Comparison of Spatial Correlation Parameters between Full and Model Scale Launch Vehicles

Acoustical Society of America

5th Joint Meeting, Session 2aPA

Acoustics of Supersonic Jets: Launch Vehicle and Military Jet Acoustics I

November 29, 2016

Clothilde Giacomoni* and Jeremy Kenny+

*All Points Logistics/ESSSA Group, NASA MSFC

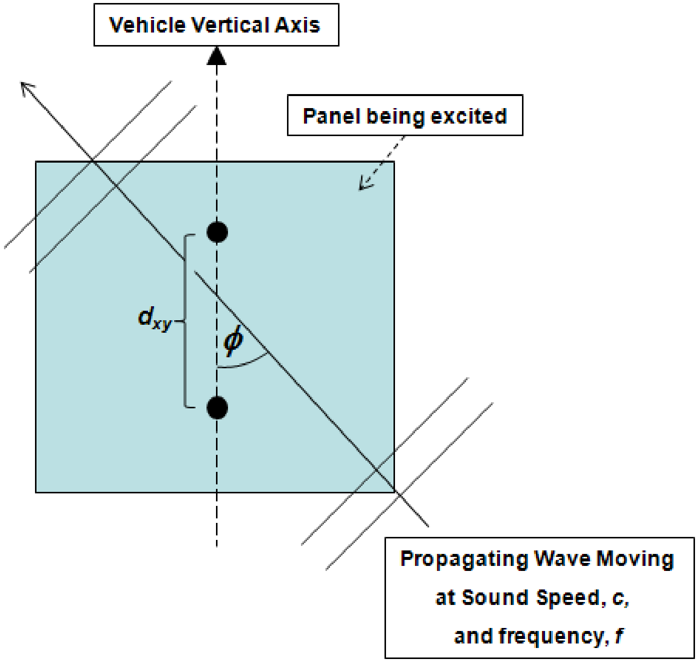
+Fluid Dynamics Branch, NASA Marshall Space Flight Center

Introduction and Background

- Launch vehicle liftoff acoustic environment defined by multiple sound sources and vehicle/launch pad geometry
- Characterize the acoustic field generated by the propulsion system
  - Ratio of diffuse to propagating field
  - Decay coefficient
  - Angle of incidence
- Critical input to the vibro-acoustic modeling software to determine structural/component response to the acoustic loading prescribed by the liftoff acoustic environments
- State of the art application and a first in the field of heavy-lift launch vehicles

Introduction and Background

- Spatial definition of fluctuating pressure environments are needed to better determine hardware responses to a given acoustic spectra
- Use acoustic pressure measurement pairs to characterize cross-spectral relationships between individual locations within the acoustic field



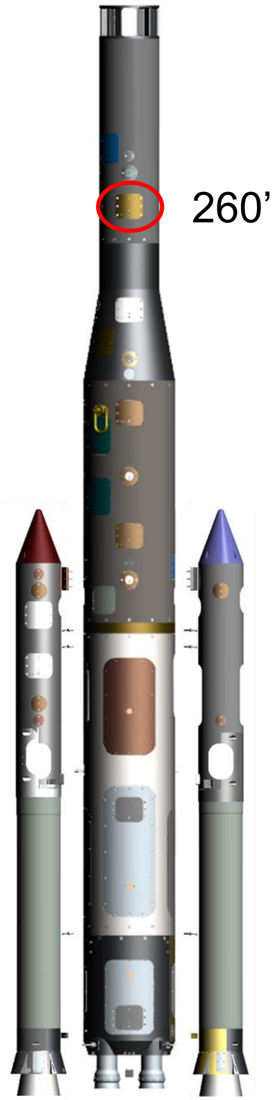
Objective and Approach

- Compare spatial correlation parameters (R, β, φ) between two scale model tests (ASMAT, SMAT) and one full-scale vehicle flight (Delta IV Heavy)
  - Only time a full scale vehicle was instrumented with sensors capable of measuring this
  - **Unique opportunity!**

- Calculate auto- and cross-spectral densities during time window of largest pressure readings
  - Spatial correlation parameters can be calculated from these
- Convert spatial correlation parameters to 1/3 octave band
  - Scale model test results were converted to “full-scale” frequency

JACOBS
ESSSA Group

Measurement Location



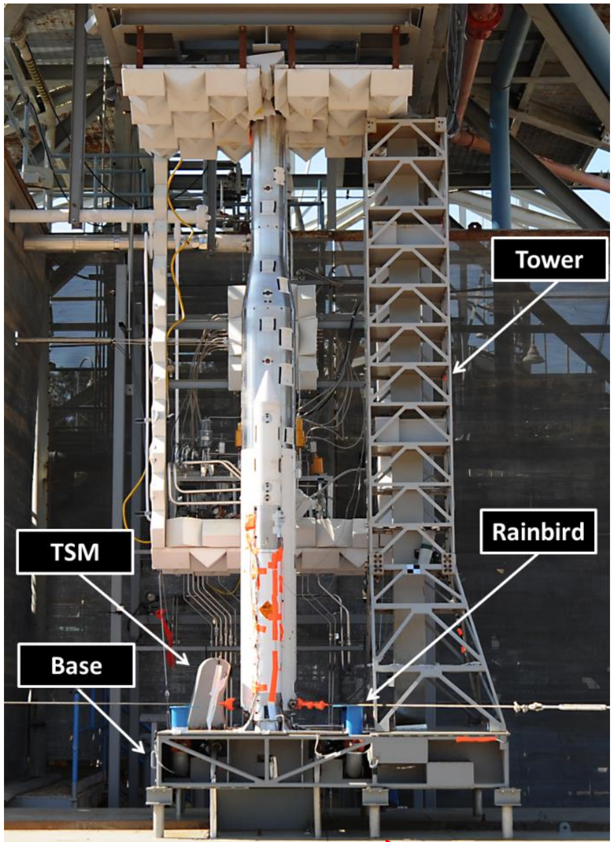
Model (SMAT)

Model (ASMAT)

Full Scale (EFT-1)

JACOBS
ESSSA Group

Tower Side v. Open Side



Tower side

(out of the page)
Open side

Tower side

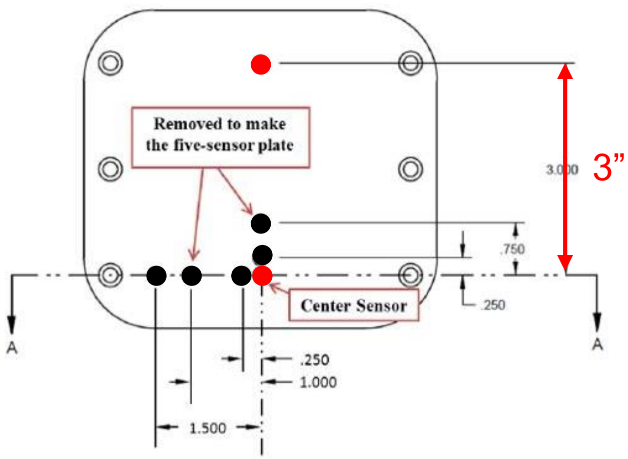
(out of the page)
Open side

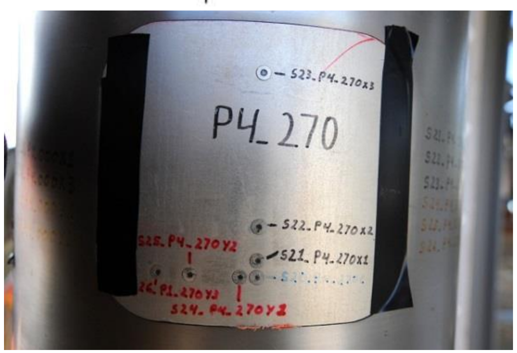
Tower side

(out of the page)
Open side

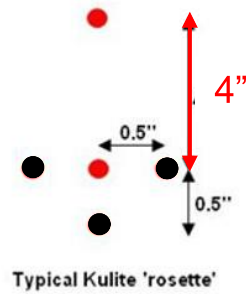
Spatial Plates

SMAT Plate

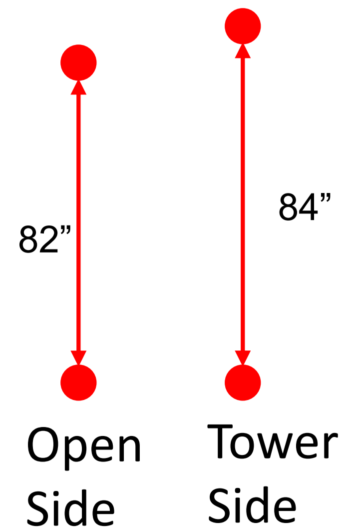




ASMAT Plate



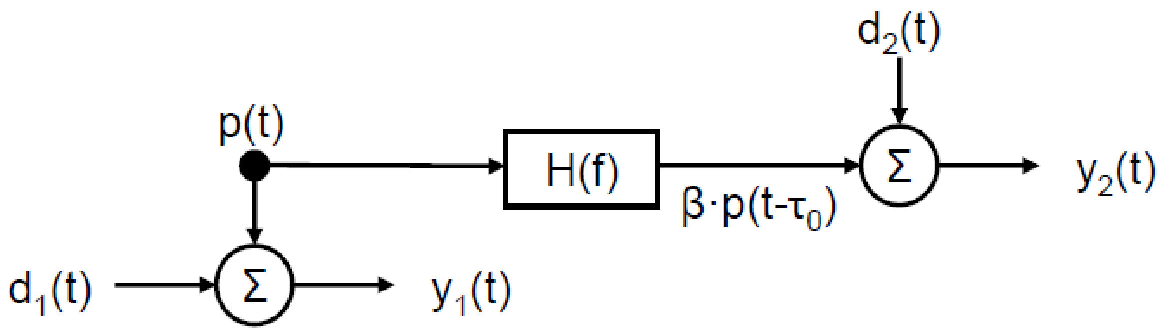
Delta IV “Plate”



Model Scale dimensions are 5% size of full scale dimensions.
Roughly same spacing

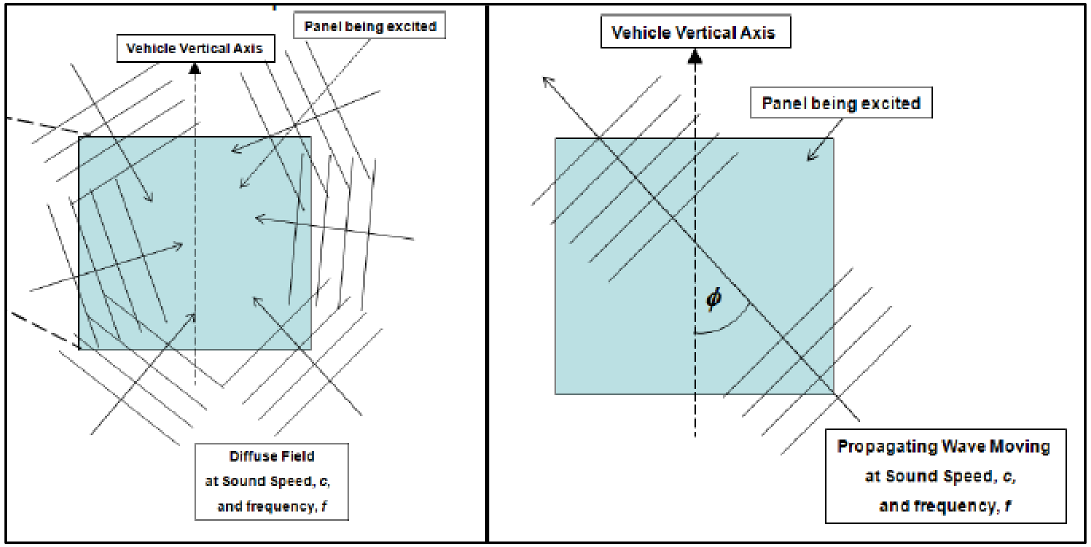
Decay Coefficient, β

- Describes how sound field decays as it propagates along vehicle
- $\beta = \left(\frac{r_1}{r_2}\right)^n e^{-\alpha * d * \cos\phi}$
  - r_1, r_2 :
  - *n:* geometric decay coefficient
  - α: atmospheric decay coefficient
  - *d*: spacing between sensors
  - *φ:* angle of incidence
- Frequency dependent



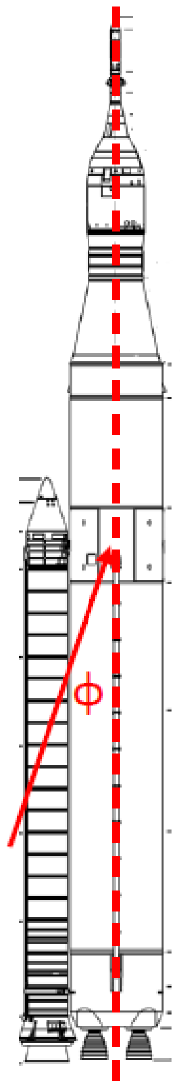
Ratio of Diffuse to Propagating Wave, R

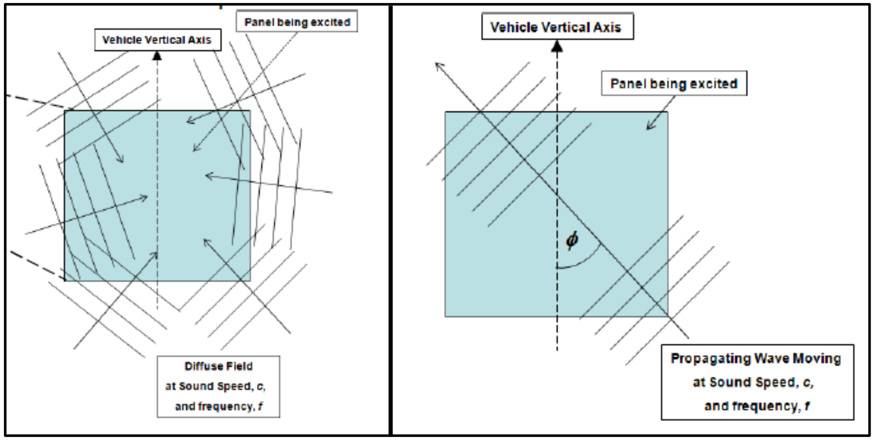
- Defines the relative relationship between the two primary field types, diffuse and propagating
- $R = \dfrac{p_{diffuse}(r,t)}{p_{propagating}(r,t)} \therefore R = \dfrac{R_{dd}(\tau)}{R_{pp}(\tau)} = \dfrac{G_{dd}(f)}{G_{pp}(f)}$
- Frequency dependent



Angle of Incidence

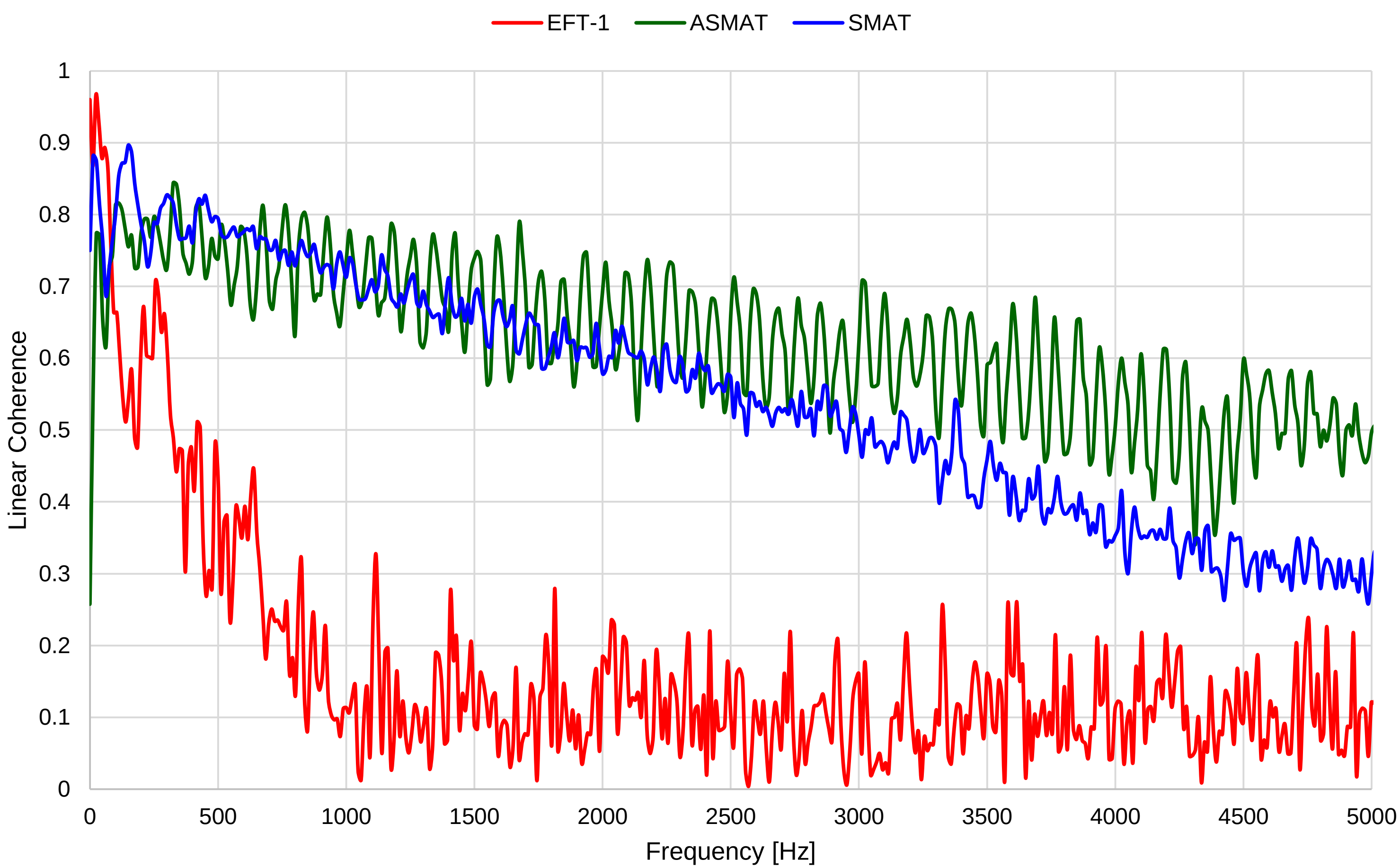
- Defines directionality of field
  - Measured relative to the vertical axis of vehicle
- $\cos\phi = \frac{\theta * c}{2\pi f * d}$
  - θ: relative phase
  - *c*: speed of sound
  - *2πf* : angular frequency
  - *d*: spacing between sensors
- Frequency independent





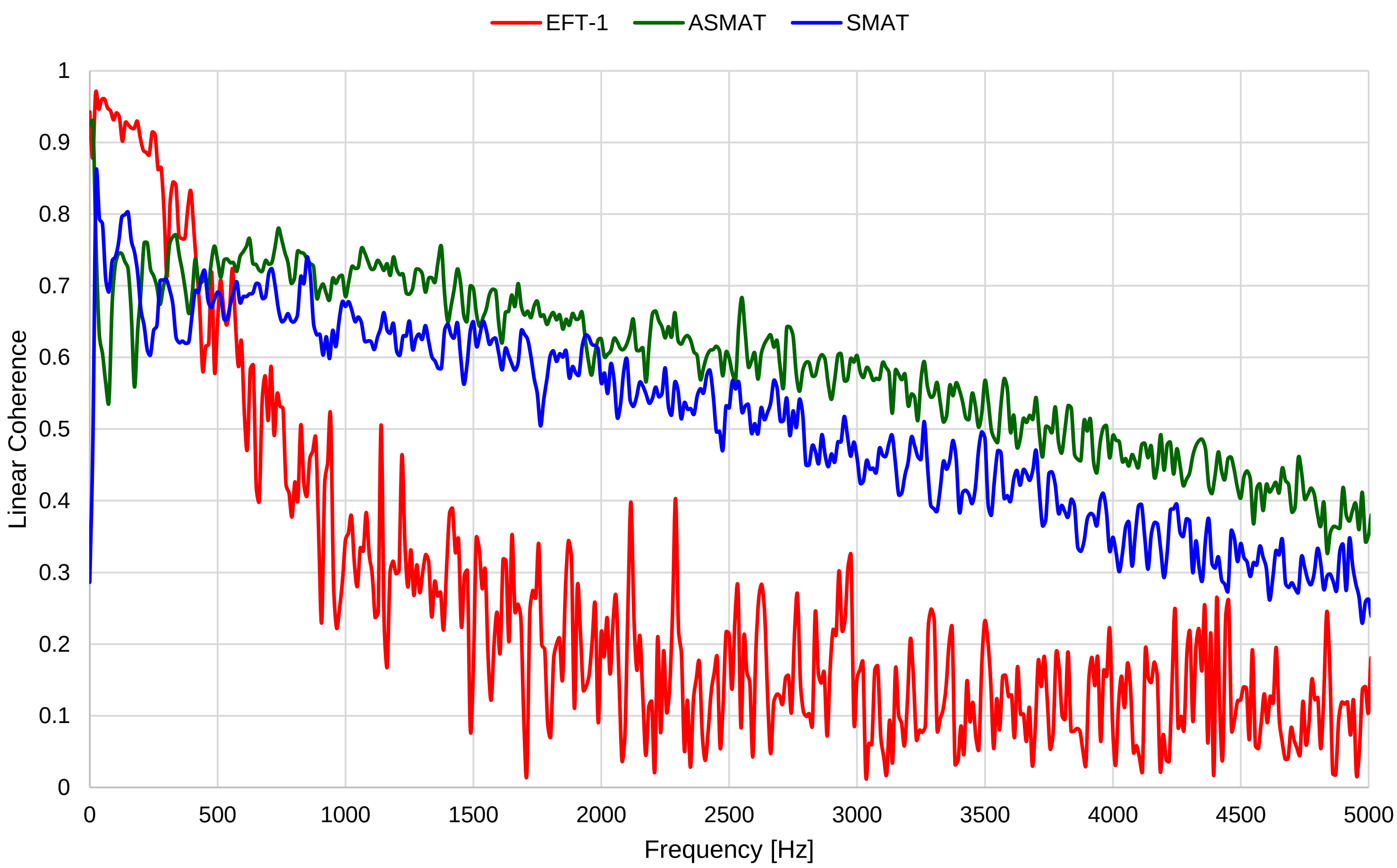
C. Giacomoni

Linear Coherence, OS



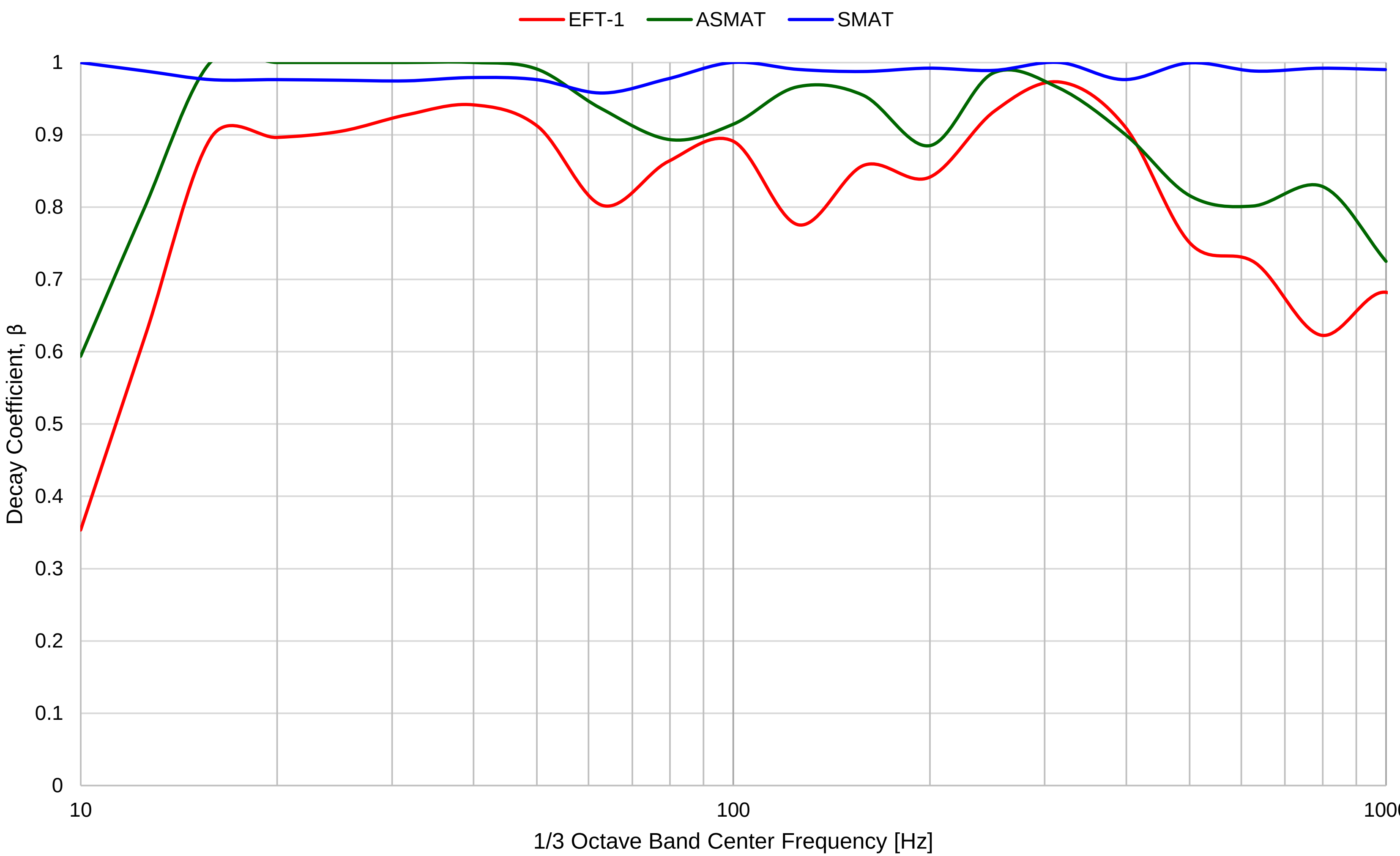
ESSSA Group

Linear Coherence, TS

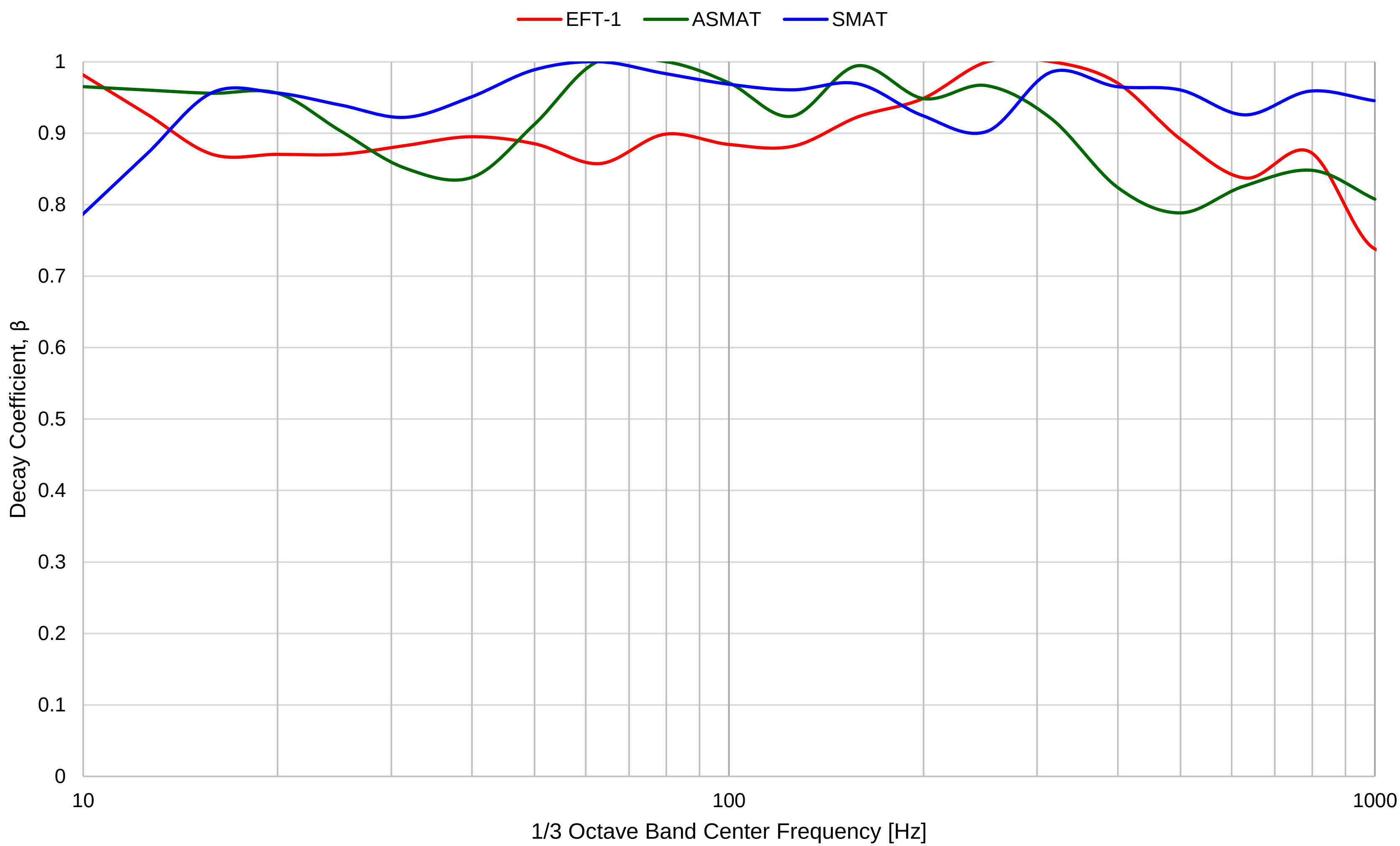


JACOBS
ESSSA Group

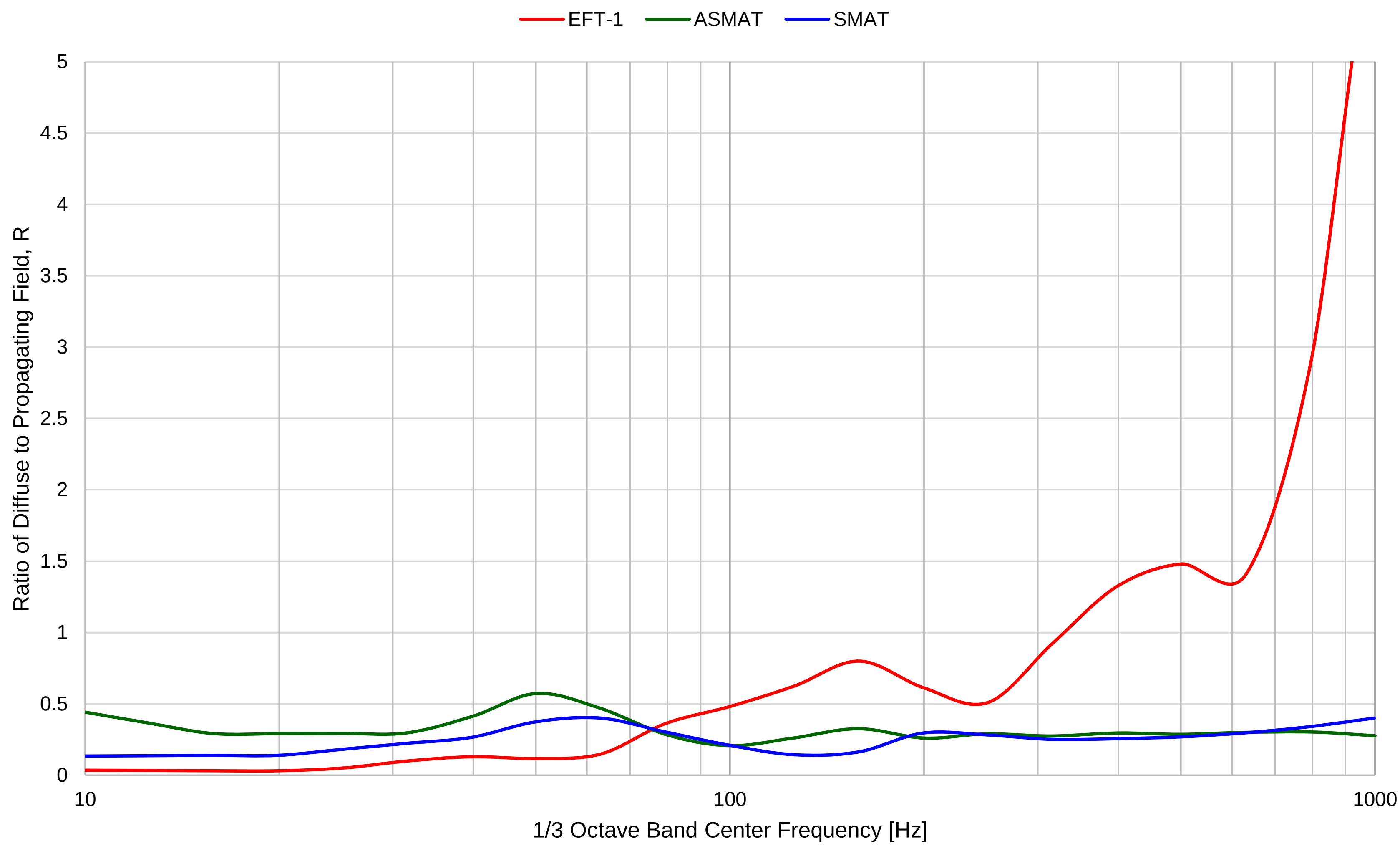
Decay Coefficient, β, OS



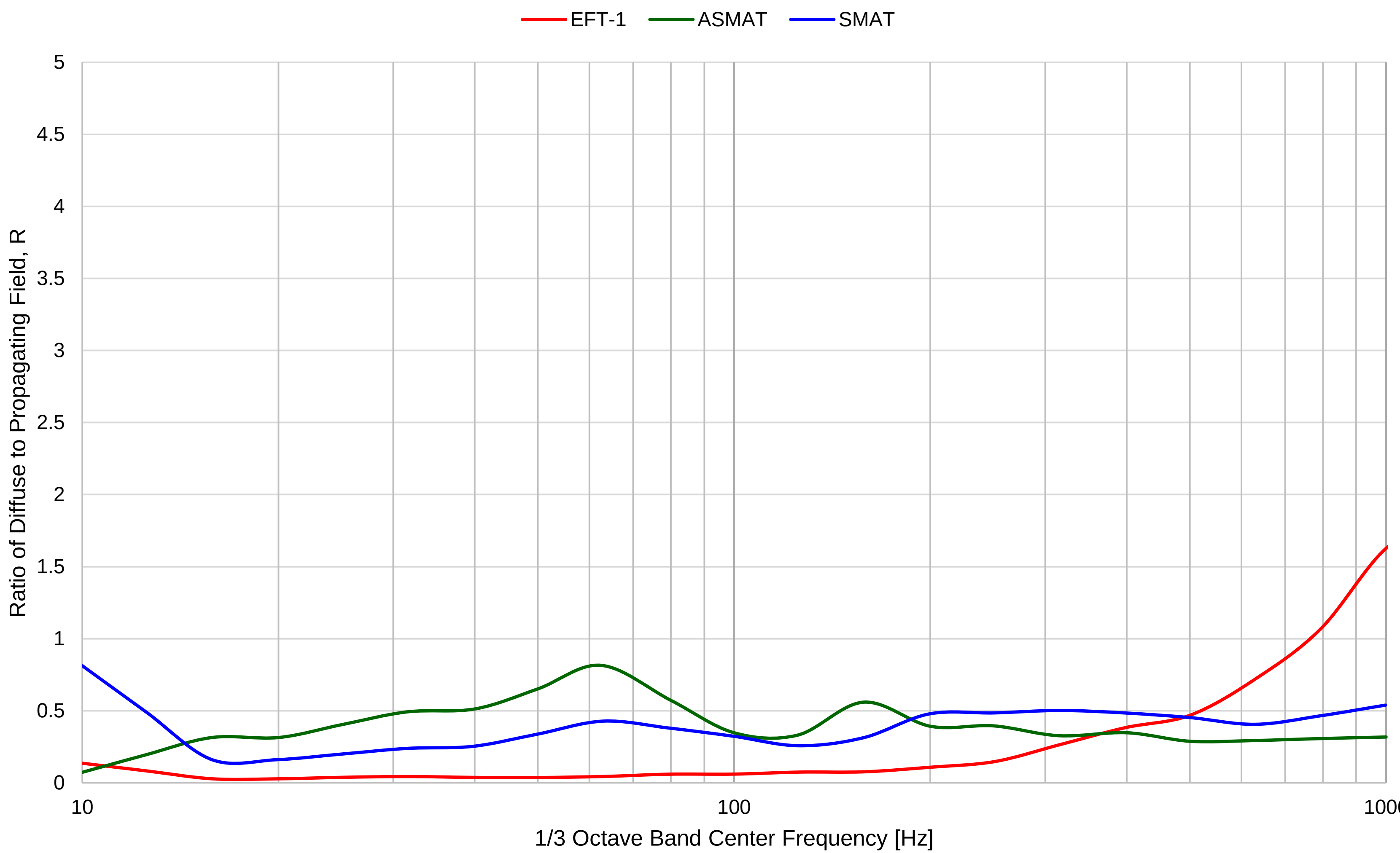
Decay Coefficient, β, TS



Ratio of Diffuse to Propagating Field, R, OS



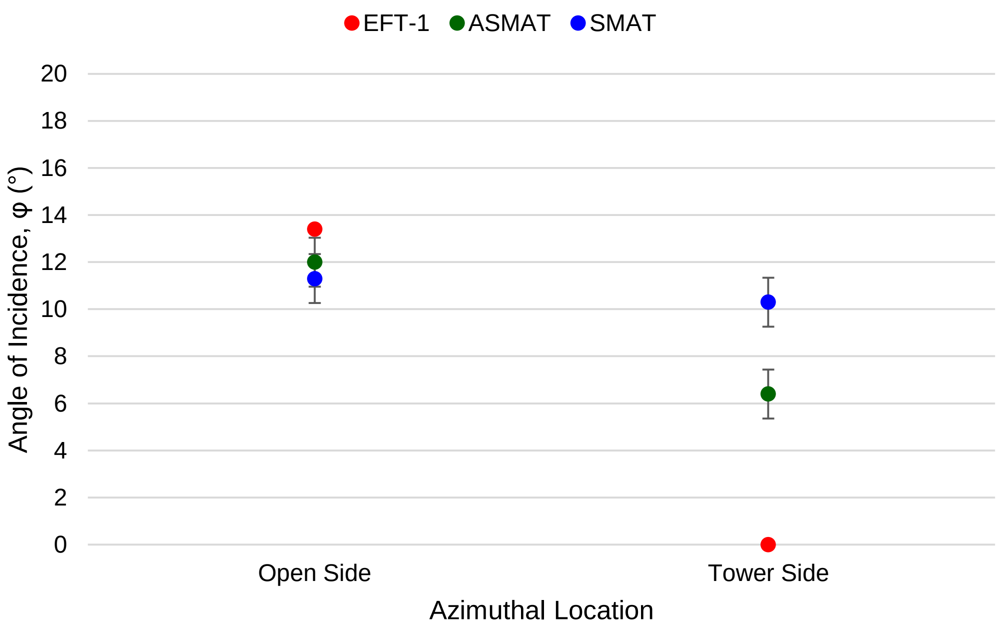
Ratio of Diffuse to Propagating Field, R, TS



C. Giacomoni

Angle of Incidence, φ

	Open Side	Tower Side
EFT-1	13.4	0
SMAT	11.3	10.3
ASMAT	12	6.4



Conclusions

- Sound field is propagating at stations high up on vehicle
  - True for both open side and tower side
- Beta near 1 at all frequencies
  - Indicates a small amount of decay for the distances investigated
  - True for both open side and tower side
- Angle of incidence
  - Good agreement for open side
  - Tower side may have been too diffuse for our method to capture angle of incidence accurately

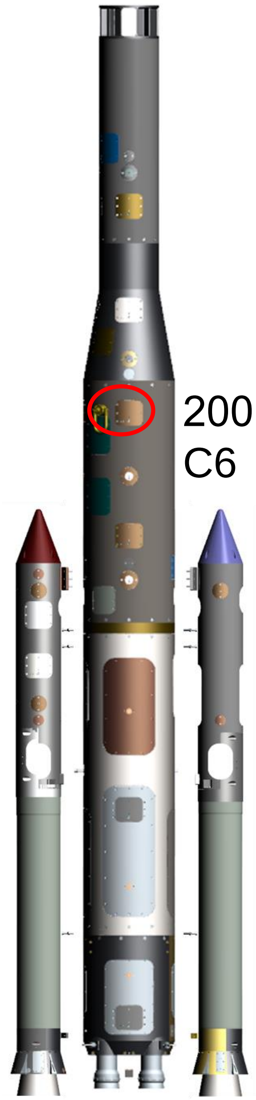
- Agreement between model scale and full scale results suggest that using model scale spatial correlation parameters to predict full scale sound field is reasonable.

THANK YOU

QUESTIONS?

BACKUP

Measurement Location

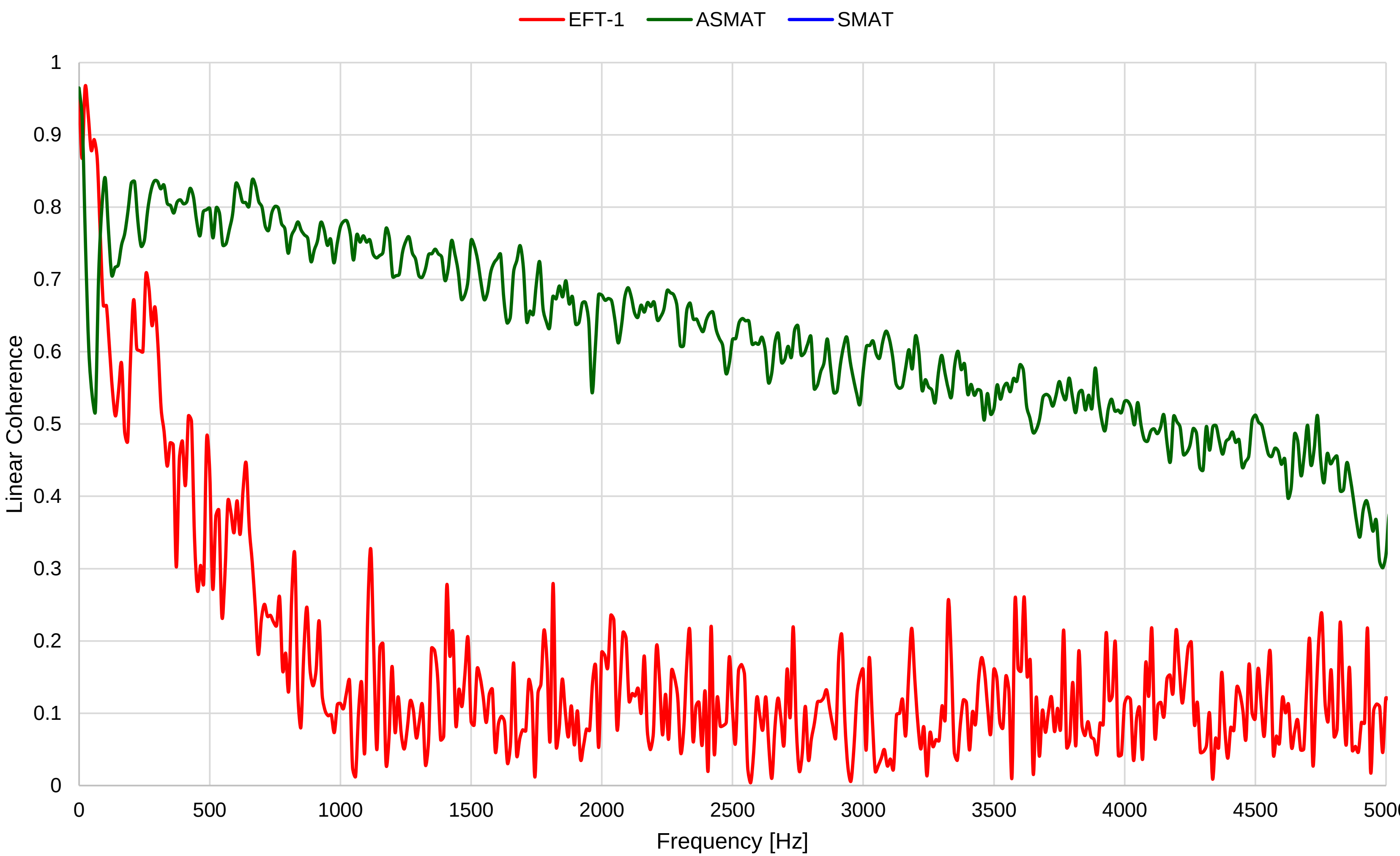


Model (SMAT)

Model (ASMAT)

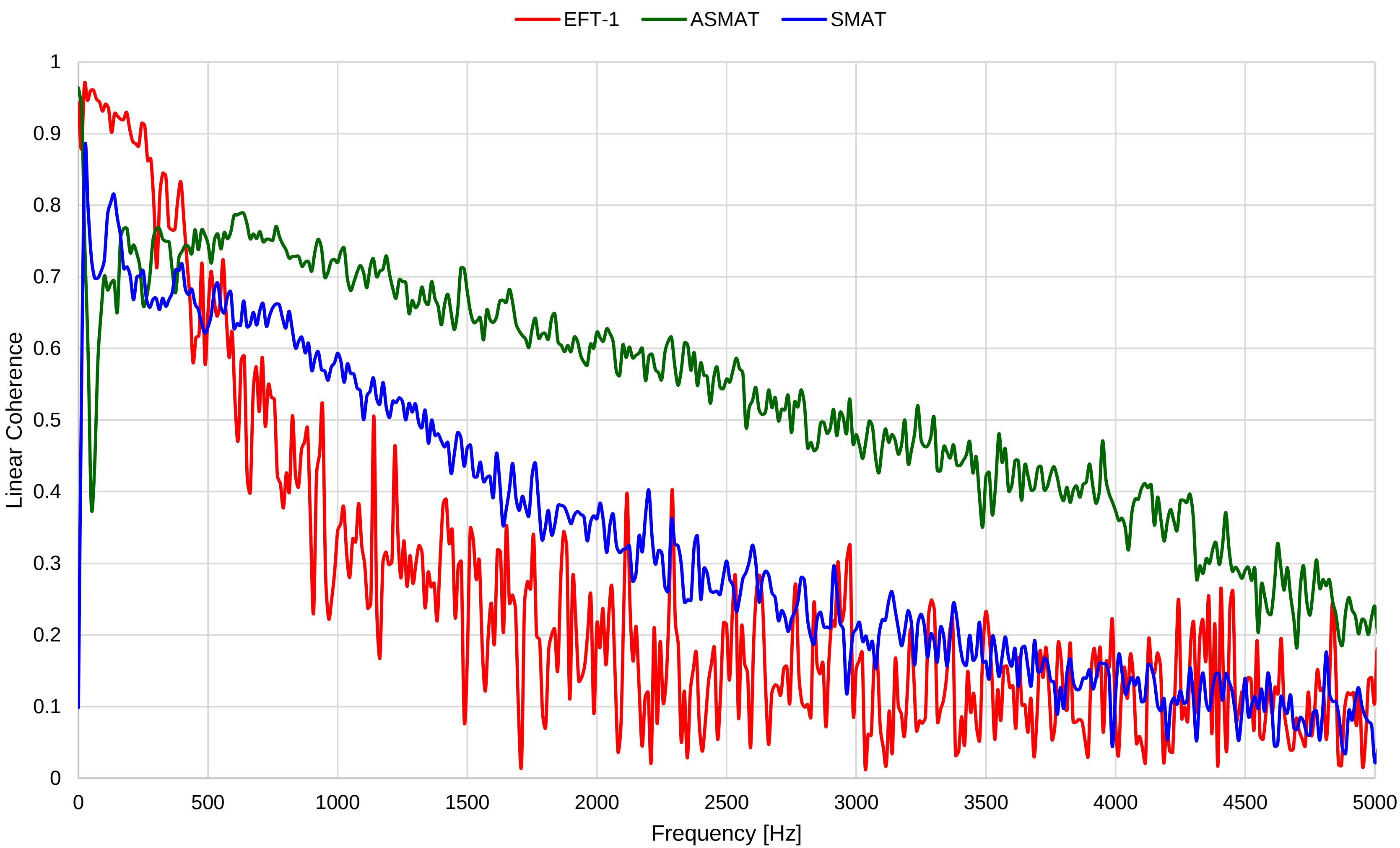
Full Scale (EFT-1)

Linear Coherence, OS

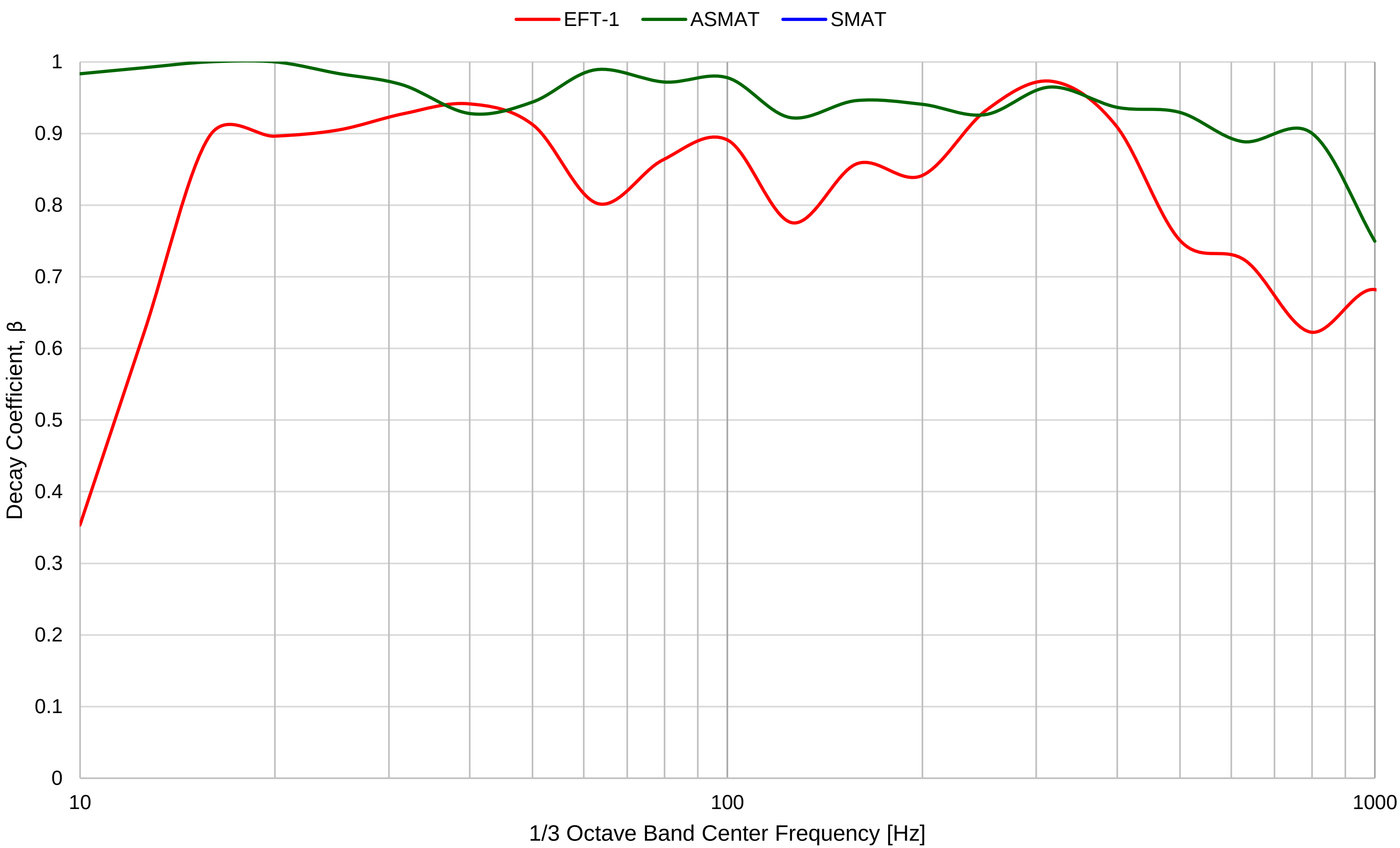


JACOBS
ESSSA Group

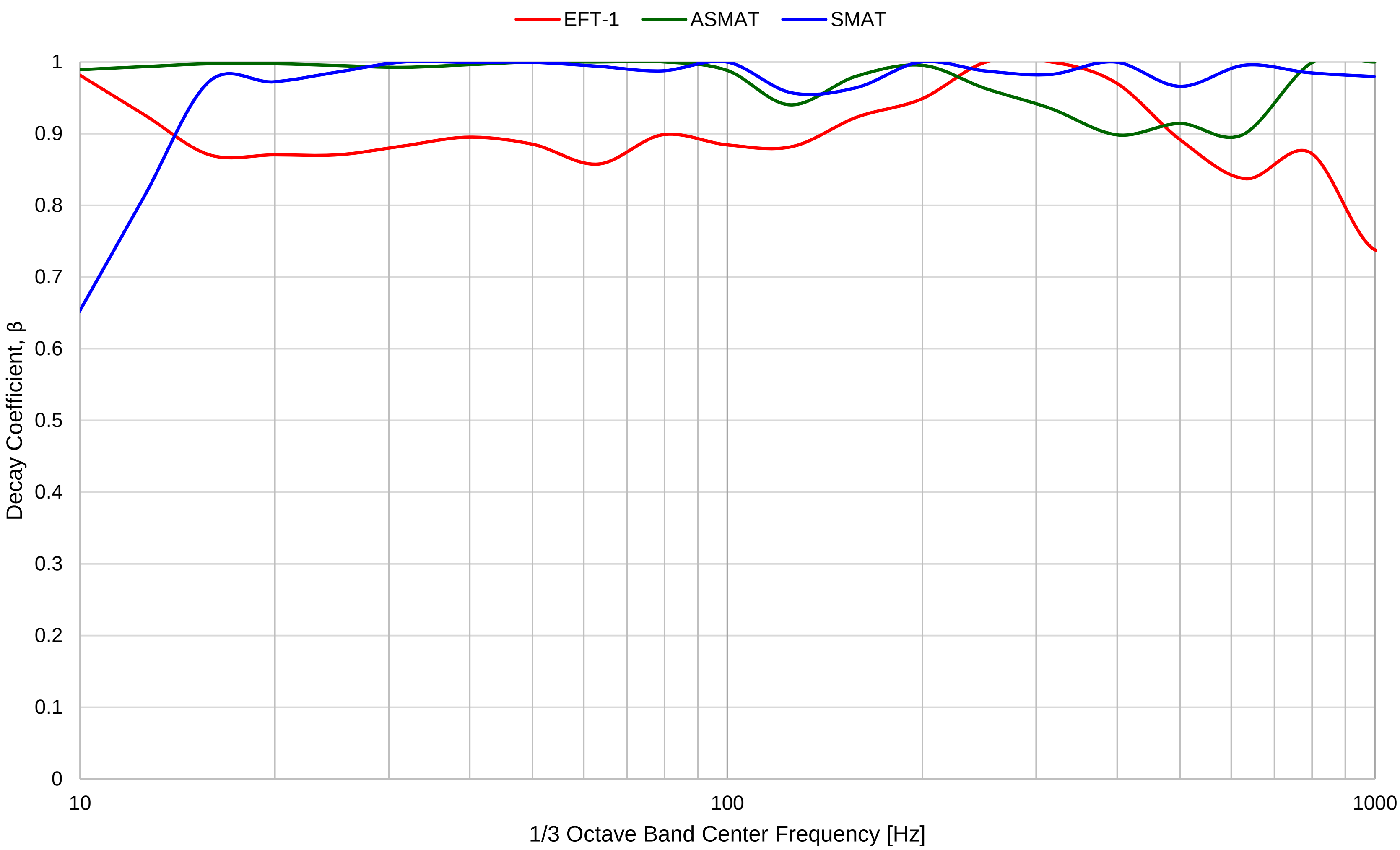
Linear Coherence, TS



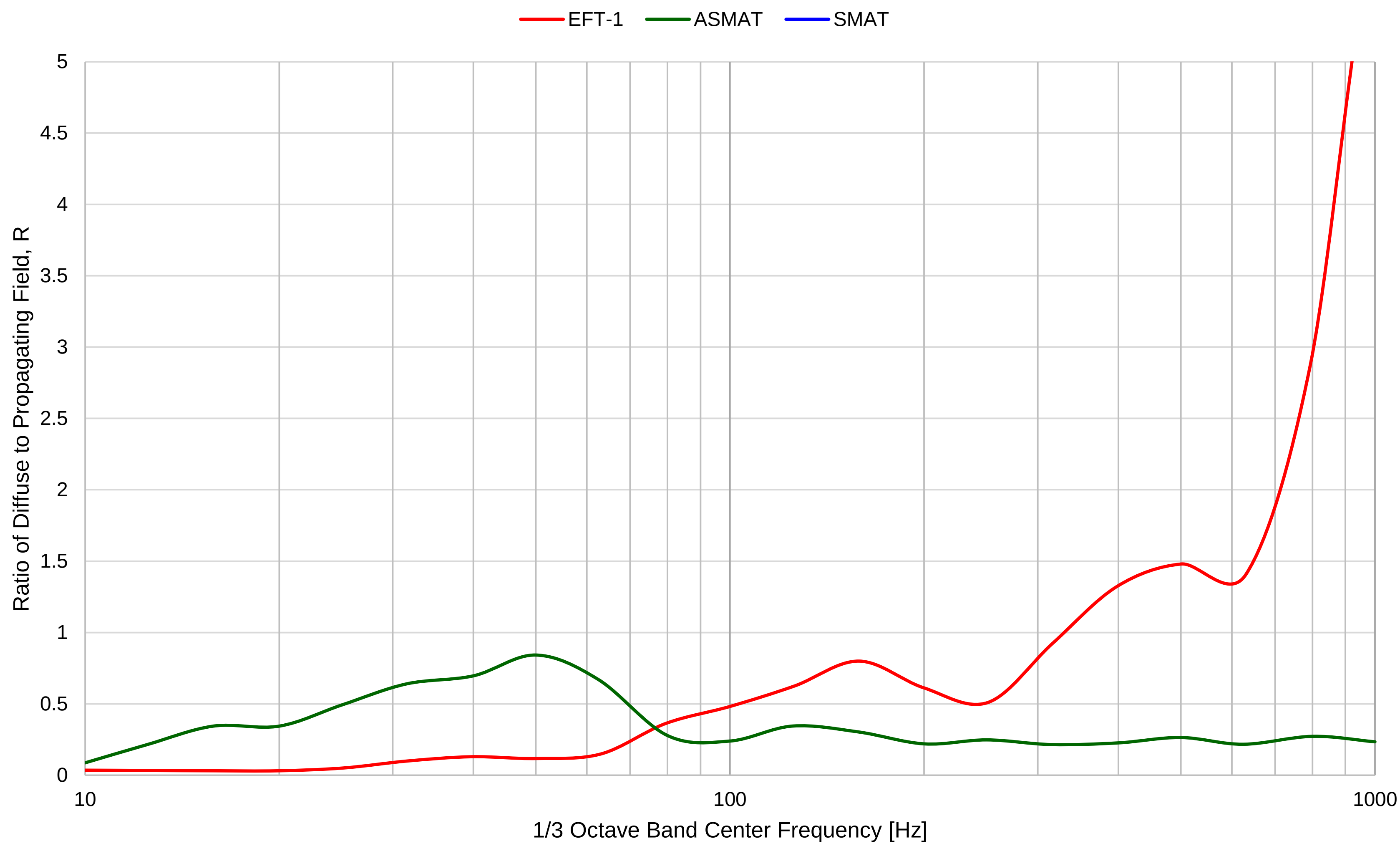
Decay Coefficient, β, OS



Decay Coefficient, β, TS



Ratio of Diffuse to Propagating Field, R, OS



C. Giacomoni

Ratio of Diffuse to Propagating Field, R, TS