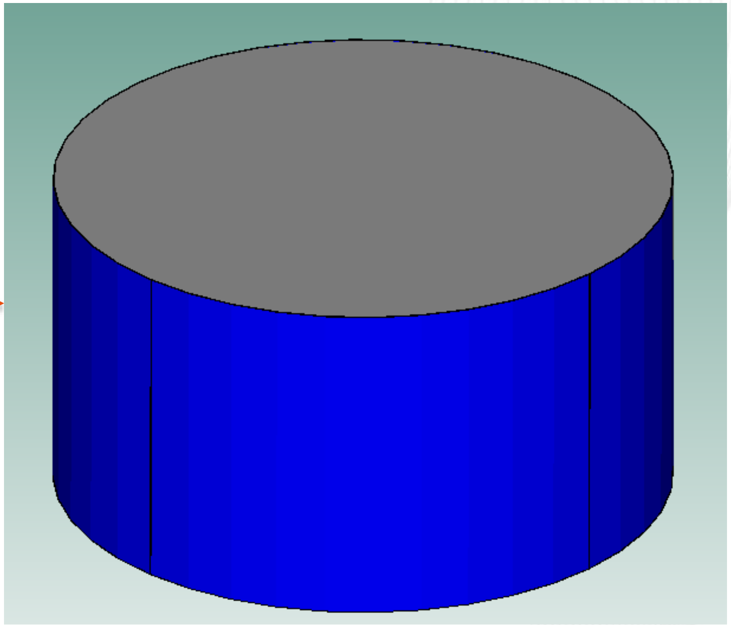
- Alexis Castel,
  - Vibro-Acoustic application engineer at ESI Group
  - Part of VA One's Engineering Services and Support group
  - Ph.D. from Burgundy University, France

Introduction/Motivation

- Can we better predict the high frequency transmission loss (noise reduction) of an isogrid panel using SEA?

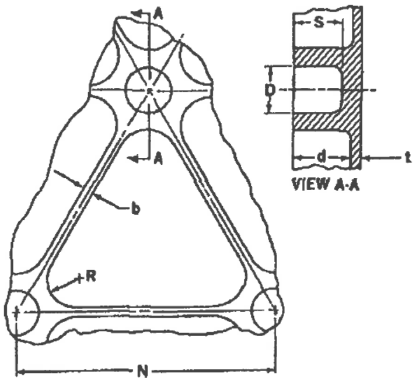
- Specific applications pertaining to launch vehicle payload fairings and cavities





Introduction/Motivation

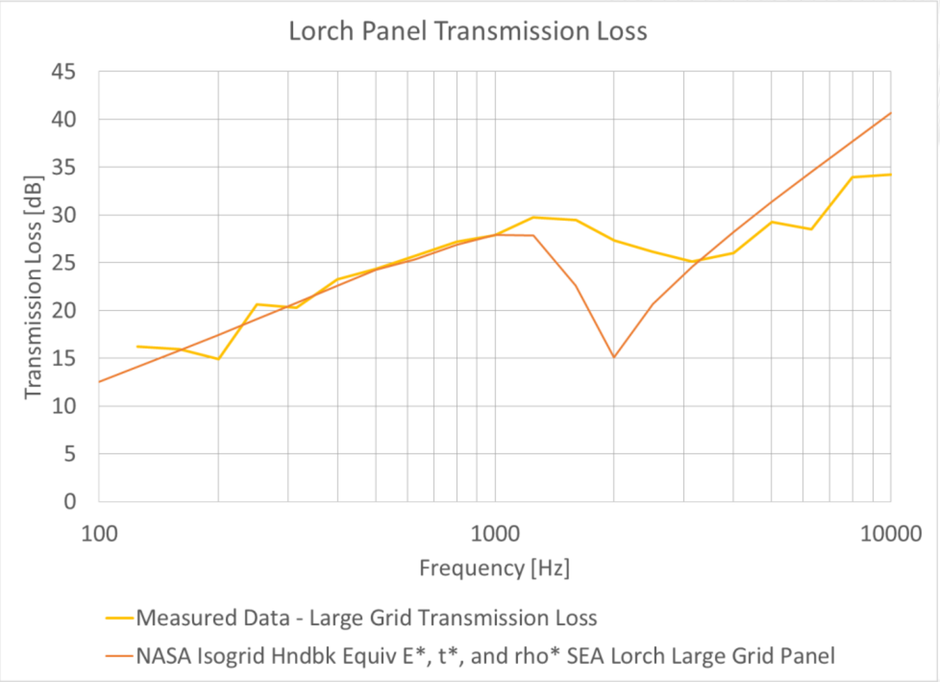
- SEA uniform plates formulation have difficulty capturing the transmission loss characteristics of an isogrid panel.
  - Advanced formulations exist: e.g. ribbed panel SEA formulation
- NASA isogrid handbook proposes a formulation for an equivalent property panel
  - E*, t*, and rho* approach correlates well with test data in the low frequency range.
  - Correlation issues are present in the high frequency range.



DIMENSIONS (INCHES)

	LARGE GRID	SMALL GRID
t	0.069	0.046
d	0.44	0.46
D	0.75	0.75
S	0.37	0.46
R	0.50	0.38
N	4.60	3.5
b	0.075	0.04

FIGURE 5. ISOGRID STRUCTURE



Introduction/Motivation

- In 1980, D.R. Lorch measured the sound transmission loss across a rib stiffened panel (isogrid) using a reverberant source room and an anechoic receiver room. [1]
  - Test data is available for comparison
  - Author details panel design information
- Bruce LaVerde and Andrew Smith verified the VA One Hybrid Transmission Loss function. [2]
  - Finite elements / Hybrid Transmission Loss model yields a good prediction however, computationally expensive
- VA One's periodic module allows to model only a "cell" of a panel using FE and predict the response and characteristic of the entire Panel.

Presentation Goals

- **How will the periodic module solution compare to the LaVerde/Smith results?**
- **What is the comparable solve time?**
- **Could that information be used to adequately refine an SEA equivalent panel?**

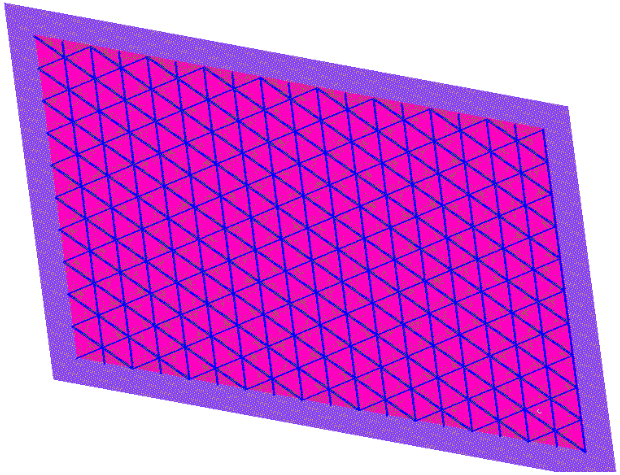
Hybrid Transmission Loss – LaVerde/Smith Results (SCLV 2015)

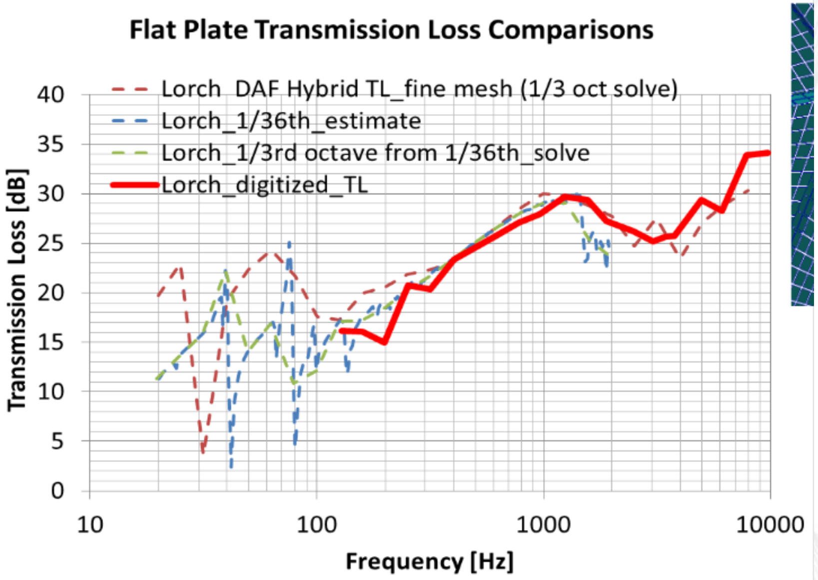
LaVerde/Smith Results

- LaVerde/Smith achieved good correlation up to 2000 Hz with coarse mesh FE model
- Fine mesh Hybrid TL model was to solve to 10KHz
  - Solve time is several days due to model size

- *Nodes: 204647 Nodes*
- *Elements: 205136*

High Frequency FEM (10 KHz)

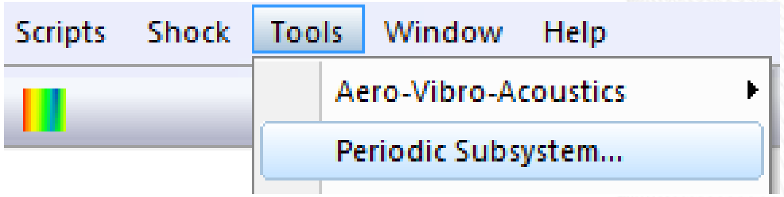


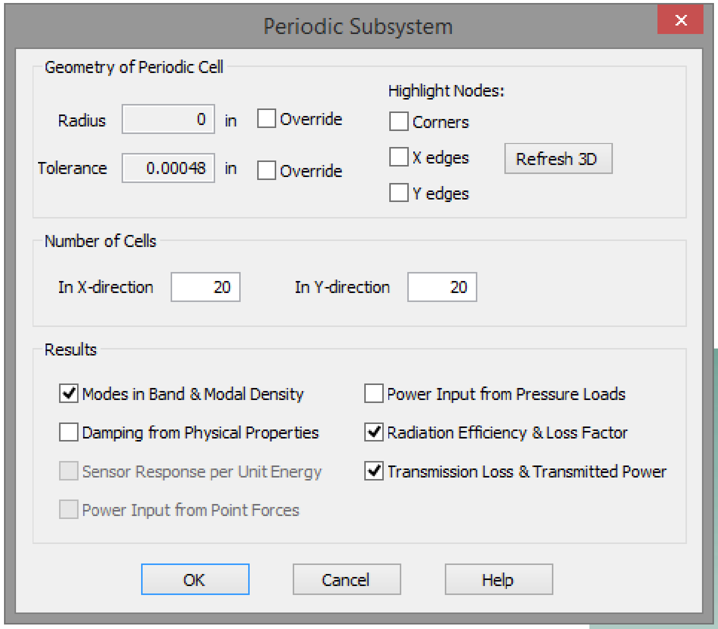


Periodic Module Setup

Inputs

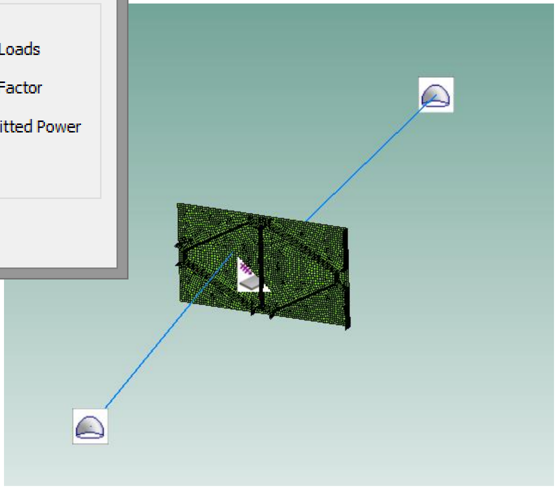
- Hybrid TL setup for one cell
- Solution computed in VA-One internally (COSMIC NASTRAN)

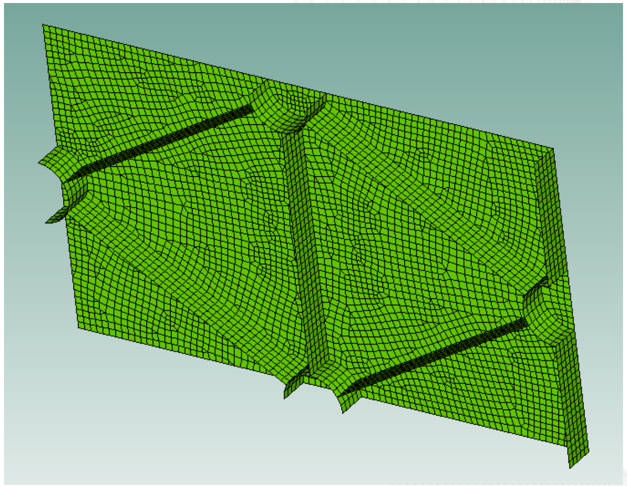




Outputs

- TL (resonant and non-resonant)
- Radiation efficiency
- Radiation Loss Factor
- Modal density

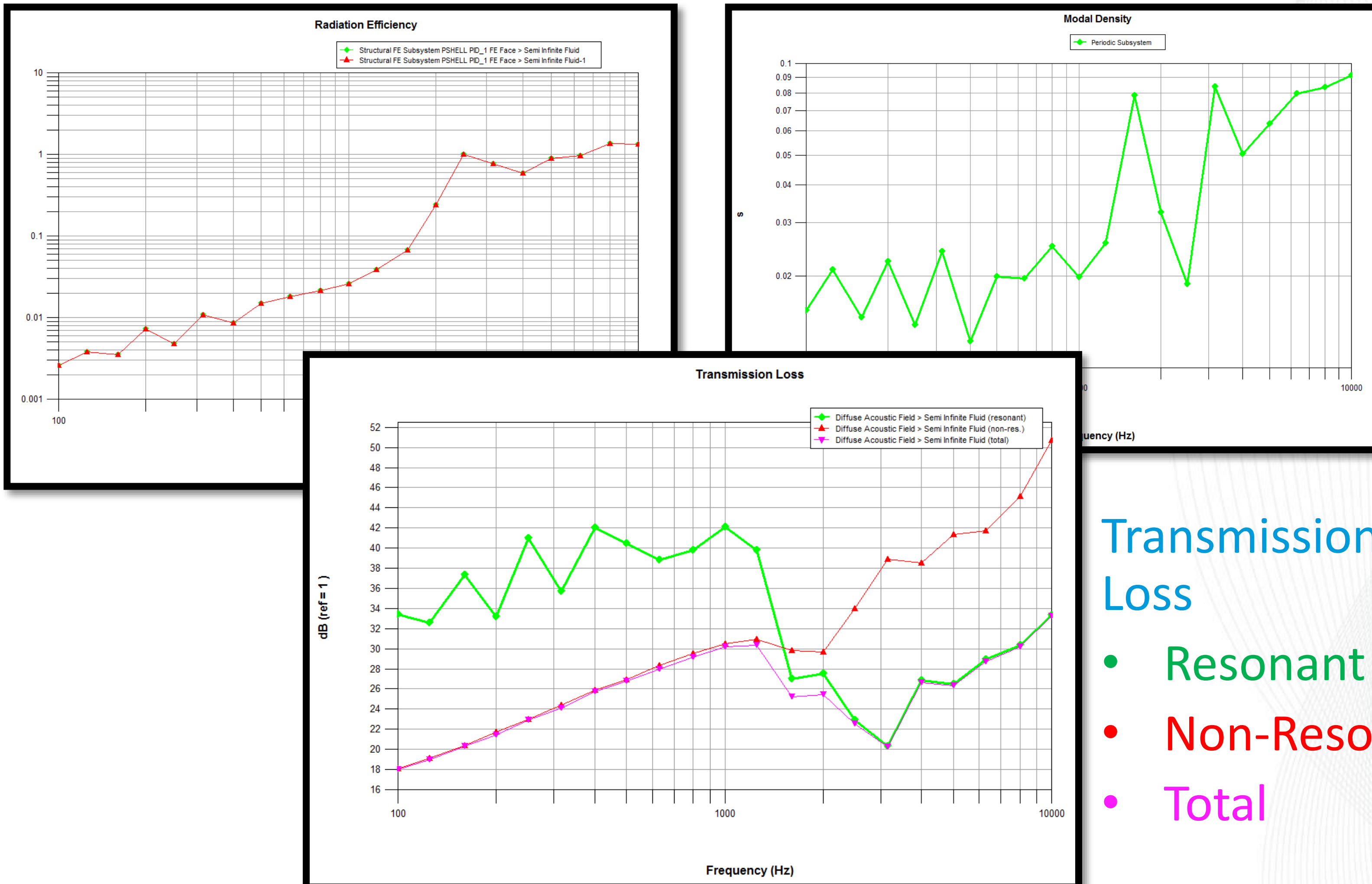




Periodic Module Output

Radiation Efficiency

Modal Density

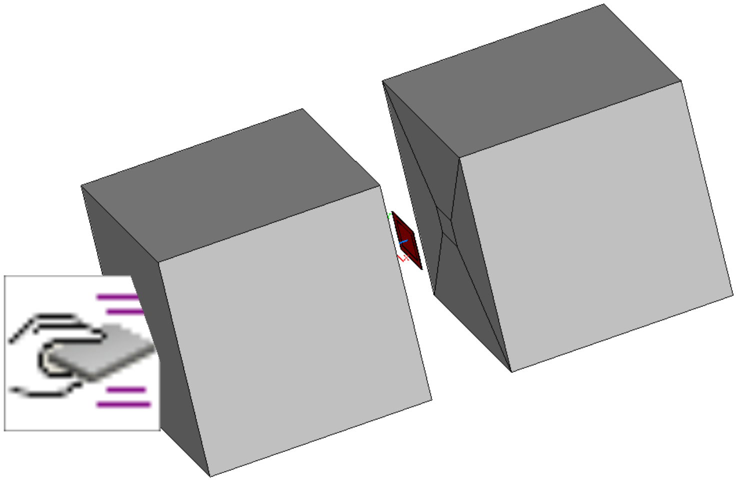


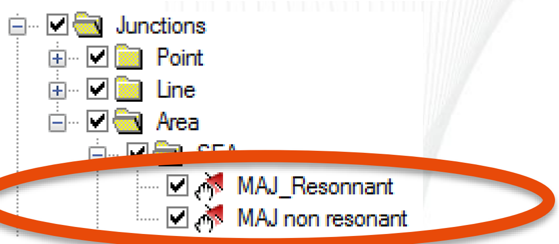
Transmission Loss

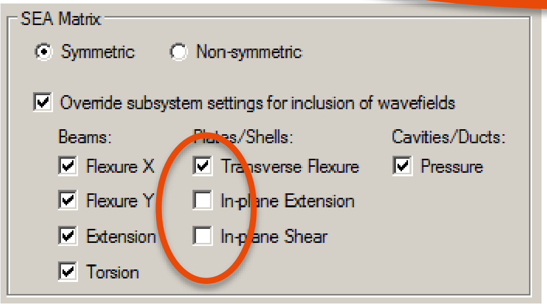
- Resonant
- Non-Resonant
- Total

SEA Model setup : Modified VTL setup

- Use VTL script and save xml
- Two large cavities connected by a plate
- Volume over the cavities is overridden to 6.102e+7 in^3 (1000 m^3)
- Cavities are physically separated from the plate
- **Two overlapping manual area junctions create the link between the two plates:**
  - One for the resonant path
  - One for the non resonant path
- To minimize the matrix size the Shear and Extension wavefields have been deactivated (no influence on results in this setup)







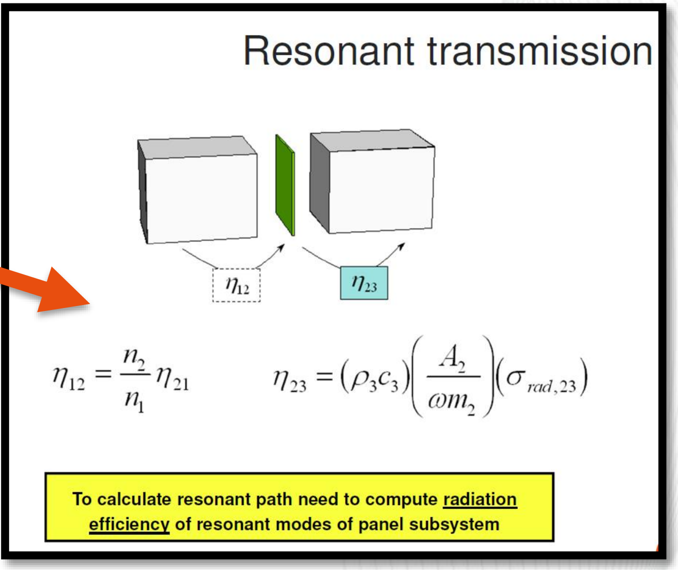
Using the Periodic Module to obtain an Equivalent Resonant CLF

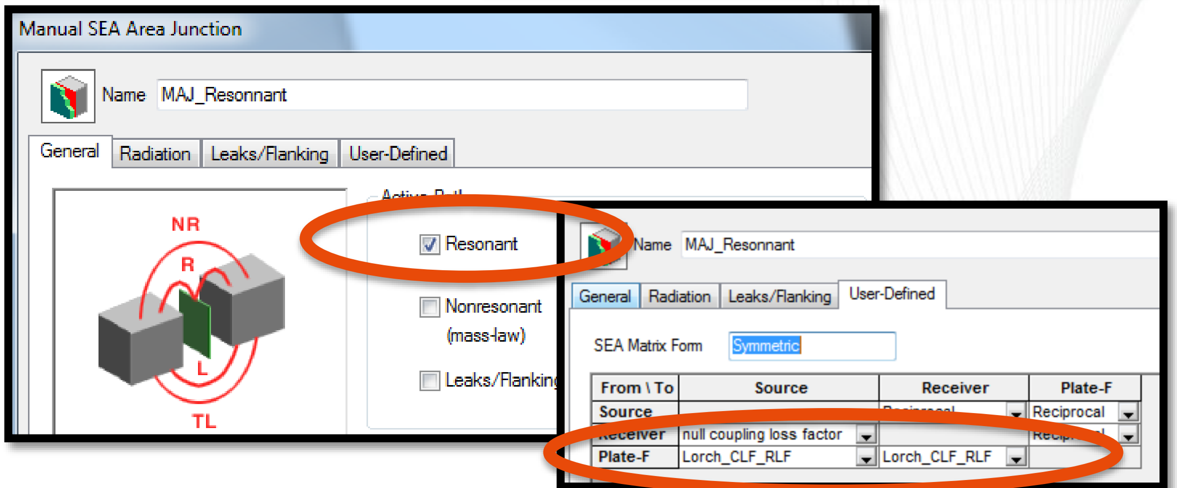
Junction # 1: Resonant Manual Area Junction

The user can override the Coupling Loss Factors in a junction.

In order to obtain new CLFs

- Use the radiation efficiency out of the periodic module to compute a coupling loss factor (n_{12} and n_{23}) using an analytical formula
- Apply a user-defined coupling loss factor to the junction
  - Panel to Source
  - Panel to Receiver

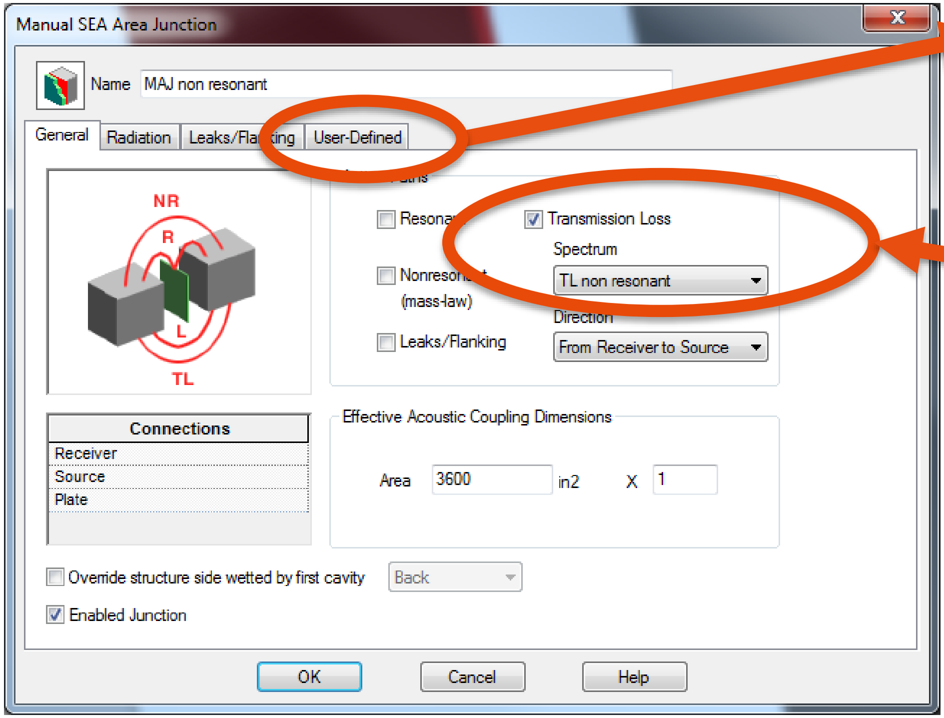


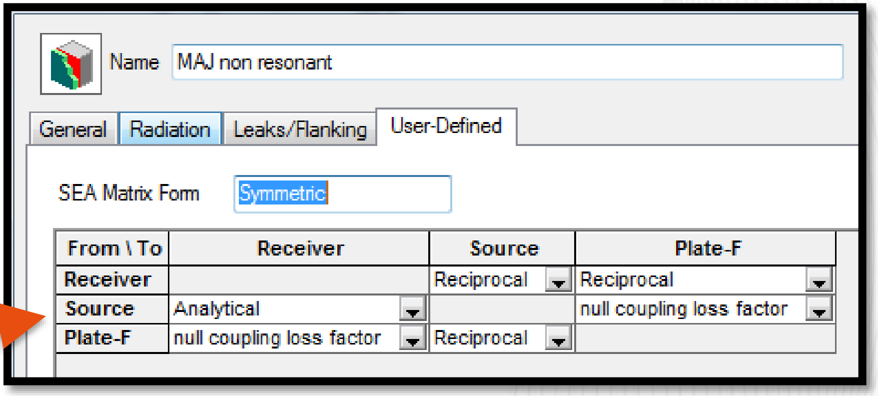


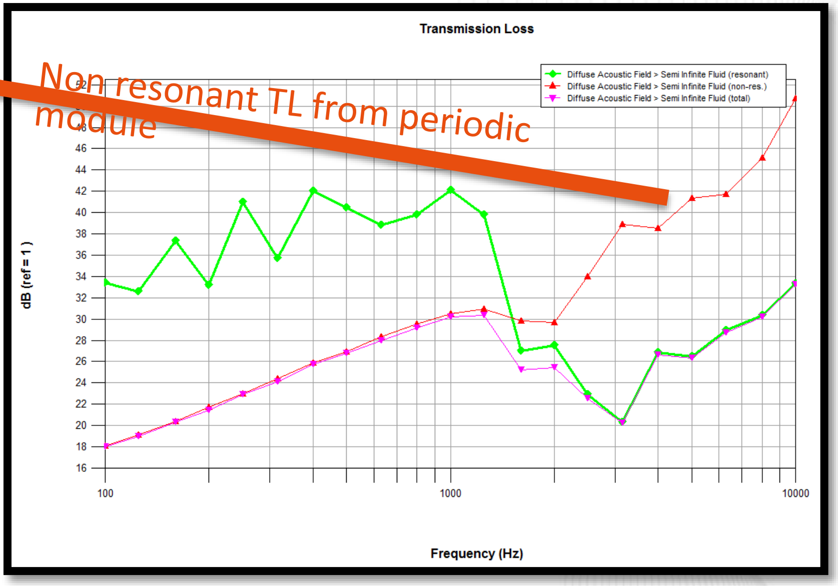
Controlling the non-resonant path

Junction # 2: Non-Resonant Manual Area Junction

- Include non-resonant transmission loss spectra from Periodic Module

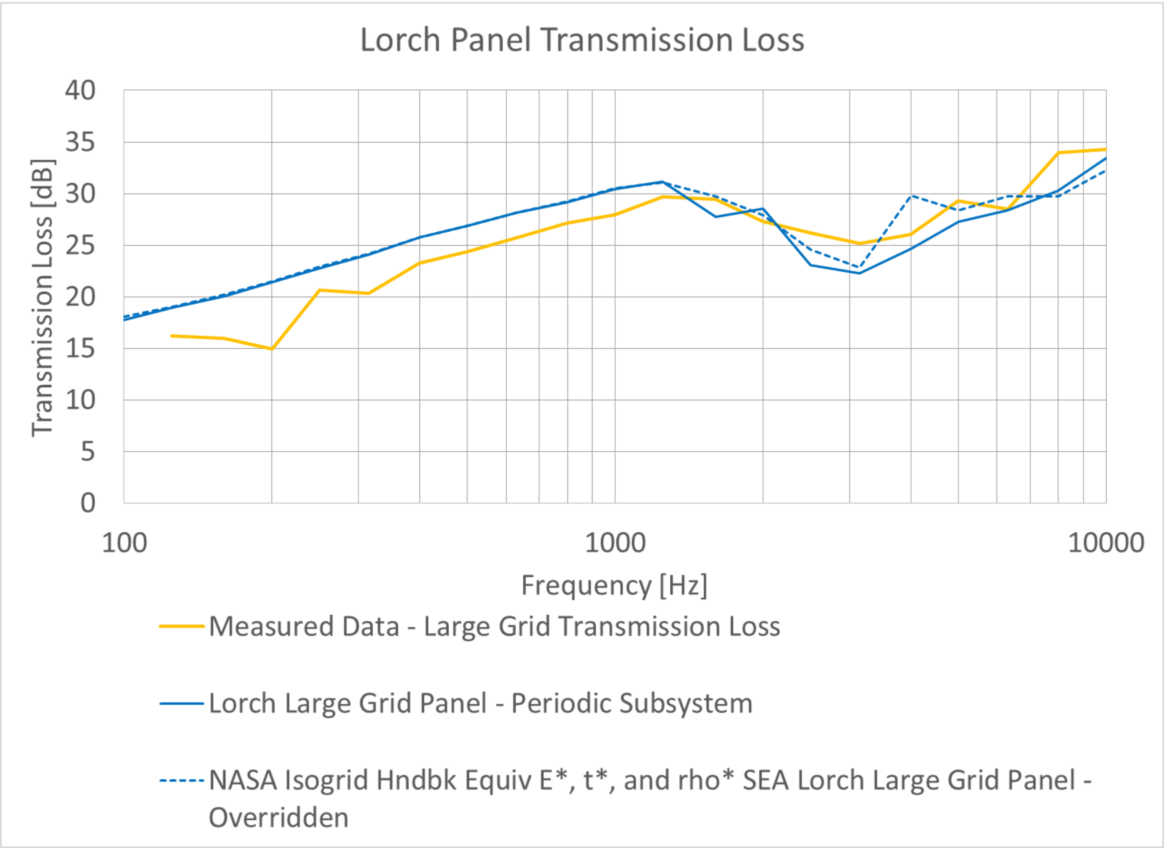






Equivalent SEA Panel using Periodic Module Output

Override SEA Coupling Loss Factor and Modal Density

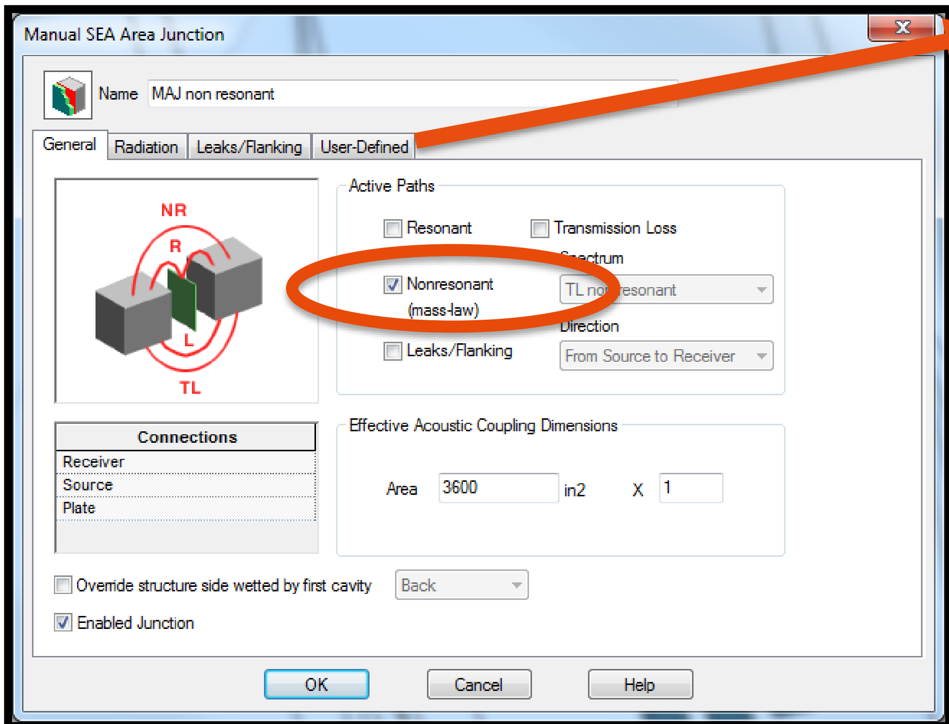


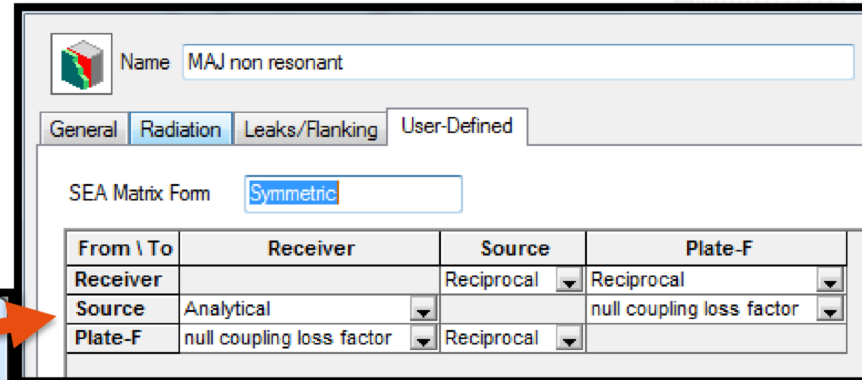
- High frequency behavior is well captured
- Mass Law region does not match test data.
- Windowing effect on periodic module creates this effect, Mass Law region matches FTMM results.

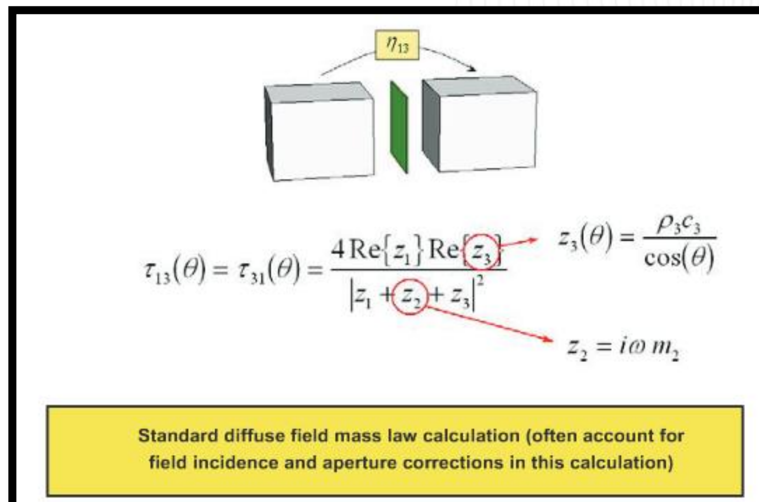
Controlling the non-resonant path

Junction # 2: Non-Resonant Manual Area Junction

- The non-resonant CLFs are analytically calculated within VA-One using the NASA's equivalent panel properties







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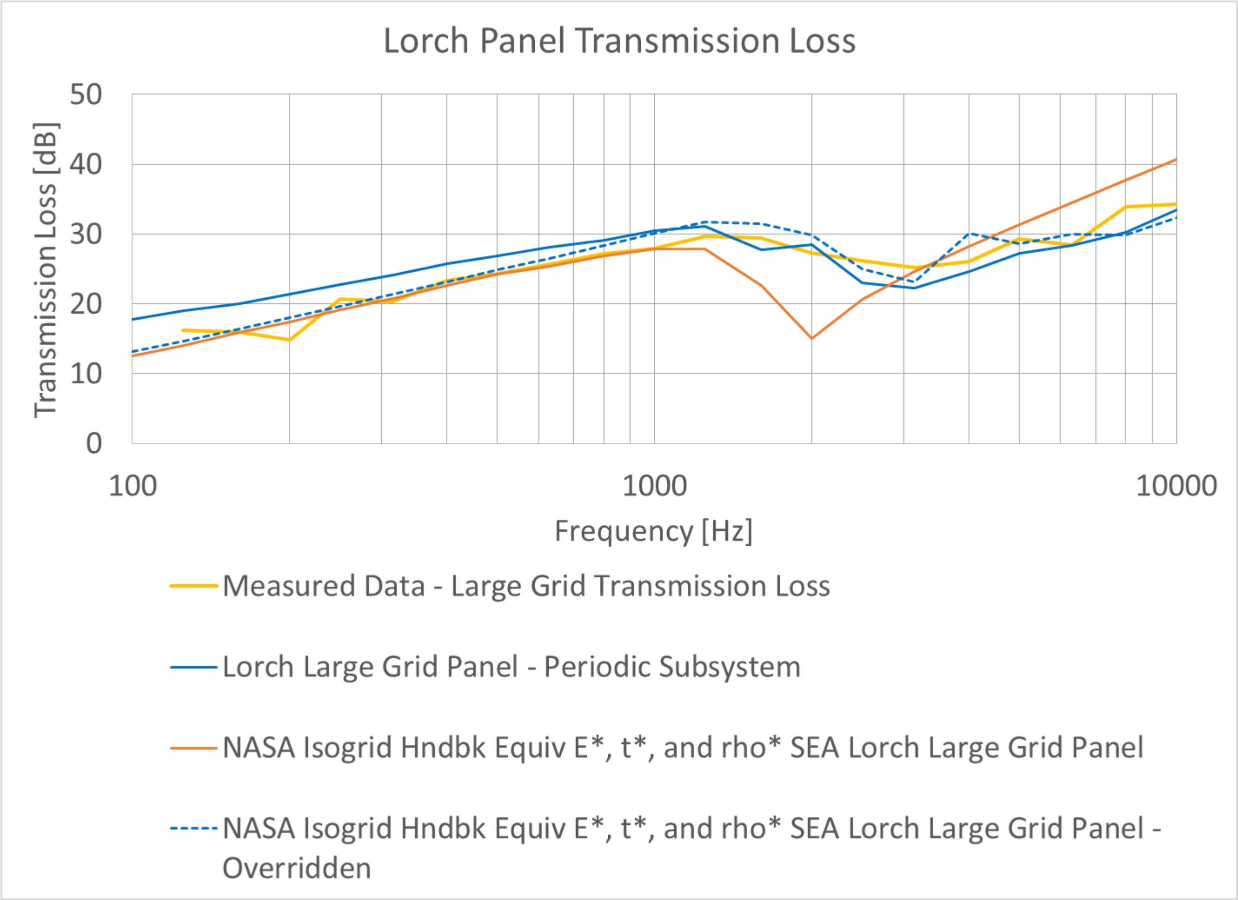
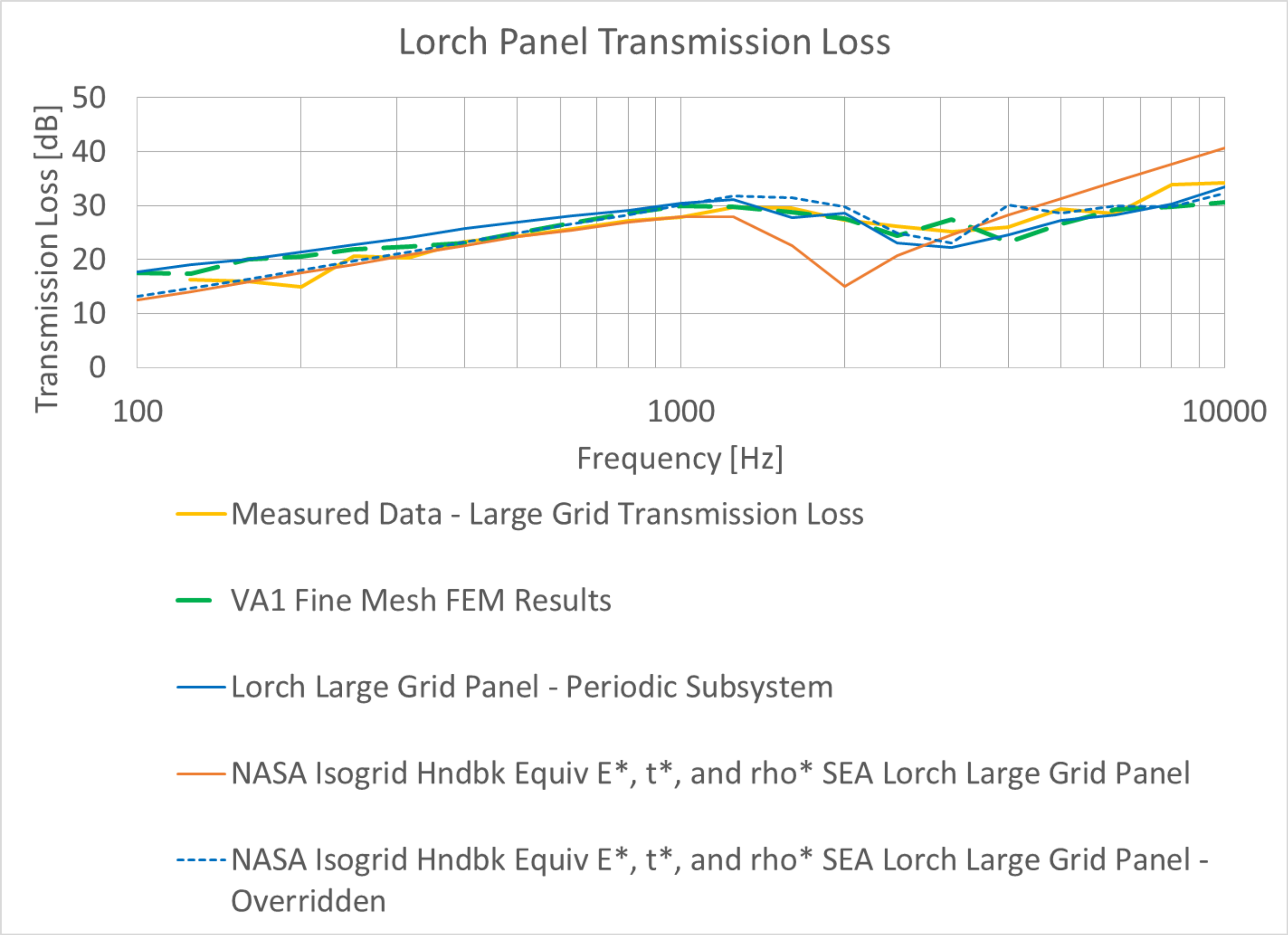


- Both High and low frequency regions match test data.
- Mass Law region is better captured by SEA formulation using equivalent panel properties.

Conclusion Results

Periodic Model vs Measured Data vs Fine Mesh Model



Conclusions

- **How will the periodic module solution compare to the LaVerde/Smith results?**
  - Periodic module solution for resonant path gives very good correlation when compared to both test and Hybrid Transmission Loss results.

- **What is the comparable solve time?**
  - Periodic module solution allows one to obtain results in a matter of minutes.
  - Speed gain is considerable compared to full panel Hybrid Transmission Loss setup.

- **Could that information be used to adequately refine an SEA equivalent panel?**
  - Periodic module results are designed to be used in SEA equivalent panel. Coupling loss factors and modal densities obtained with the periodic module can directly be applied to an SEA panel.

Forward work

- Expanded study to curved geometries (cylinders, cones, ogives)

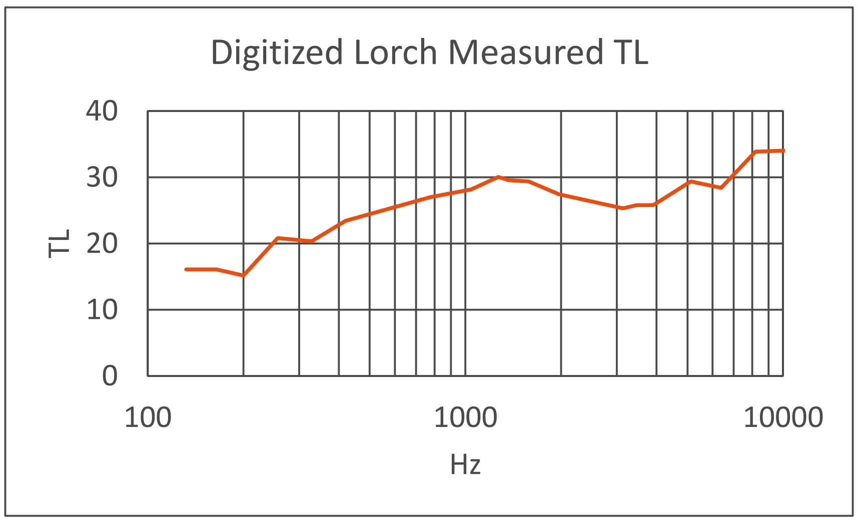
Appendix

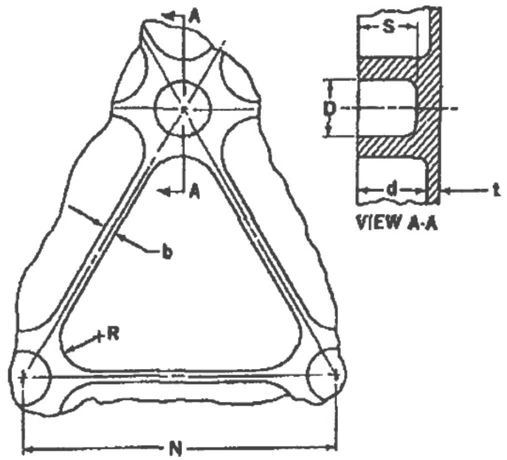
Lorch Panel description

Lorch ‘Large Grid’ Panel

E0	1.05E+07	Elastic Modulus of Parent Material
Rho	0.000268	Density slinch/inches^3
Rib Height	0.44	inches
Triangle Height	4.16	inches
Triangle Width	4.80	inches
Skin Thick	0.069	inches
Rib Thick	0.075	inches

- Panel size: 75 x 48 inches
- SWD = 1.6 lbf/ft^2





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S	0.37	0.46
R	0.50	0.38
N	4.80	3.5
b	0.075	0.04

FIGURE 5. ISOGRID STRUCTURE

Periodic Module Setup

Key Requirements

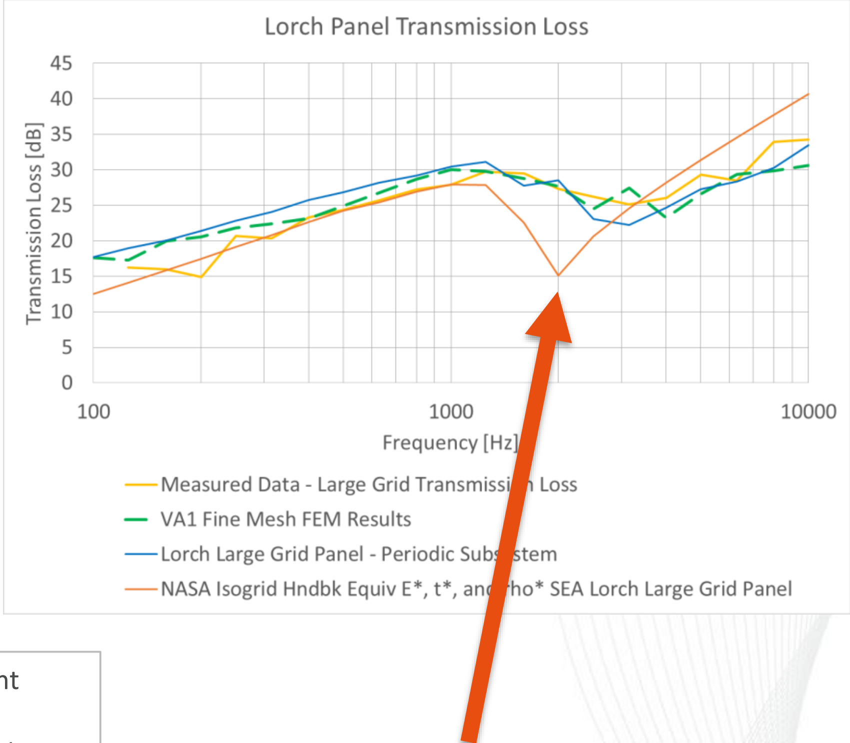
- The cell must form a rectangular region aligned with the global axis and confined in the region x ≥ 0, y ≥ 0.
- A node must be located at the origin.
- Periodicity is assumed along the x and y axis)
- The cell mesh must have corresponding nodes on opposite edges
- The cell can only contain elements that can be interpreted by the internal FE solver.
- No structural boundary conditions (SPC), multipoint constraints (MPC) or rigid elements can be used in the FE subsystems.

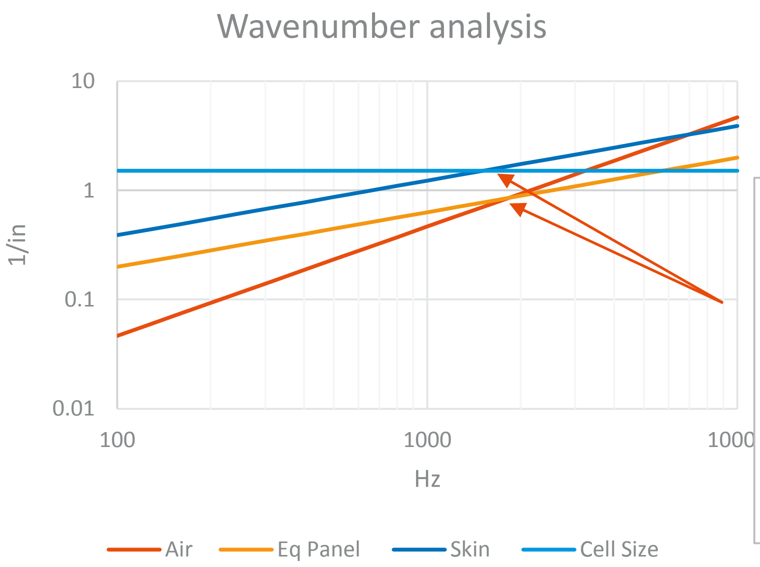
Periodic cell parameters

- Hybrid Transmission Loss Formulation "SIF – DAF – Cell – SIF" setup
- Cell size: 8.31 x 4.80
- Repetitions: 9 over X, 10 over Y
- Cell Mass = 0.001143 slinch
- Panel Mass = 0.10287 slinch

Standard Equivalent SEA Panel vs Periodic Module vs Measurements

- For SEA model, equivalent uniform isotropic properties (E*, t*, and rho*) are calculated using NASA's Handbook
- E* = equivalent modulus of elasticity
- t* = equivalent thickness
- rho* = equivalent mass density





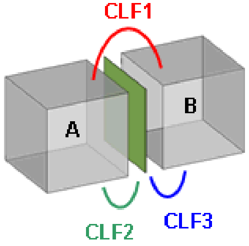
Equivalent panel is designed to have coincident frequency very close to where the skin wavelength meets the cell wavelength

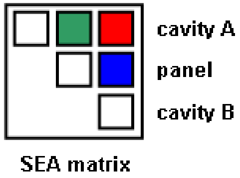
The NASA handbook equivalent SEA Panel formulation represents the mass law response well however, the formulation cannot capture the high frequency response of the isogrid panel

SEA Area Junction

EFFECTS OF OVERRIDING DEFAULT SEA AREA JUNCTION PROPERTIES

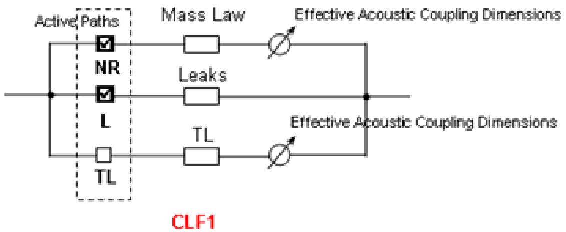
A SEA area junction is used to describe various energy flow paths between a panel and any adjacent SEA cavity subsystems. As depicted in the figures below, the energy flow paths are described in the SEA matrix by three CLF spectrums.





1. CLF1 a direct CLF between the two cavities that accounts for (i) the non-resonant mass law transmission between the two cavities through the non-resonant modes of the panel, (ii) the flanking transmission due to the presence of leaks and (iii) additional flanking transmission specified by the user as a user defined transmission loss.
2. CLF2 a CLF between the source cavity and the panel that accounts for the resonant transmission between the source cavity and the resonant modes of the panel.
3. CLF3 a CLF between the panel and the receiving cavity that accounts for the resonant transmission between the receiver cavity and the resonant modes of the panel.

It is possible to apply various override factors within the area junction dialog. These override factors modify the way in which the various paths are combined when calculating a given CLF as shown in the figures below.



References

1. Lorch, D. R., AIAA-80-1033, "Noise Reduction Measurements of integrally Stiffened Fuselage Panels," Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach California. AIAA 6th Acoustics Conference, June 1980.
2. Smith, A. M., LaVerde, B. T., SCLV 2015, "Validation of Transmission Loss Simulation Approach with Goal to Estimate Launch Vehicle Internal Cavity Acoustics", June 2015