Three Drivers in a MEH

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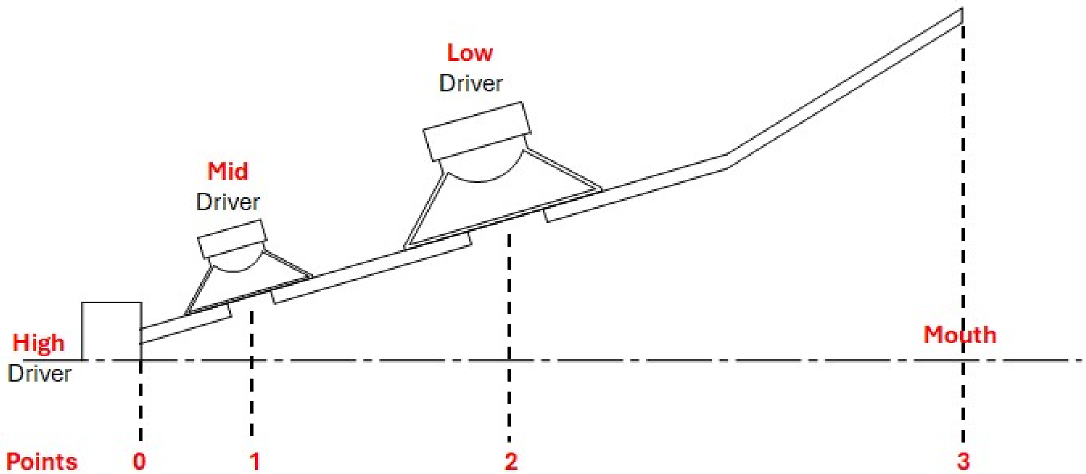

Horn Locations

Points 0, 1, 2, and 3 are axial positions along the horn length
Point 0 is at the High Frequency Driver throat (Compression Driver), z = 0
Point 1 is at the Mid Driver Throat axial dimension
Point 2 is at the Low Driver Throat axial dimension (not used for two drivers)
Point 3 is at the Open End (Mouth), $z = L_{horn}$

Goal : Calculate the selected driver's U and p that produce the Open End boundary conditions U_m and p_m. Calculate the pressure on the other driver's stationary cones to calculate coupling terms.

At each driver location :
U = volume velocity arriving from the open end direction
U' = volume velocity towards the driver passing through the throat and coupling volume
U" = volume velocity towards the closed end

Coupling volumes and throats can exist at each driver location.

All variables and expressions are functions of frequency and geometry, all expressions are matrices.

Transfer Matrix Notations

$[U_i \;\; p_i]^T = [Transfer_{i\_j}] \times [U_j \;\; p_j]^T$ where i = 0, 1, 2 and j = 1, 2, 3

and the inverse for the opposite direction

$[U_j \;\; p_j]^T = [Transfer_{i\_j}]^{-1} \times [U_i \;\; p_i]^T$

Transfer Matrices and Notations

- Horn - Mouth ---> Throat

$[U_0 \;\; p_0]^T = [Transfer_{0\_1}] \times [Transfer_{1\_2}] \times [Transfer_{2\_3}] \times [U_m \;\; p_m]^T$

- Horn Holes to Drivers

$[U_{low}\ \ p_{low}]^T = [Transfer_{low\_2}] \times [U_2\ \ p_2]^T$

$[U_{mid}\ \ p_{mid}]^T = [Transfer_{mid\_1}] \times [U_1\ \ p_1]^T$

$[U_{high}\ \ p_{high}]^T = [Transfer_{high\_0}] \times [U_0\ \ p_0]^T$

Calculation Algorithm for High Frequency Driver

- at the Mouth

$U_m = 1$
$p_m = Z_{mouth} \times U_m$

- at point 2 in the Horn coming from the Mouth

$[U_2\ \ p_2]^T = [Transfer_{2\_mouth}] \times [U_m\ \ p_m]^T$

- at the Cone of the Low Frequency Driver

$U_{low} = 0$
$p_{low} = 1$

$[U\ \ p]^T = [Transfer_{low\_2}]^{-1} \times [U_{low}\ \ p_{low}]^T$

$Z = p / U$ at the throat of the low frequency driver

$U_2' = p_2 / Z$

$U_2'' = U_2 - U_2'$ and p_2 is unchanged

using U_2' and p_2 calculate p_{low}

$[U_{low}\ \ p_{low}]^T = [Transfer_{low\_2}] \times [U_2'\ \ p_2]^T$

p_{low} used to calculate coupling term between low and high frequency drivers

U_{low} should be zero

- at point 1 in the Horn coming from the point 2

$[U_1\ \ p_1]^T = [Transfer_{1\_2}] \times [U_2''\ \ p_2]^T$

- at the Cone of the Mid Frequency Driver

$U_{mid} = 0$
$p_{mid} = 1$

$[U\ \ p]^T = [Transfer_{mid\_1}] \times [U_{mid}\ \ p_{mid}]^T$

$Z = p / U$ at the throat of the mid frequency driver

$U_1' = p_1 / Z$

$U_1'' = U_1 - U_1'$ and p_1 is unchanged

using U_1' and p_1 calculate p_{mid}

$[U_{mid}\ \ p_{mid}]^T = [Transfer_{mid\_1}]^{-1} \times [U_1'\ \ p_1]^T$

p_{mid} used to calculate coupling term between mid and high frequency drivers

U_{mid} should be zero

- at the Cone of the High Frequency Driver

$[U_{high}\ \ p_{high}]^T = [Transfer_{high\_0}] \times [Transfer_{0\_1}] \times [U_1''\ \ p_1]^T$

p_{high} used to calculate impedance at the high frequency driver

U_{high} used to calculate coupling term between mid and low frequency drivers

Outputs

$Z_{high\_high} = p_{high} / U_{high}$

$Z_{mid\_high} = p_{mid} / U_{high}$

$Z_{low\_high} = p_{low} / U_{high}$

$\varepsilon_{high} = (S_{d\_high} / S_{mouth}) \times (1 / U_{high})$ = air velocity ratio

Calculation Algorithm for Mid Frequency Driver

- at the Mouth

$U_m = 1$
$p_m = Z_{mouth} \times U_m$

- at point 2 in the Horn coming from the Mouth

$[U_2\ \ p_2]^T = [Transfer_{2\_mouth}] \times [U_m\ \ p_m]^T$

- at the Cone of the Low Frequency Driver

$U_{low} = 0$
$p_{low} = 1$

$[U\ \ p]^T = [Transfer_{low\_2}]^{-1} \times [U_{low}\ \ p_{low}]^T$

$Z = p / U$ at the throat of the low frequency driver

$U_2' = p_2 / Z$

$U_2'' = U_2 - U_2'$ and p_2 is unchanged

using U_2' and p_2 calculate p_{low}

$[U_{low}\ \ p_{low}]^T = [Transfer_{low\_2}] \times [U_2'\ \ p_2]^T$

p_{low} used to calculate coupling term between low and mid frequency drivers

U_{low} should be zero

- at point 1 in the Horn coming from the point 2

$[U_1\ \ p_1]^T = [Transfer_{1\_2}] \times [U_2''\ \ p_2]^T$

- at the Cone of the High Frequency Driver

$U_{high} = 0$
$p_{high} = 1$

$[U\ \ p]^T = [[Transfer_{high\_0}] \times [Transfer_{0\_1}]]^{-1} \times [U_{high}\ \ p_{high}]^T$

$Z = p / U$

$U_1'' = p_1 / Z$

$[U_{high}\ \ p_{high}]^T = [Transfer_{high\_0}] \times [Transfer_{0\_1}] \times [U_1''\ \ p_1]^T$

p_{high} used to calculate coupling term between high and mid frequency drivers

U_{high} should be zero

- at point 1 in the Horn

U_1, U_1'', and p_1

$U_1' = U_1 - U_1''$ and p_1 is unchanged

- at the Cone of the Mid Frequency Driver

$[U_{mid}\ \ p_{mid}]^T = [Transfer_{mid\_1}] \times [U_1'\ \ p_1]^T$

p_{mid} used to calculate impedance at the mid frequency driver

U_{mid} used to calculate coupling term between high and low frequency drivers

- Outputs

$Z_{high\_mid} = p_{high} / U_{mid}$

$Z_{mid\_mid} = p_{mid} / U_{mid}$

$Z_{low\_mid} = p_{low} / U_{mid}$

$\varepsilon_{mid} = (S_{d\_mid} / S_{mouth}) \times (1 / U_{mid})$ = air velocity ratio

Calculation Algorithm for Low Frequency Driver

- at the Mouth

$U_m = 1$
$p_m = Z_{mouth} \times U_m$

- at point 2 in the Horn coming from the Mouth

$[U_2\ \ p_2]^T = [Transfer_{2\_mouth}] \times [U_m\ \ p_m]^T$

- at the Cone of the High Frequency Driver working towards point 1

$U_{high} = 0$
$p_{high} = 1$

$[U_1''\ \ p_1]^T = [[Transfer_{high\_0}] \times [Transfer_{0\_1}]]^{-1} \times [U_{high}\ \ p_{high}]^T$

$Z_{high} = p_1 / U_1''$

- at the Cone of the Mid Frequency Driver

$U_{mid} = 0$
$p_{mid} = 1$

$[U\ \ p]^T = [Transfer_{mid\_1}]^{-1} \times [U_{mid}\ \ p_{mid}]^T$

$Z_{mid} = p / U$

$U_1' = p_1 / Z$

$U_1 = U_1' + U_1''$ and p_1 is unchanged

using U_1 and p_1 calculate values at point 2

$[U\ \ p]^T = [Transfer_{1\_2}]^{-1} \times [U_1\ \ p_1]^T$

$Z = p / U$

$U_2'' = p_2 / Z$ volume velocity into the horn towards the mid and high frequency drivers

$U_2' = U_2 - U_2''$ and p_2 is unchanged, volume velocity at the throat of the low frequency driver

using U_2' and p_2 calculate p_{low} and U_{low}

$[U_{low}\ \ p_{low}]^T = [Transfer_{low\_2}] \times [U_2'\ \ p_2]^T$

back calculating p_{mid} and p_{high} since U_{mid} and U_{high} are zero

$[U_1 \ \ p_1]^T = [Transfer_{1\_2}] \times [U_2" \ \ p_2]^T$

- at the Cone of the Mid Frequency Driver

$U_1' = p_1 / Z_{mid}$ volume velocity into the throat at the mid frequency driver

$U_1" = U_1 - U_1'$

$[U_{mid} \ \ p_{mid}]^T = [Transfer_{mid\_1}] \times [U_1' \ \ p_1]^T$

U_{mid} should be zero

- at the Cone of the High Frequency Driver

$[U_0 \ \ p_0]^T = [Transfer_{0\_1}] \times [U_1" \ \ p_1]^T$

$[U_{high} \ \ p_{high}]^T = [Transfer_{high\_0}] \times [U_0 \ \ p_0]^T$

U_{high} should be zero

p_{high} and p_{mid} used to calculate coupling term between high and mid frequency drivers

- Outputs

$Z_{high\_low} = p_{high} / U_{low}$

$Z_{mid\_low} = p_{mid} / U_{low}$

$Z_{low\_low} = p_{low} / U_{low}$

$\varepsilon_{low} = (S_{d\_low} / S_{mouth}) \times (1 / U_{low})$ = air velocity ratio