A Simple Approach for the Auralization of Moving Sources

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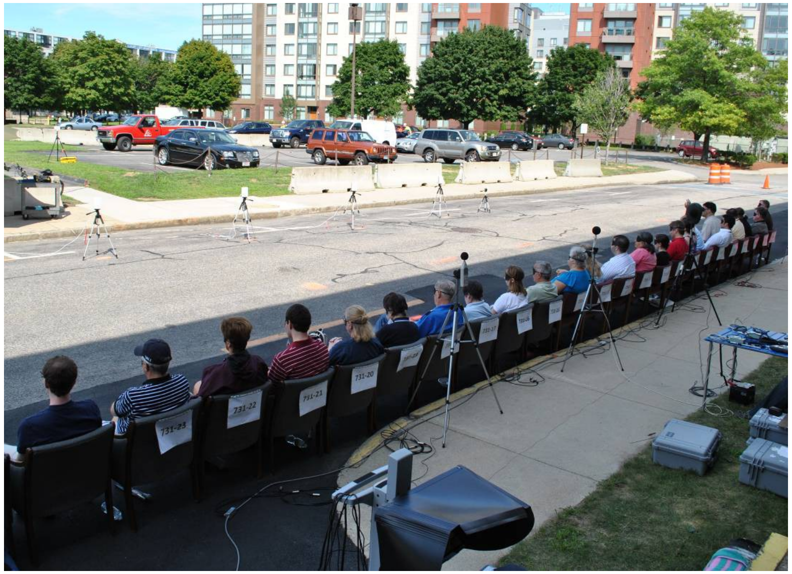
Background

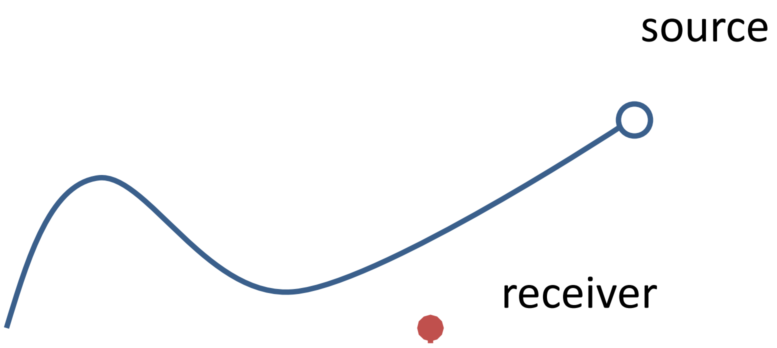
- Needs
  - Sound Signal Development – Human Response Testing
  - Soundscape Simulation – Community Outreach
- Software to Auralize Moving Sources
  - Commercial / Proprietary
  - Source / Environment Specific
  - Optimized for Speed
- Method Requirements
  - Signal and Processing Agnostic
  - Modifiable / Extensible
  - Open / Transparent Implementation
  - Near Real-time
  - Batch Processing



In Situ Testing: Time, Expense, Accuracy

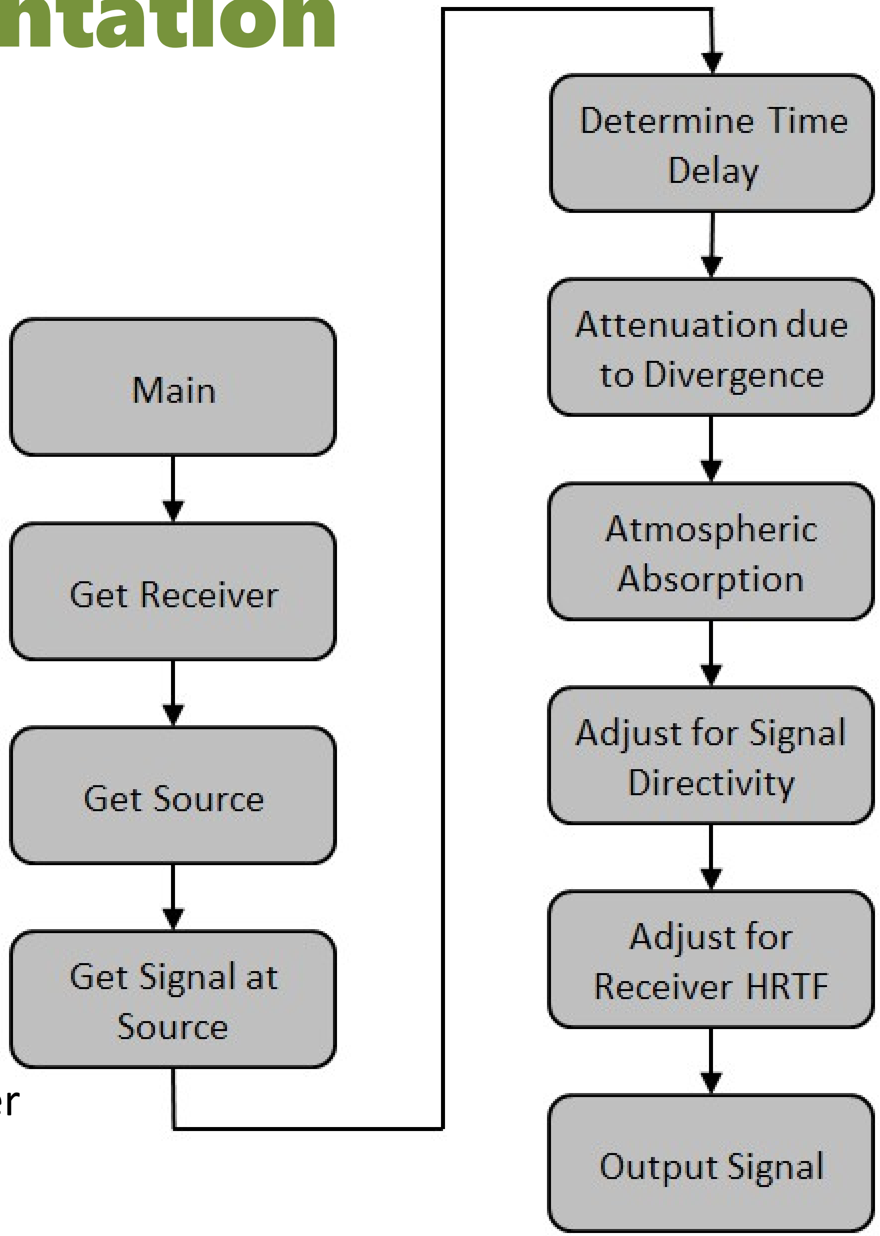
Assumptions

- Point Source in Far Field
- Ray Acoustics
- Homogeneous Atmosphere
- Free Field Propagation
  - No reflections, edge diffractions, etc
  - Add hard ground using image sources
- Receiver & Source:
  - Translate in X, Y, Z
  - Rotate horizontally (azimuth) & vertically (elevation)
- Receiver
  - Translation removed after source defined



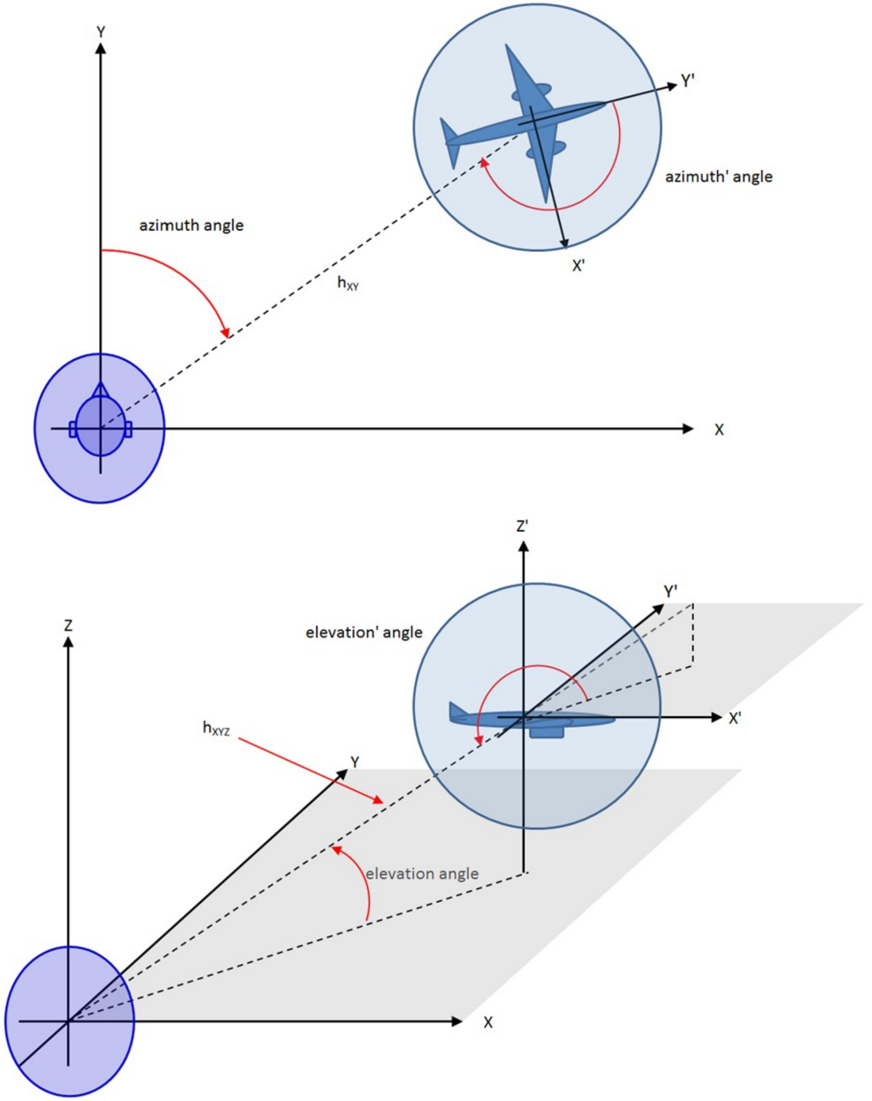
Implementation

- Matlab Main Function
- Sub-routines
  - Allow Switching Methodologies
  - May Require Additional Assumptions
- Sub-routines:
  1. Define Receiver
  2. Define Source
  3. Define Signal at Source
  4. Determine Time Delay for Propagation
  5. Determine Attenuation (Divergence, Atmospheric Absorption)
  6. Adjust for Signal Directivity
  7. Adjust for Receiver Head Related Transfer Functions (HRTFs)
  8. Output Signal



Defining Receiver and Source

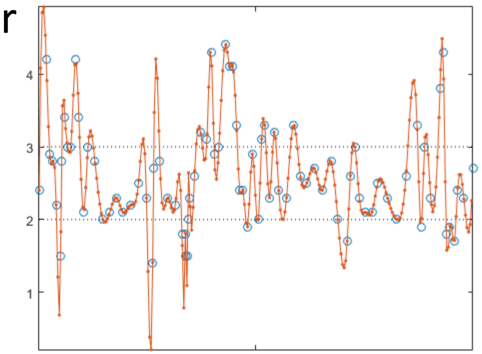
- Flat Earth X, Y, Z (RHR)
- Horizontal (Azimuth) Angle
- Vertical (Elevation) Angle
- Receiver Defined First
- Receiver Translation Removed during Source Definition
  - Subtract Receiver Translation Vector from Source Translation Vector
  - Receiver and Source Angles Computed after Receiver Translation Removed
- Final Distances and Angles Defined for Fix Reference Frame Centered on Receiver



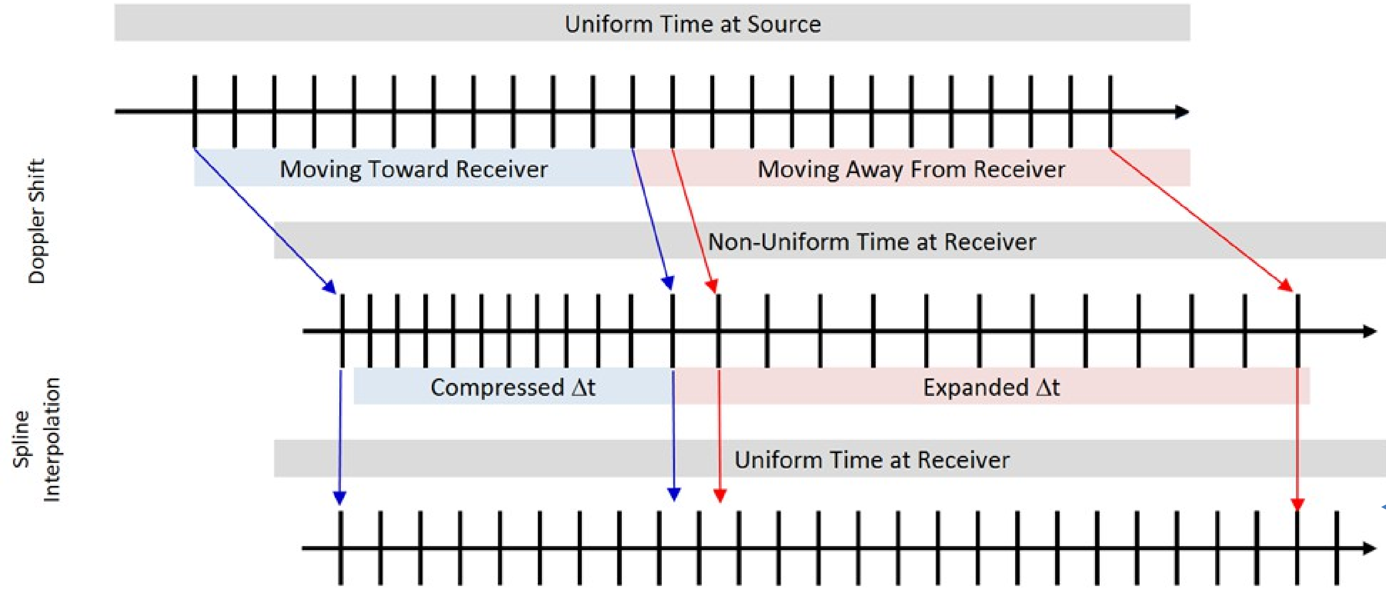
Defining Signal

- Signal can be Defined Using:
  - Stationary time signal
  - Parametric formulae
  - Sinusoids and band-limited noise
- Propagation from Source to Receiver:
  - Time Delay → Produces Doppler Shift

- Interpolation:
  - Nearest Neighbor
  - Linear
  - Spline
  - Lagrange
  - Whittaker
  - Lanczos



Doppler Shift Obtained Here



Uniform Time Sample Recovered, Preserving Doppler Shift

Volpe

Free-field Attenuation

- Divergence – 6 dB / doubling
- Atmospheric Absorption: ISO 9613-1
  - Function of Frequency and Distance
  - Frequency Associated w/. Time Interval
  - Distance Associated w/. Single Sample
  - Approach:
    - Develop Filters for Each 3 dB of Overall Attenuation
    - Linear Interpolation: Weighted average of two nearest distances for each sample

Frequency (Hz)	Attenuation (dB/m)	Frequency (Hz)	Attenuation (dB/m)
50	7.81E-05	800	3.91E-03
63	1.22E-04	1000	4.66E-03
80	1.94E-04	1250	5.71E-03
100	2.94E-04	1600	7.45E-03
125	4.40E-04	2000	9.89E-03
160	6.71E-04	2500	1.36E-02
200	9.54E-04	3150	1.97E-02
250	1.31E-03	4000	2.97E-02
315	1.74E-03	5000	4.42E-02
400	2.24E-03	6300	6.76E-02
500	2.73E-03	8000	1.05E-01
630	3.27E-03	10000	1.59E-01

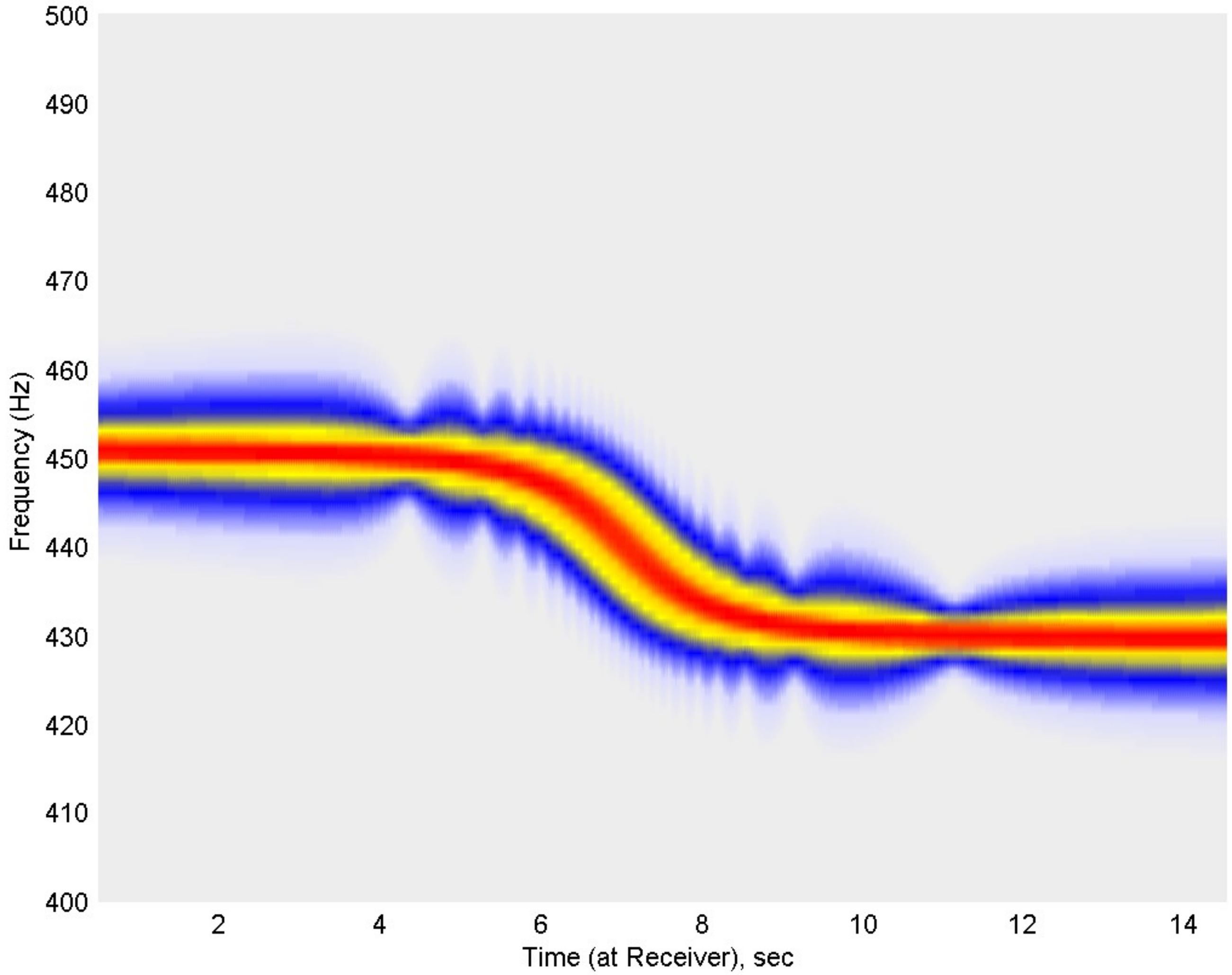
$$p(d_i) = \frac{1}{2}p(d_i, h_{nearer})\frac{d_{farther} - d_i}{d_{farther} - d_{nearer}} + \frac{1}{2}p\left(d_i, h_{farther}\right)\frac{d_i - d_{nearer}}{d_{farther} - d_{nearer}}$$

$$p(d_i, h_{nearer}) = (p * h_{nearer})(t)|_{t \to d_i}$$

Adjusting for Directivity and HRTFs

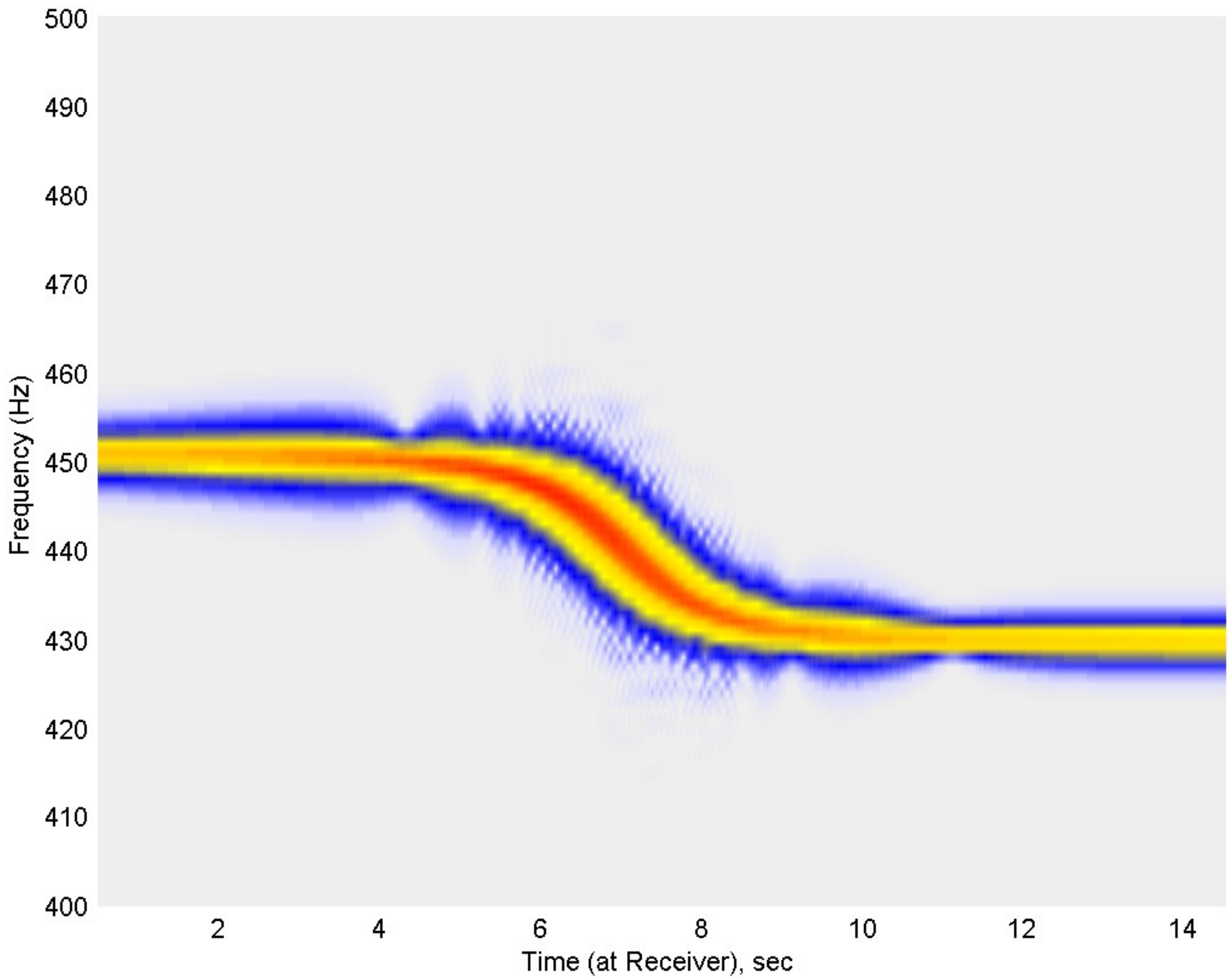
- Measured HRTFs
  - Center for Image Processing and Integrated Computing (CIPIC) at U.C. Davis
  - Azimuth Angles: +/- 80, 65, 55, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0 deg
  - Elevation Angles: : -45 to 230.625 deg (5.625 degree increments)
  - Angles Relative to Head Orientation
- Directivity
  - Uses Monopole unless directivity provided
  - Same format as for HRTFs
  - Angles based on Fixed Reference Frame (Independent of Head Rotation)
- Interpolation
  - Similar to that used for Atmospheric Absorption
  - Except nearest neighbors determined for azimuth and elevation: Bilinear Interpolation

Sample Results



Spectrogram of 440 Hz pure tone source signal passing by receiver at 8.33 m/s with perpendicular distance of 10 m.

Sample Results



Spectrogram of 440 Hz pure tone source signal passing by receiver at 8.33 m/s with a perpendicular distance of 10 m. Head-

Next Steps

- Extend Functionality to Include Reflections (e.g. Ground Effects) and Edge Diffractions (e.g. Shielding)
- Improve Interpolation Functions
- Add HRTFs with Higher Spatial Resolution
- Add Dipole, Cardioid, etc. Directivity Patterns
- Add other Atmospheric Absorption Standards
- Develop Library of Standard Sound Sources
- Develop Library of Standard Source Trajectories
- Add Metric Computations and Calibrations for Signal at Source and at Receiver

Questions / Comments?

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