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Klipsch® KEEPERS OF THE SOUND

Loudspeaker Response Optimization with the aid of Impulse Response

Riccardo Balistreri

Klipsch Group, Inc., Indianapolis, IN, USA

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Impulse

Physics

Psychology

Economics

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Klipsch KEEPERS OF THE SOUND

Impulse

Physics

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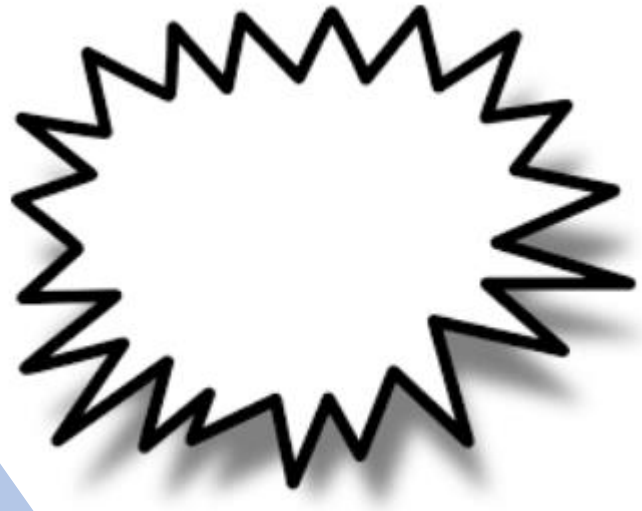
Impulse

Physics

$$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F}\,\mathrm{d}t$$



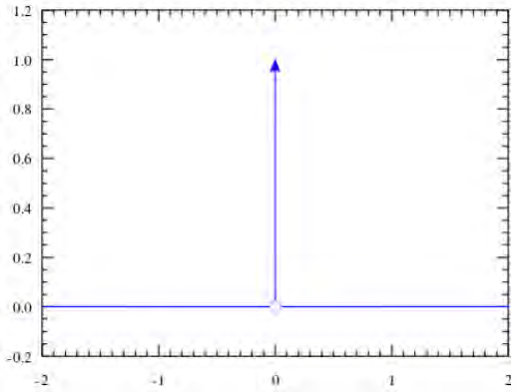
Analytically

Dirac delta

$$\delta(x) = \begin{cases} +\infty, & x = 0 \\ 0, & x \neq 0 \end{cases}$$

also

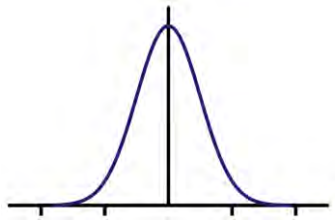
$$\int_{-\infty}^{\infty} \delta(x)\,dx = 1$$



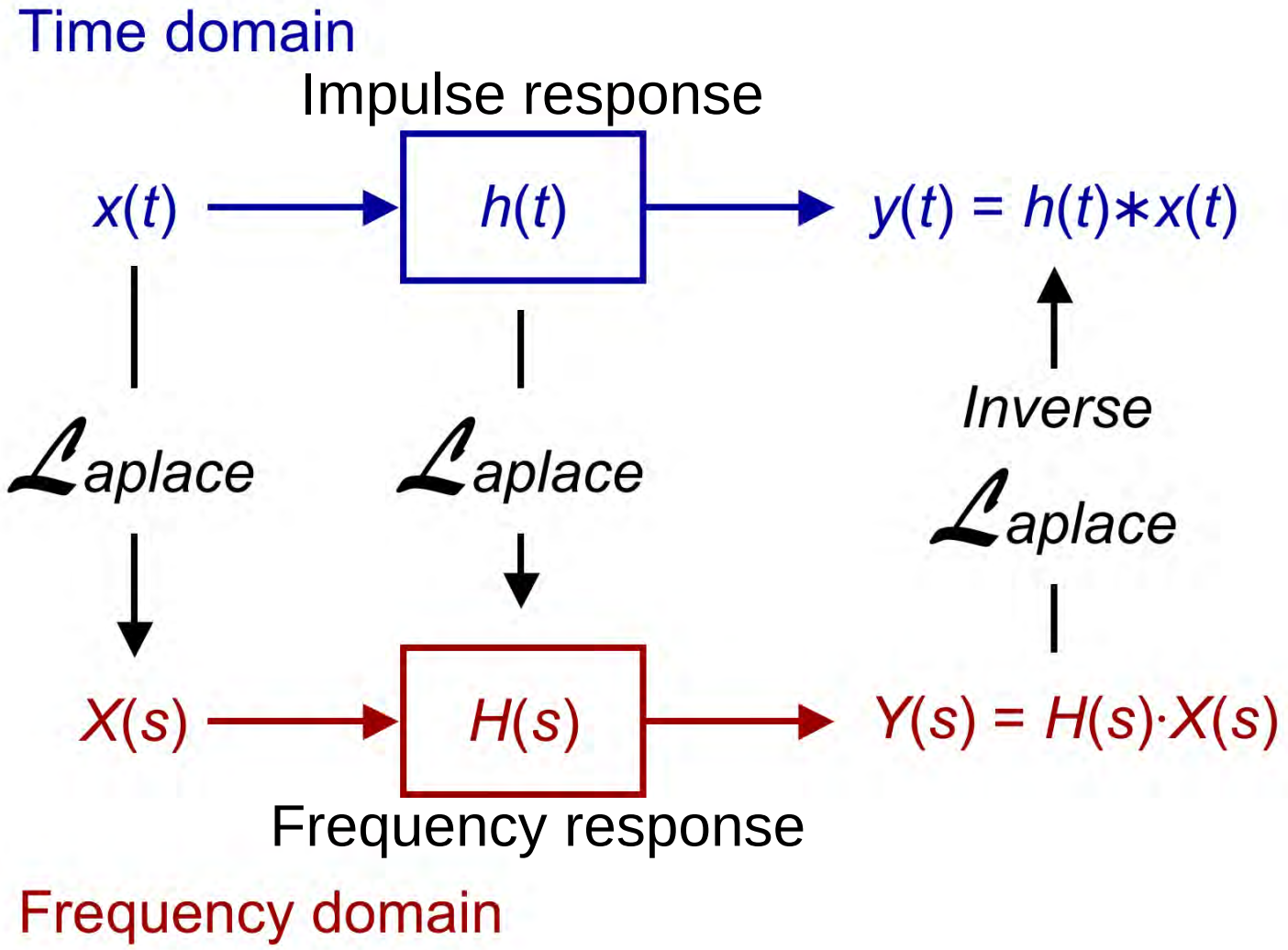
"Practically"

Gaussian

$$g(t) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{t^2}{2\sigma^2}}$$



Impulse


Time domain
Impulse response
x(t)
h(t)
y(t) = h(t)∗x(t)
Laplace
Laplace
Inverse
Laplace
X(s)
H(s)
Y(s) = H(s)·X(s)
Frequency response
Frequency domain

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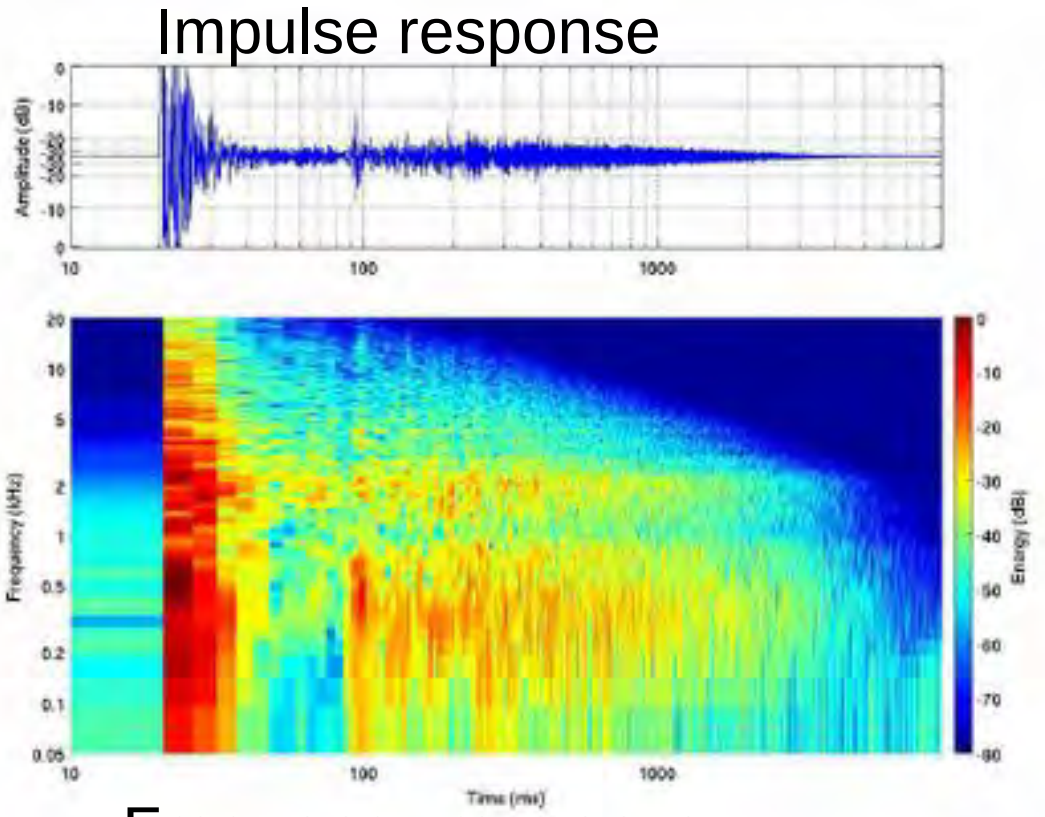
Impulse

Impulse response



Frequency response

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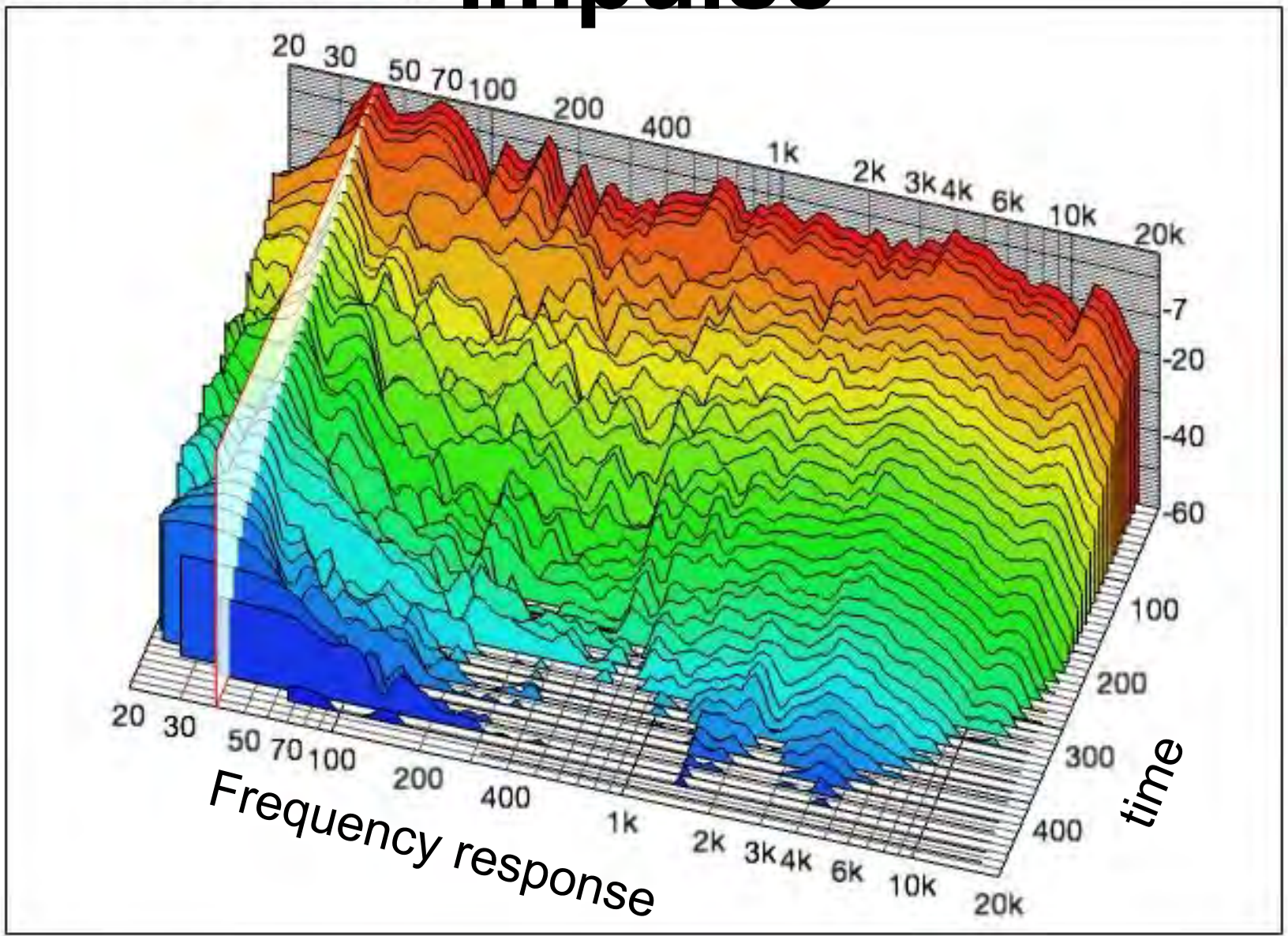
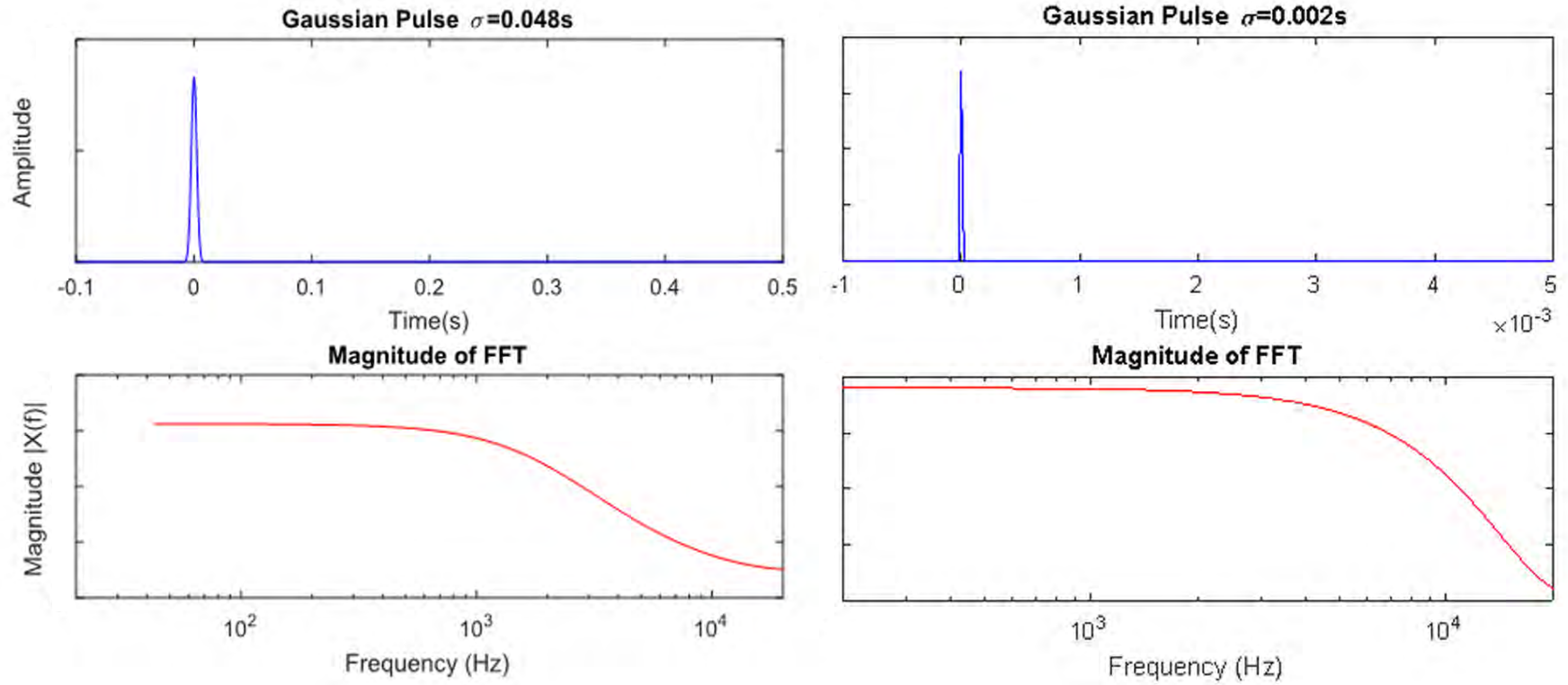
KEEPERS OF THE SOUND

Impulse




Gaussian Pulse σ=0.048s
Amplitude
-0.1
0
0.1
0.2
0.3
0.4
0.5
Time(s)
Gaussian Pulse σ=0.002s
-1
0
1
2
3
4
5
Time(s)
×10-3
Magnitude of FFT
Magnitude |X(f)|
10^2
10^3
10^4
Frequency (Hz)
Magnitude of FFT
10^3
10^4
Frequency (Hz)

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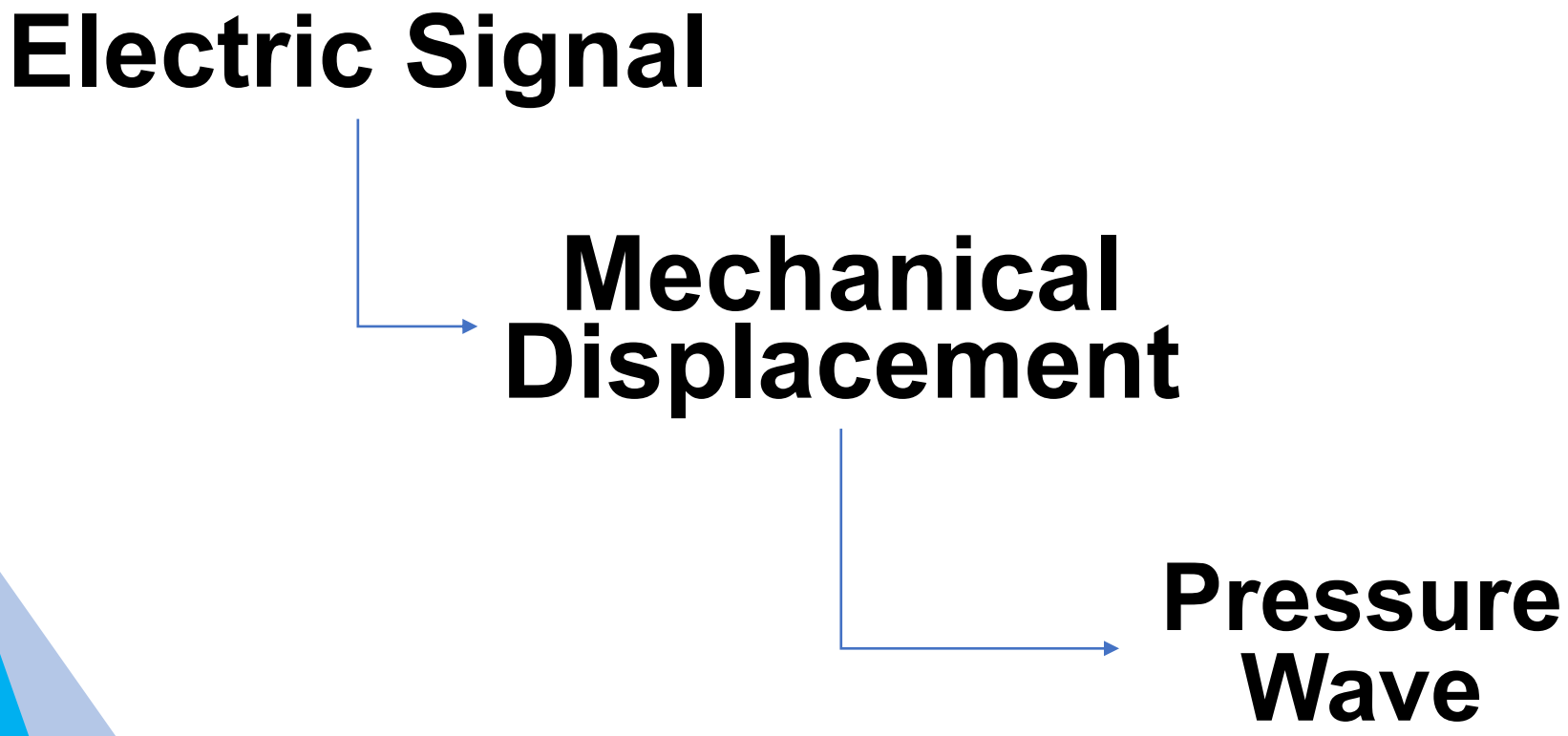
Loudspeakers

Klipsch KEEPERS OF THE SOUND



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Loudspeakers

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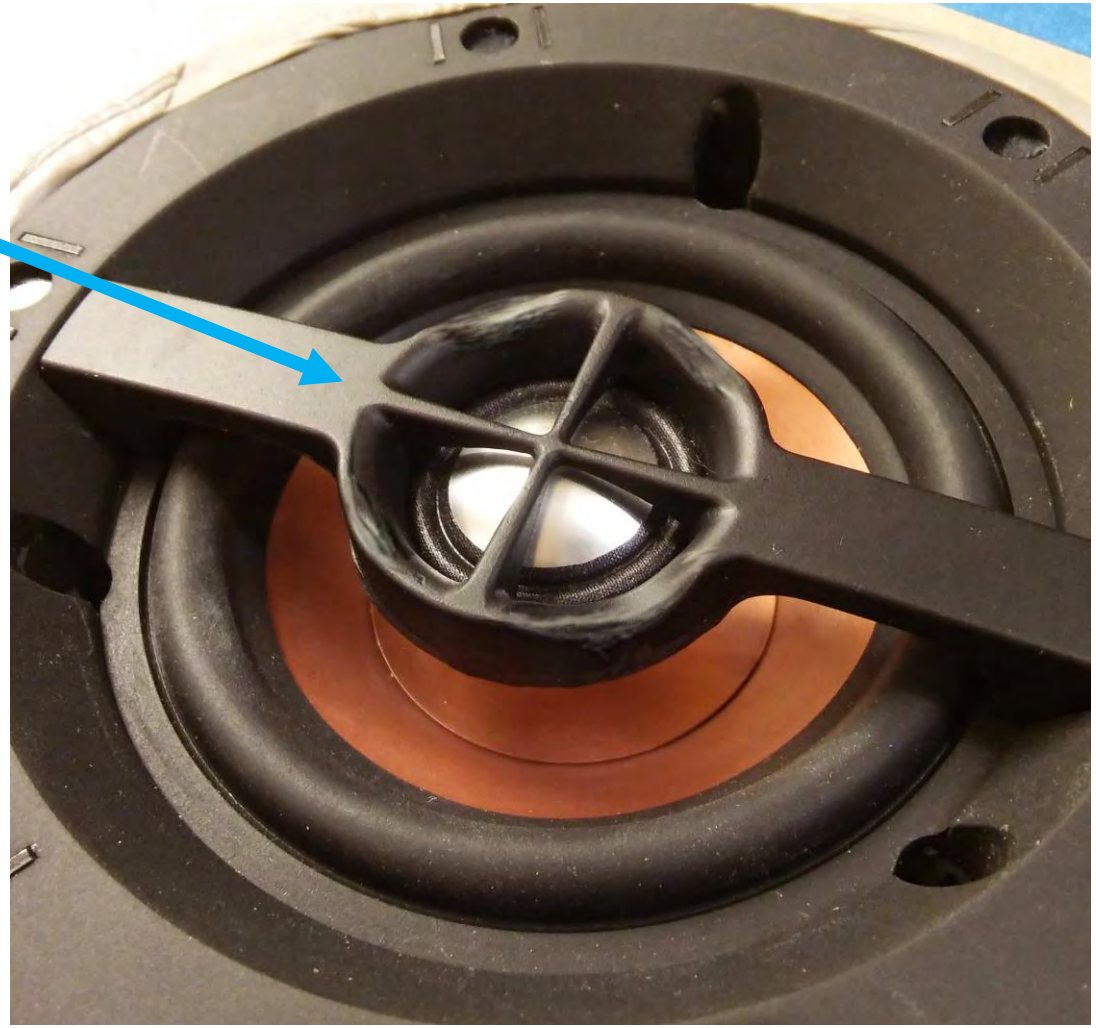
Tweeter

2kHz-20kHz operating range



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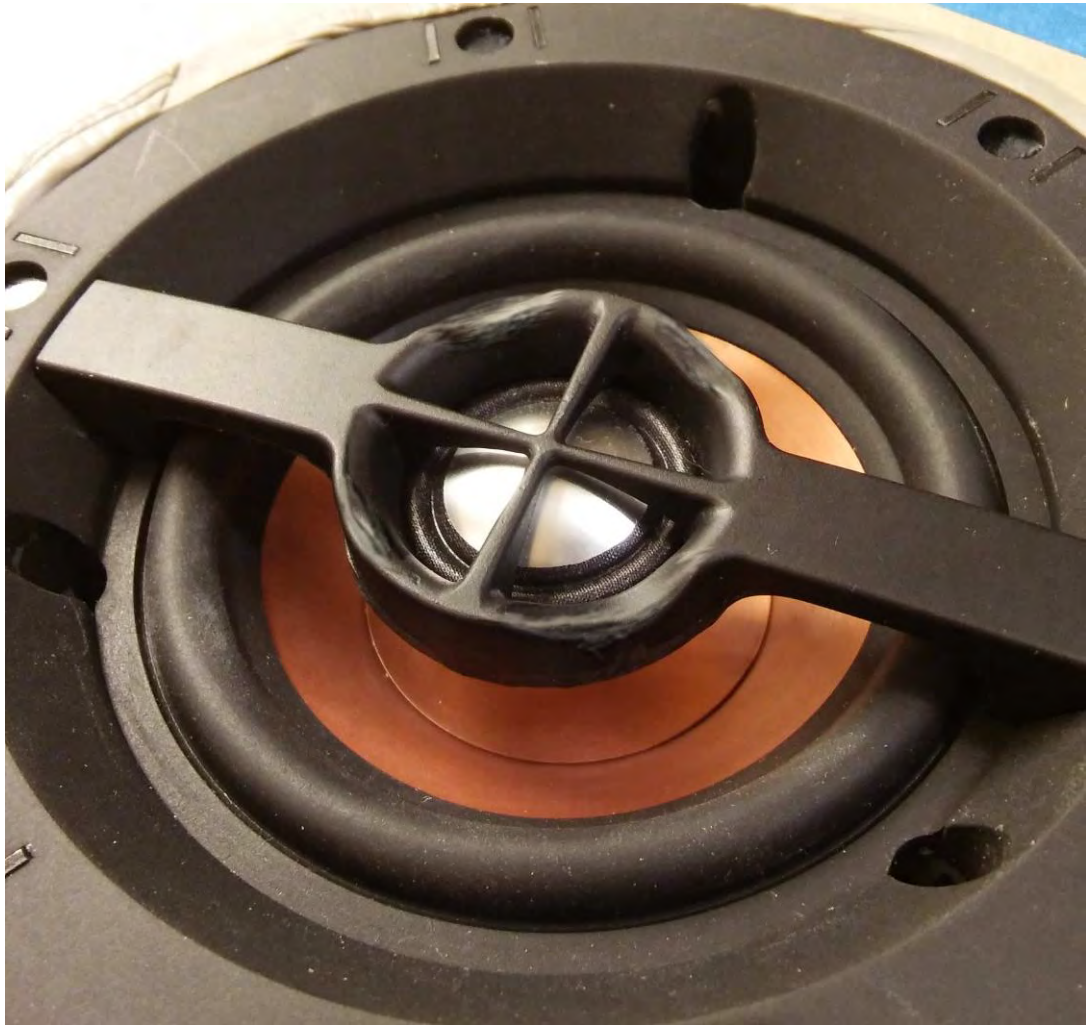
Loudspeakers

Klipsch® KEEPERS OF THE SOUND



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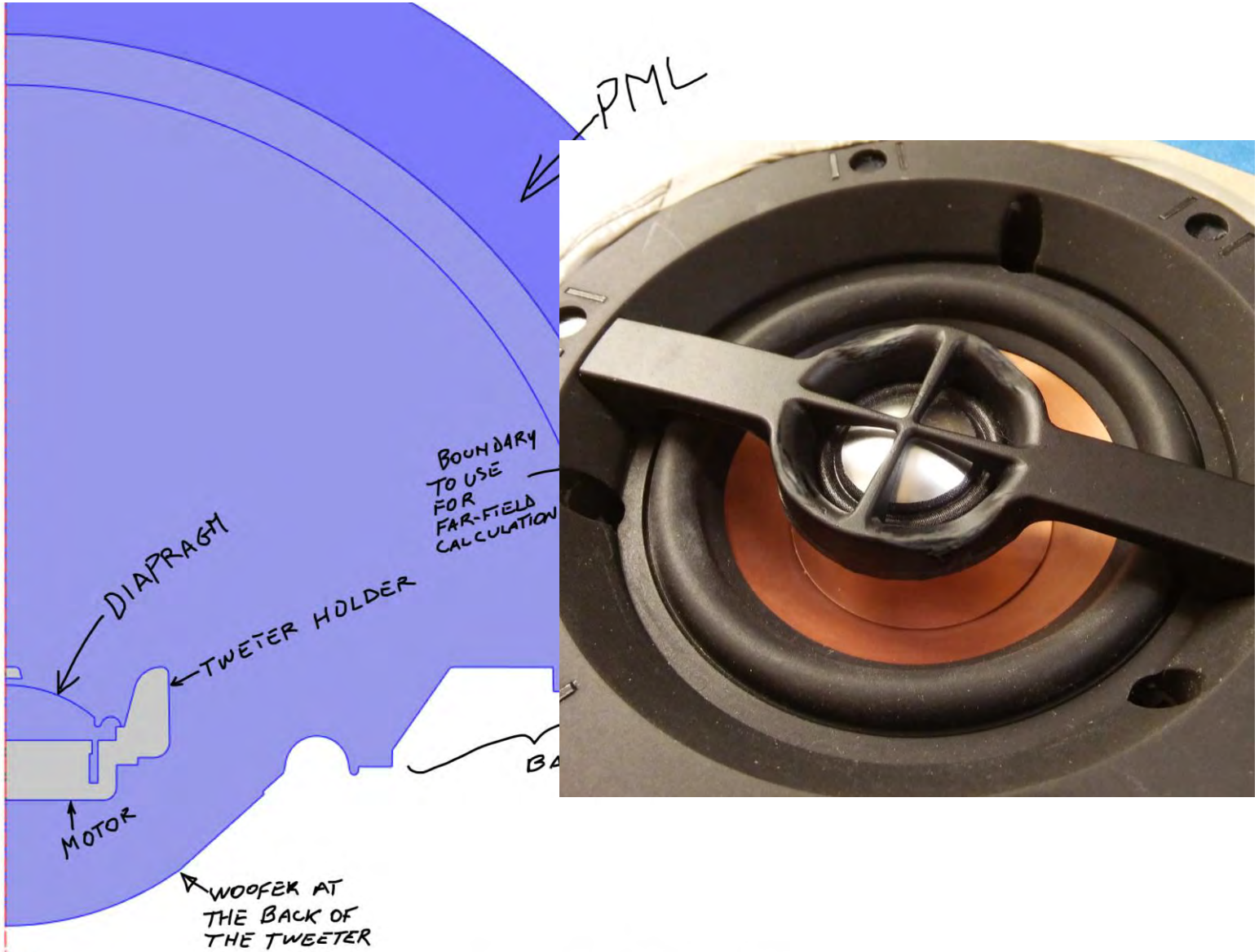
Loudspeakers

Klipsch® KEEPERS OF THE SOUND



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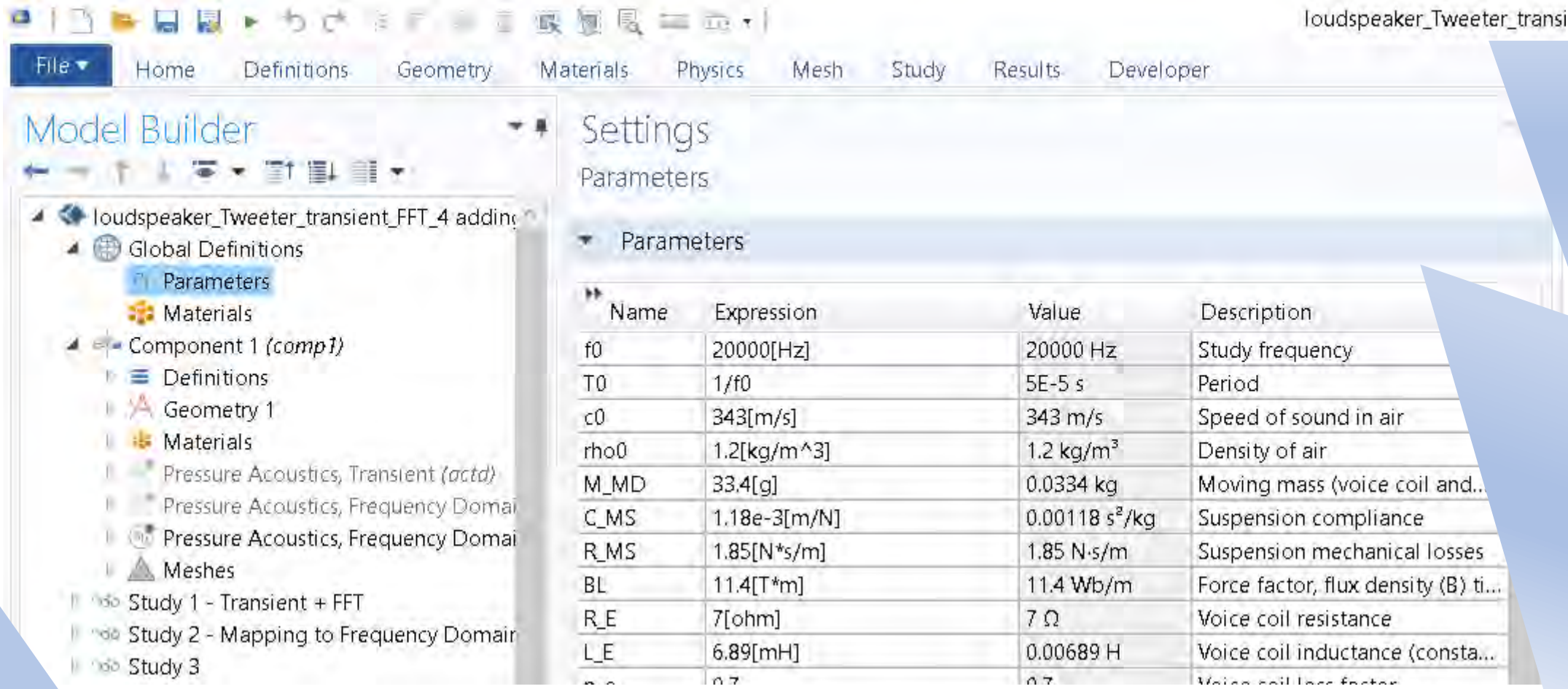
Klipsch® KEEPERS OF THE SOUND



Name	Expression	Value	Description
f0	20000[Hz]	20000 Hz	Study frequency
T0	1/f0	5E-5 s	Period
c0	343[m/s]	343 m/s	Speed of sound in air
rho0	1.2[kg/m^3]	1.2 kg/m³	Density of air
M_MD	33.4[g]	0.0334 kg	Moving mass (voice coil and...
C_MS	1.18e-3[m/N]	0.00118 s²/kg	Suspension compliance
R_MS	1.85[N*s/m]	1.85 N·s/m	Suspension mechanical losses
BL	11.4[T*m]	11.4 Wb/m	Force factor, flux density (B) ti...
R_E	7[ohm]	7 Ω	Voice coil resistance
L_E	6.89[mH]	0.00689 H	Voice coil inductance (consta...

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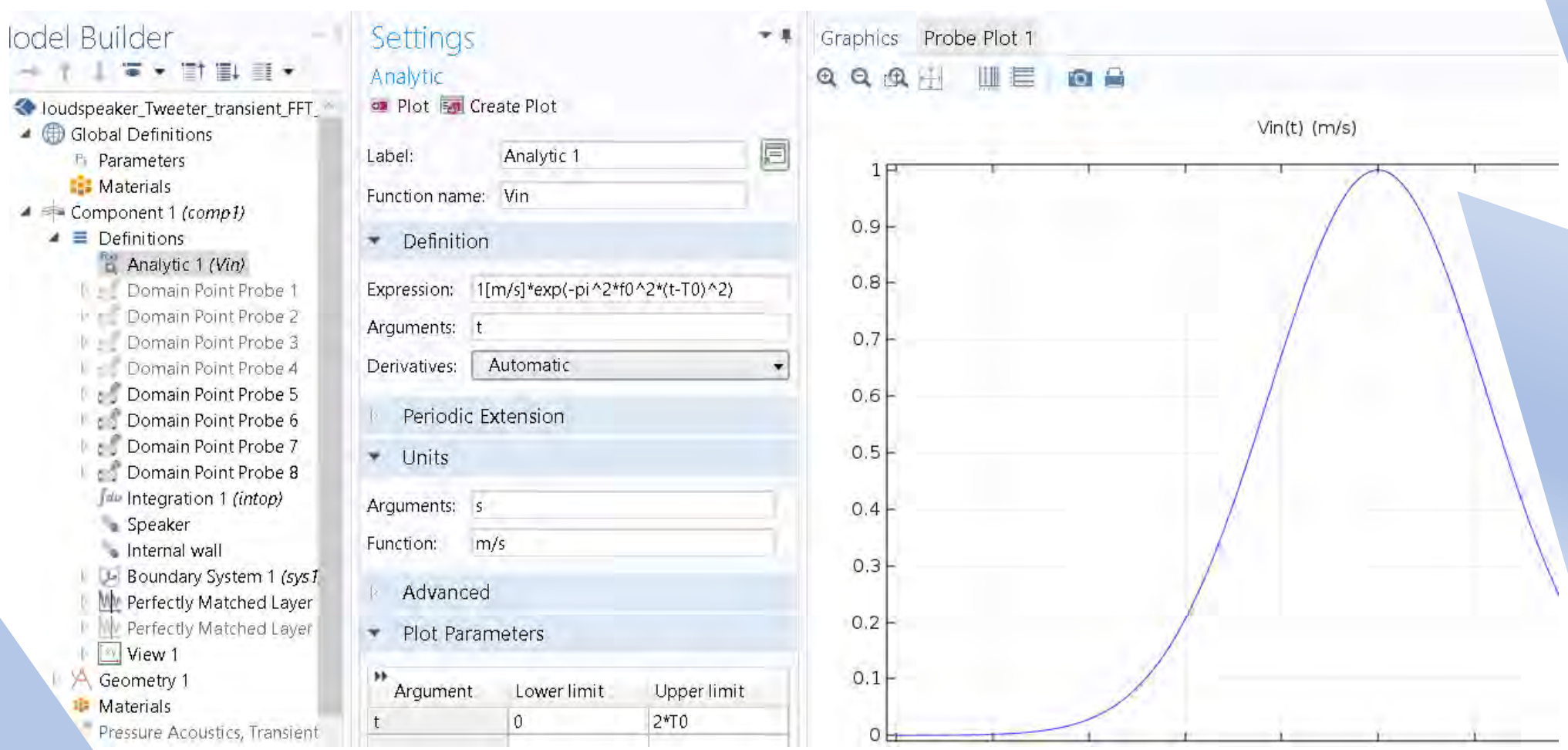
Klipsch® KEEPERS OF THE SOUND



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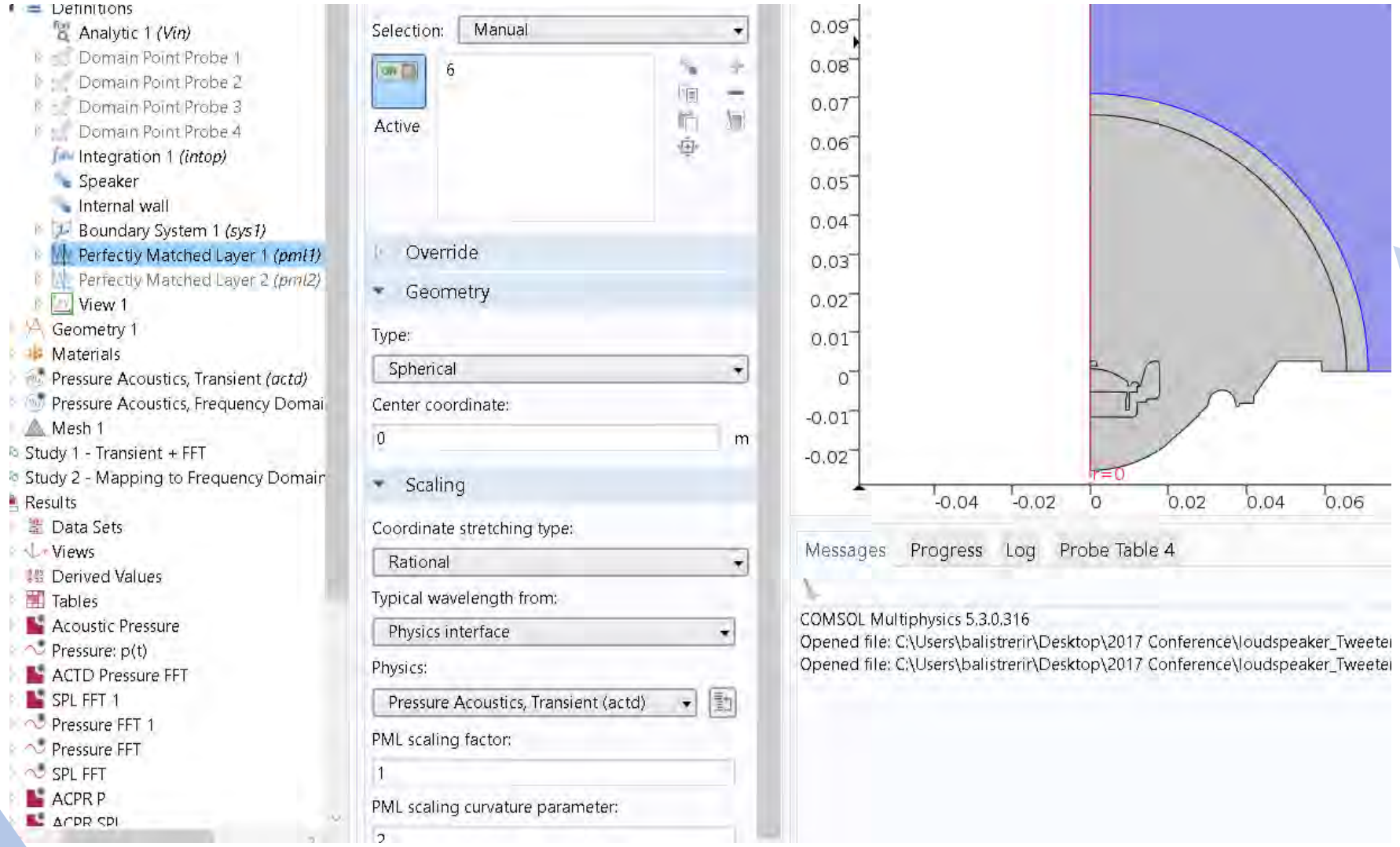
PML

Klipsch® KEEPERS OF THE SOUND



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Diaphragm Velocity

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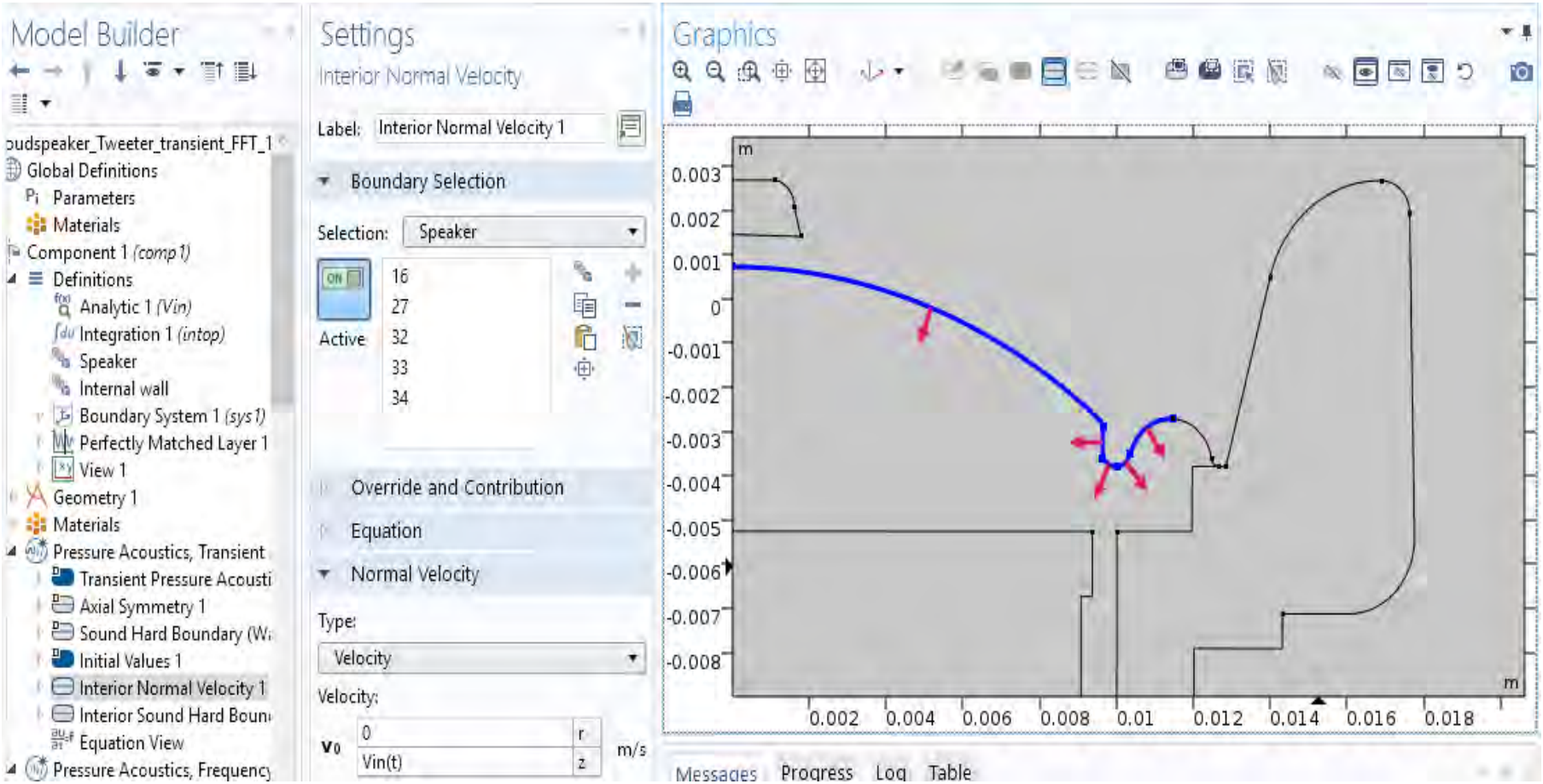

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Meshing

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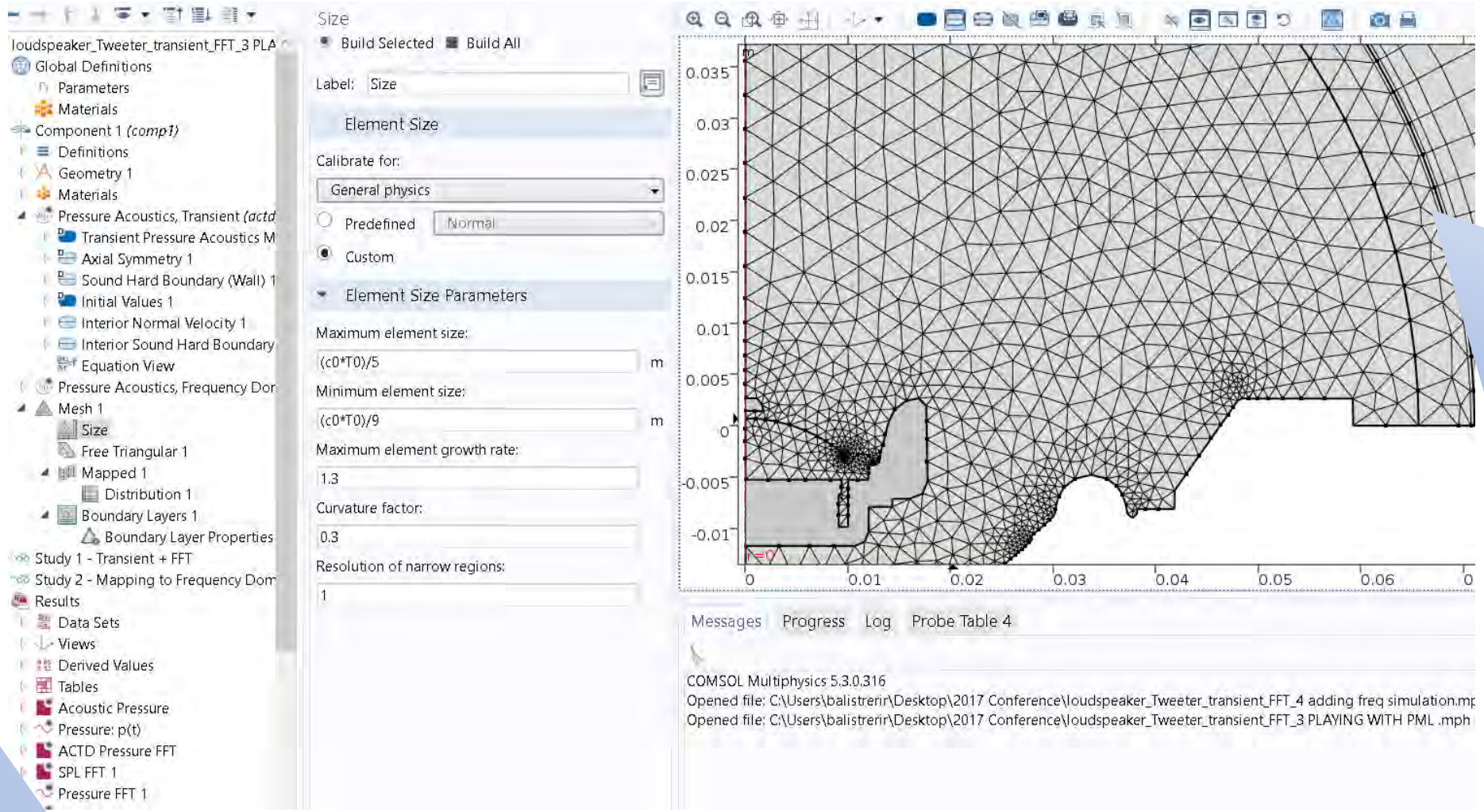

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Boundary to PLM

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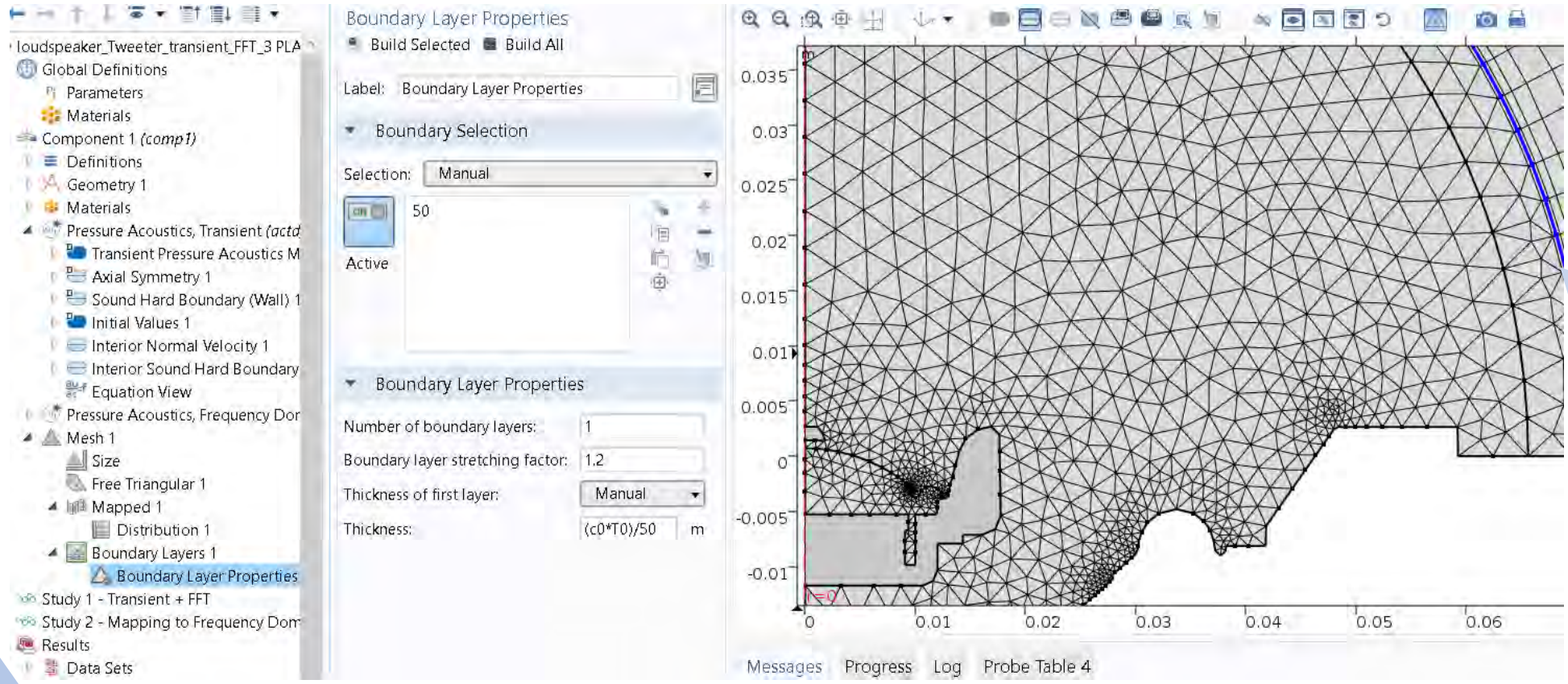

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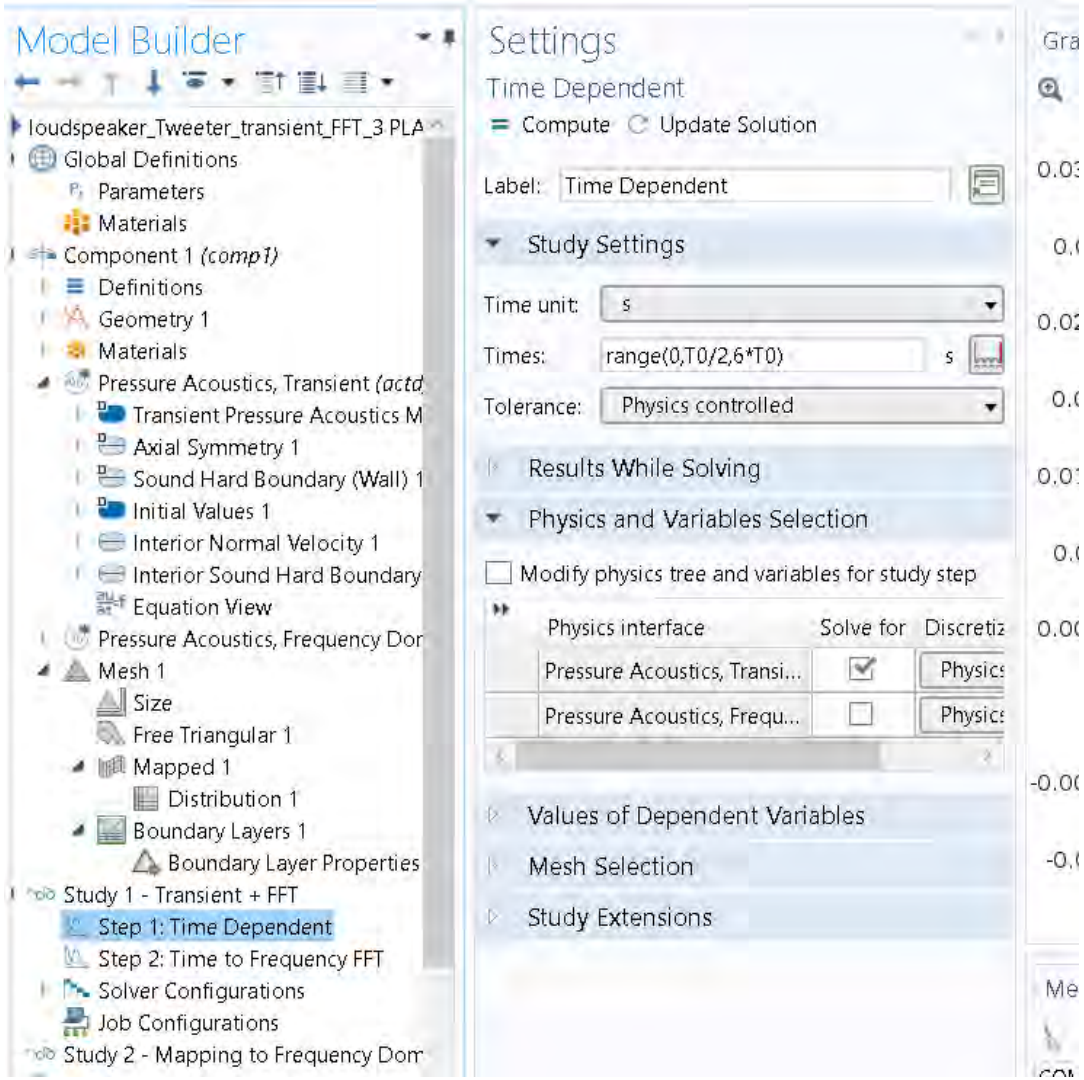
Study

Klipsch® KEEPERS OF THE SOUND



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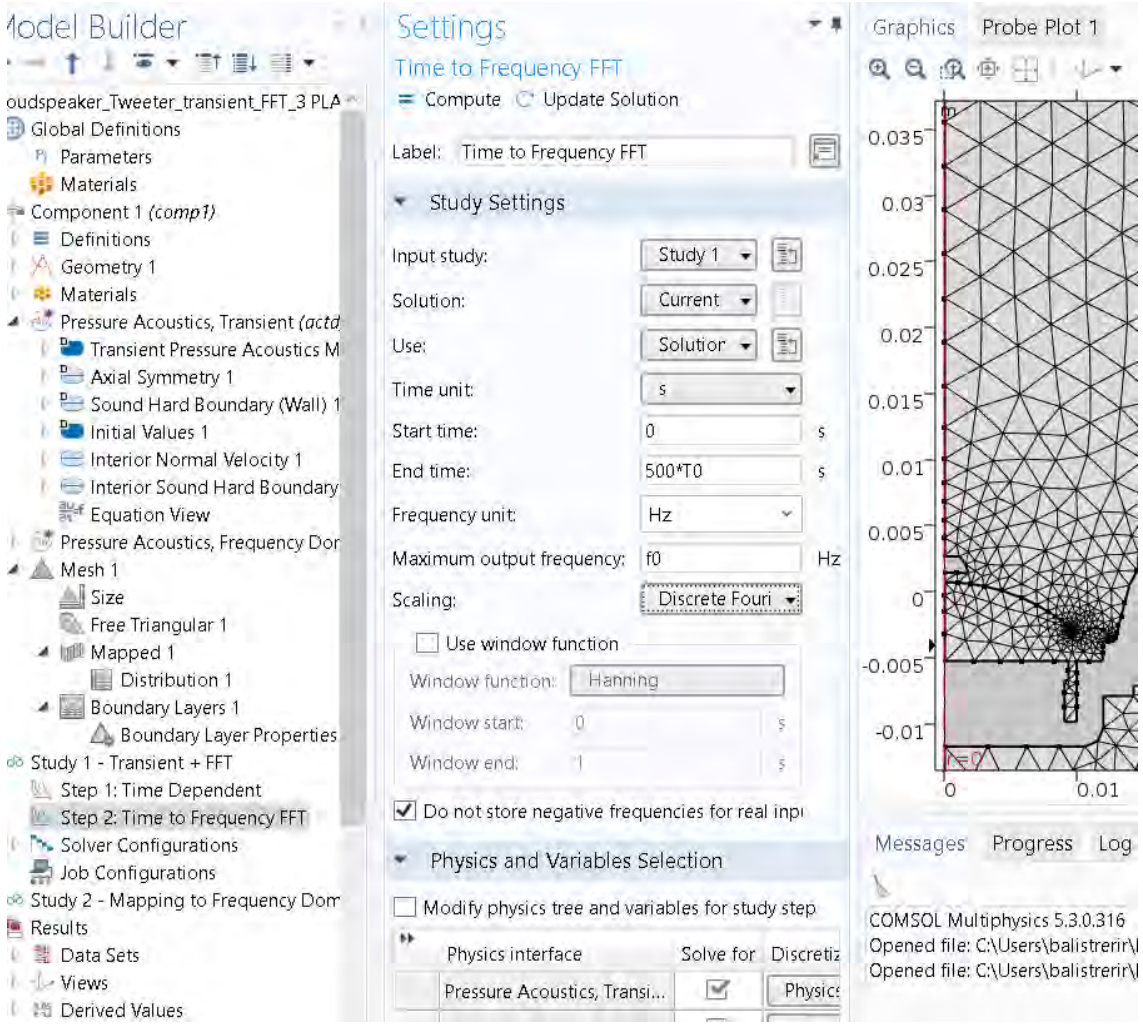
Study

Klipsch KEEPERS OF THE SOUND



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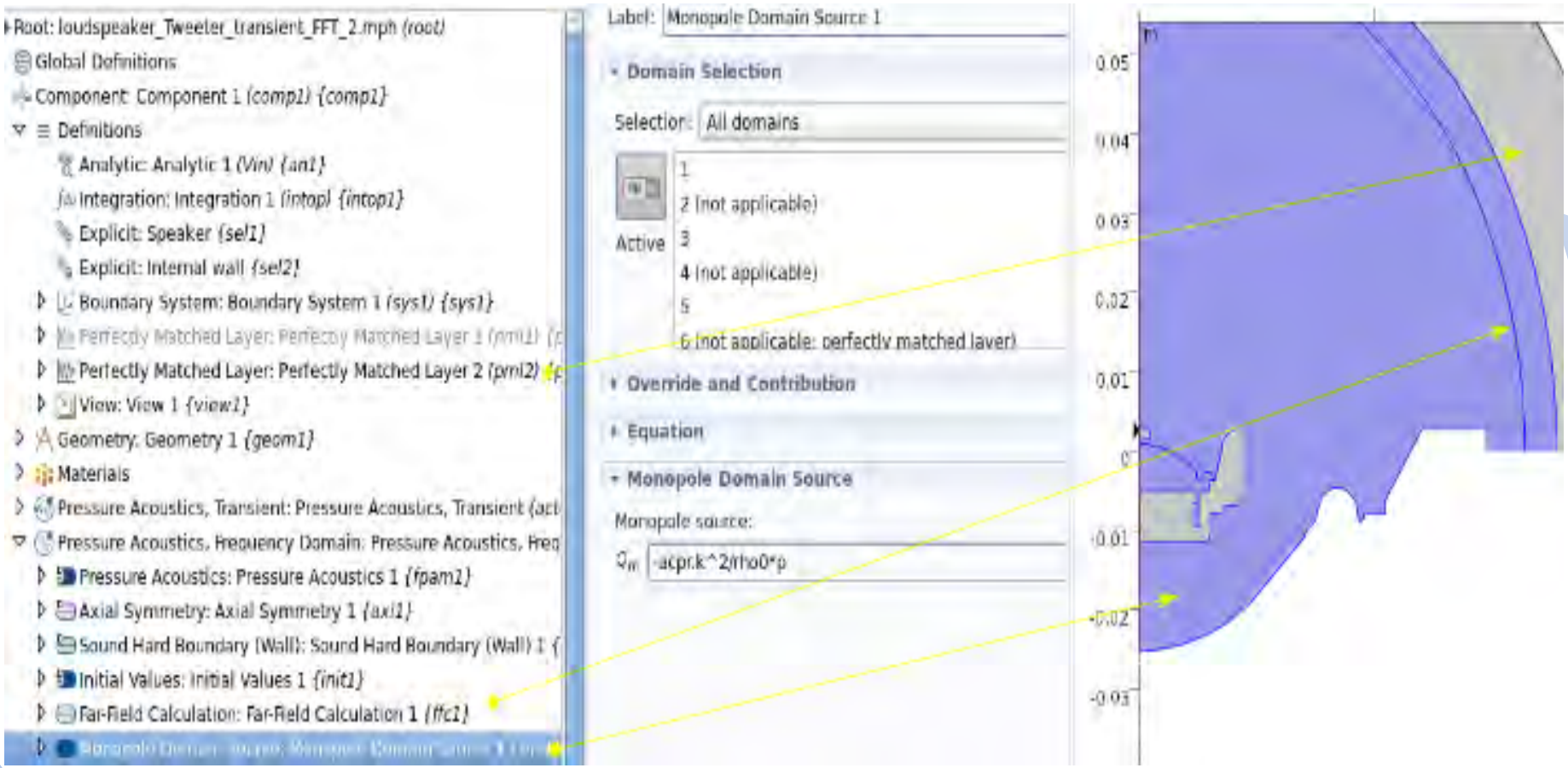
Frequency map

Klipsch® KEEPERS OF THE SOUND



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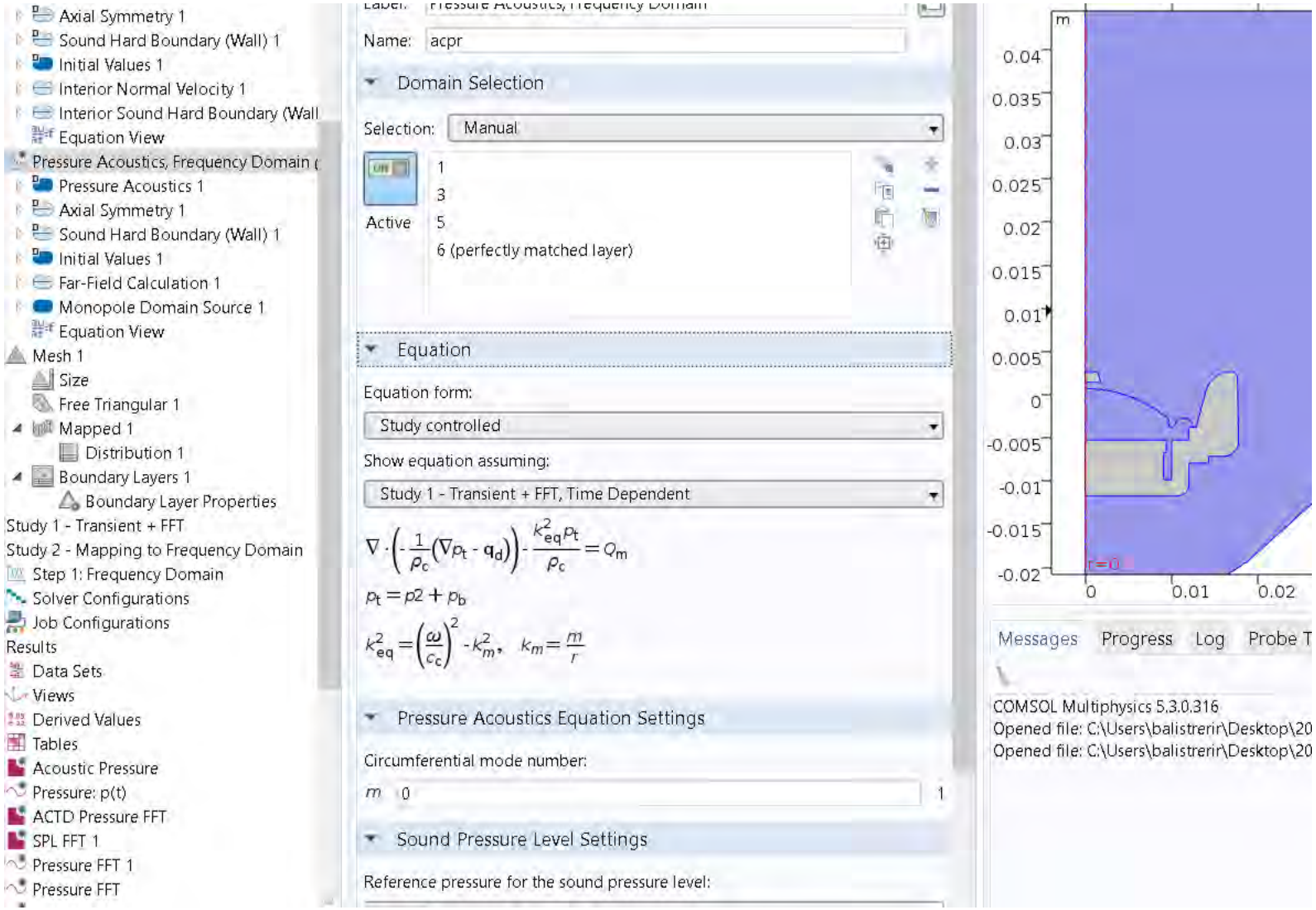
Mapping to Freq. Domain

Klipsch® KEEPERS OF THE SOUND



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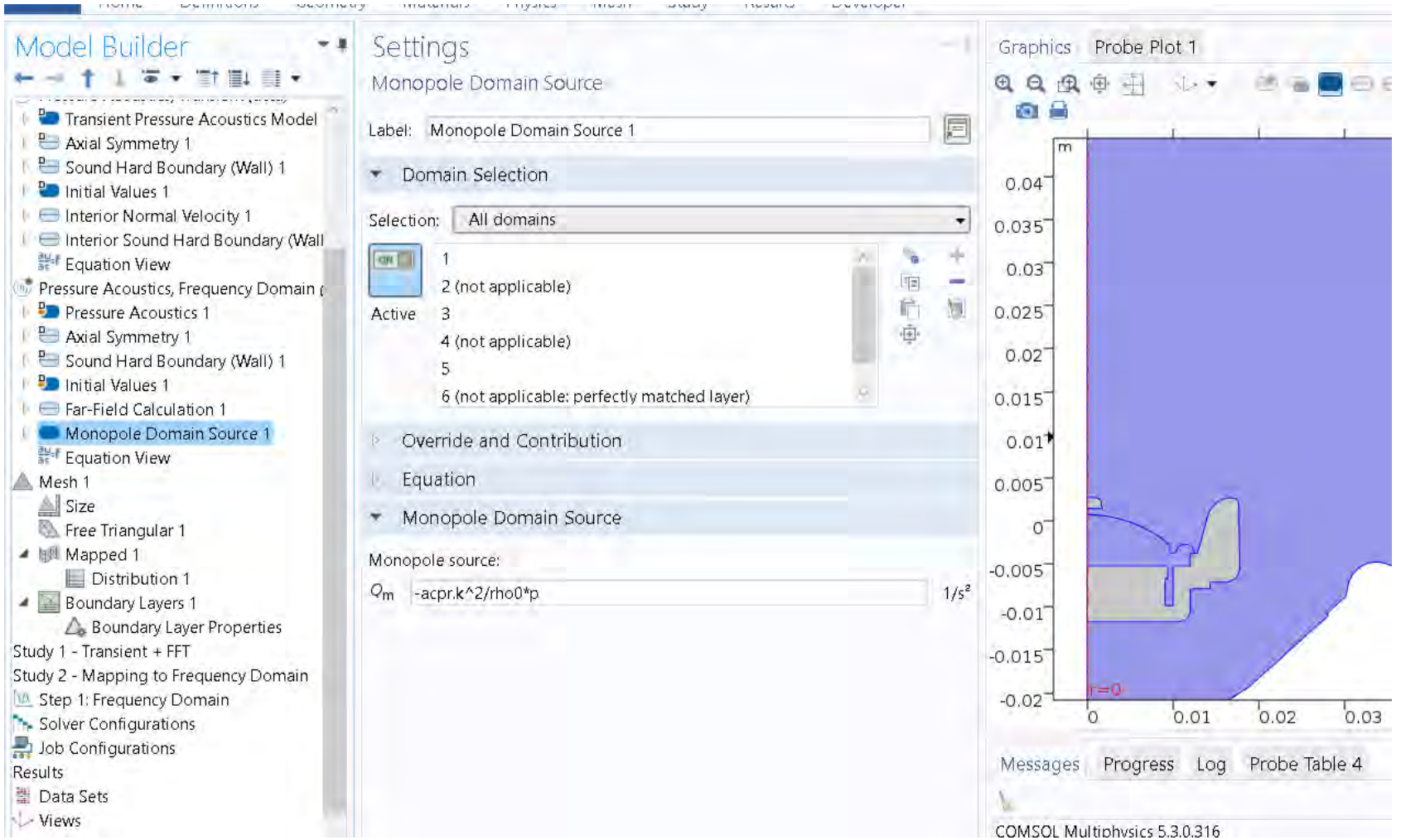
Mapping to Freq. Domain

Klipsch KEEPERS OF THE SOUND



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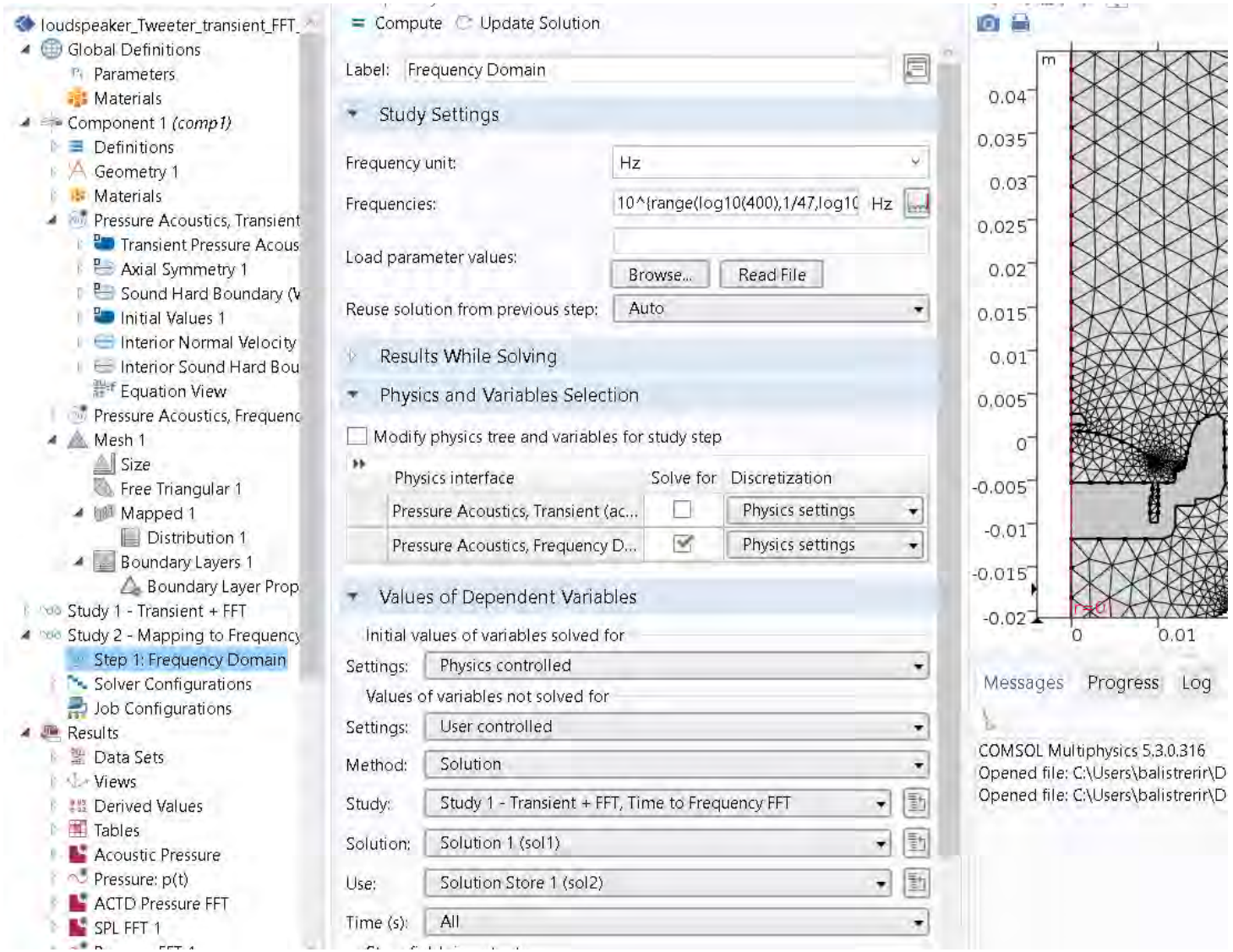
Study

Klipsch® KEEPERS OF THE SOUND



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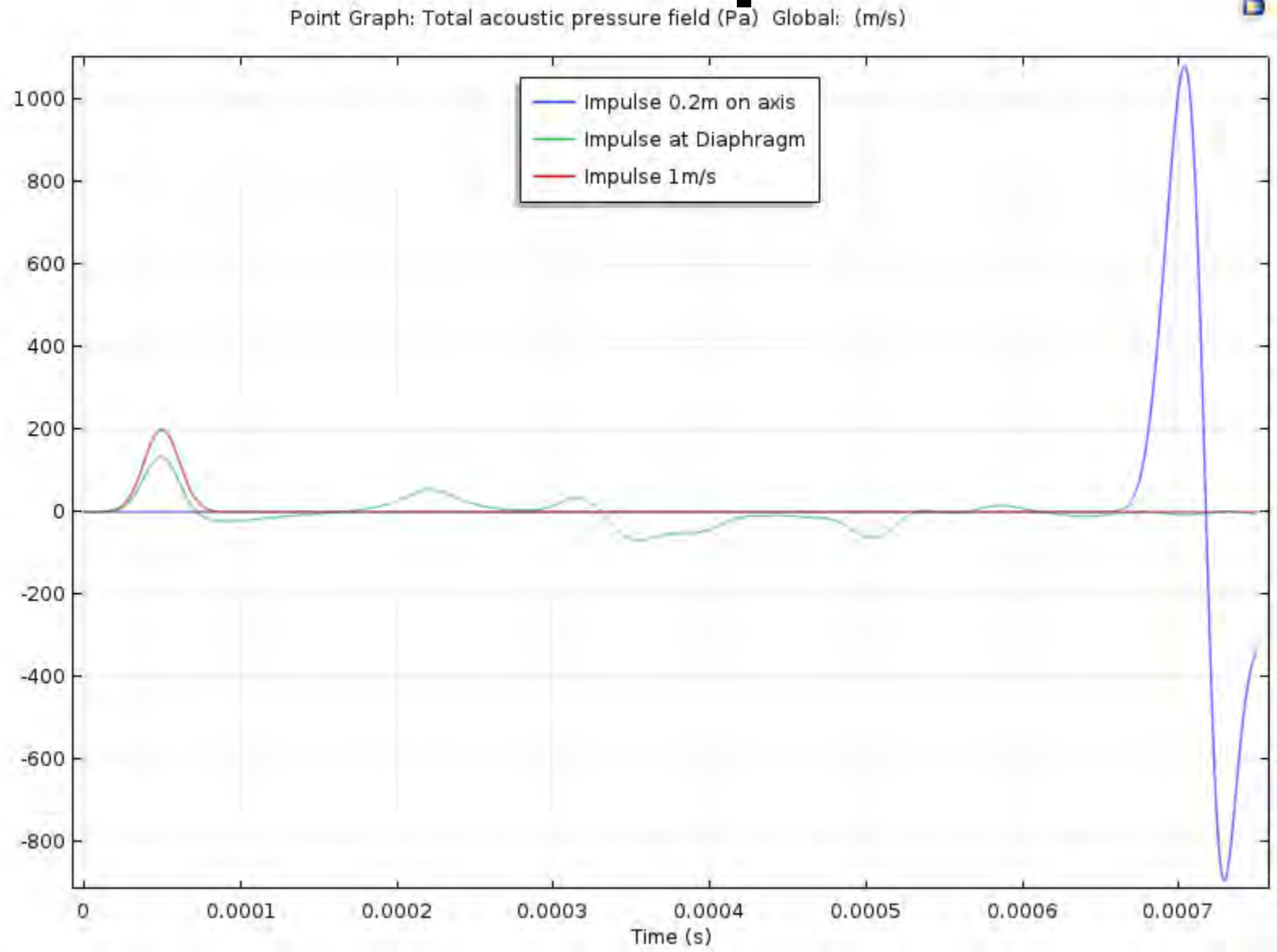
Pressure pulse

Klipsch KEEPERS OF THE SOUND



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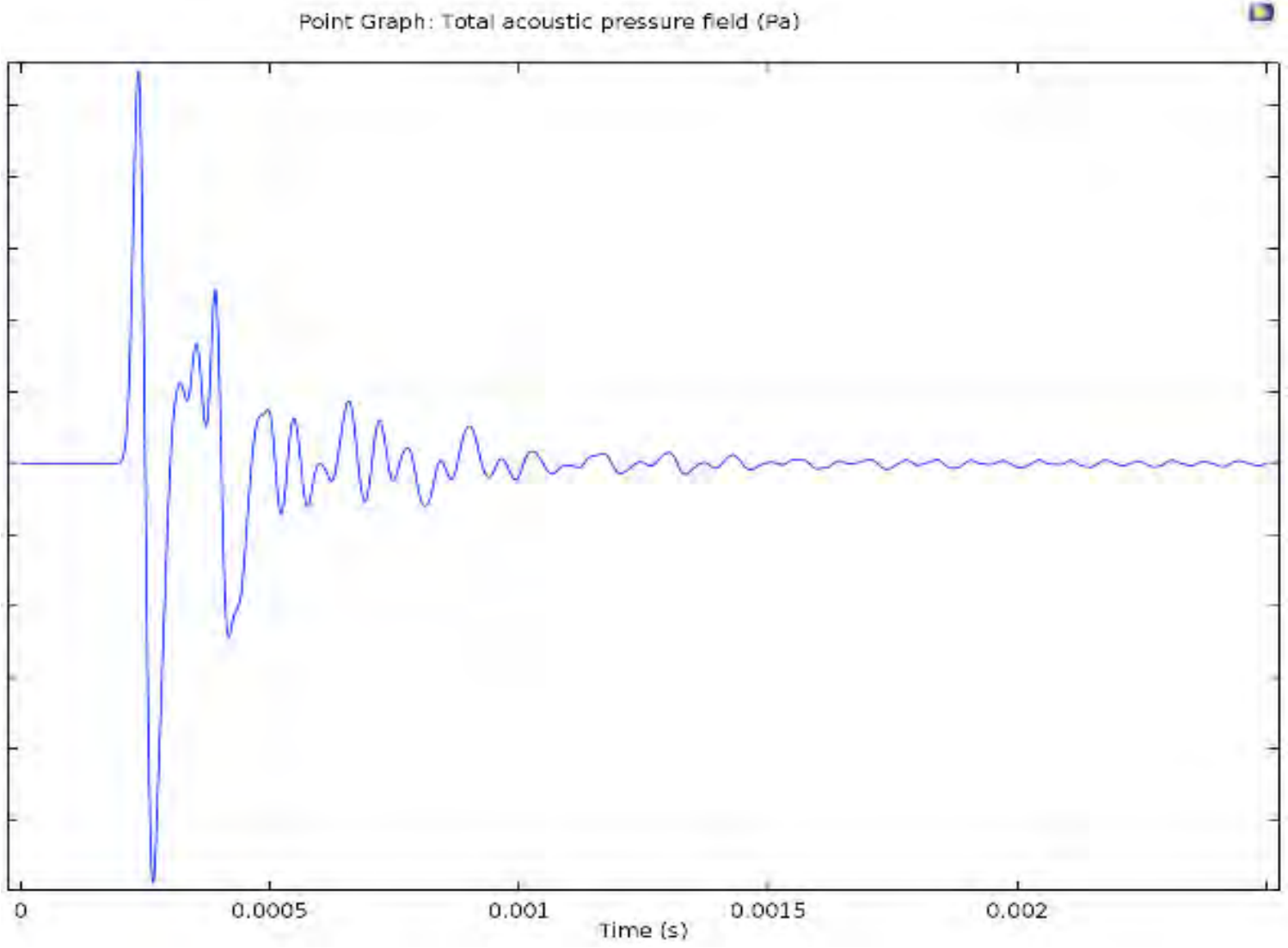
Impulse in front of tweeter

Klipsch® KEEPERS OF THE SOUND



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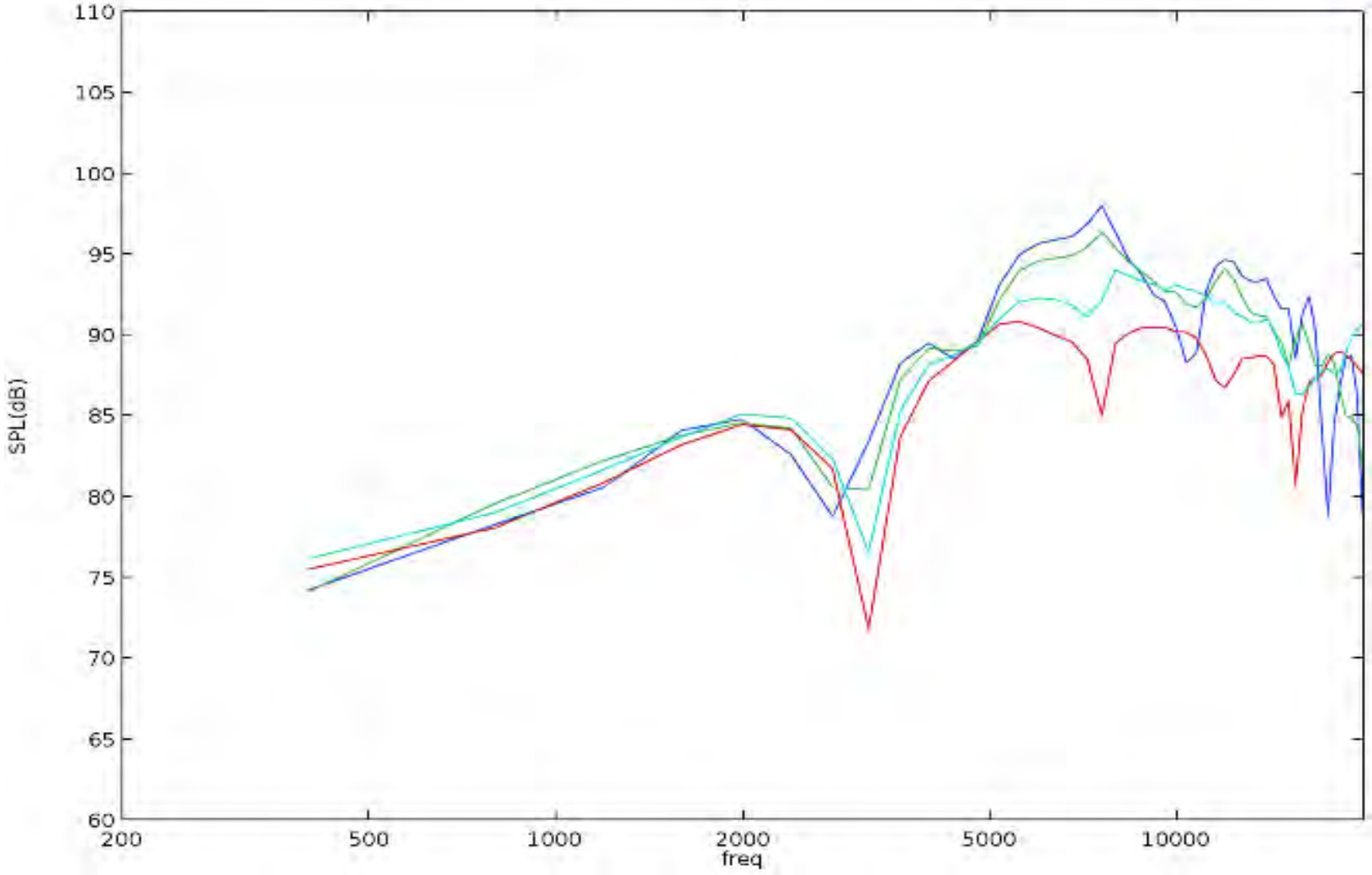
FFT of Impulse

Klipsch® KEEPERS OF THE SOUND



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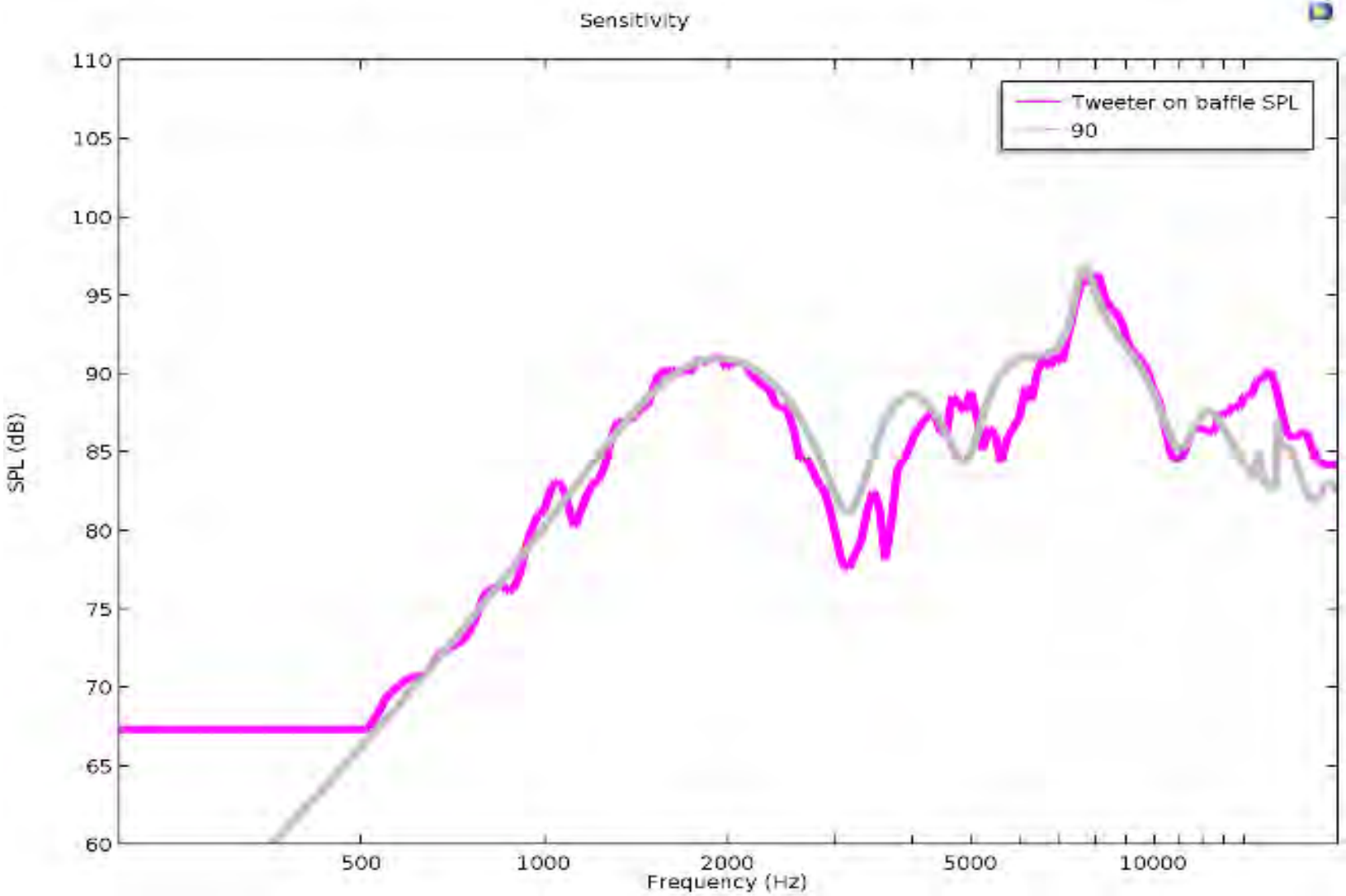
Freq. domain vs. measurement

Klipsch® KEEPERS OF THE SOUND



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Freq. domain impedance

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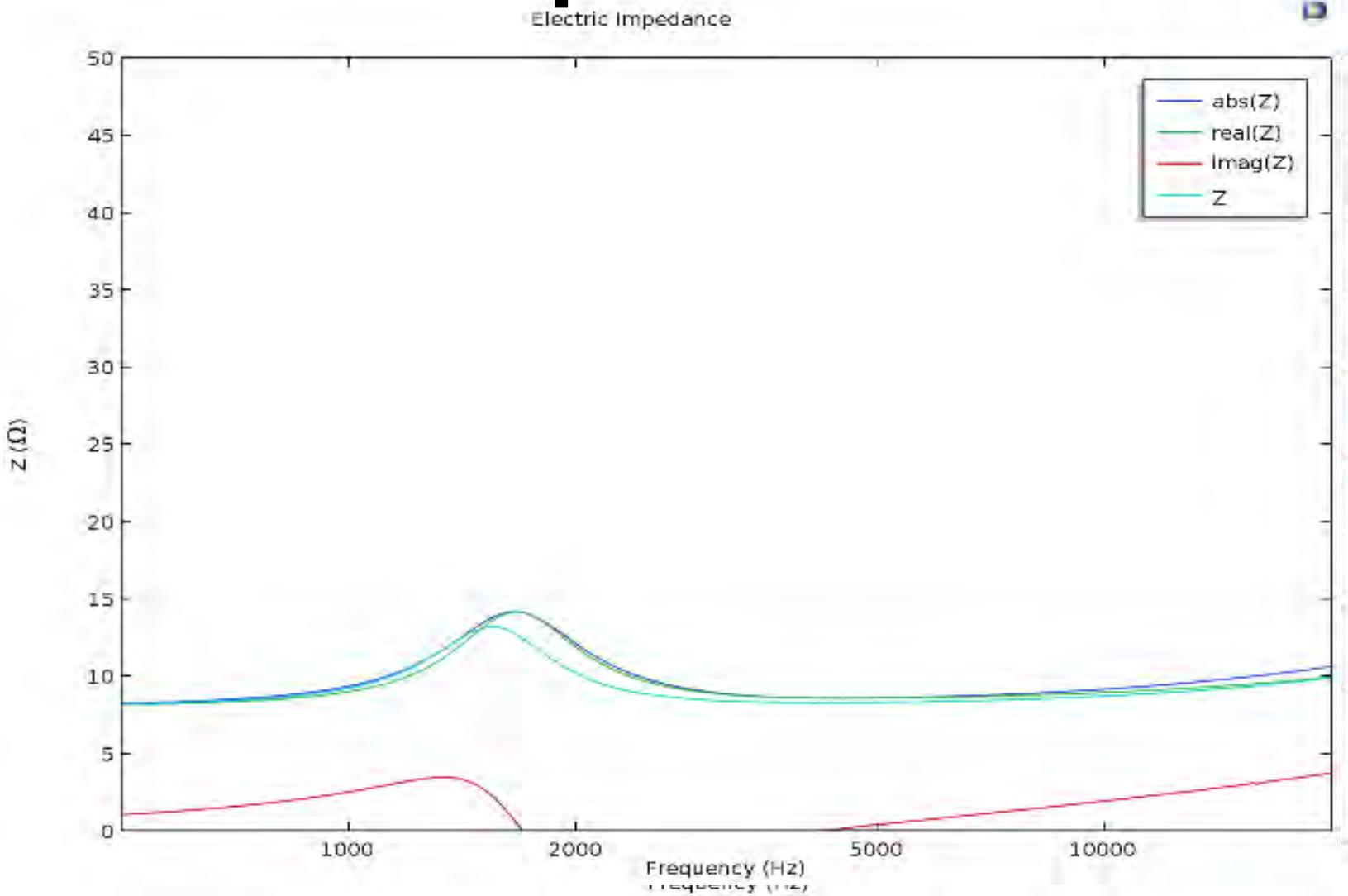

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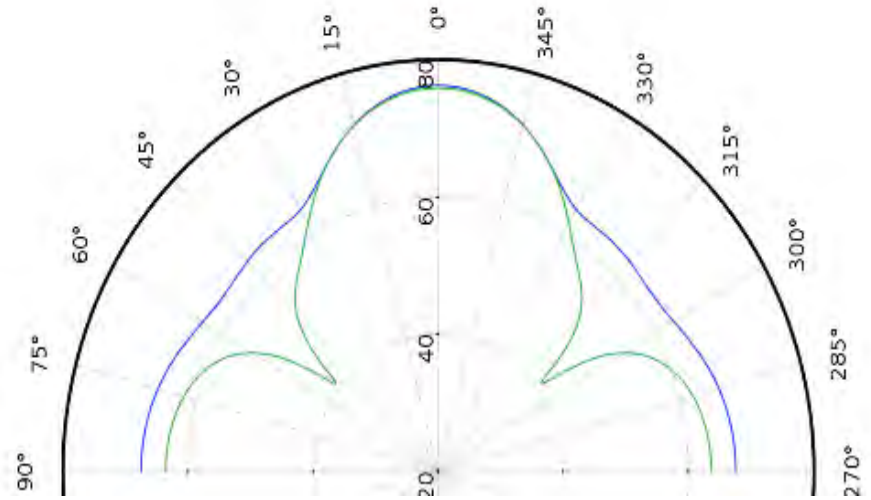
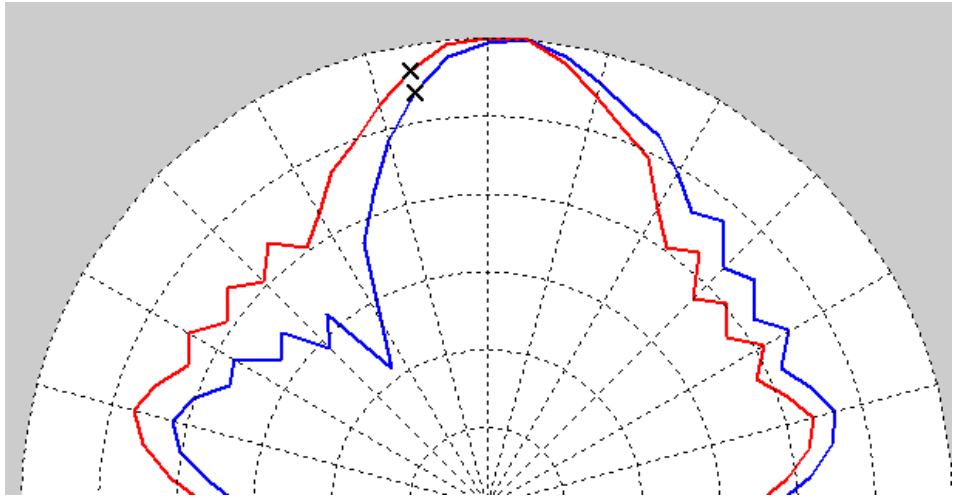
Frequency map

Klipsch® KEEPERS OF THE SOUND





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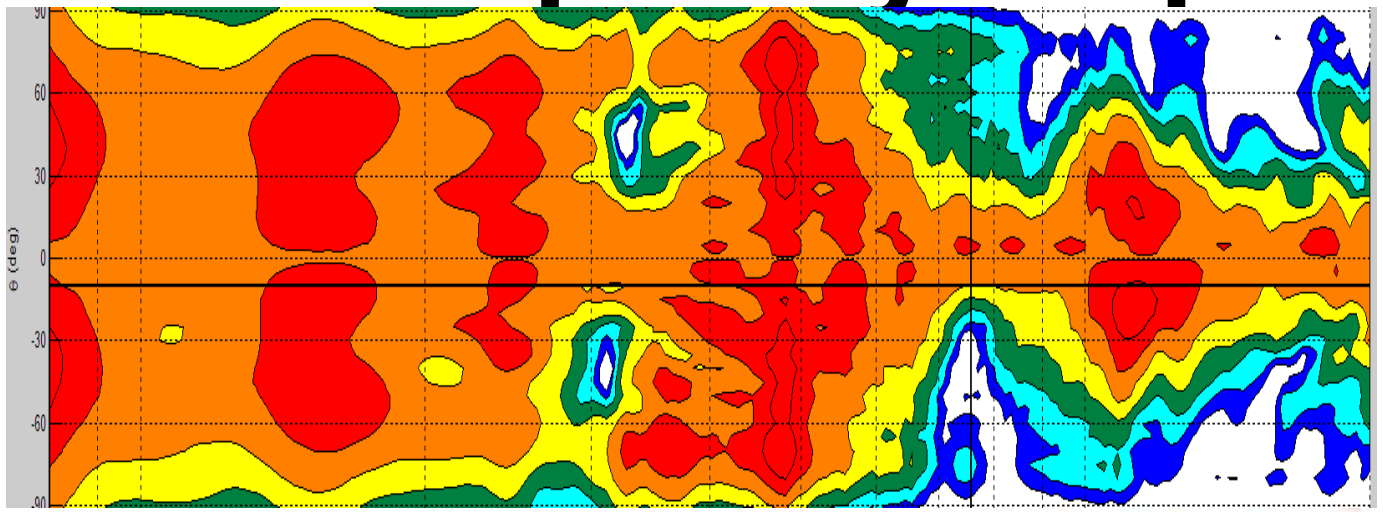
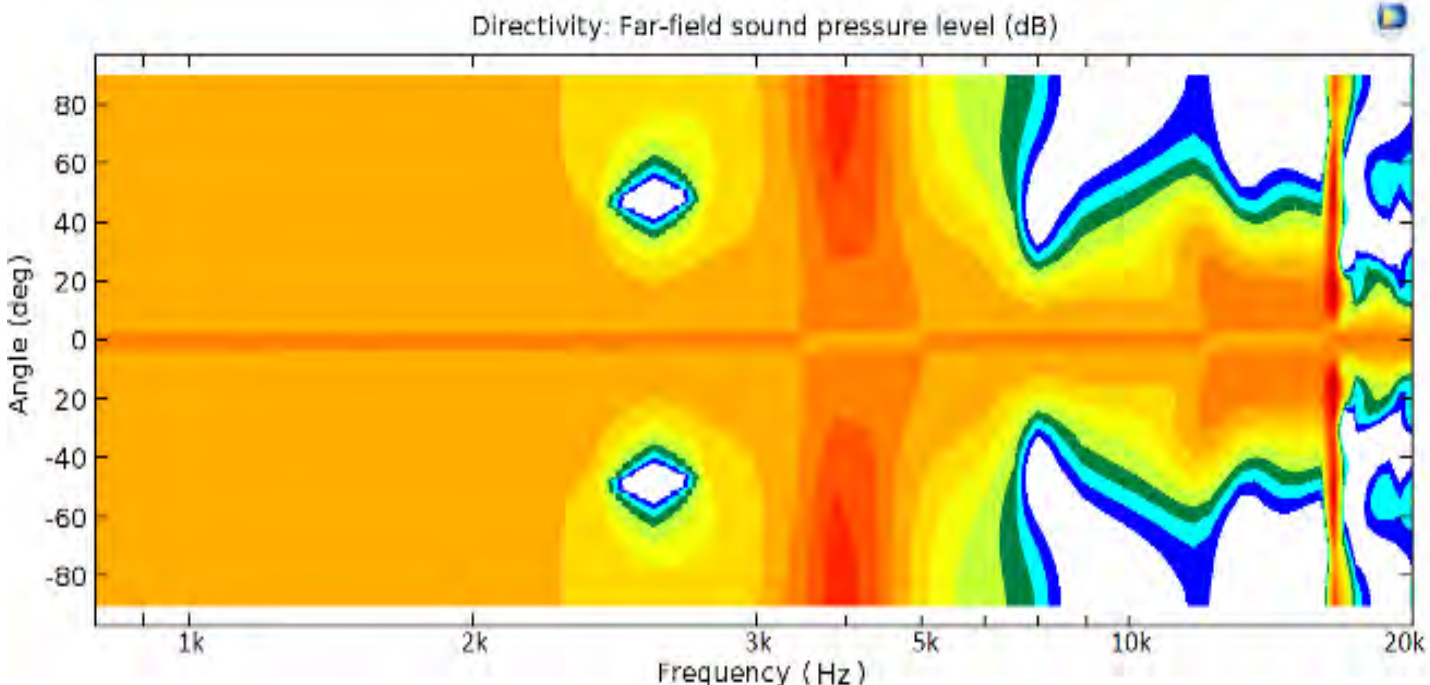
Klipsch KEEPERS OF THE SOUND

Frequency map





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Impulse Propagation

Klipsch® KEEPERS OF THE SOUND

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Impulse Propagation

Klipsch® KEEPERS OF THE SOUND

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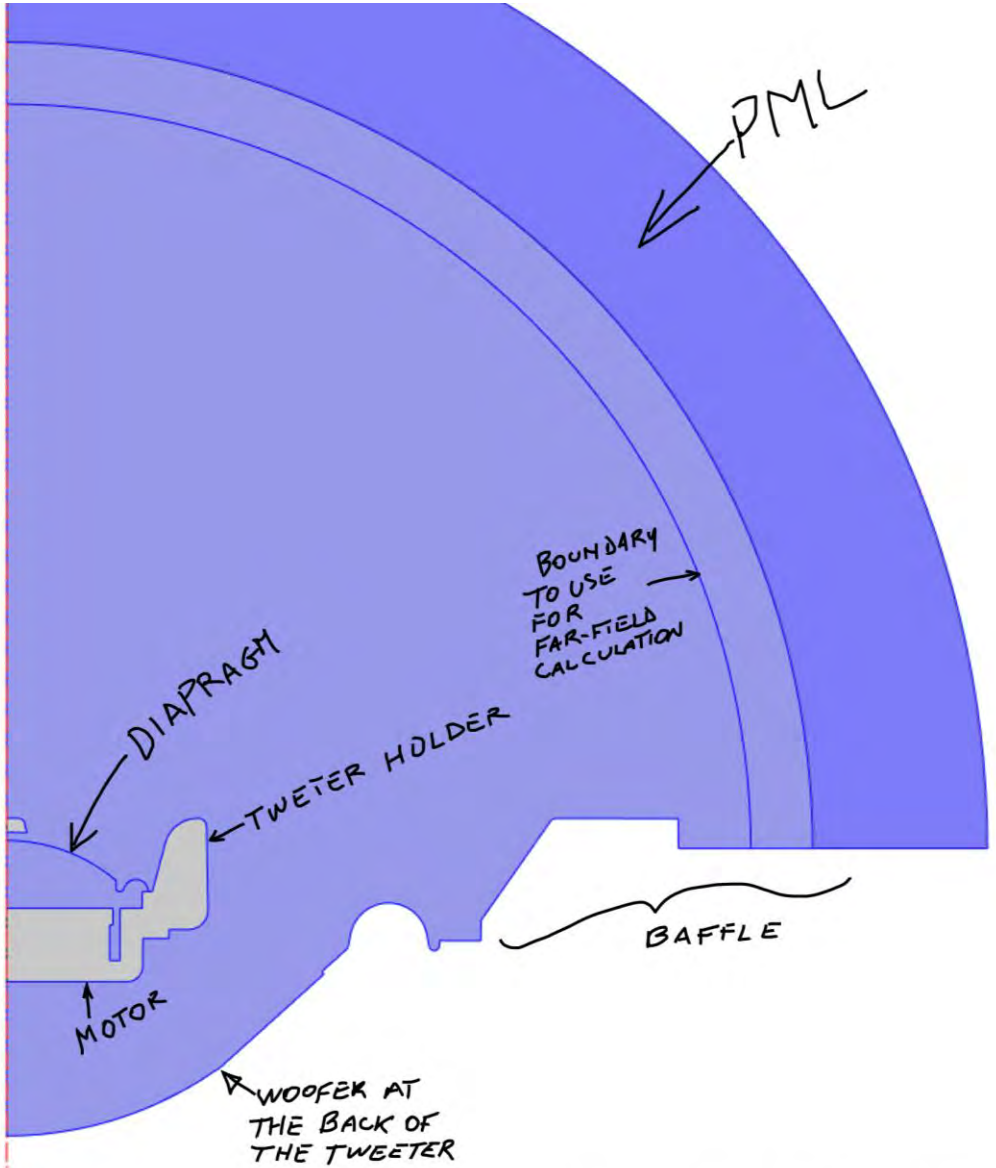
Bad Symmetry!

Klipsch® KEEPERS OF THE SOUND



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Bad Symmetry!

Klipsch KEEPERS OF THE SOUND

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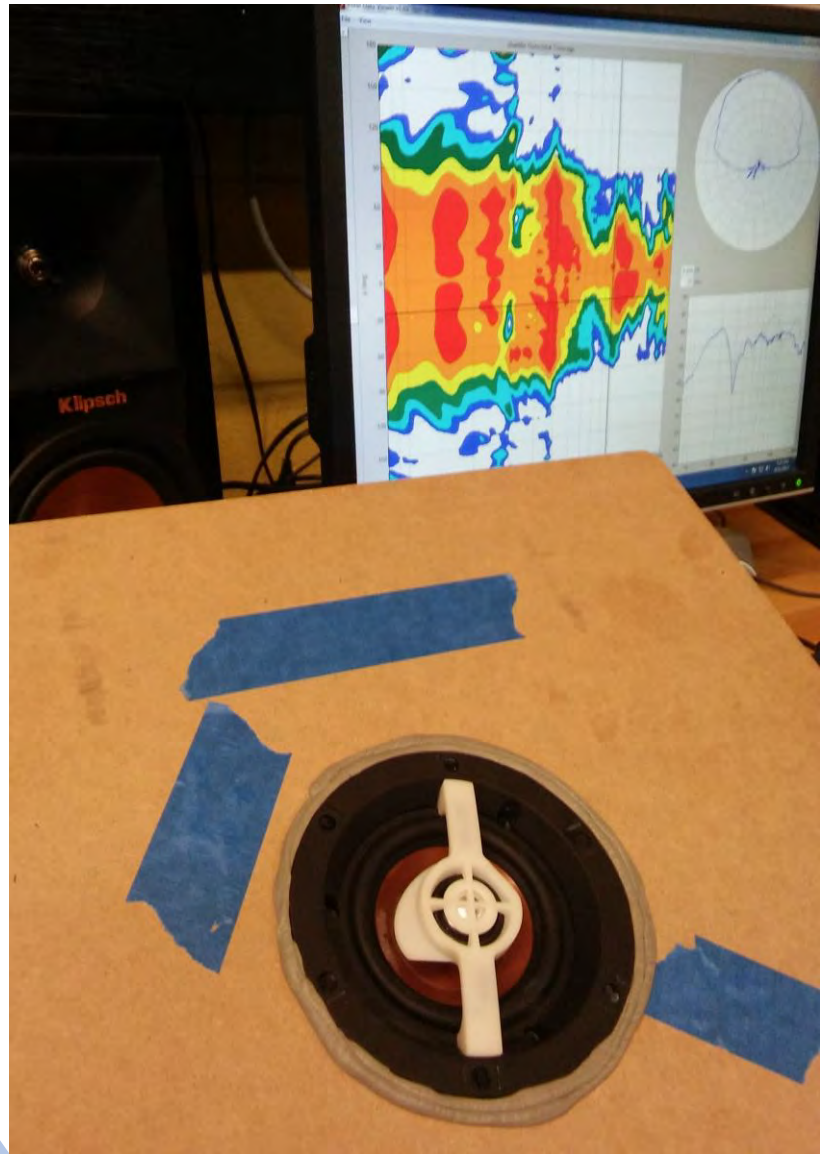
Results

Klipsch KEEPERS OF THE SOUND



Polar measurement system

DUT device under test

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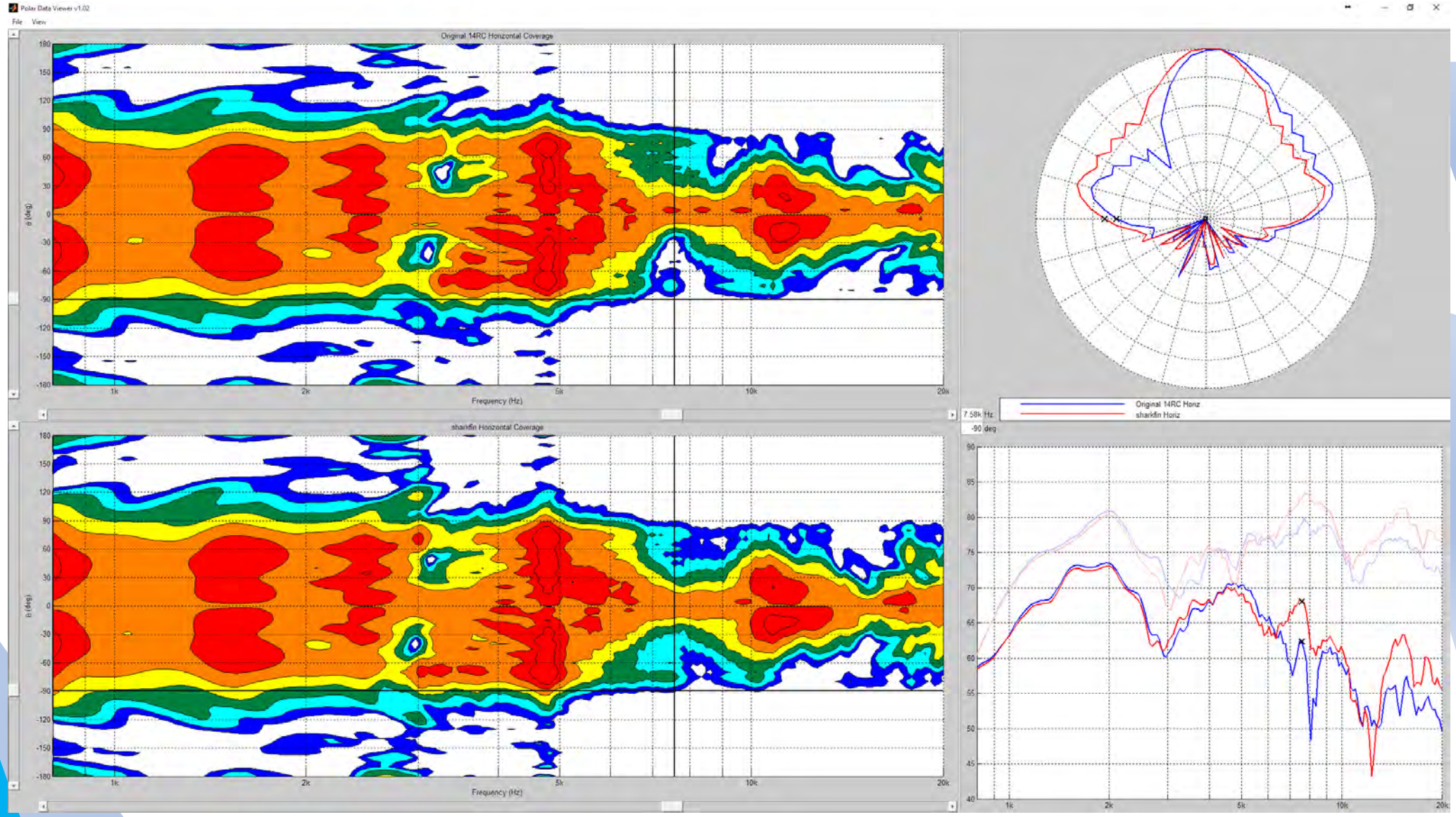
Results

Klipsch® KEEPERS OF THE SOUND



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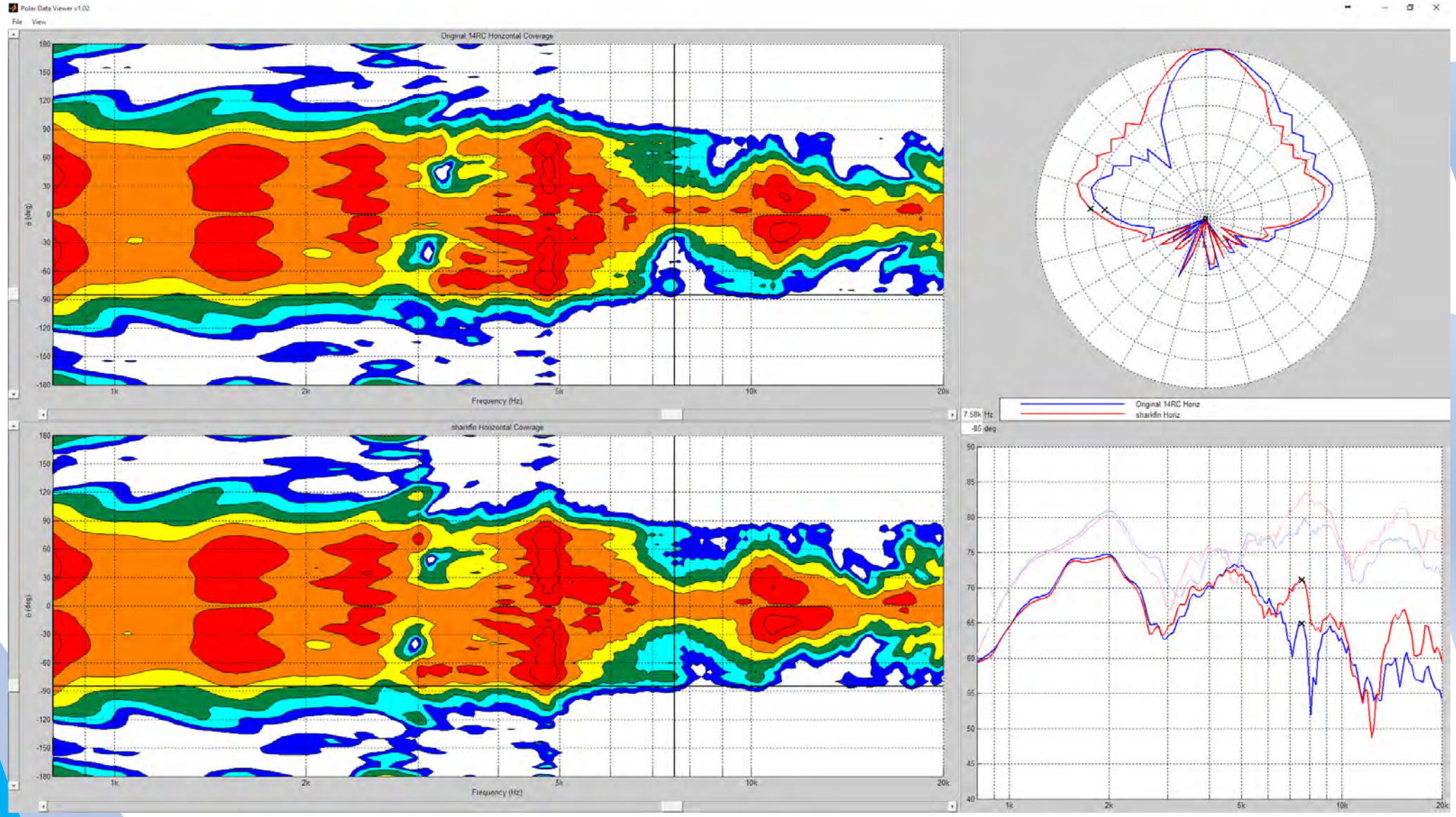

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Results

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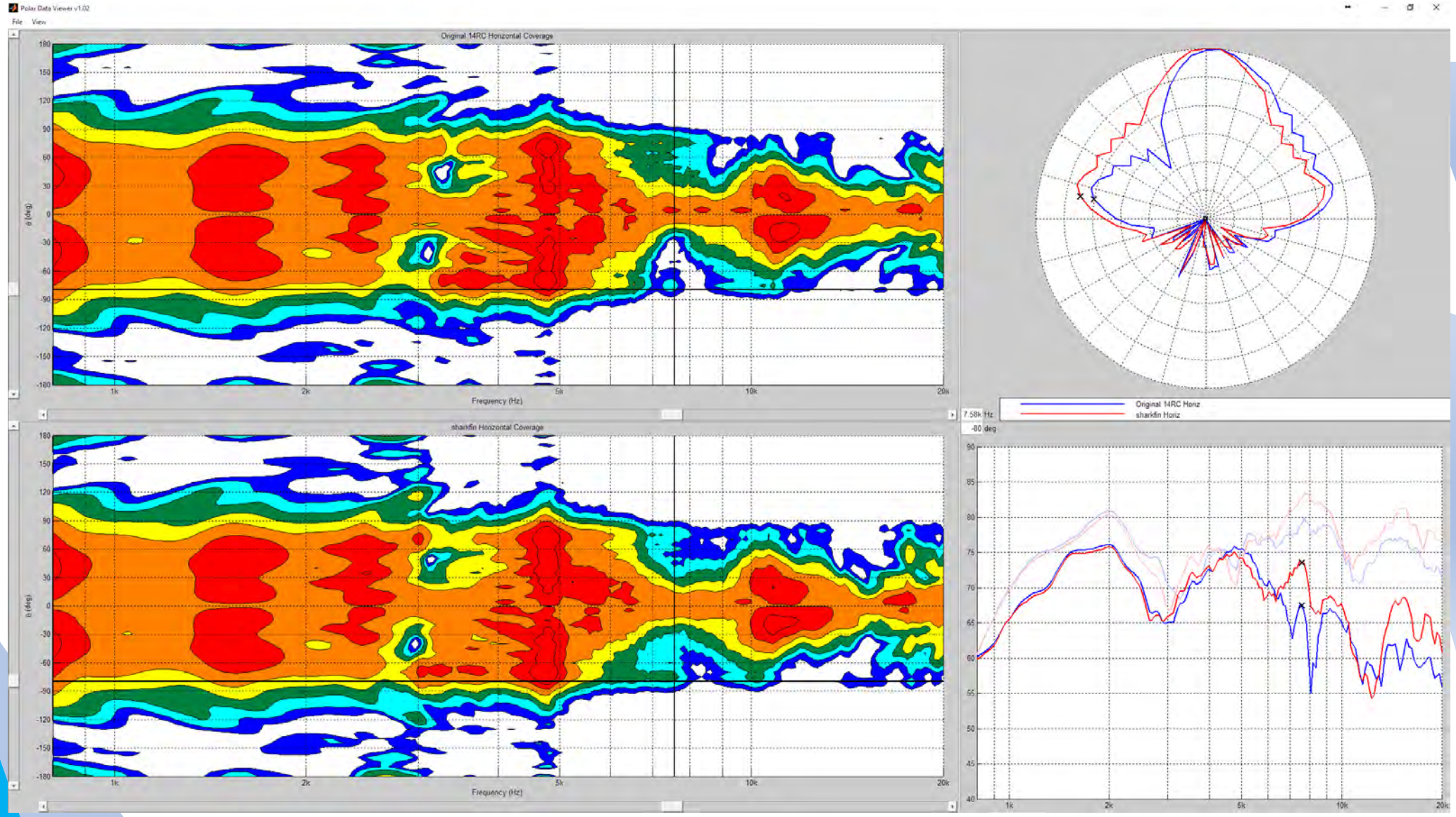

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Results

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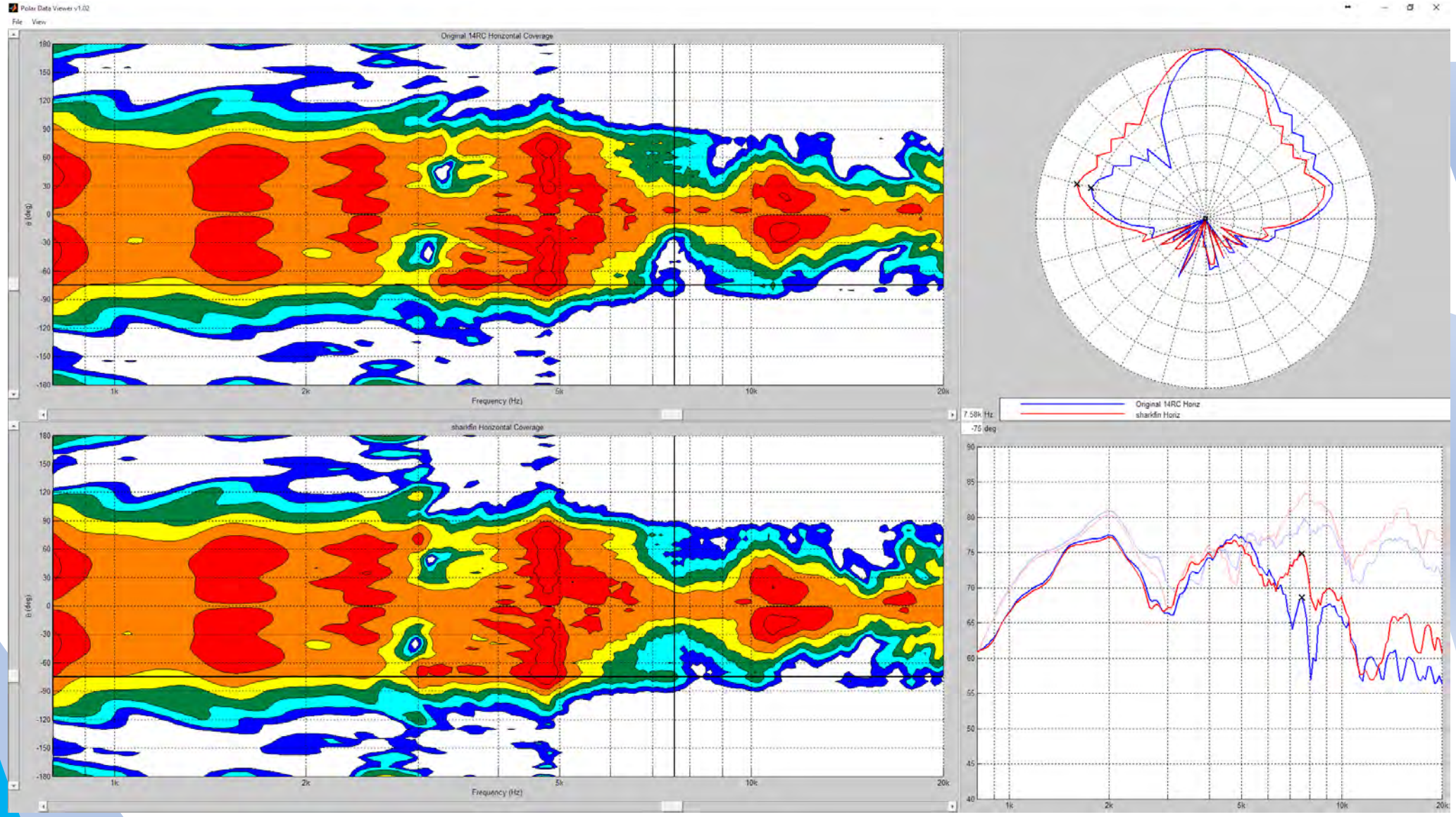

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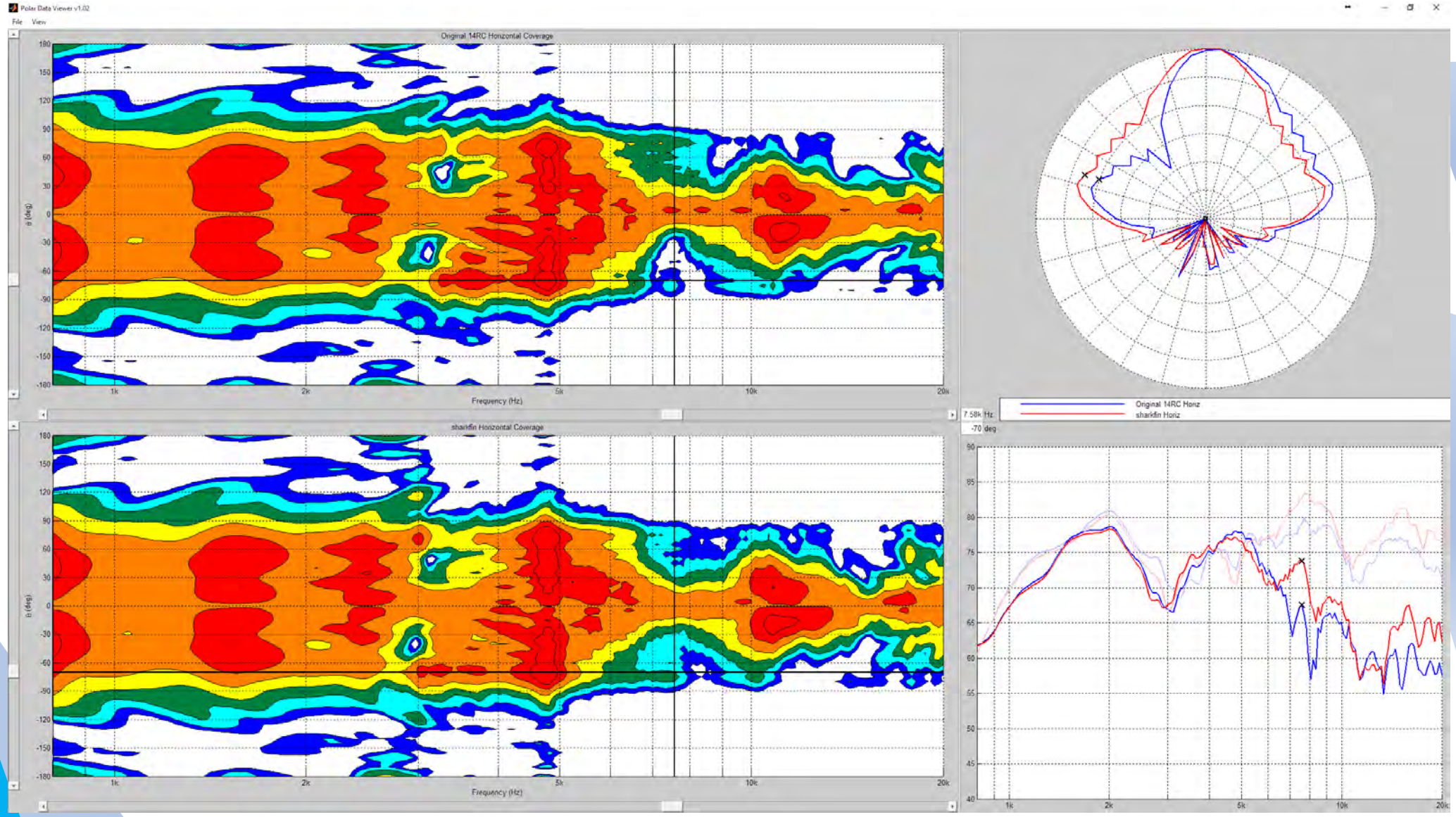

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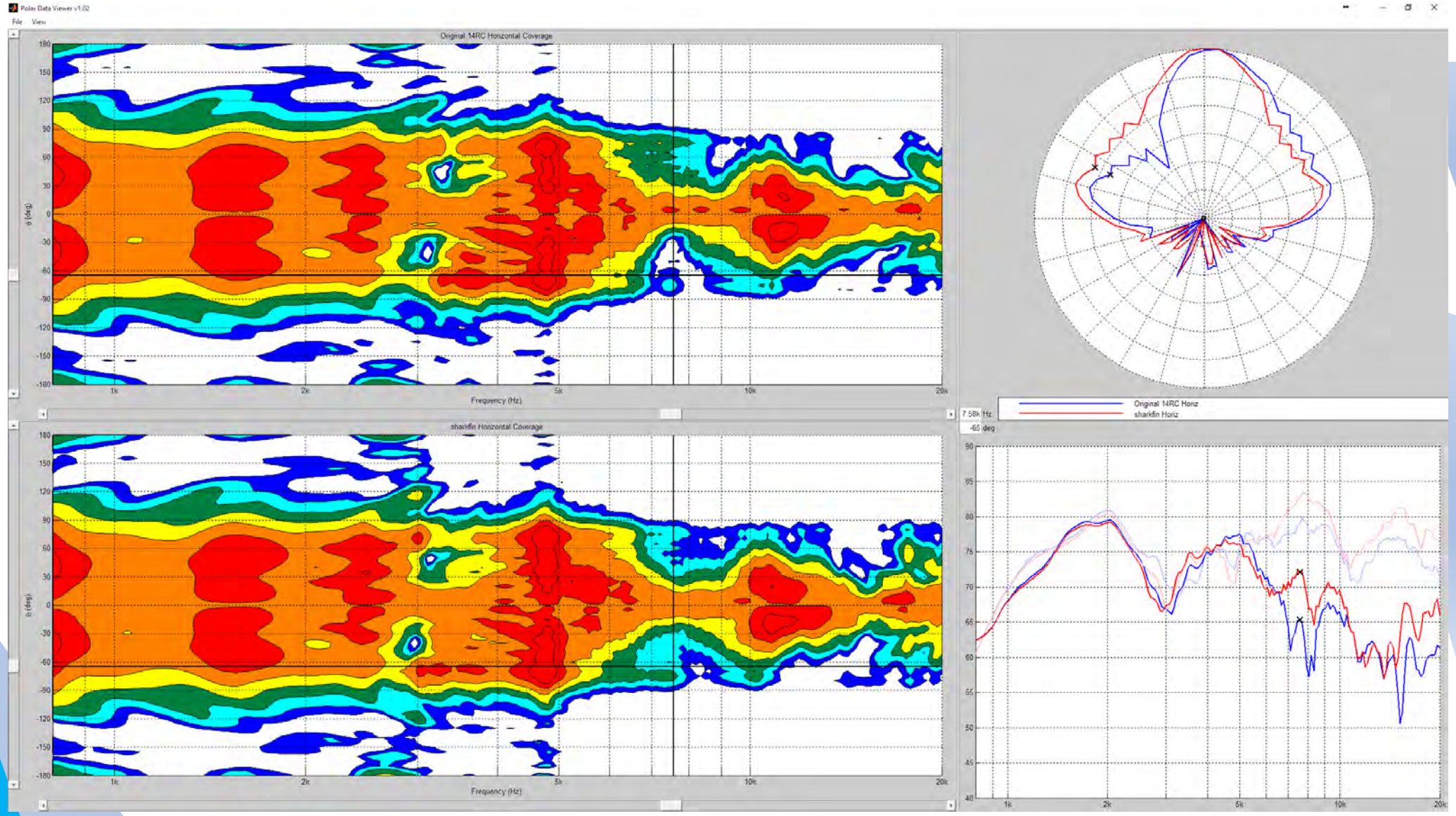

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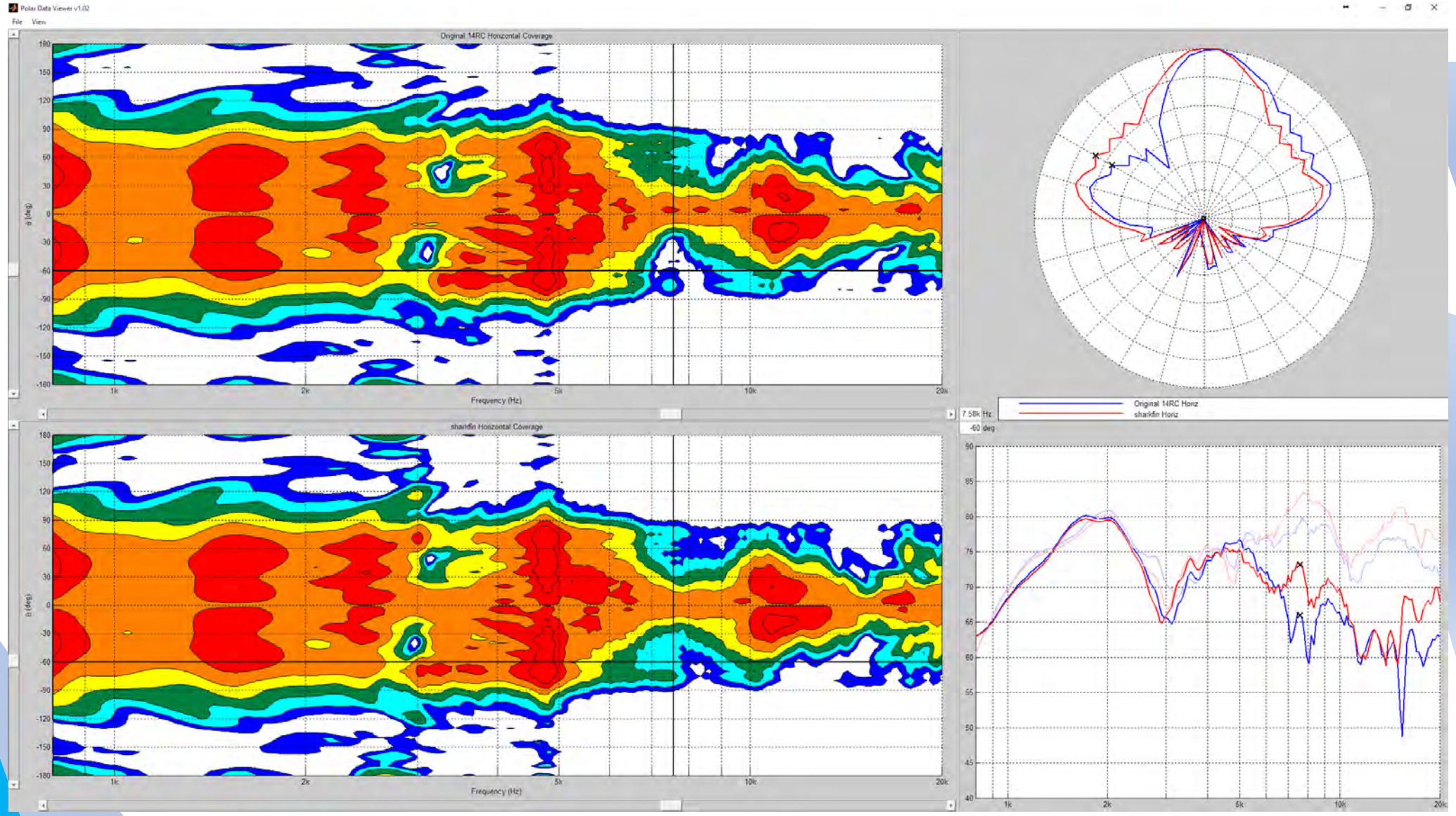

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Results

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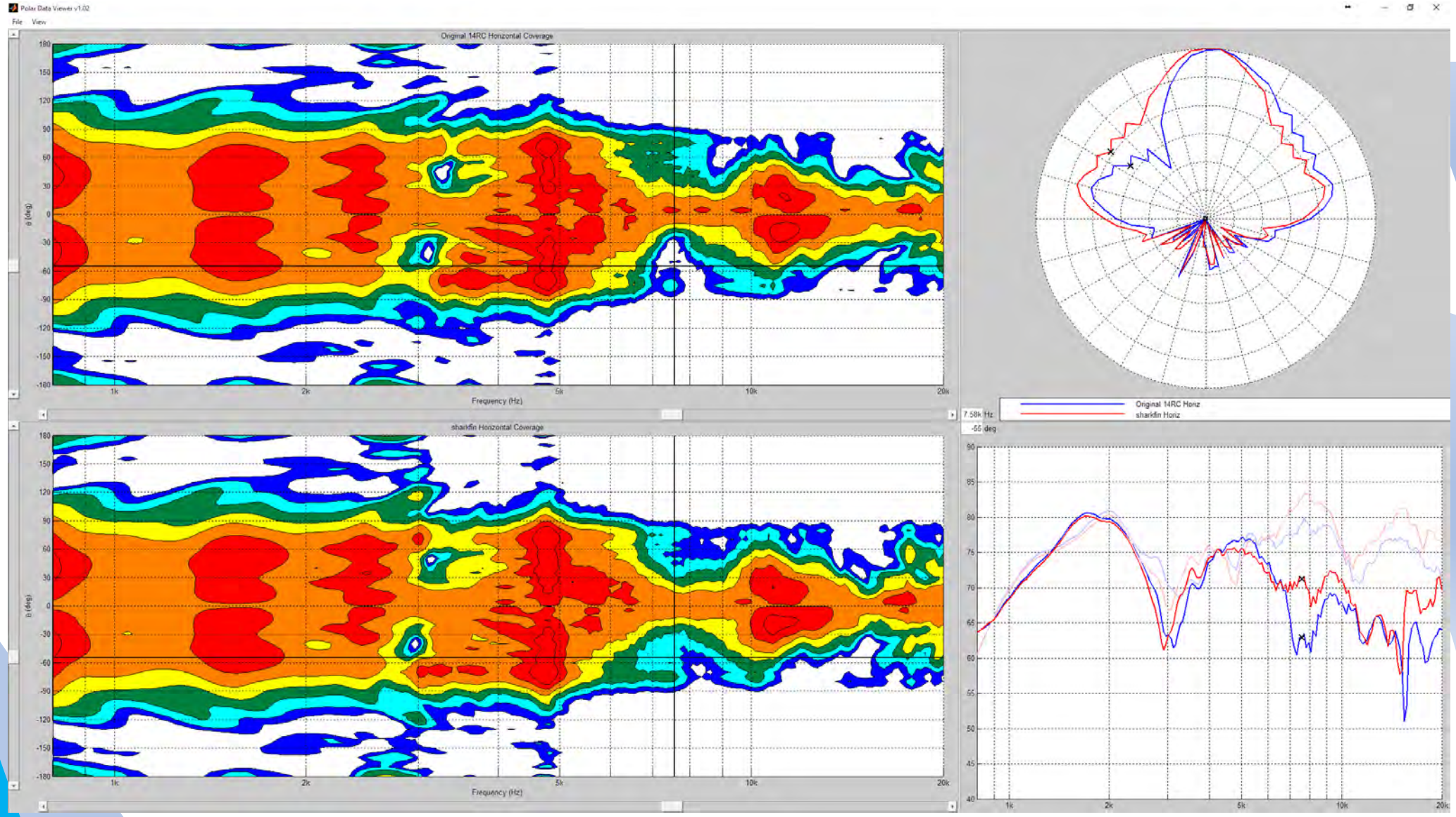

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Results

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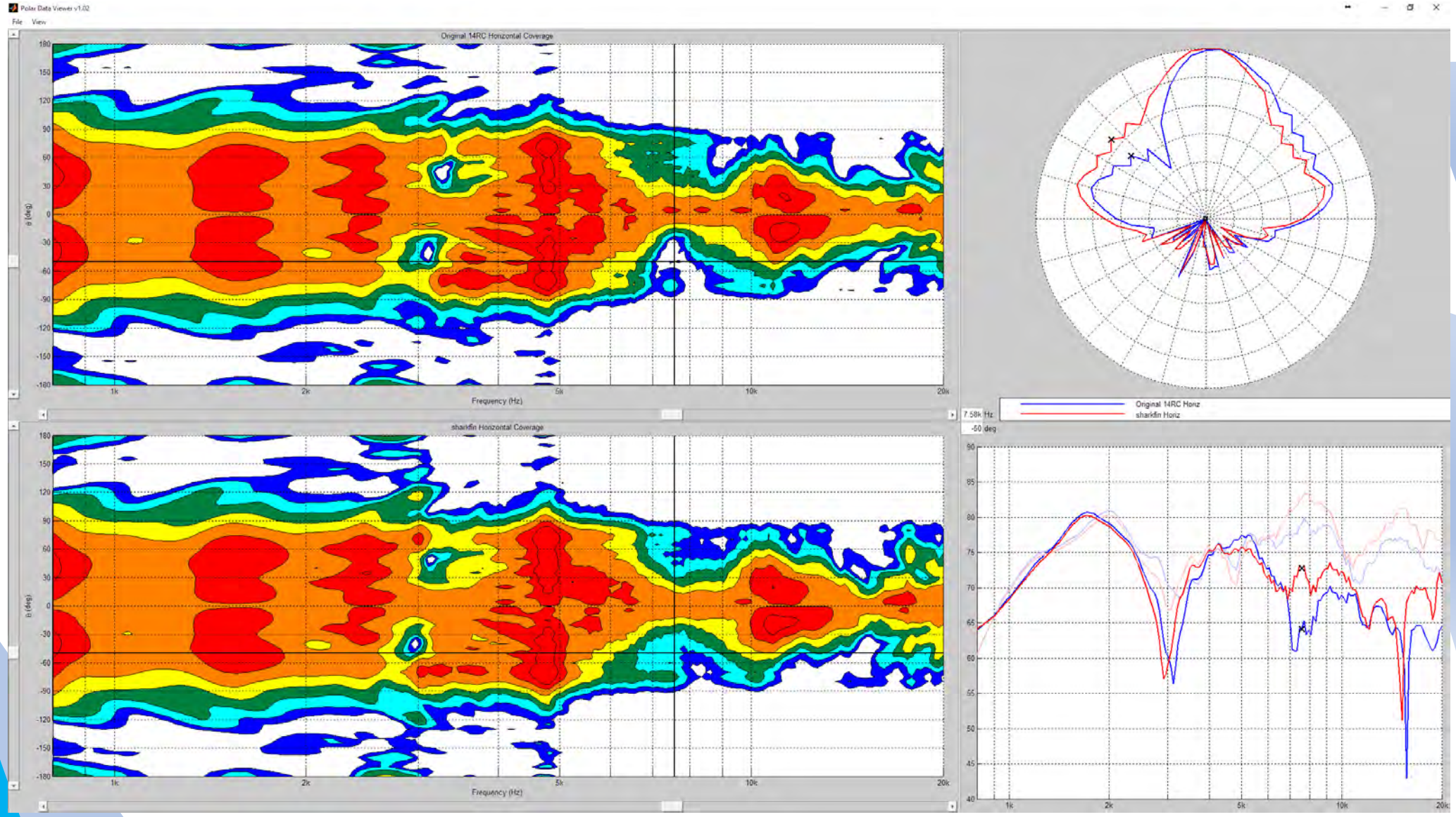

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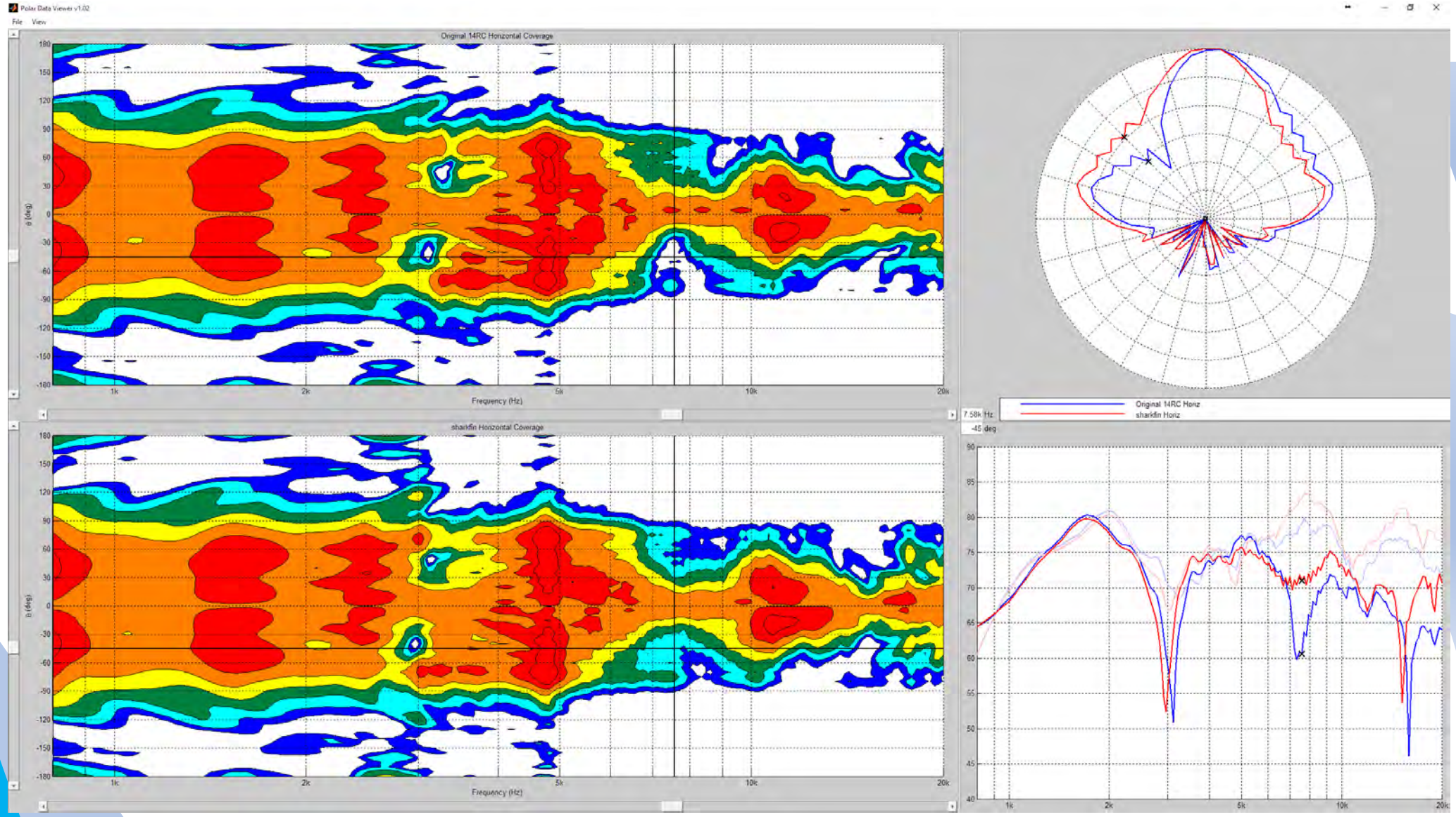
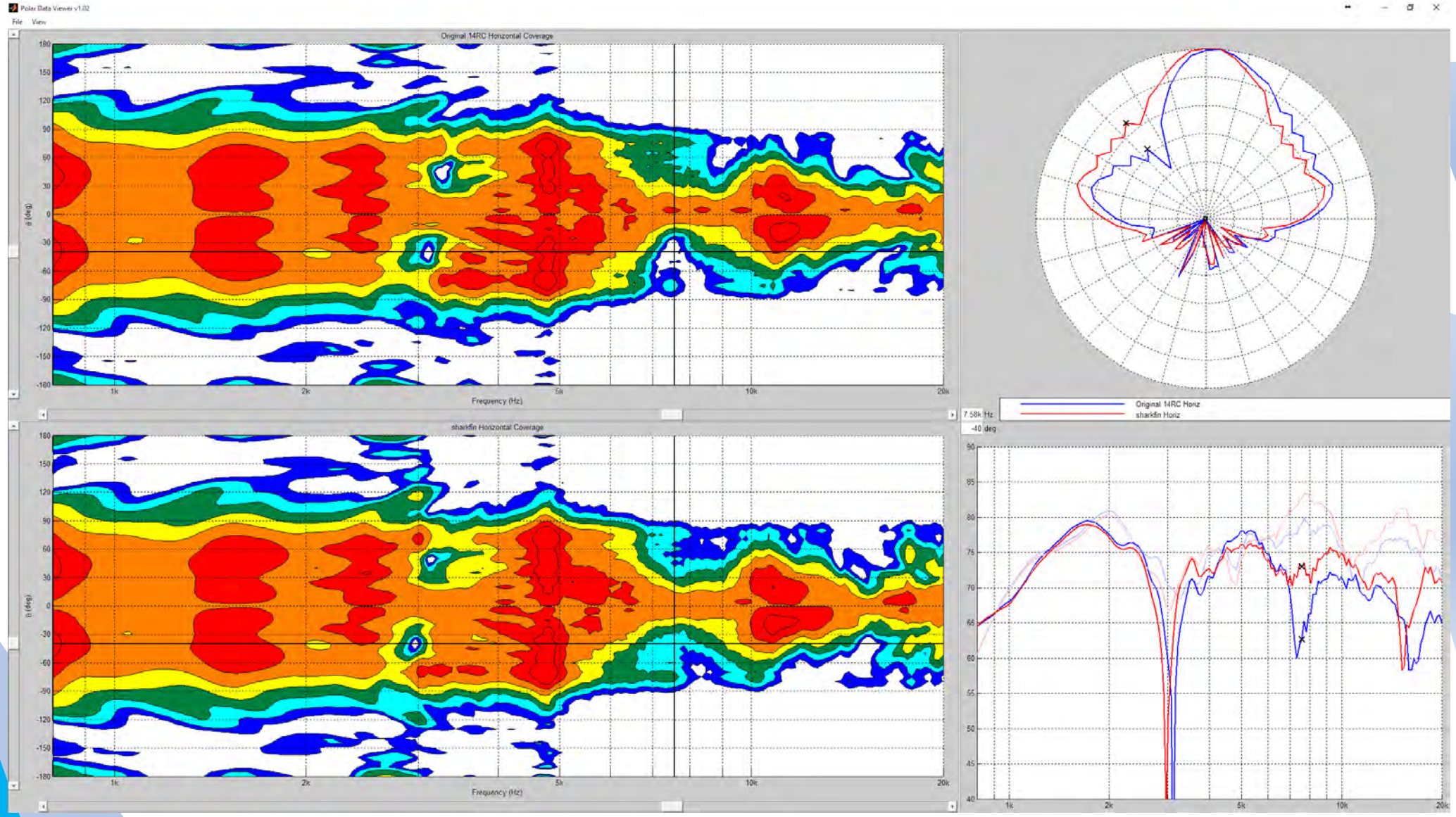
Klipsch® KEEPERS OF THE SOUND



COMSOL CONFERENCE 2017 BOSTON

Results

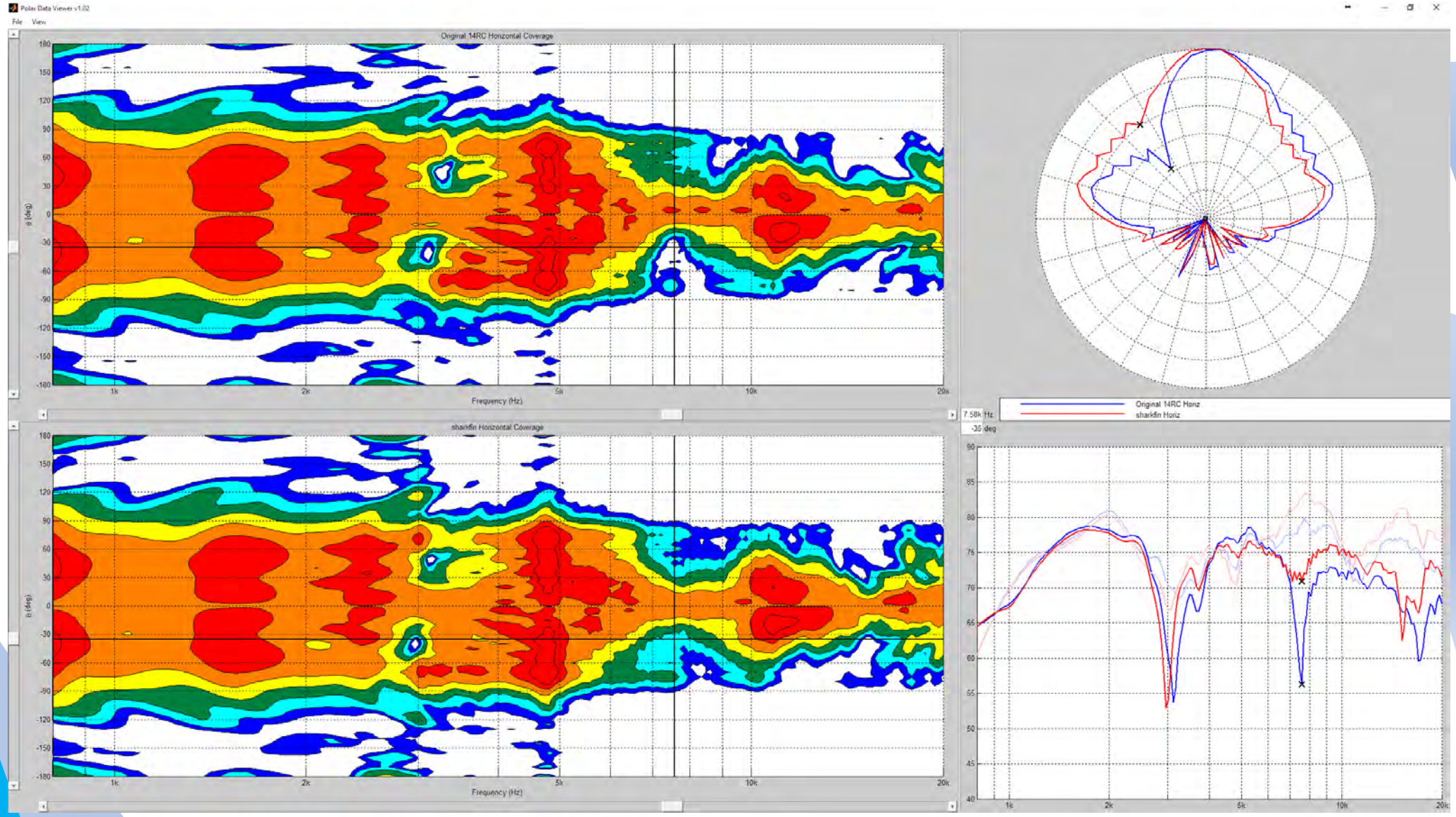
Klipsch® KEEPERS OF THE SOUND



COMSOL CONFERENCE 2017 BOSTON

Results

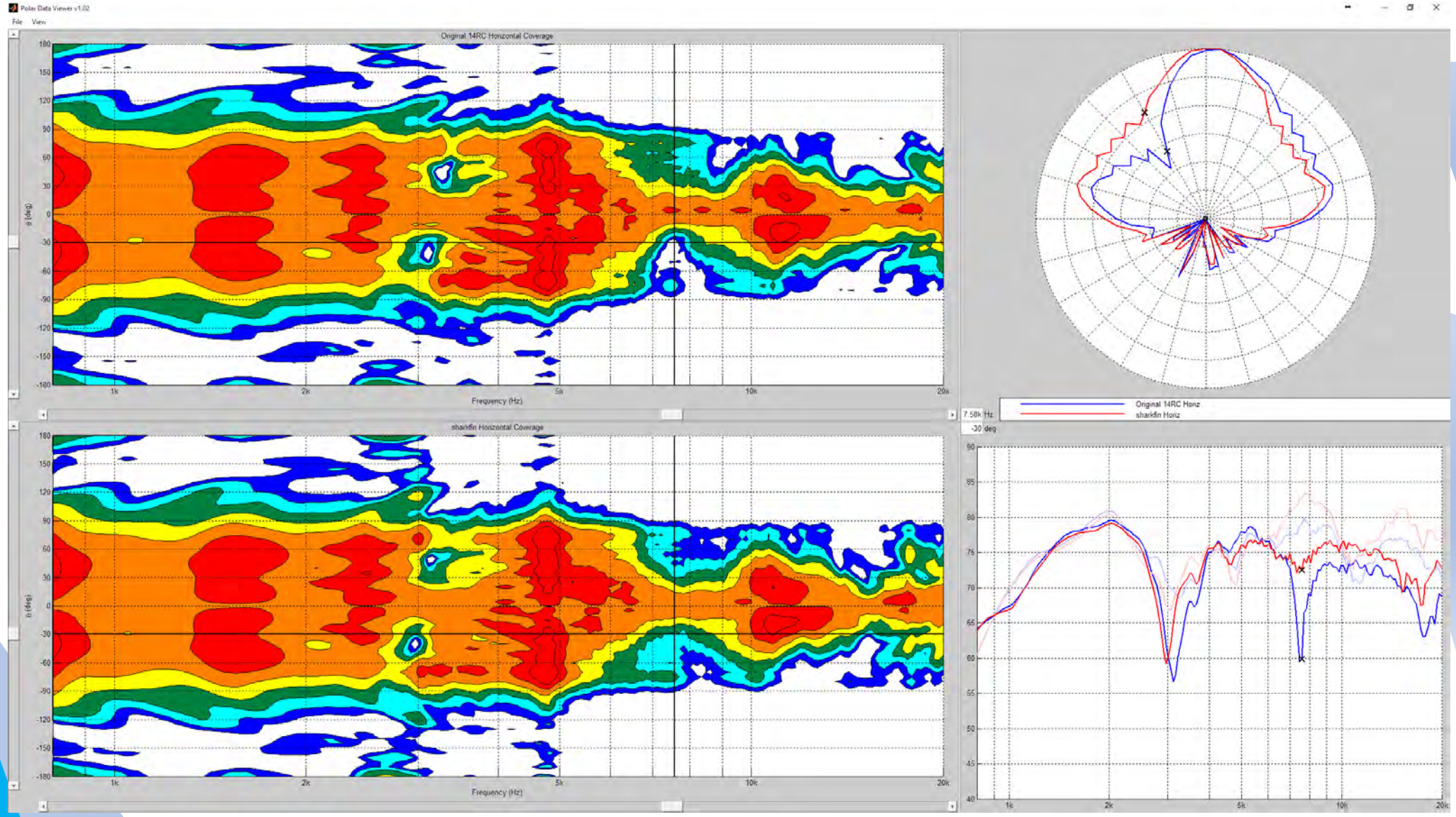
Klipsch® KEEPERS OF THE SOUND



COMSOL CONFERENCE 2017 BOSTON

Results

Klipsch® KEEPERS OF THE SOUND



COMSOL CONFERENCE 2017 BOSTON

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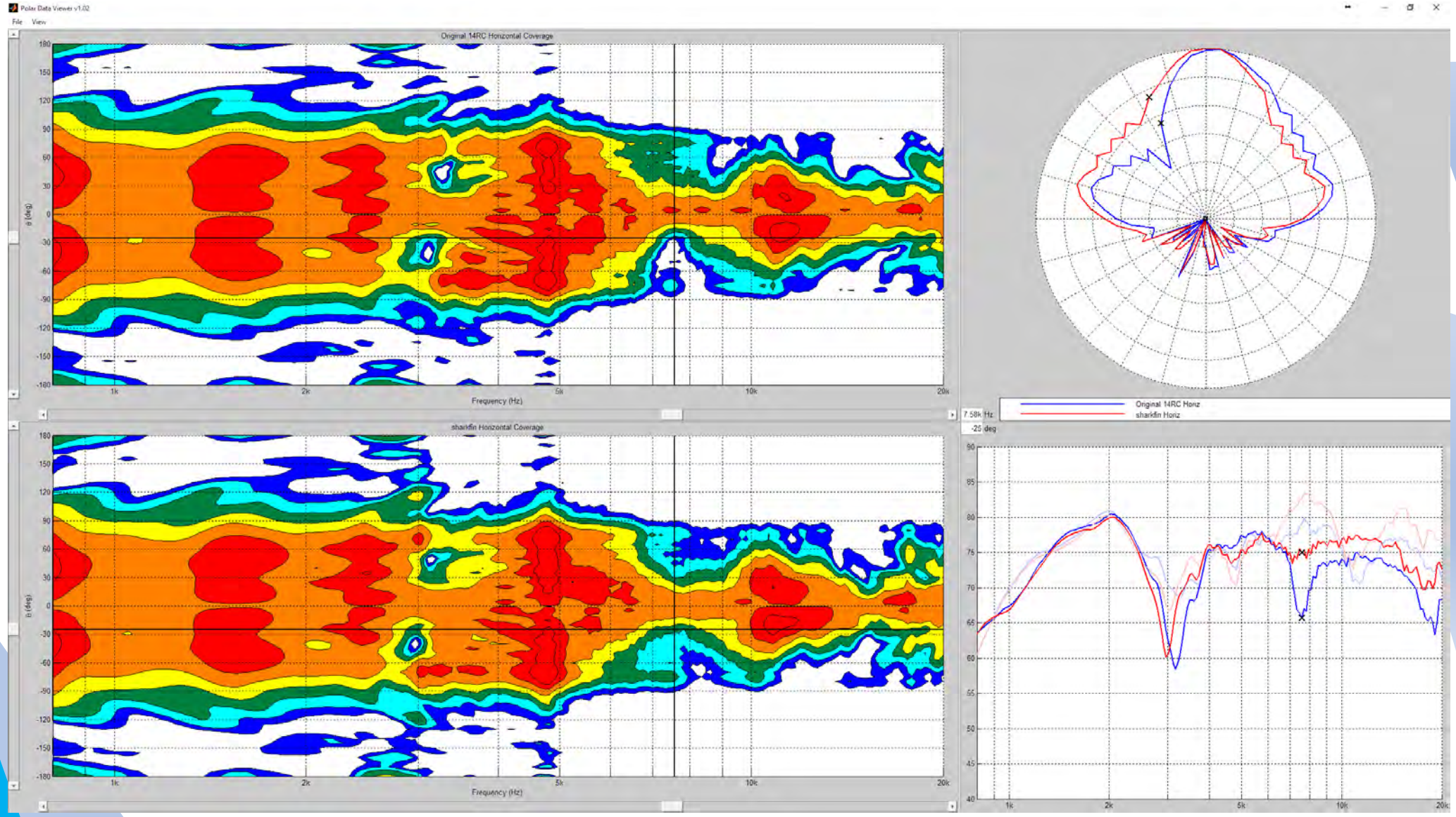
Klipsch® KEEPERS OF THE SOUND



COMSOL CONFERENCE 2017 BOSTON

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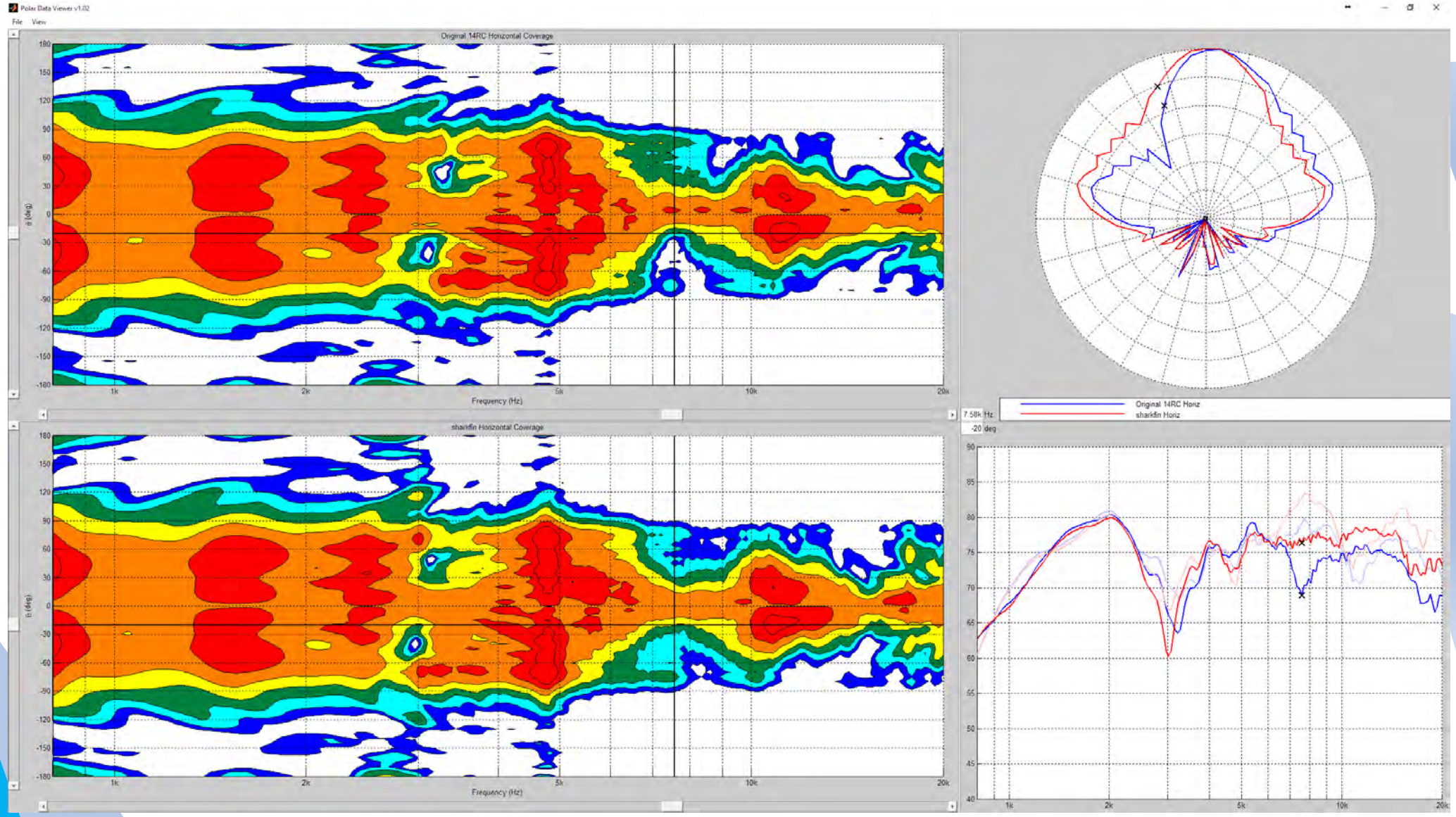

COMSOL CONFERENCE 2017 BOSTON

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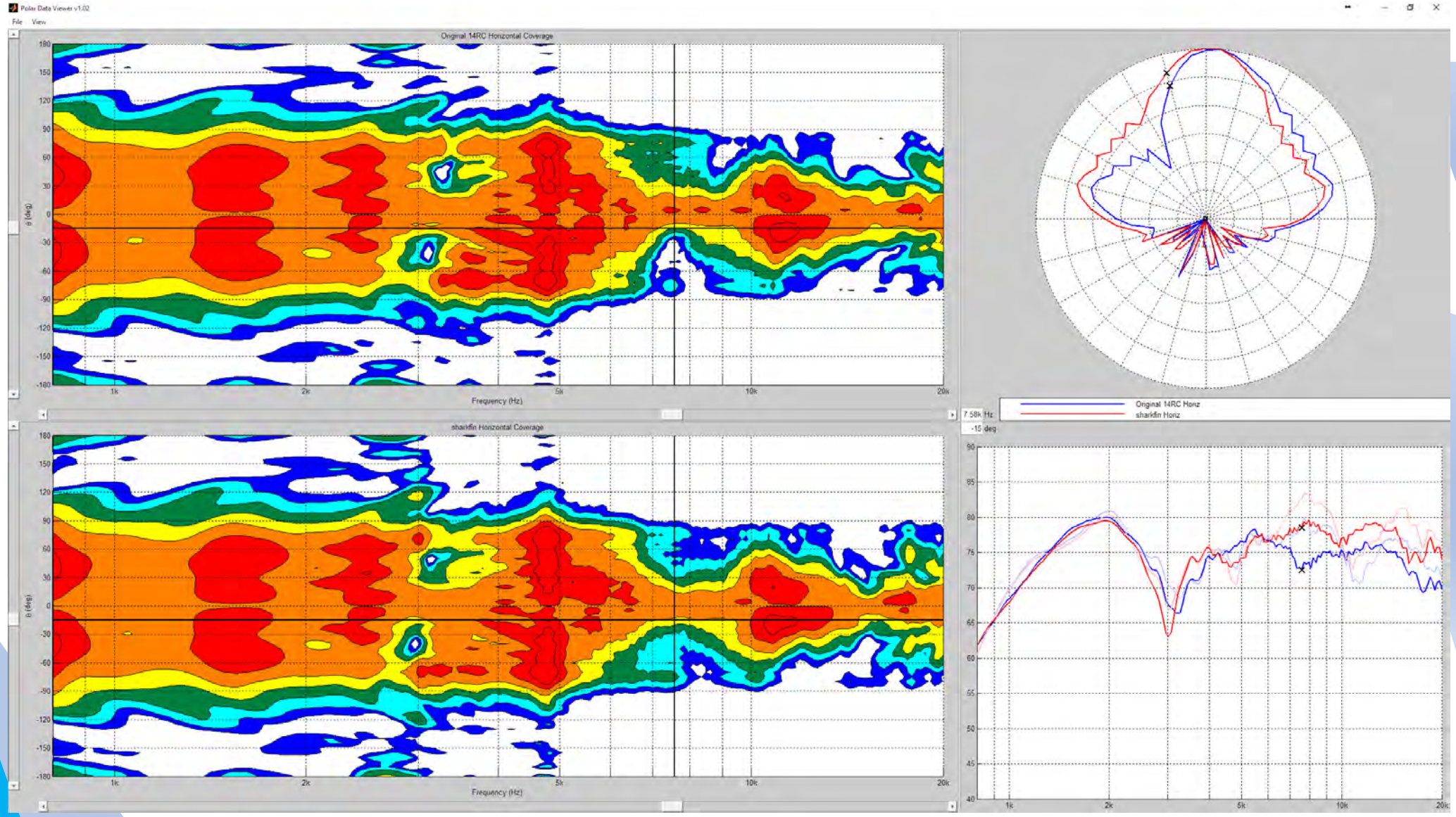

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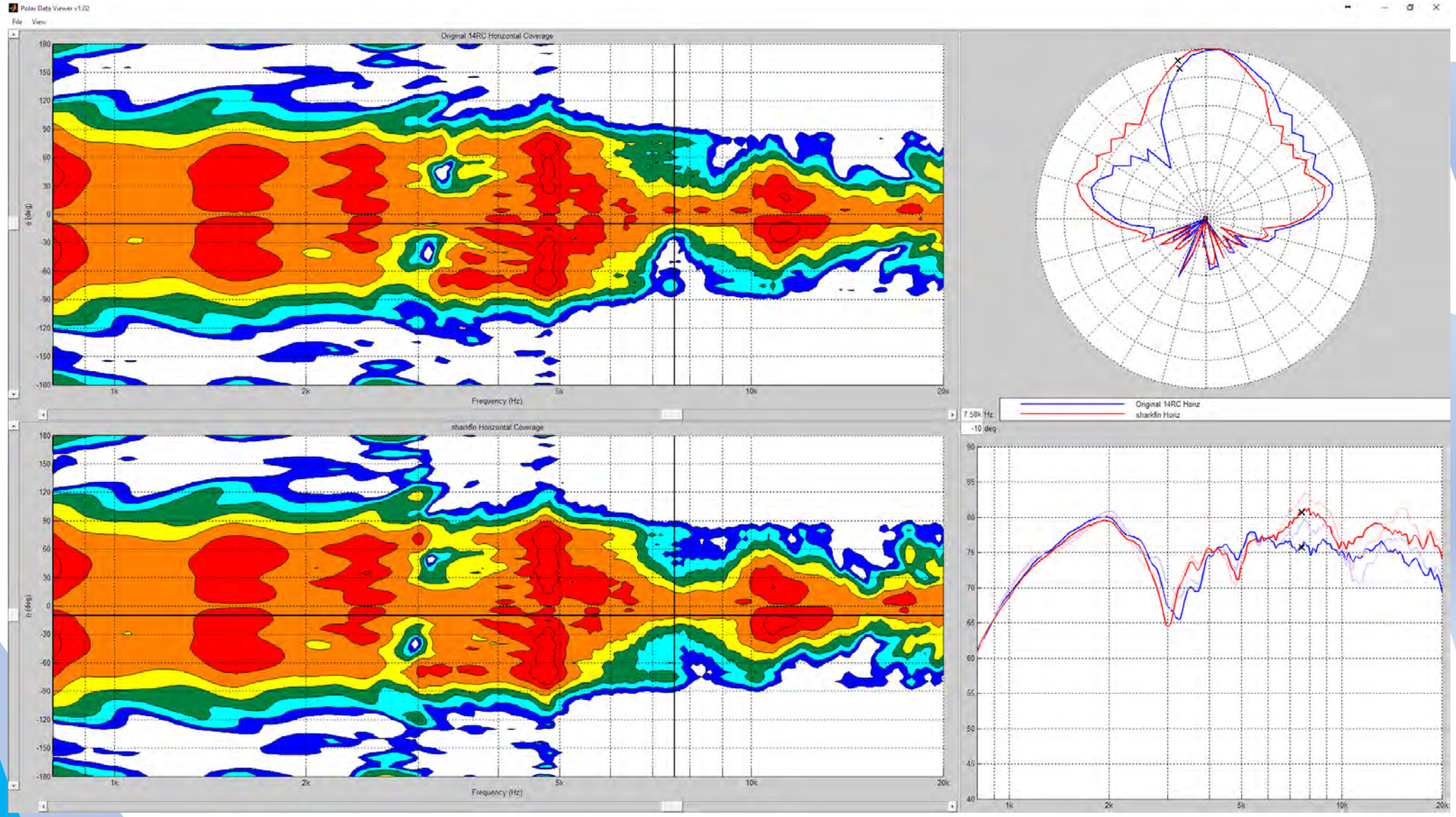

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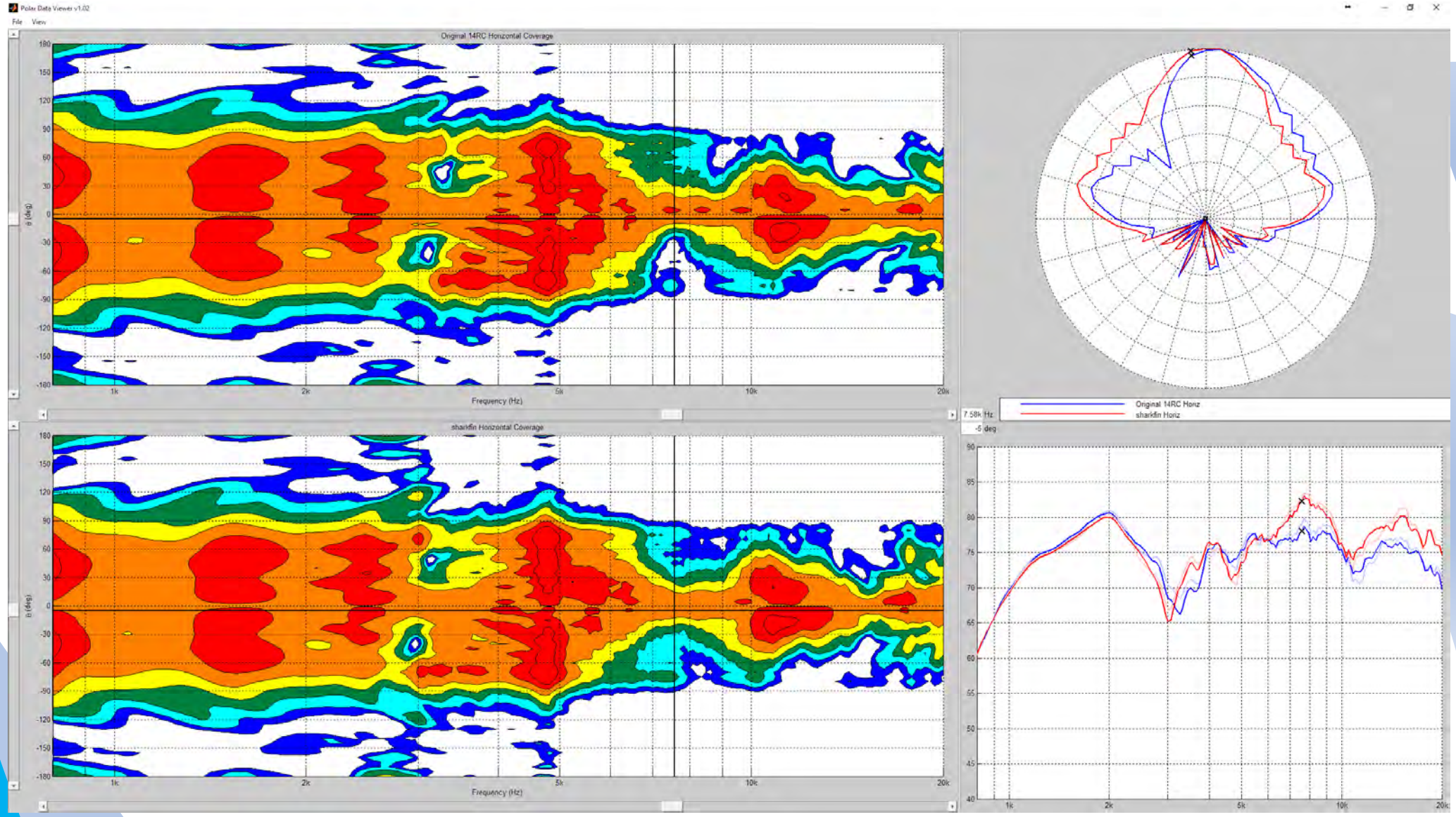

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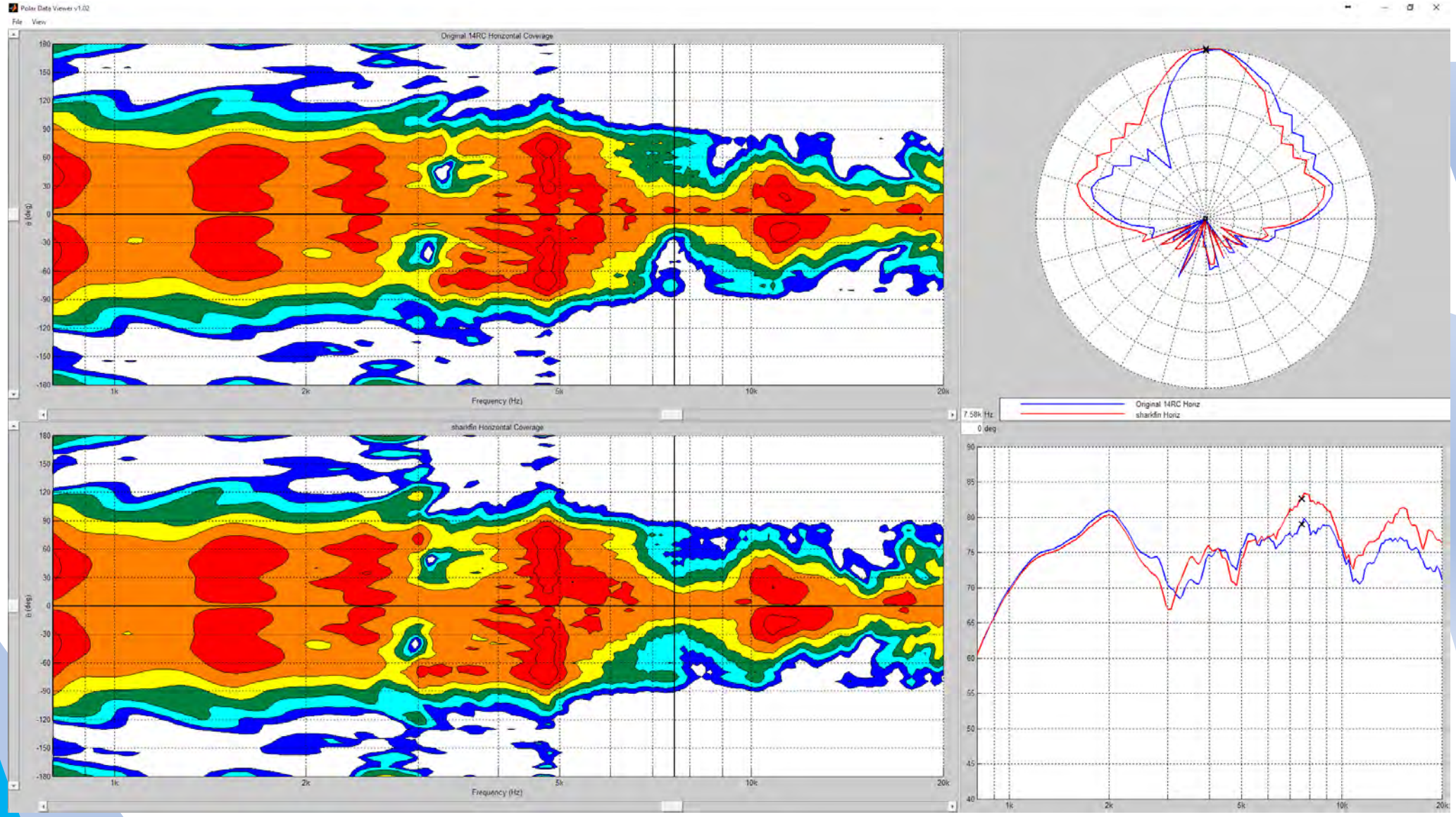

COMSOL CONFERENCE 2017 BOSTON

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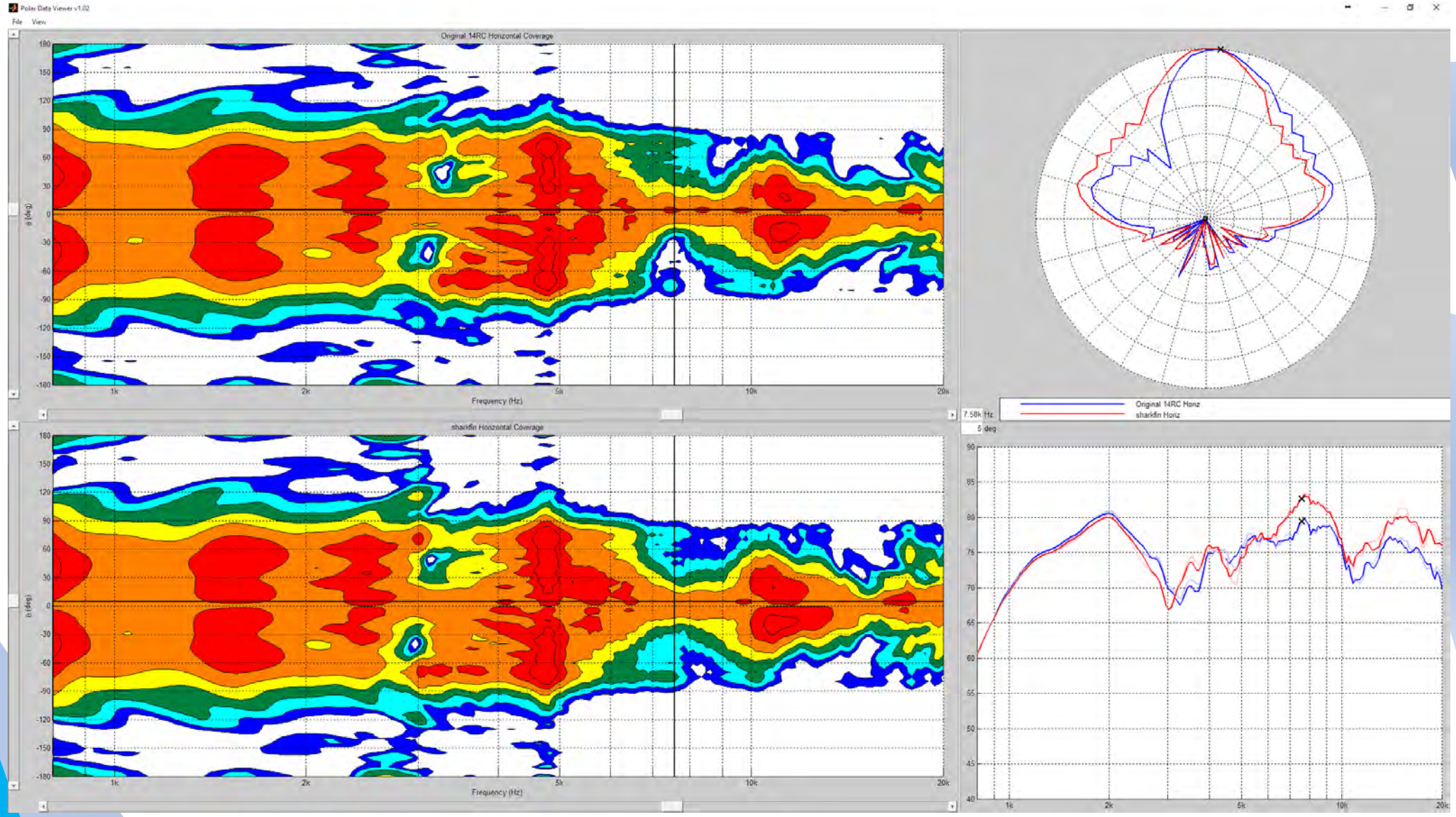

COMSOL CONFERENCE 2017 BOSTON

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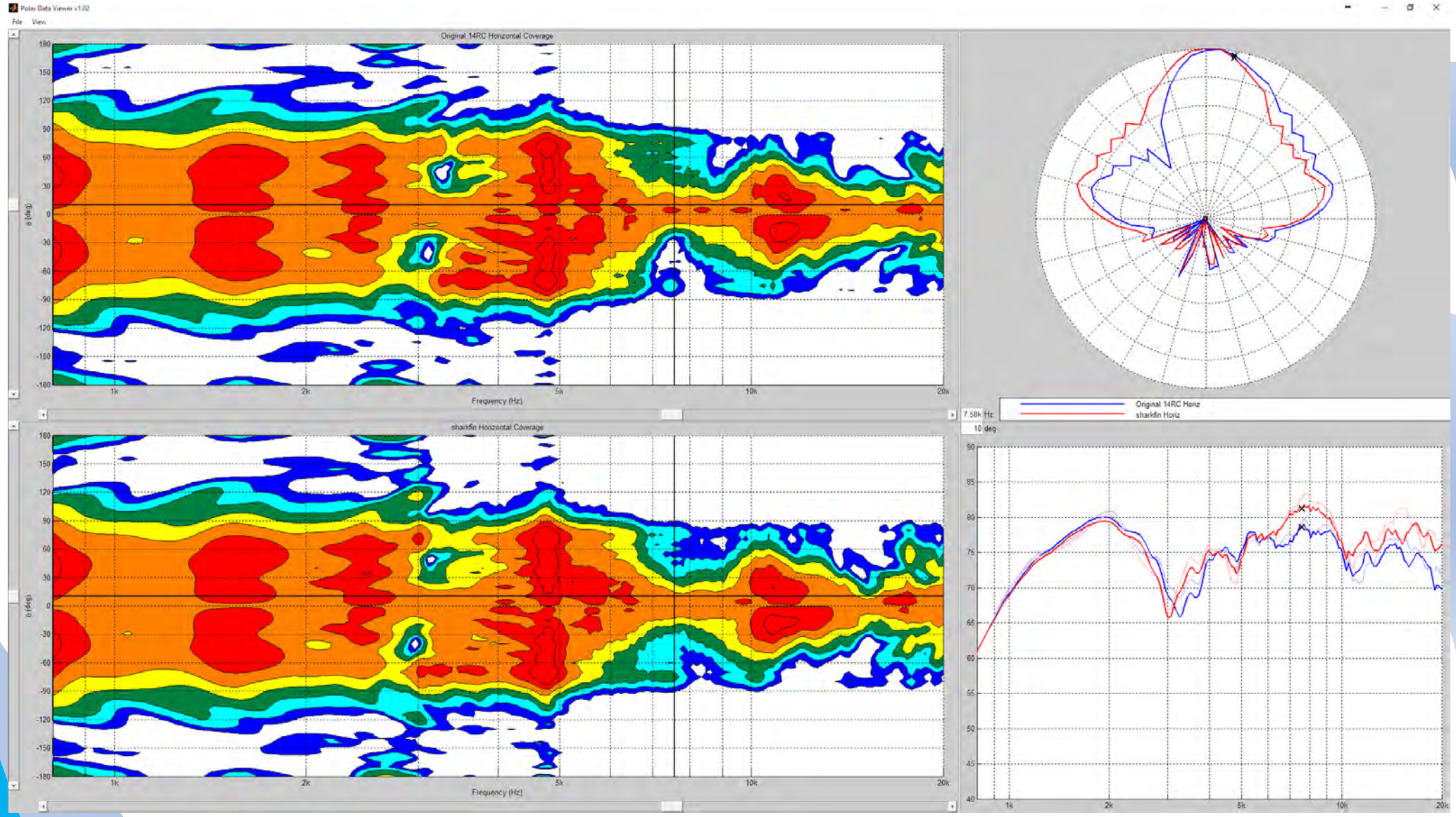

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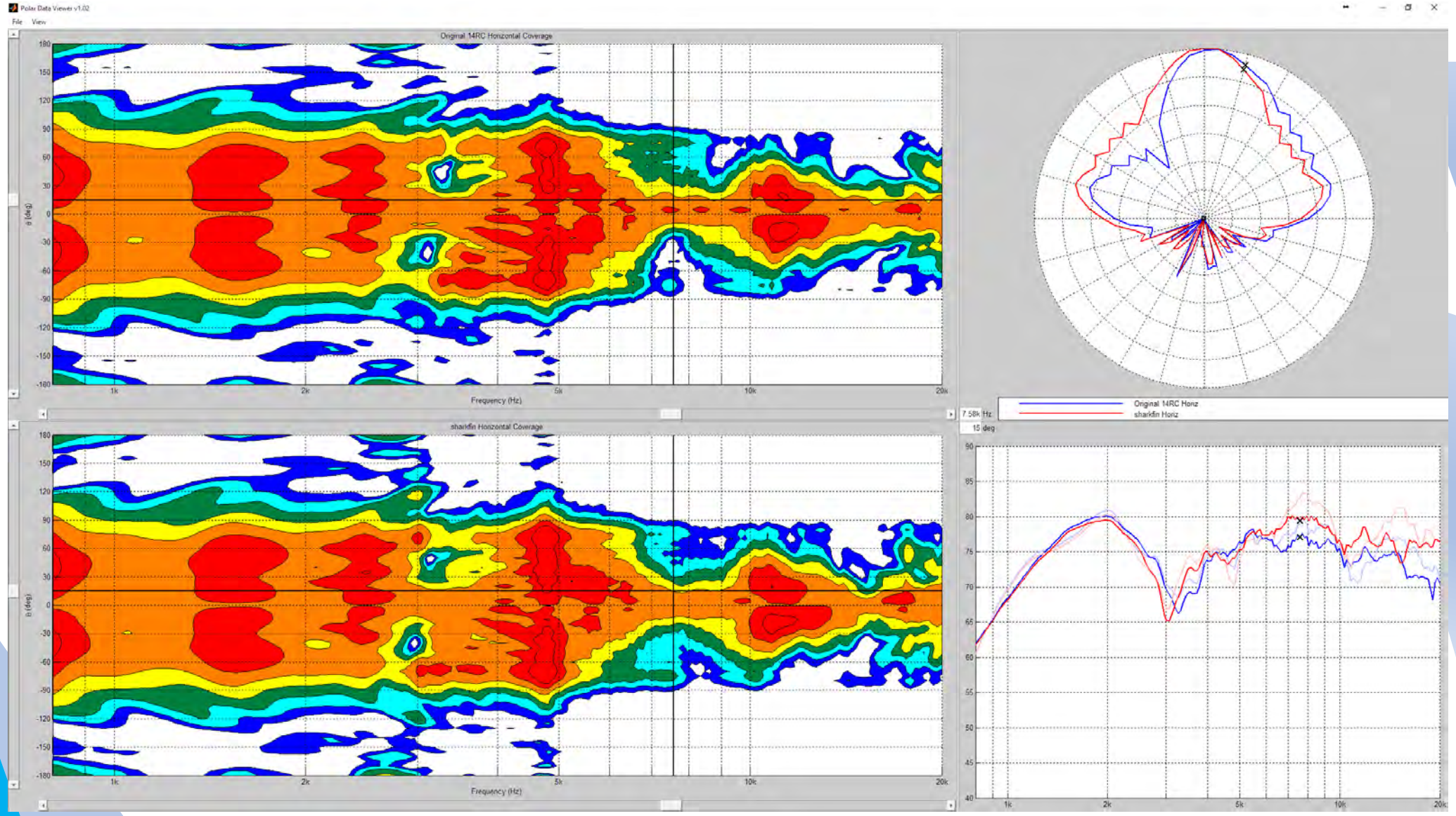

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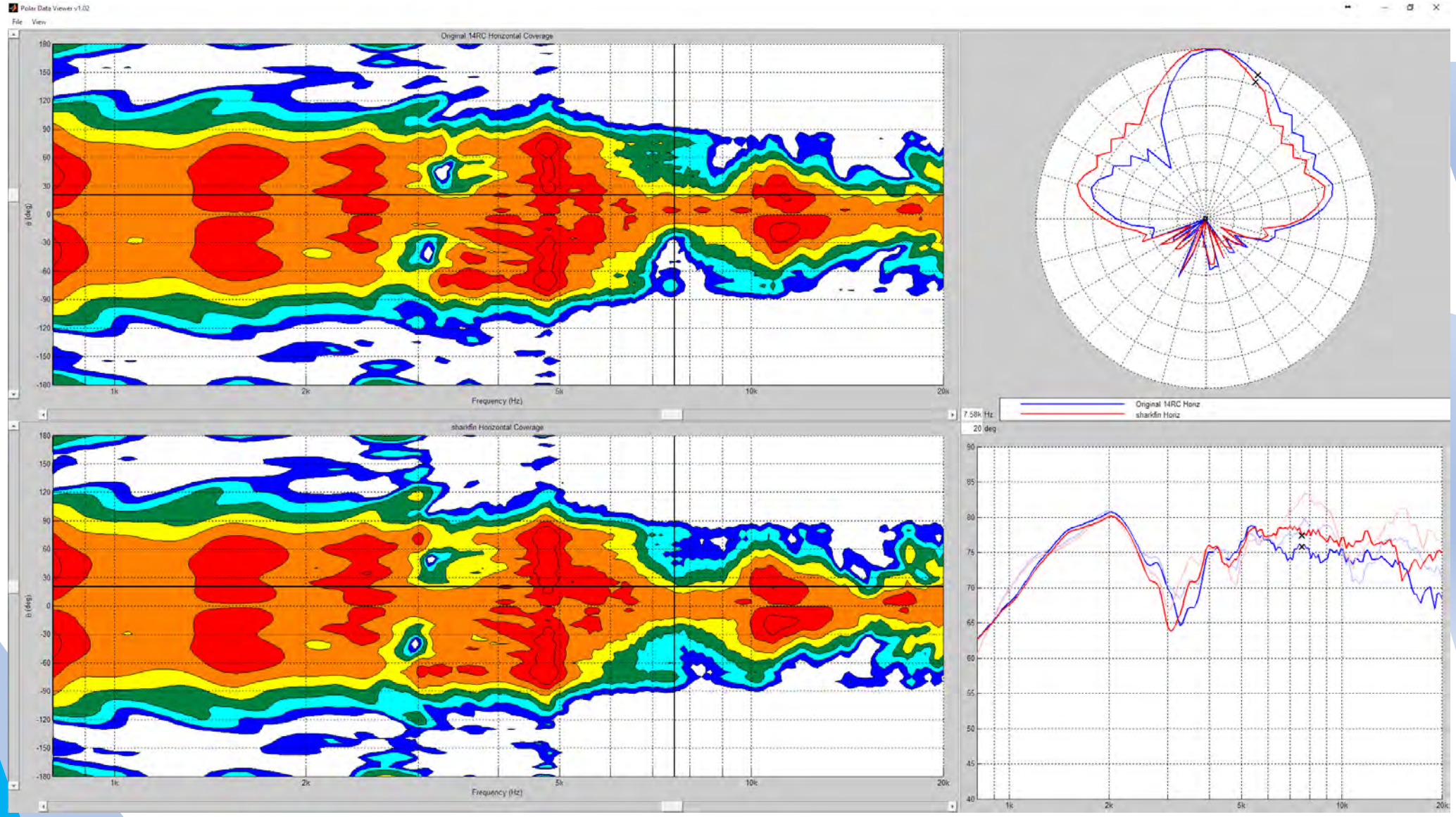

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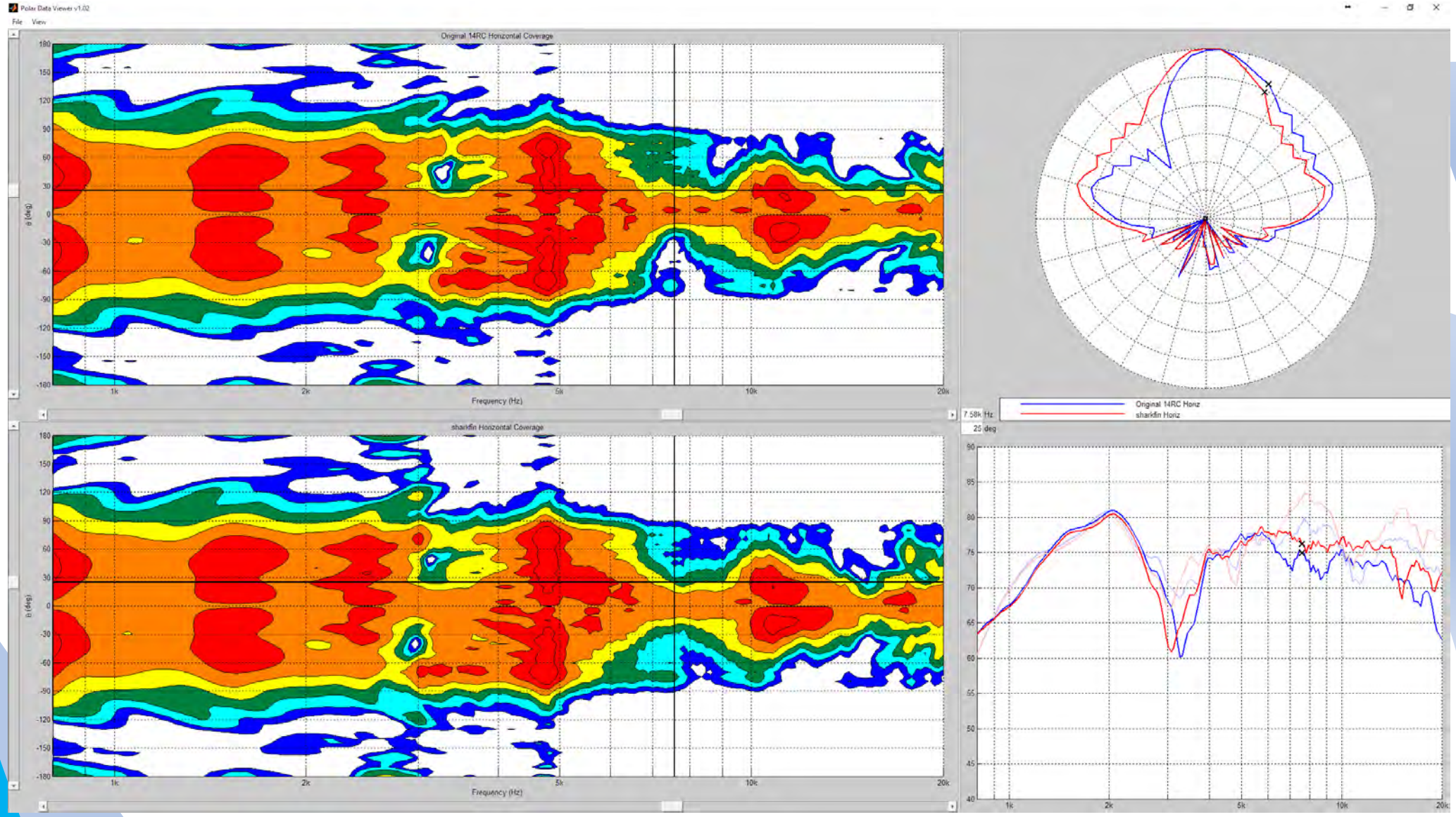

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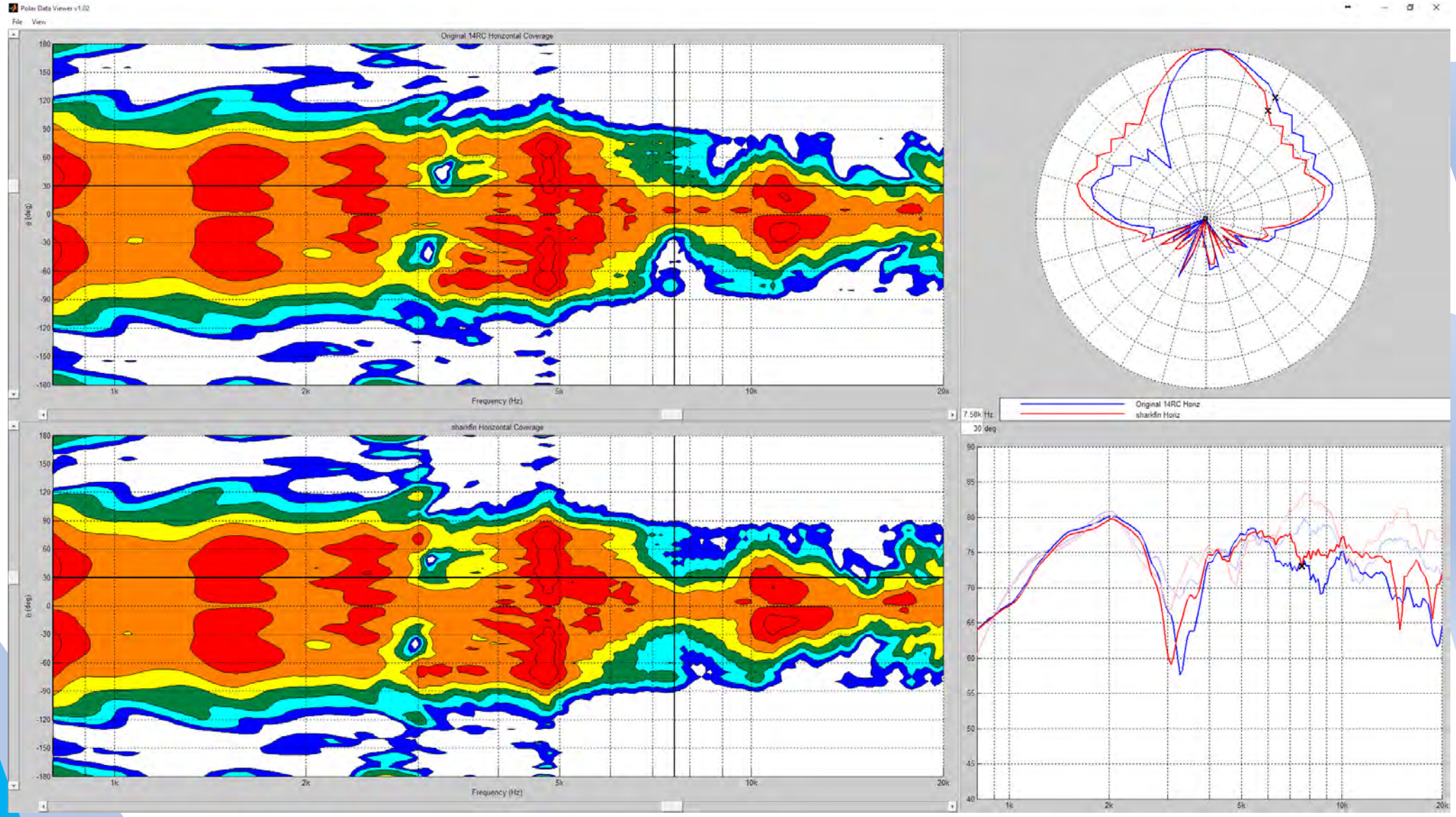

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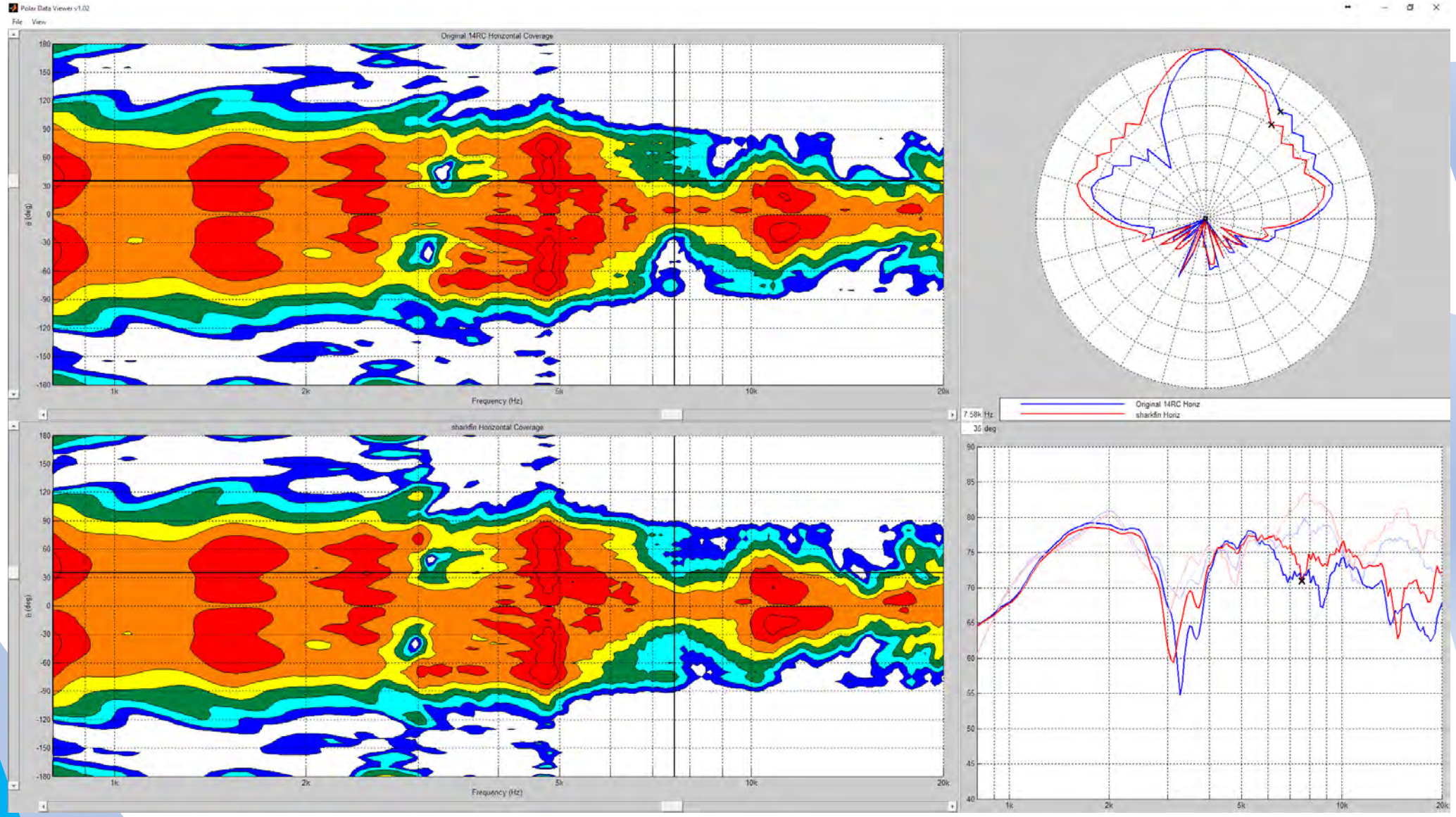

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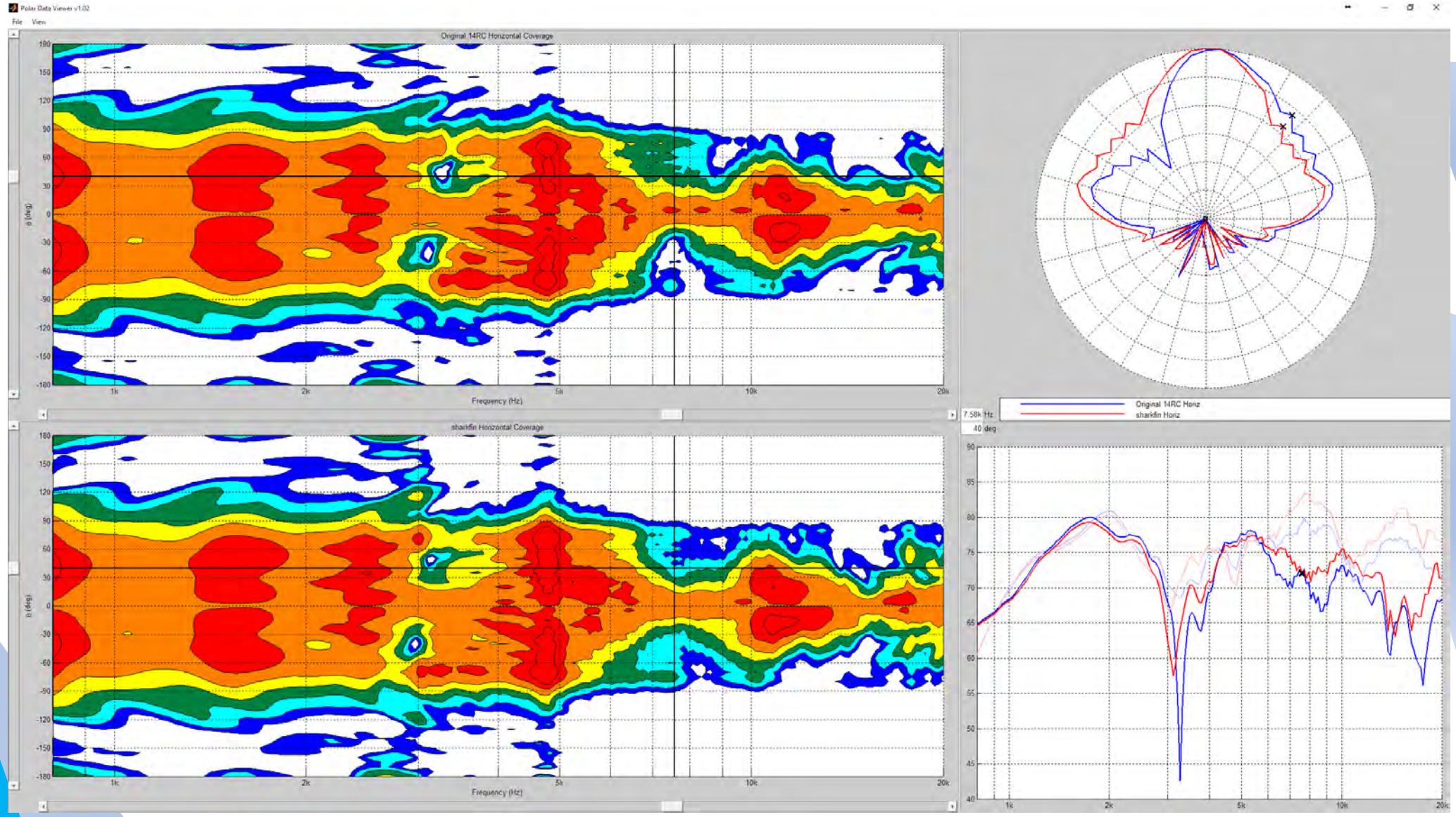

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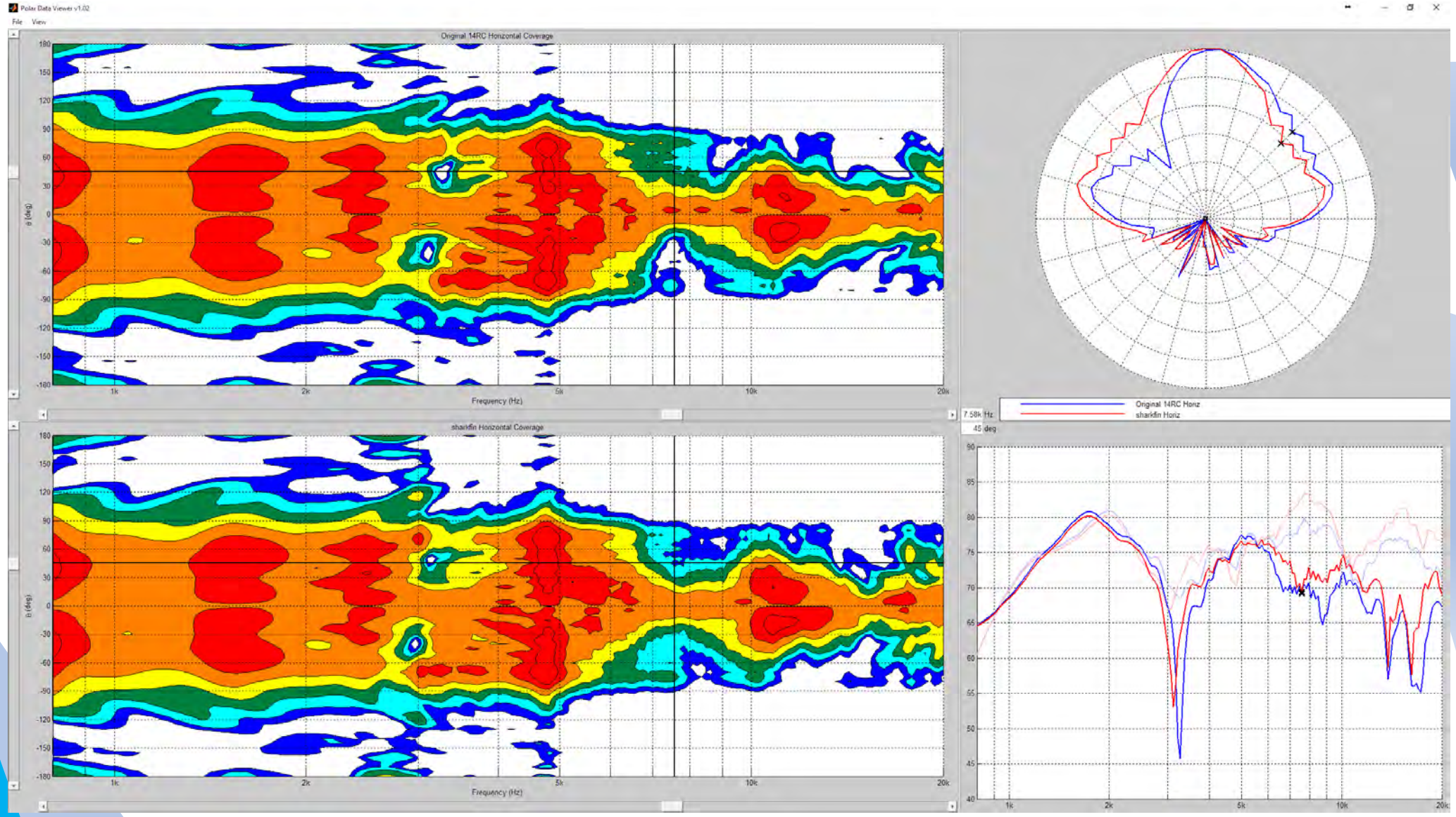

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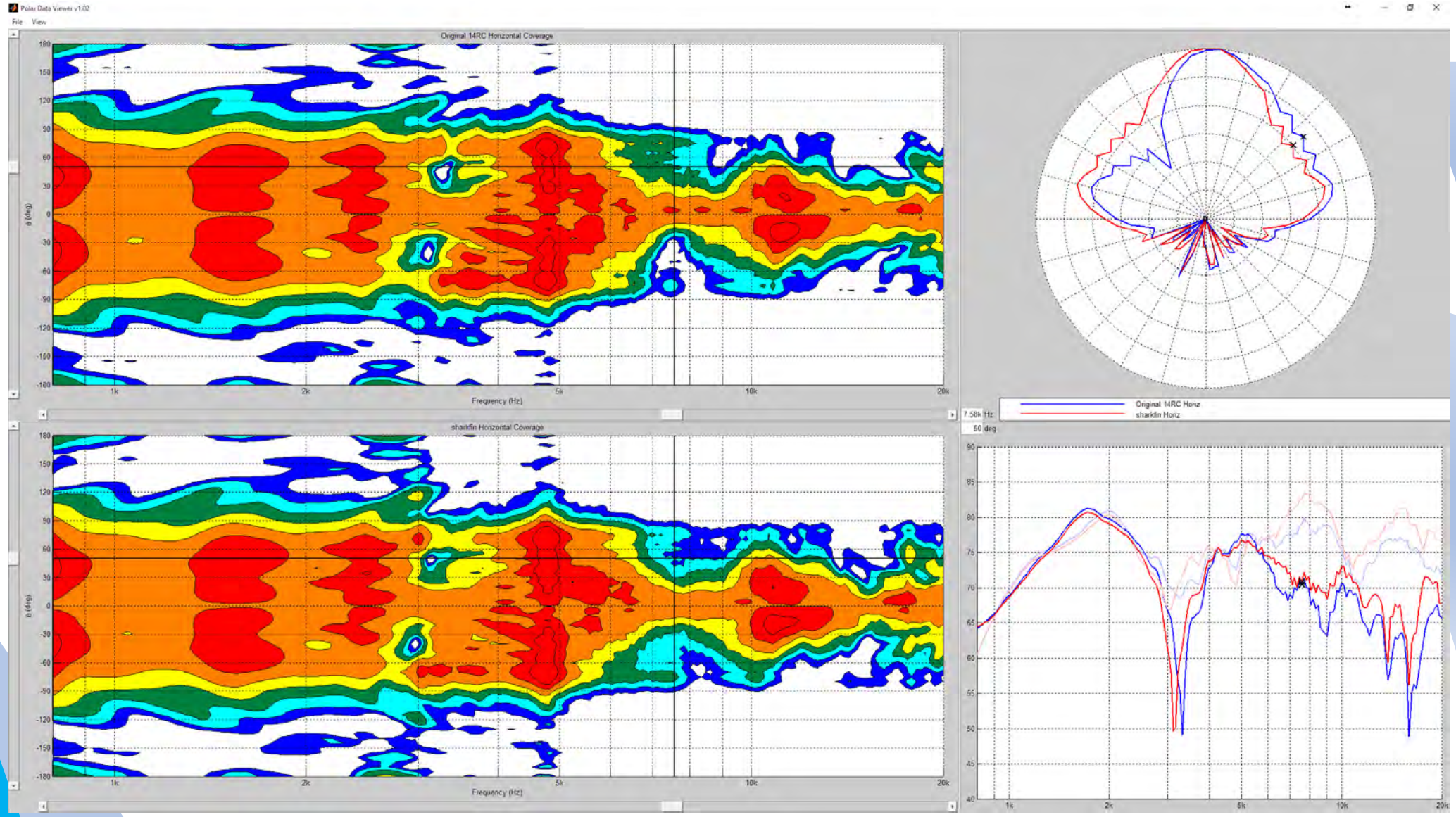

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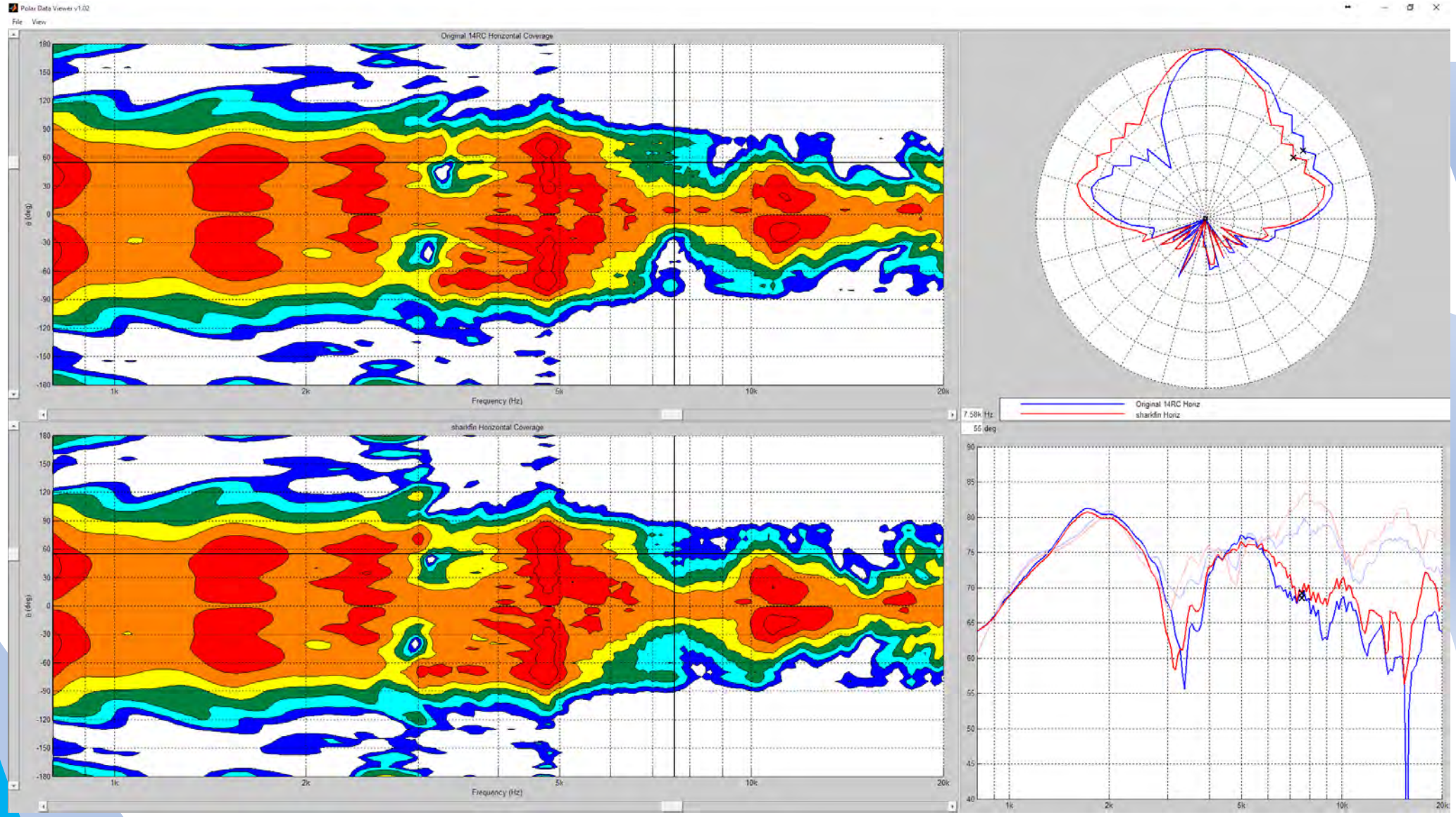

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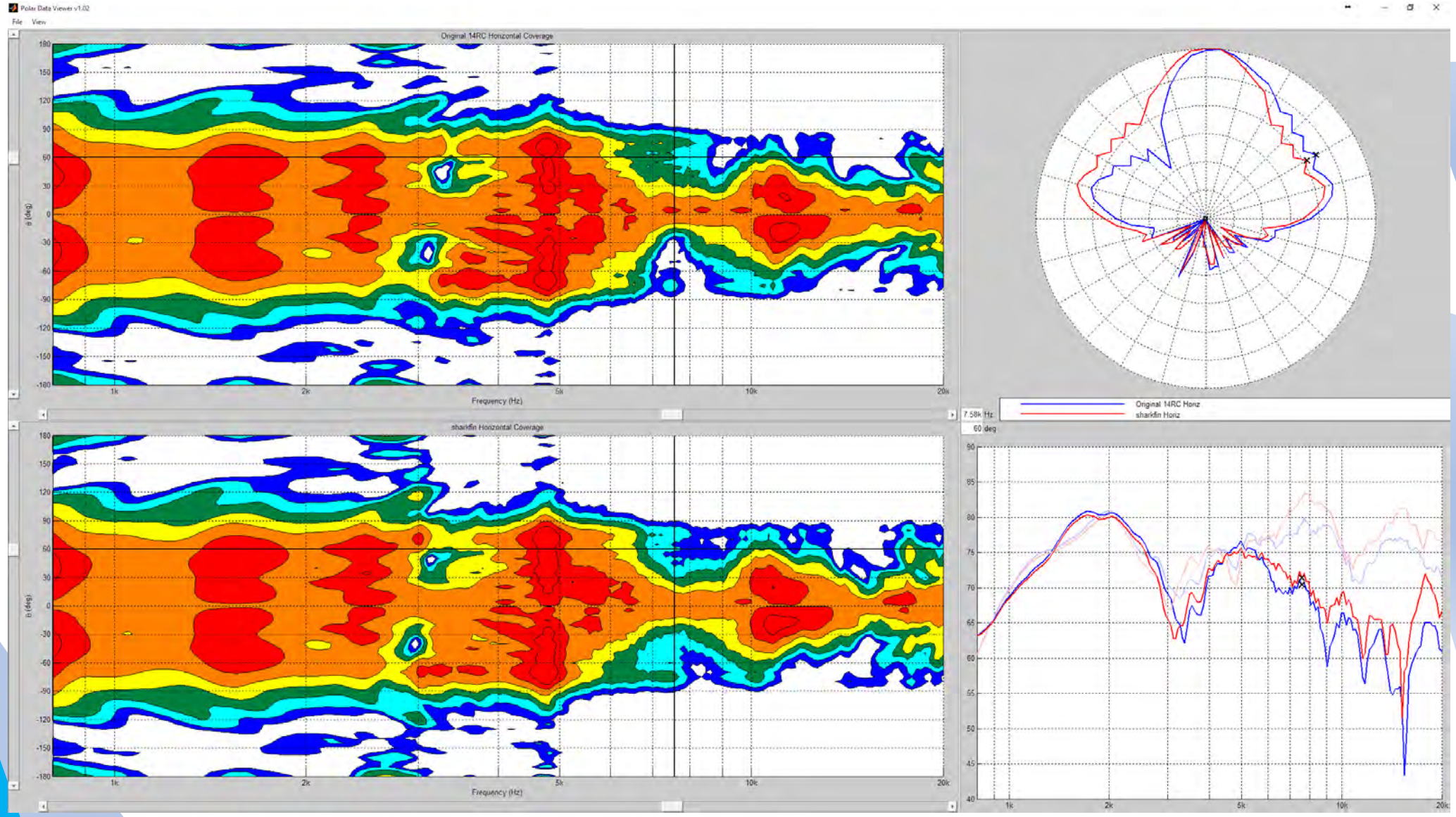

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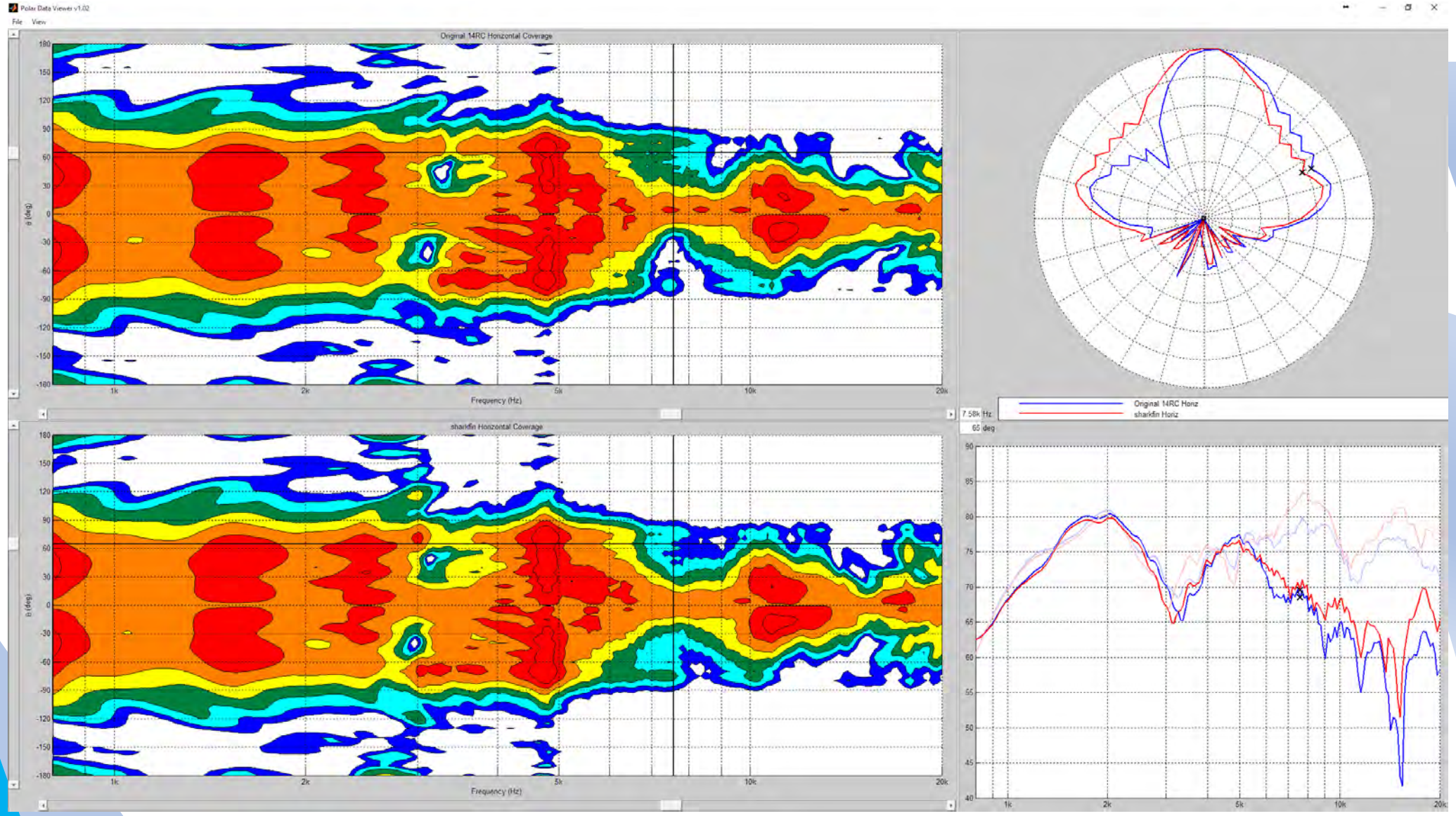

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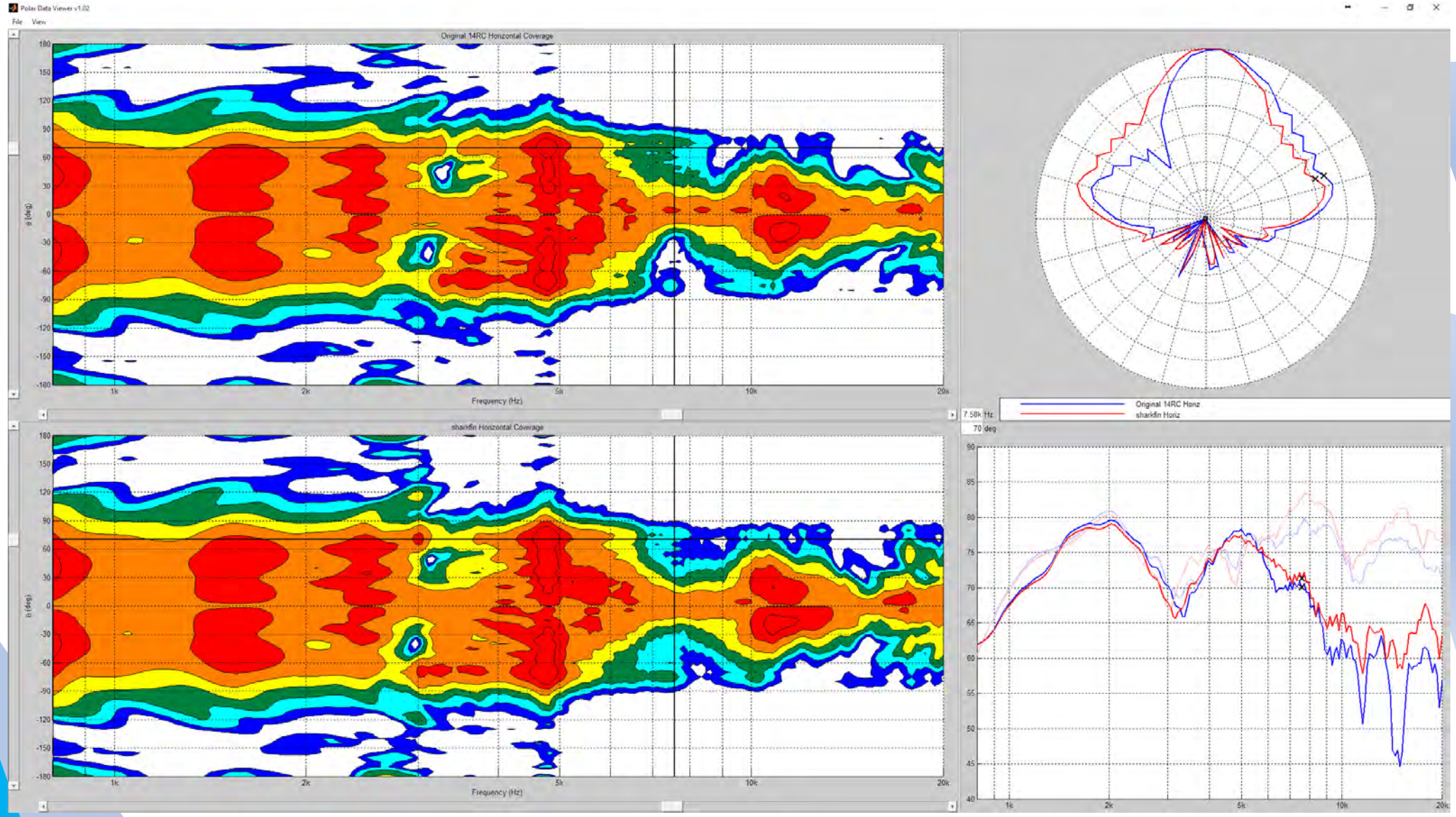

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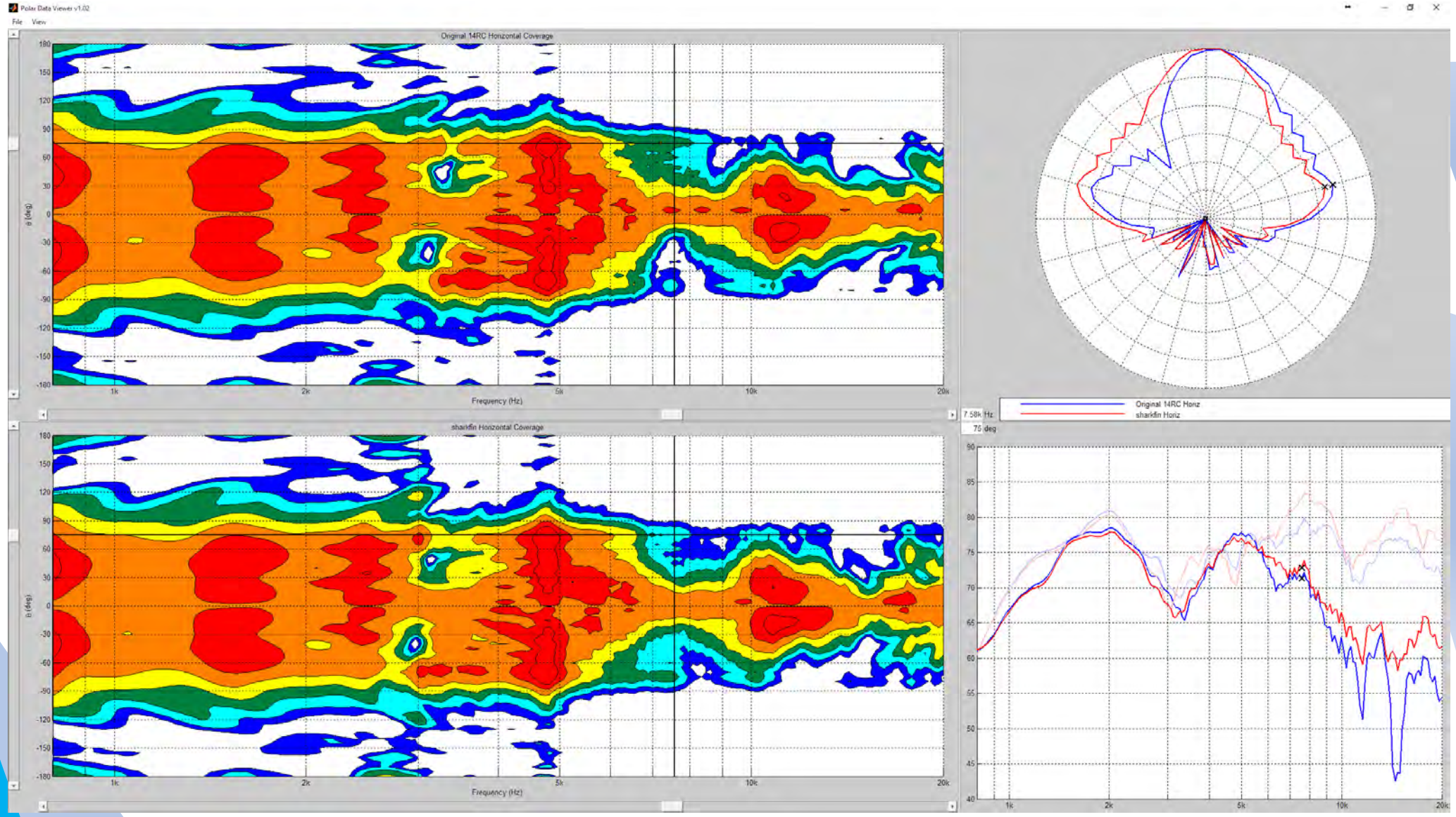

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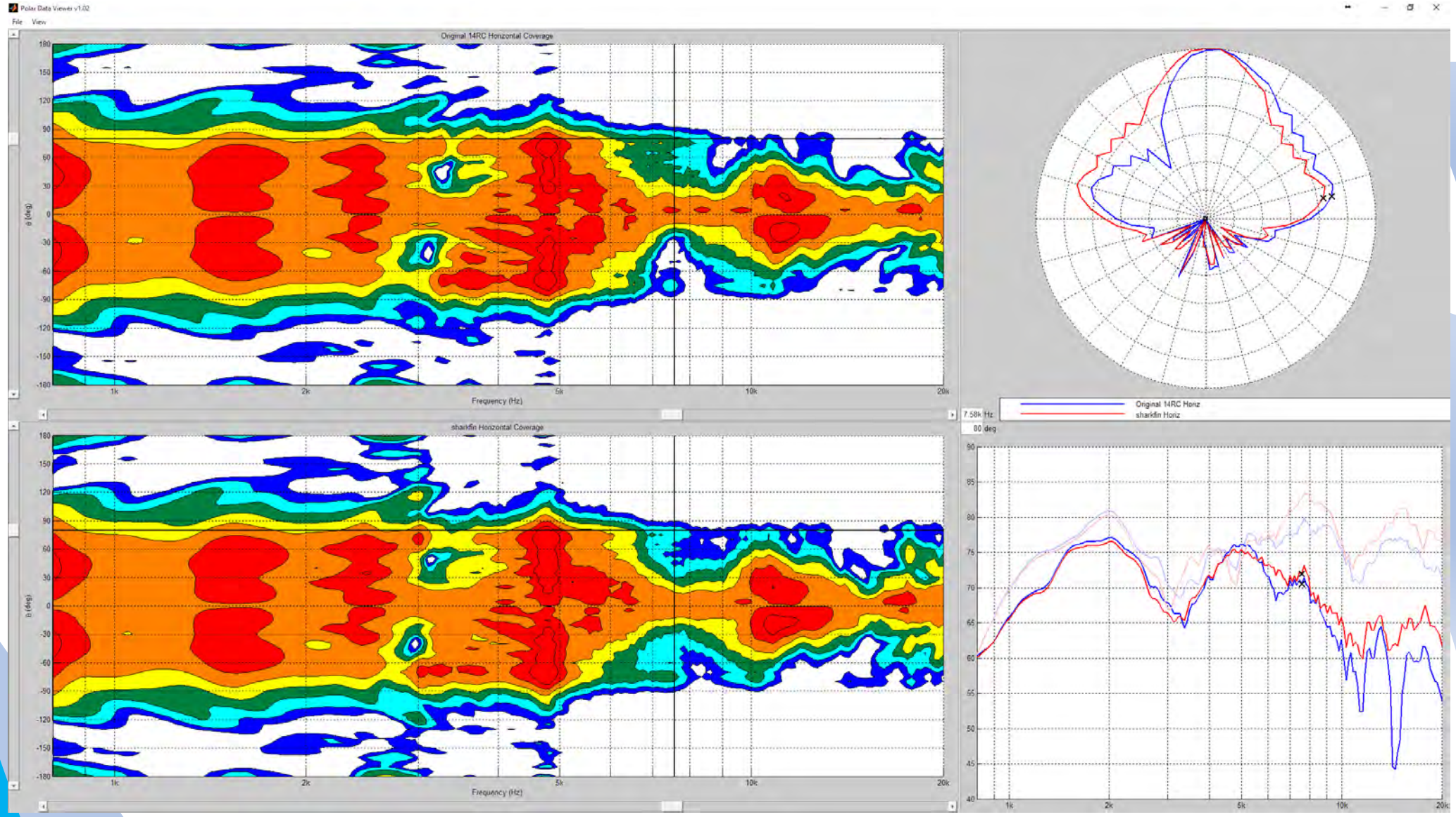

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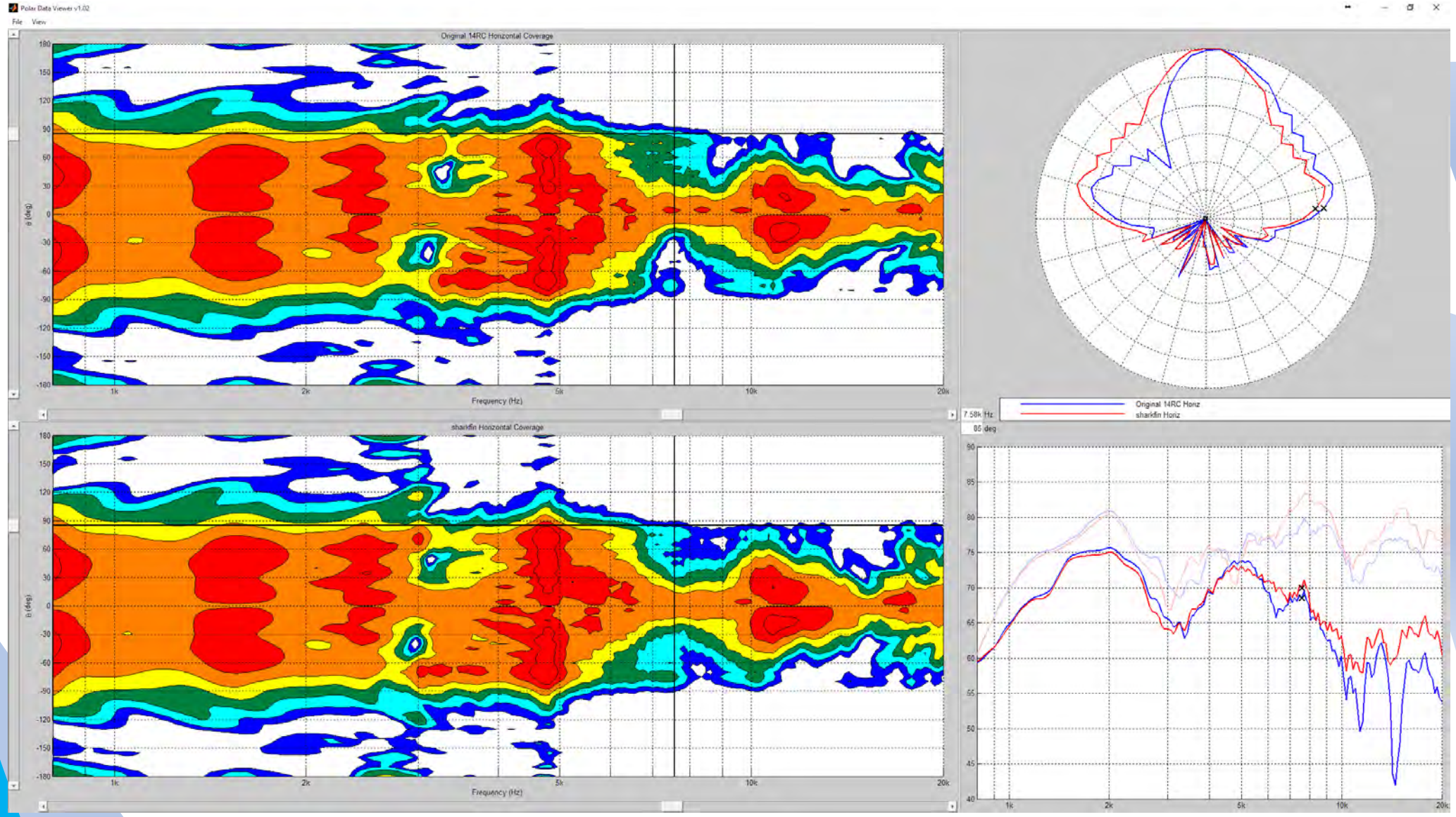

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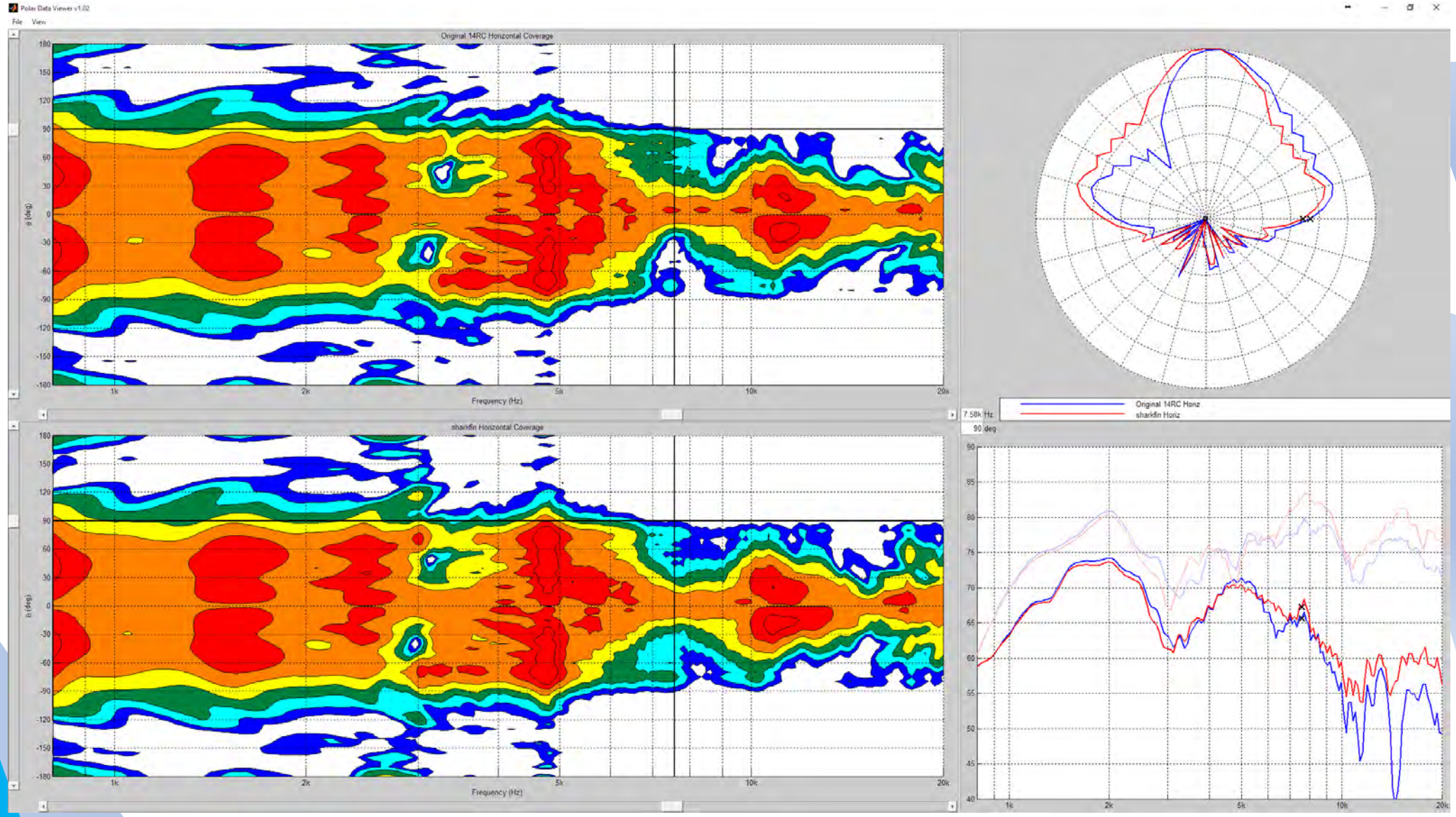

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Klipsch® KEEPERS OF THE SOUND

Thank you