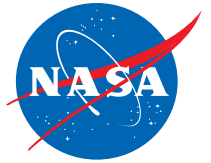


Removing Background Noise with Phased Array Signal Processing

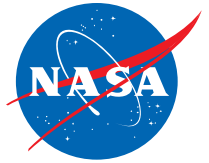
Gary Podboy NASA GRC

David Stephens NASA GRC

Acoustics Technical Working Group

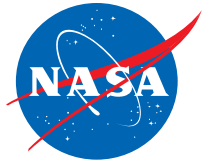
Oct 20 - 21, 2015

Support Provided by the Advanced Air Transport Technology Project



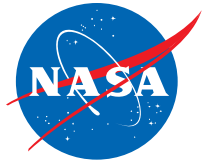
The Problem

The models we test in the 9 x 15 Ft Wind Tunnel have been getting quieter, but the wind tunnel has not.



Approach

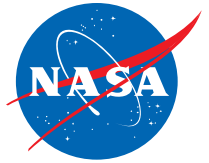
Remove wind tunnel background noise using an in-flow array and phased array signal processing techniques.



Approach

Remove wind tunnel background noise using an in-flow array and phased array signal processing techniques.

Continuation of work at NASA Ames by Clif Horne and Nate Burnside.



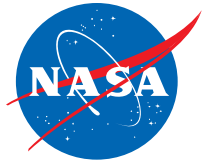
Approach

Remove wind tunnel background noise using an in-flow array and phased array signal processing techniques.

Continuation of work at NASA Ames by Clif Horne and Nate Burnside.

Use

1) Functional Beamforming developed by Optinav
   - increases dynamic range of phased array measurements



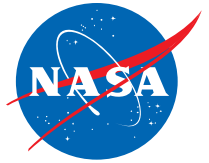
Approach

Remove wind tunnel background noise using an in-flow array and phased array signal processing techniques.

Continuation of work at NASA Ames by Clif Horne and Nate Burnside.

Use

1) Functional Beamforming developed by Optinav
   - increases dynamic range of phased array measurements
2) Cross Spectral Matrix (CSM) subtraction
   - method for “turning off” noise sources



CSM Subtraction

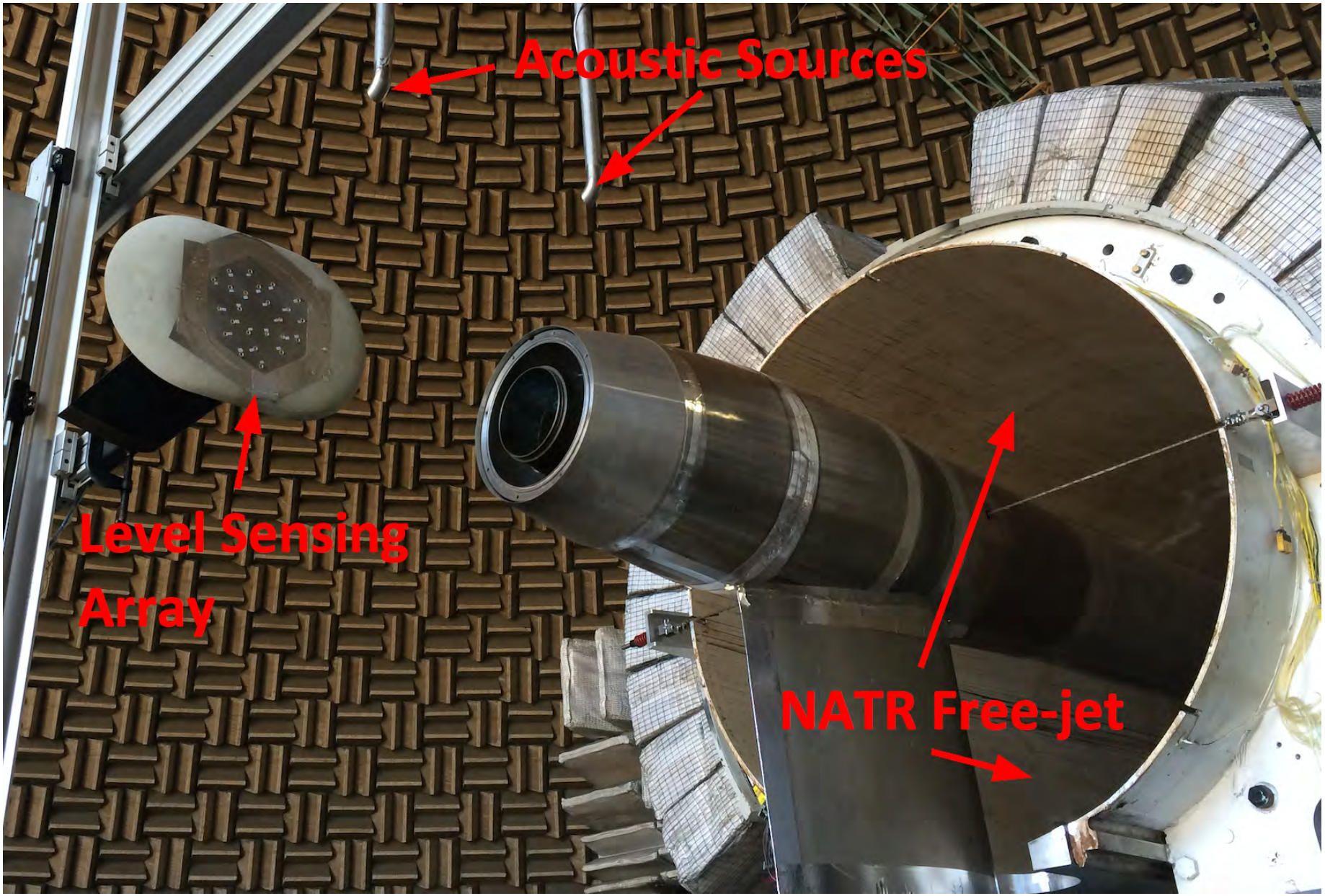
Acquire background data.

Acquire background + signal data.

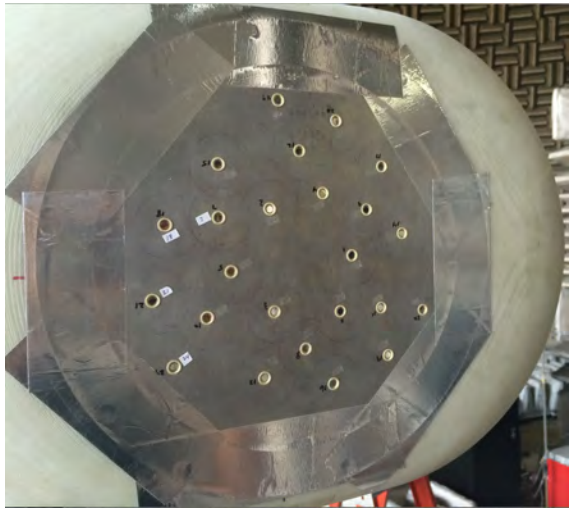
$CSM_{signal} = CSM_{background+signal} – CSM_{background}$

Process CSM_{signal} using Functional Beamforming to determine the amplitude of the signal

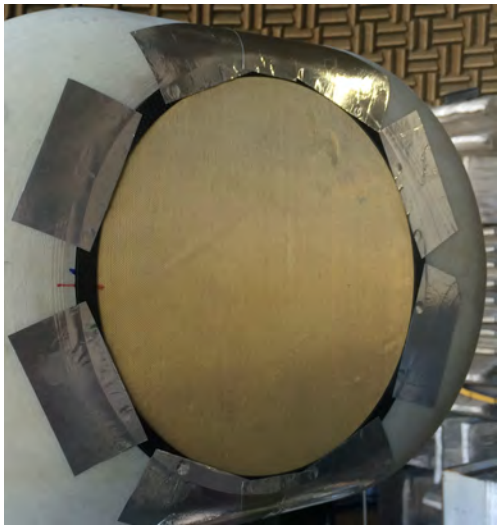
Test Setup at NATR



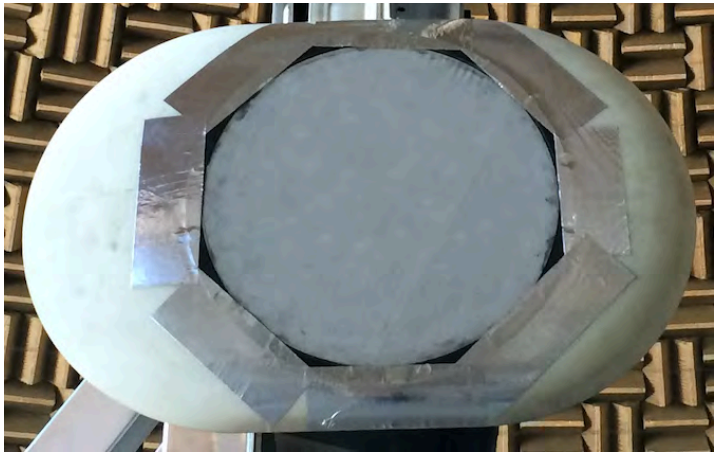
Four Array Configurations



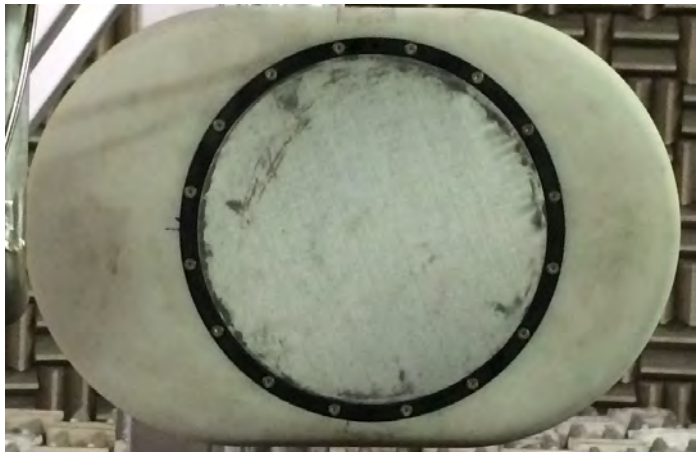
Flush



Kevlar



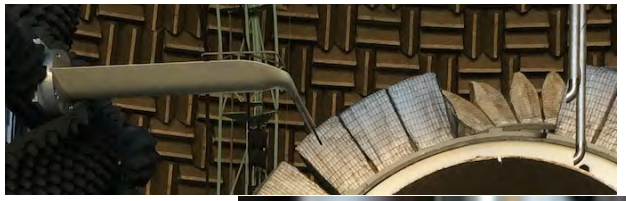
Thin Weave SS
325 x 325 threads/inch



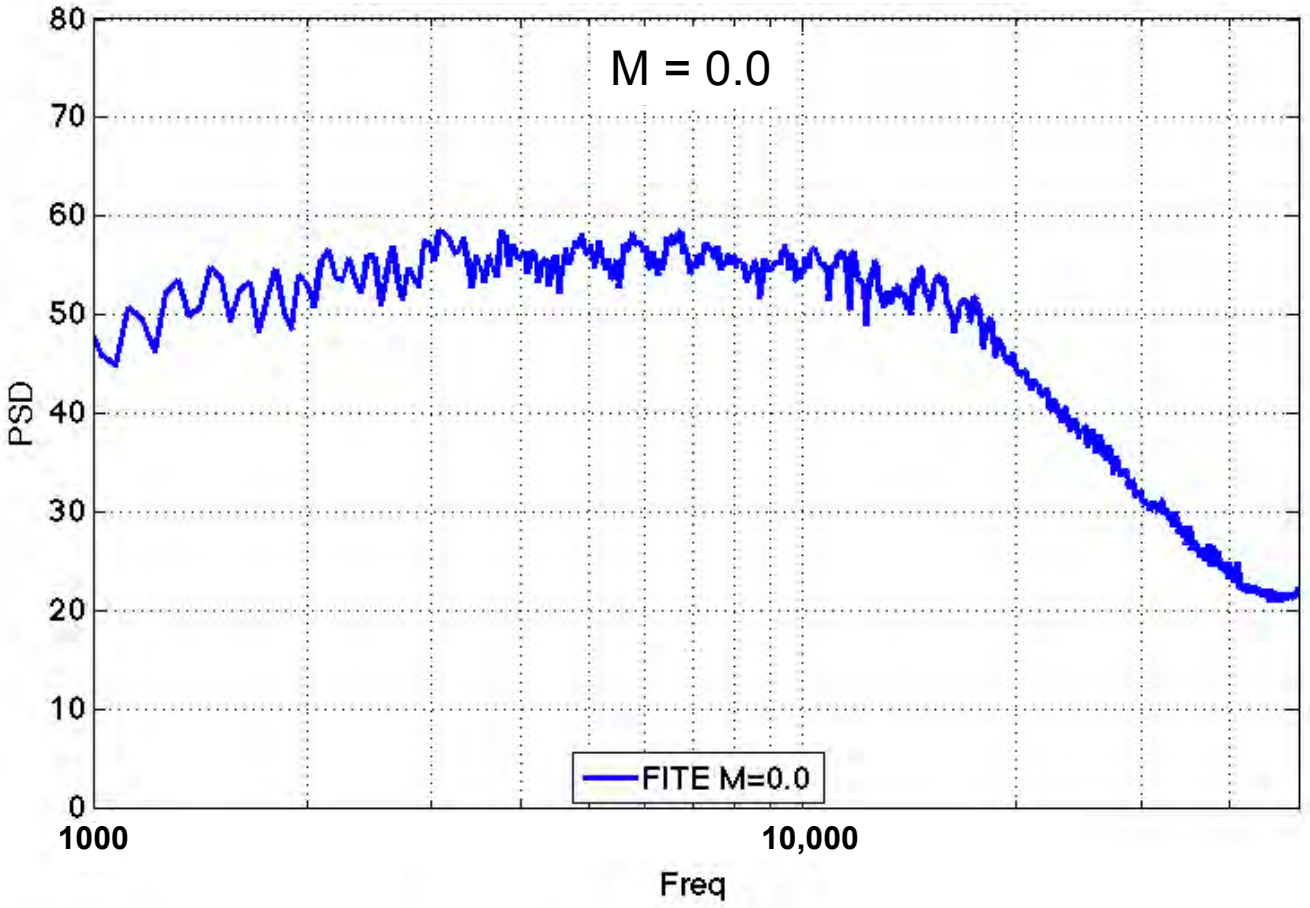
Dense Weave SS
600 x 200 threads/inch

Conventional Single Microphone

The “Correct” Answer

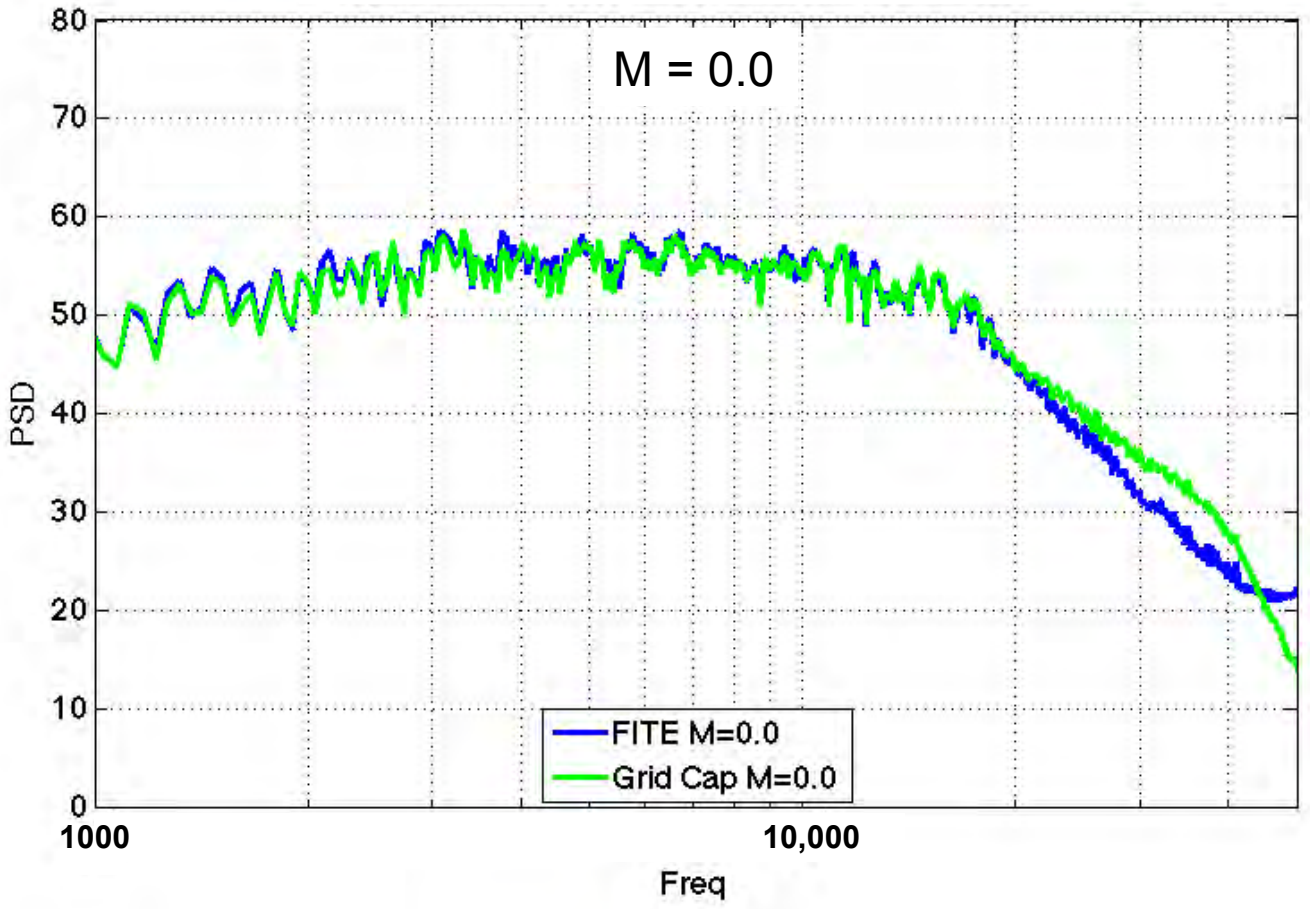


Acoustic driver signal measured by FITE microphone with no background (M = 0)



Another “Correct” Answer

Driver signal measured by Grid Cap microphone (M = 0)

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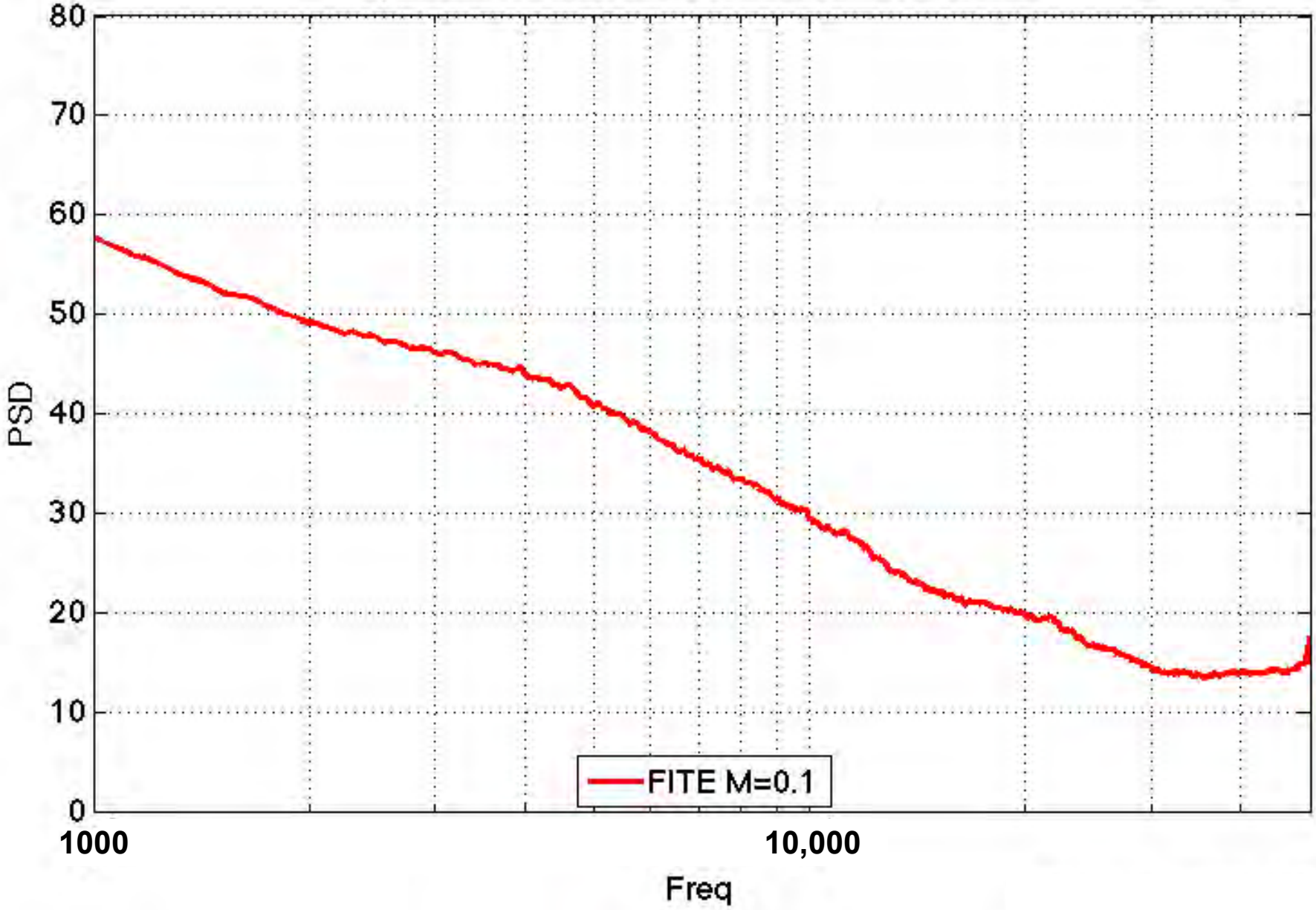
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PSD
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Freq
FITE M=0.1


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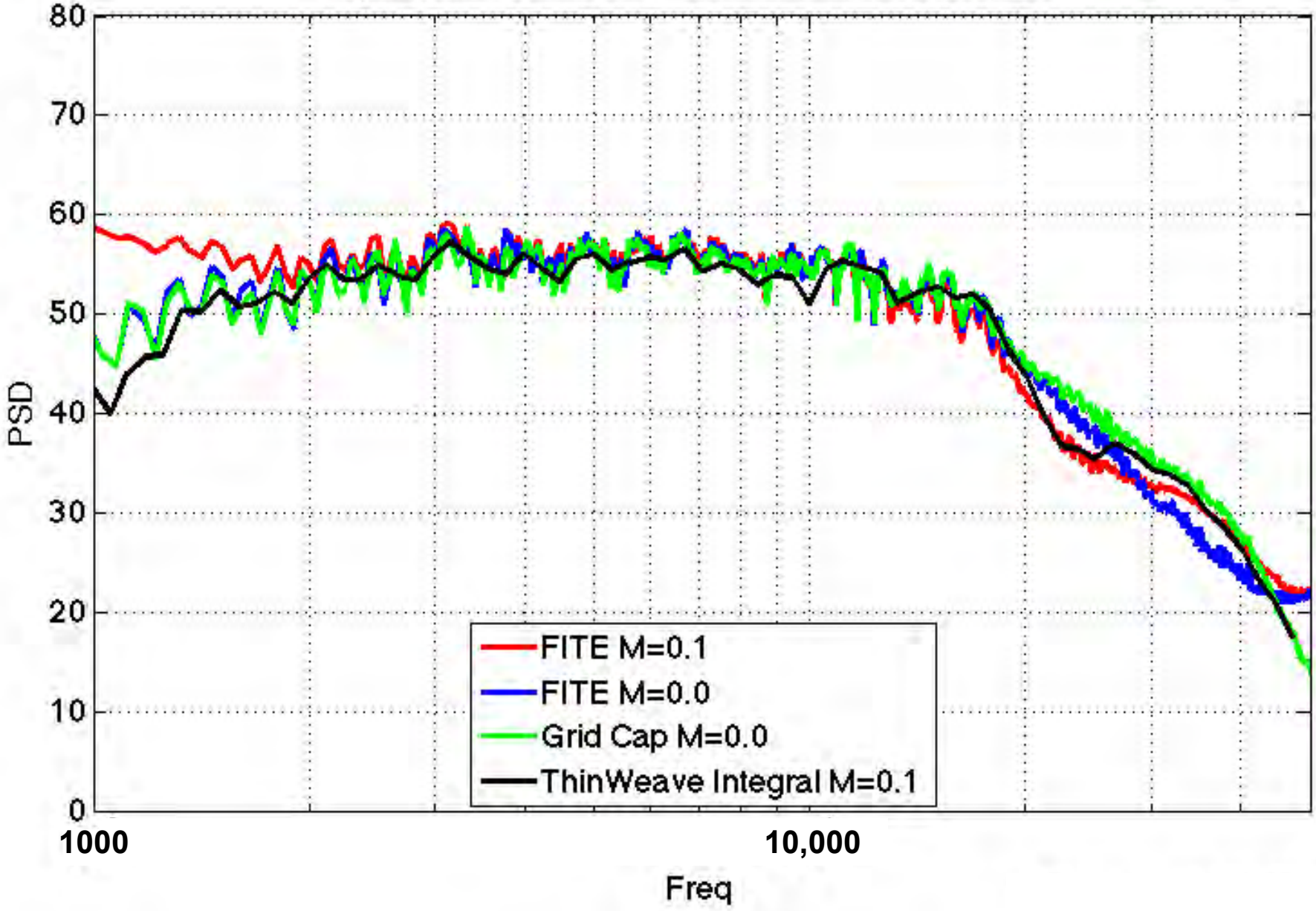
Max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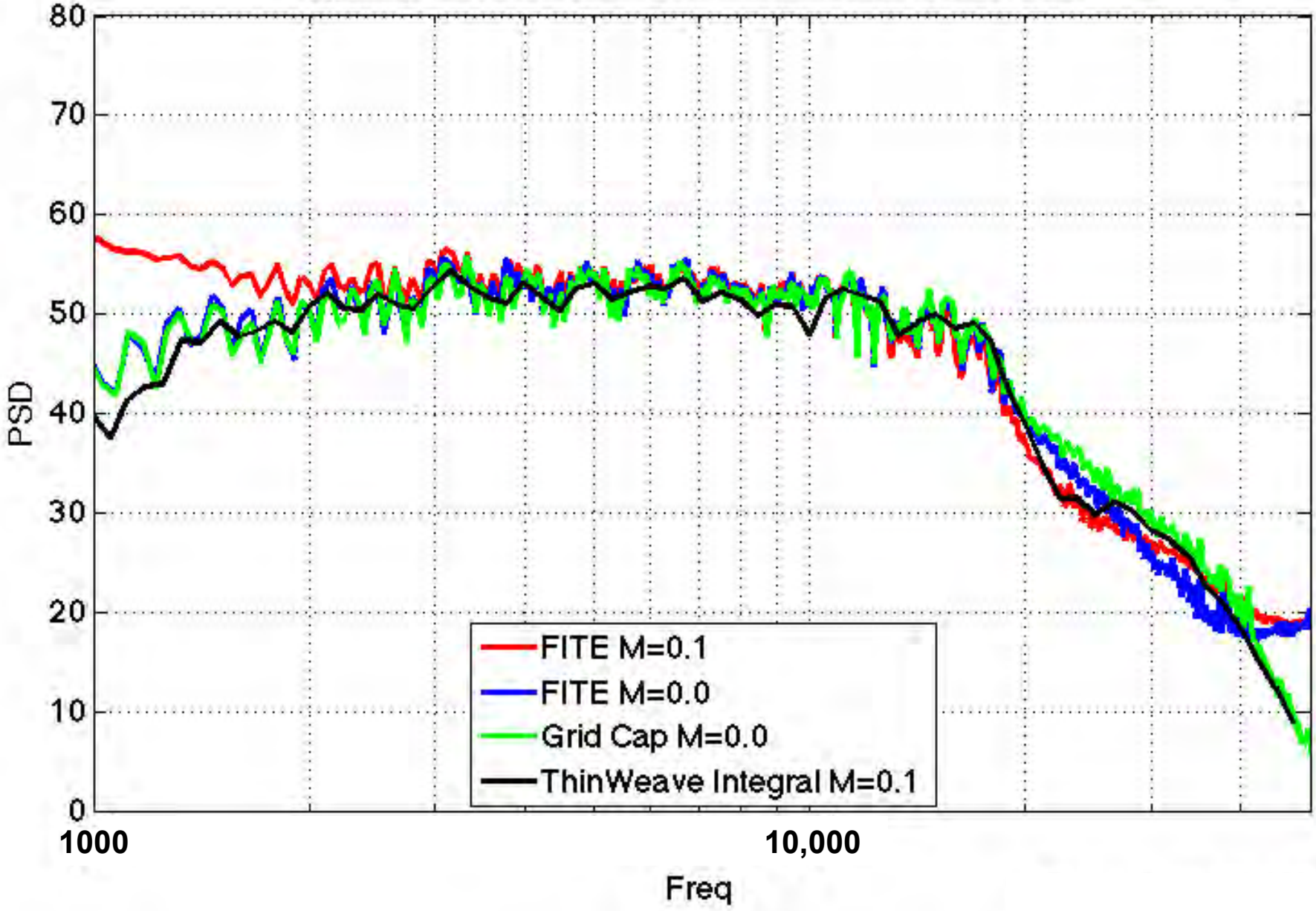
Max-3dB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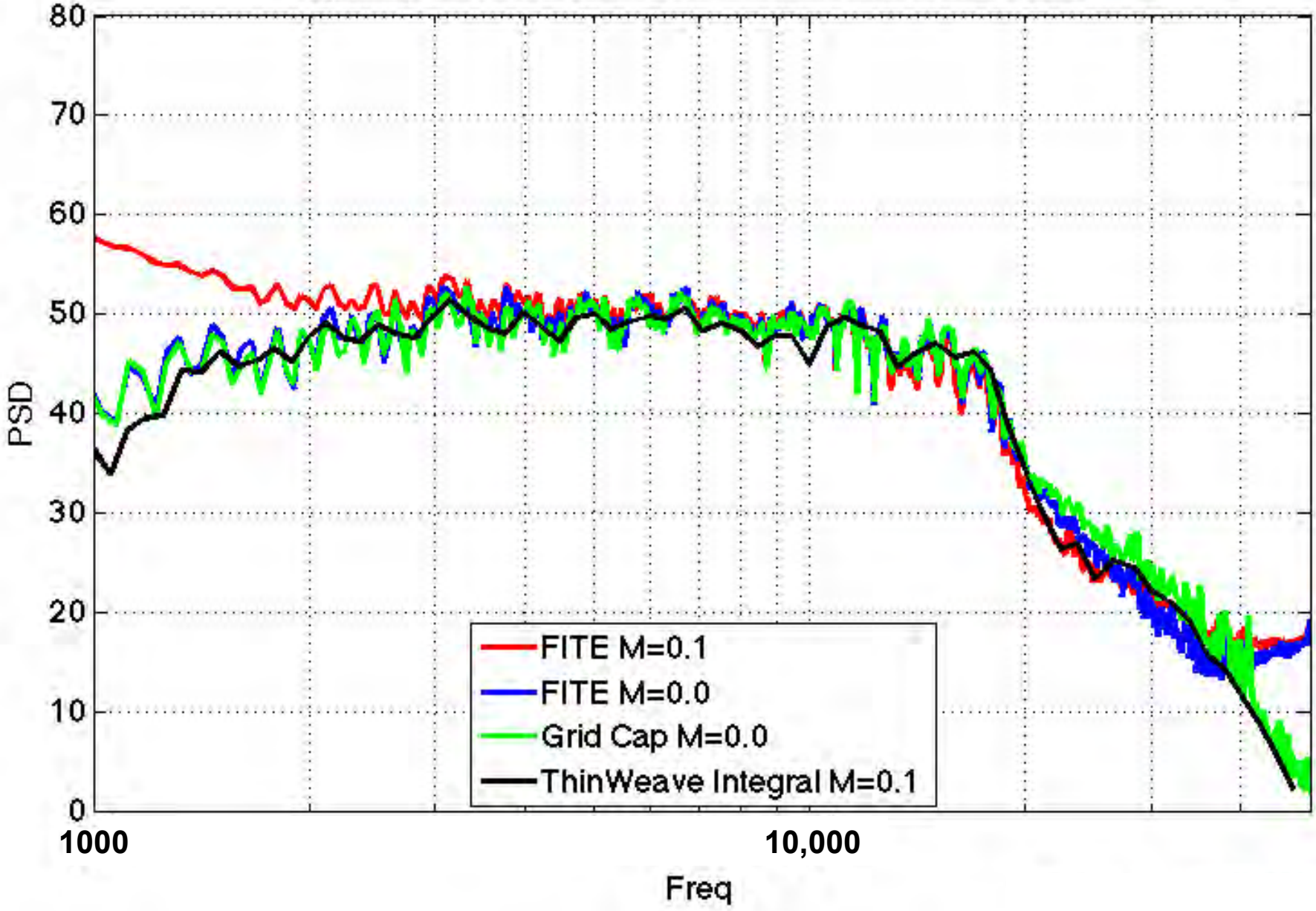
Max-6dB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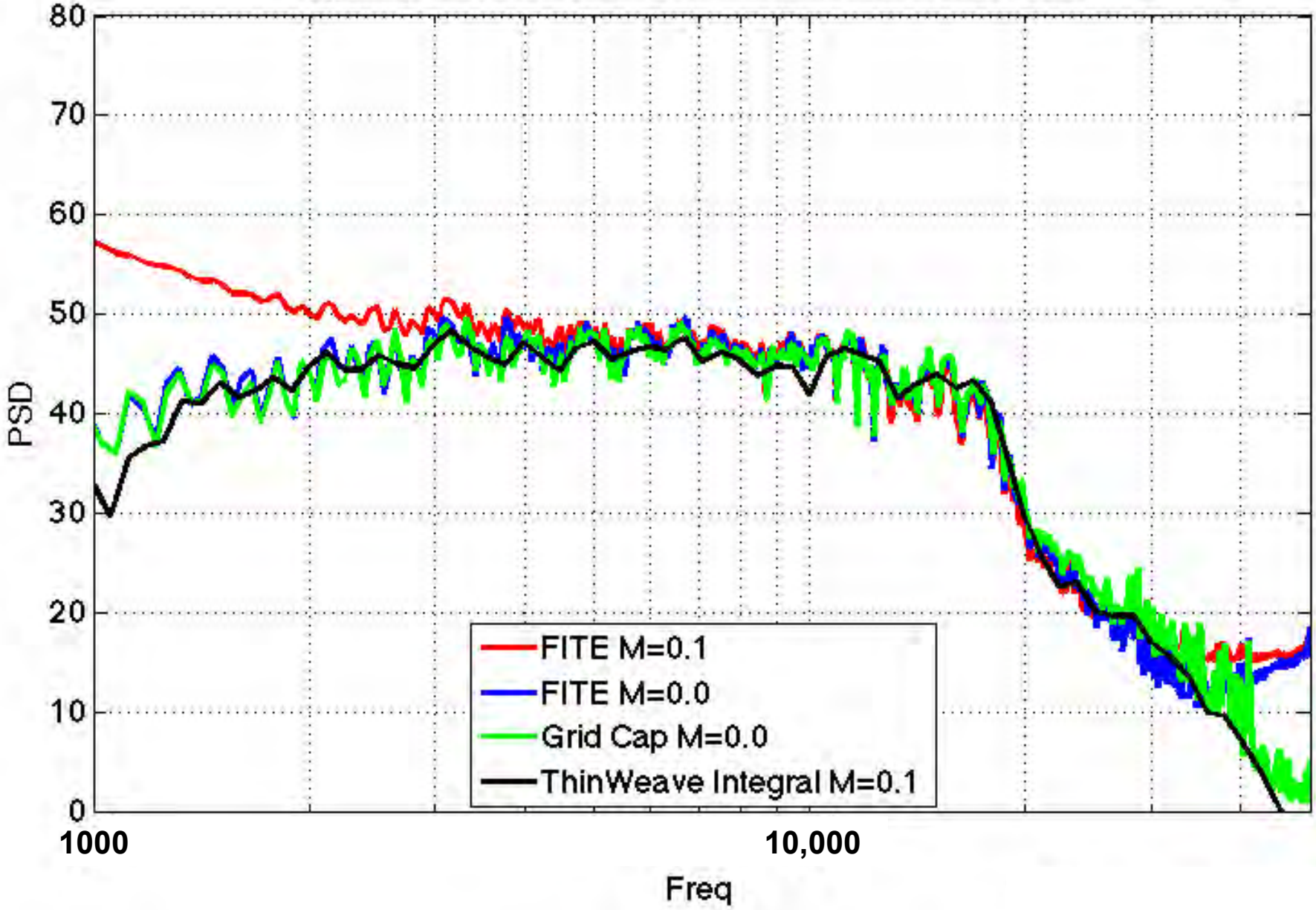
Off
Max-9dB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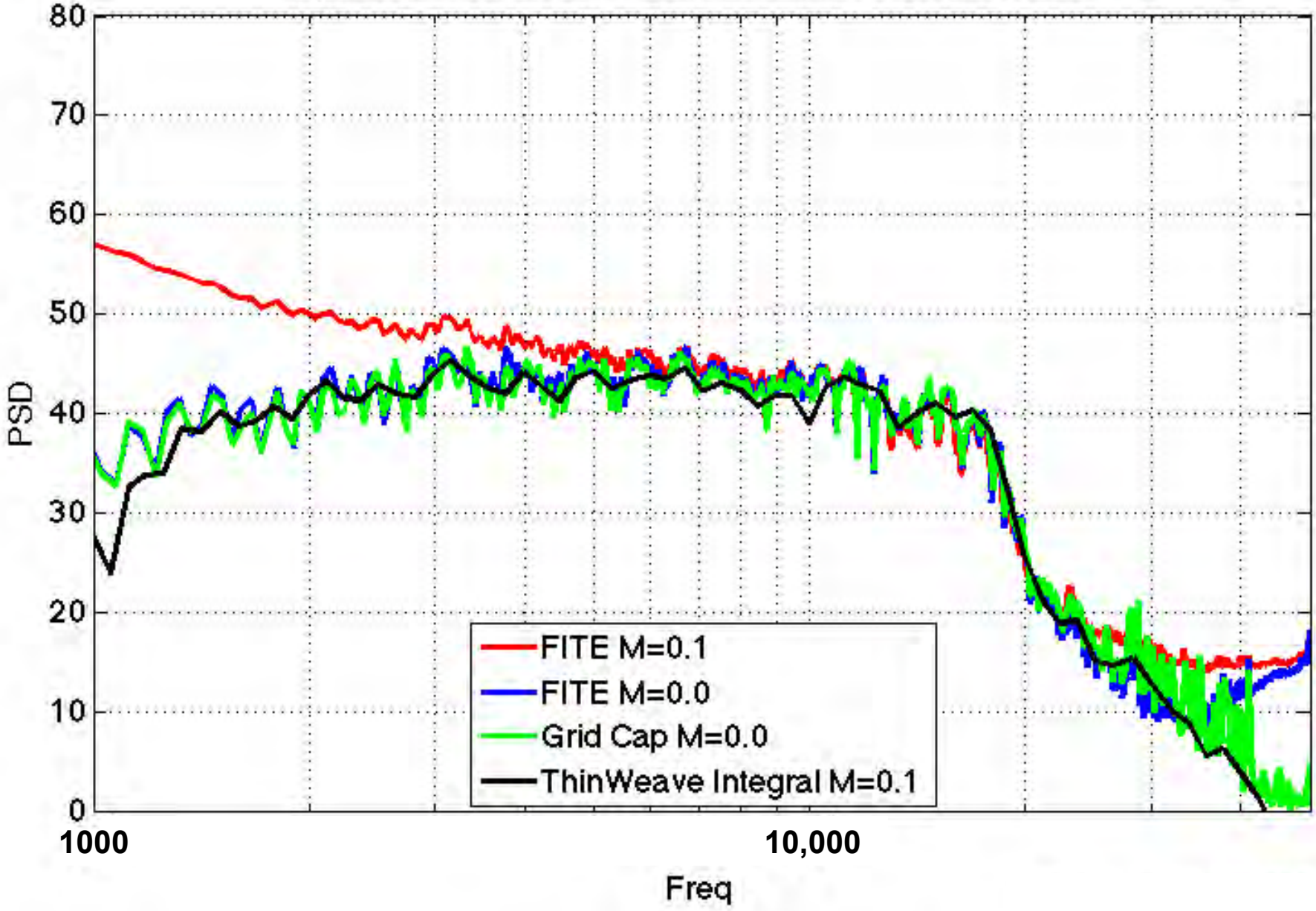
Max-12dB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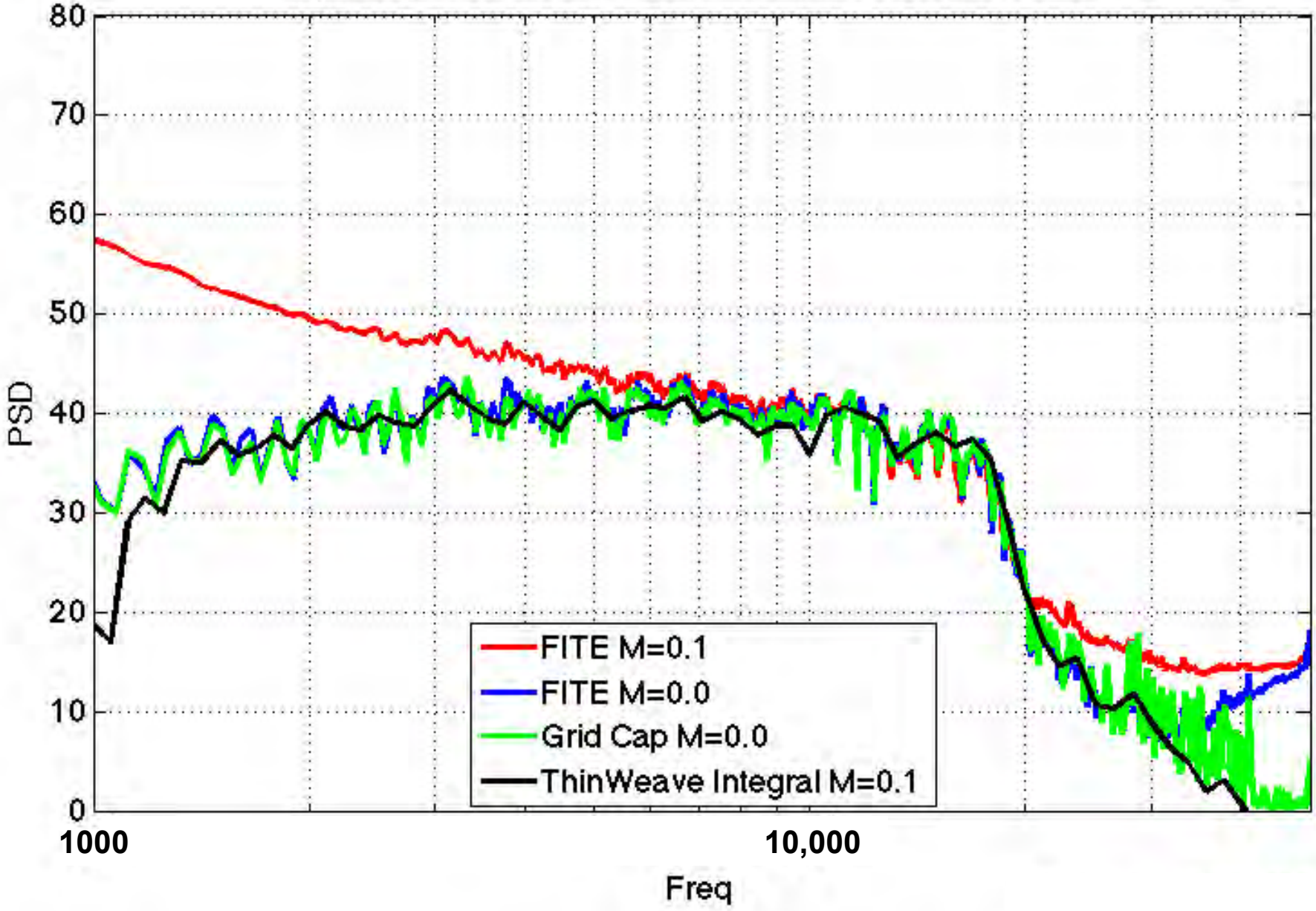
Max-15dB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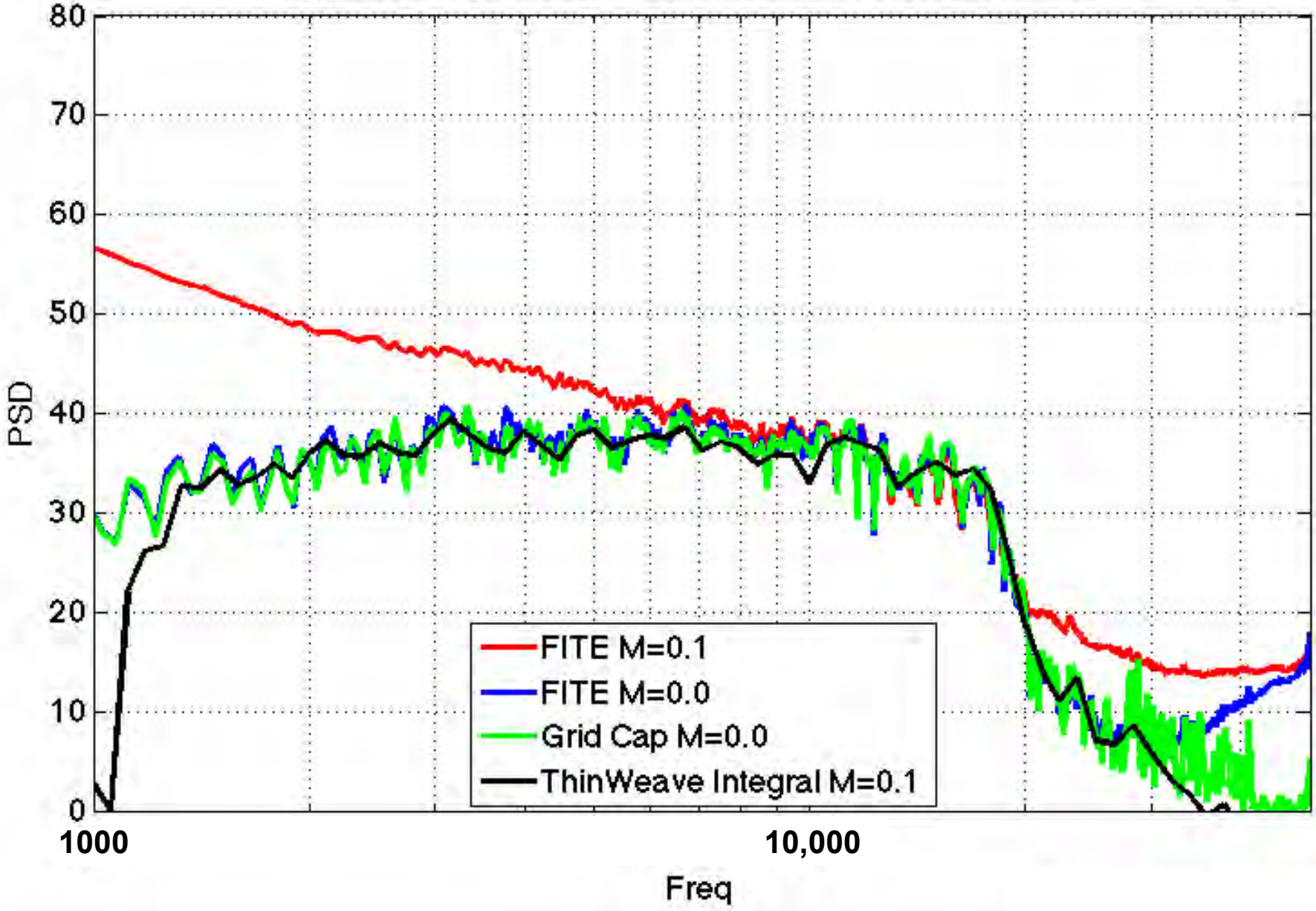
Max-18dB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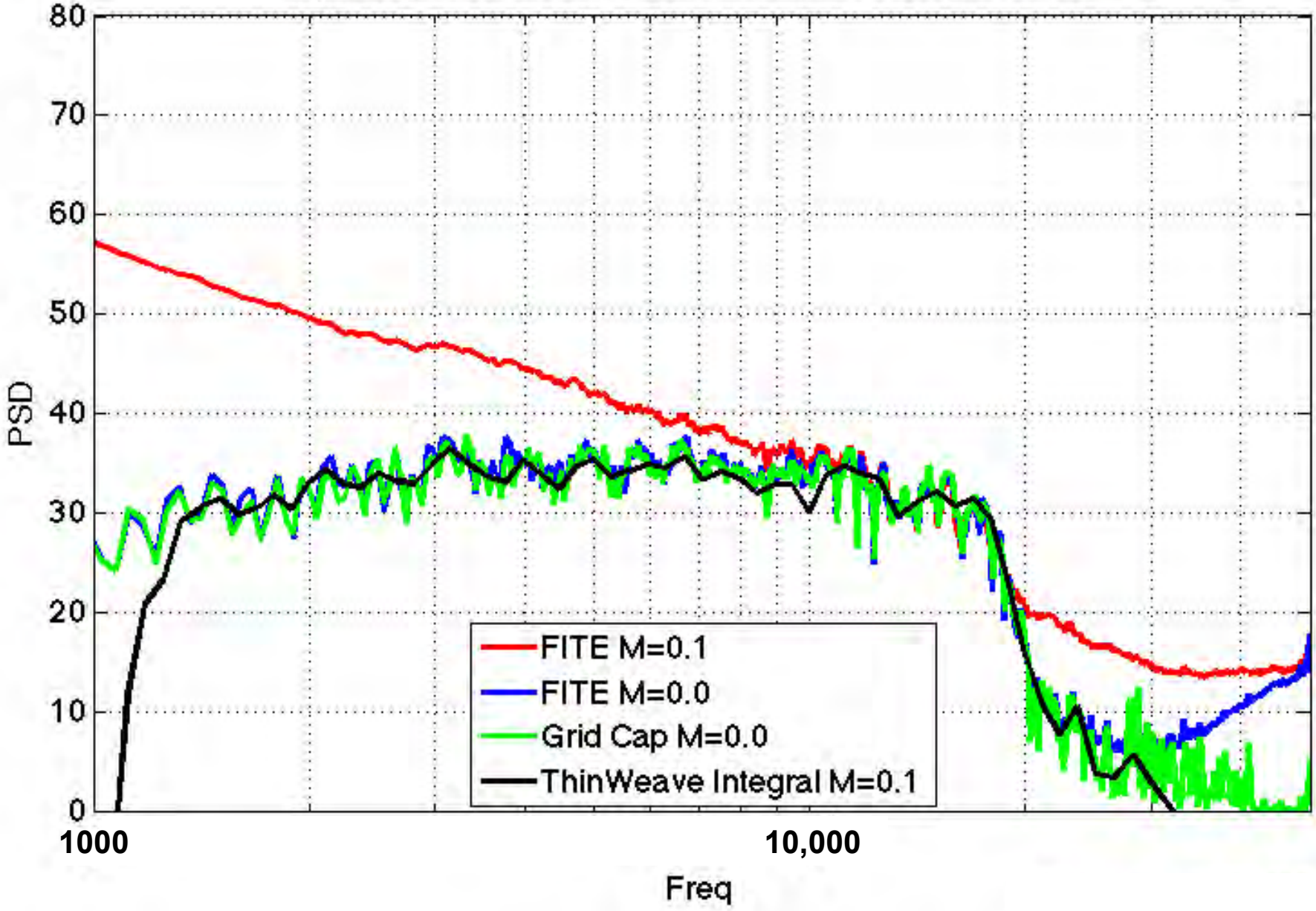
Max-21dB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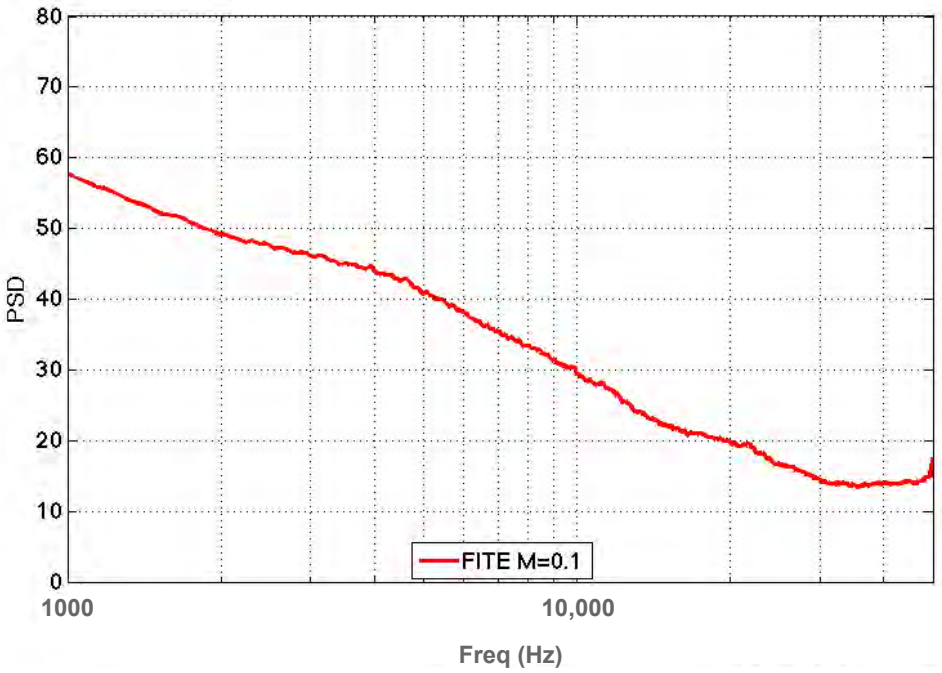
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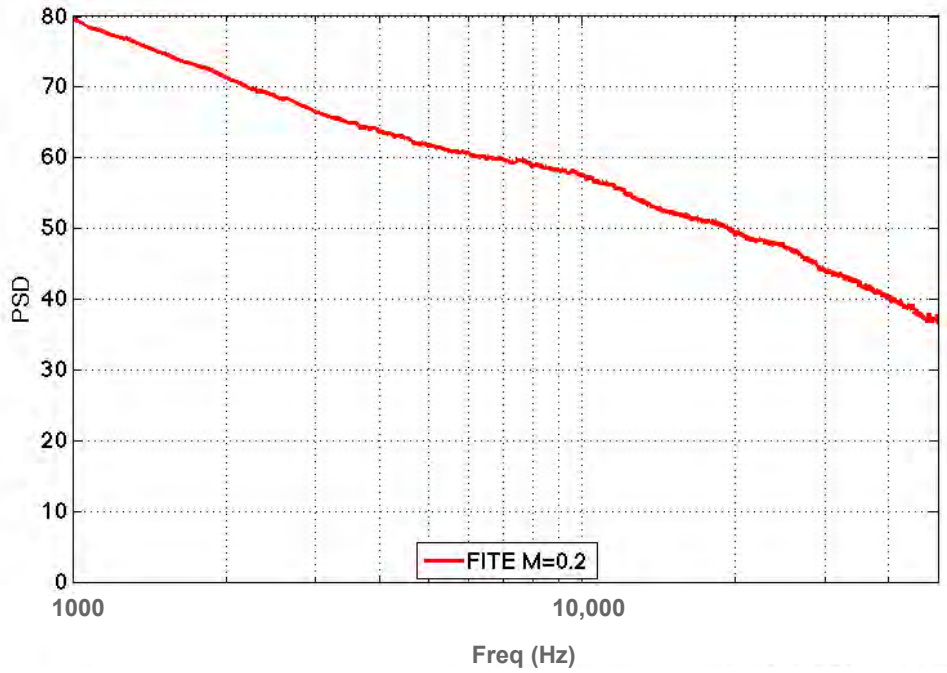
Freq (Hz)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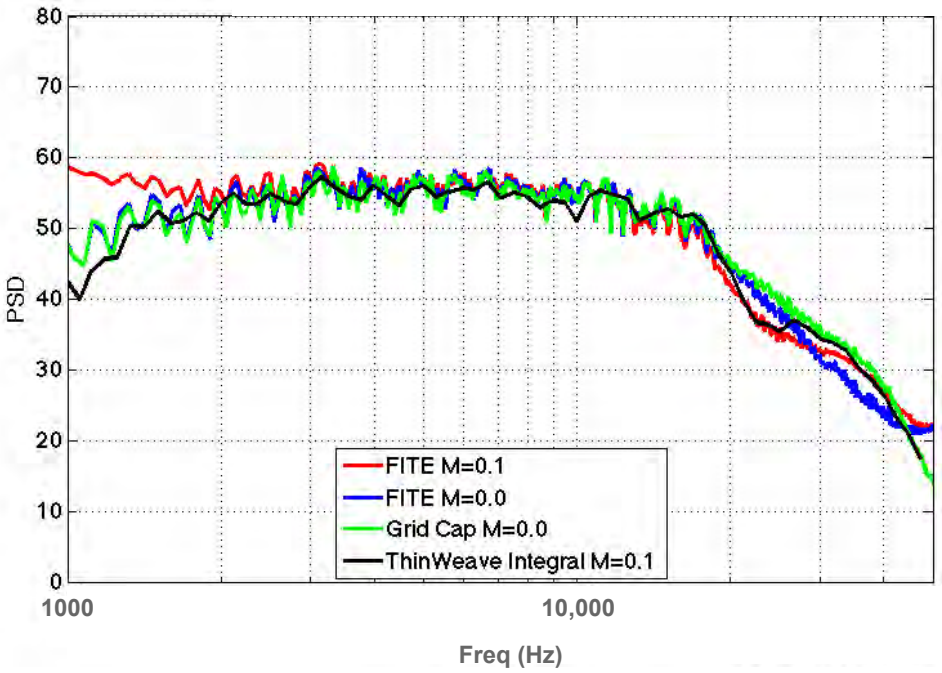
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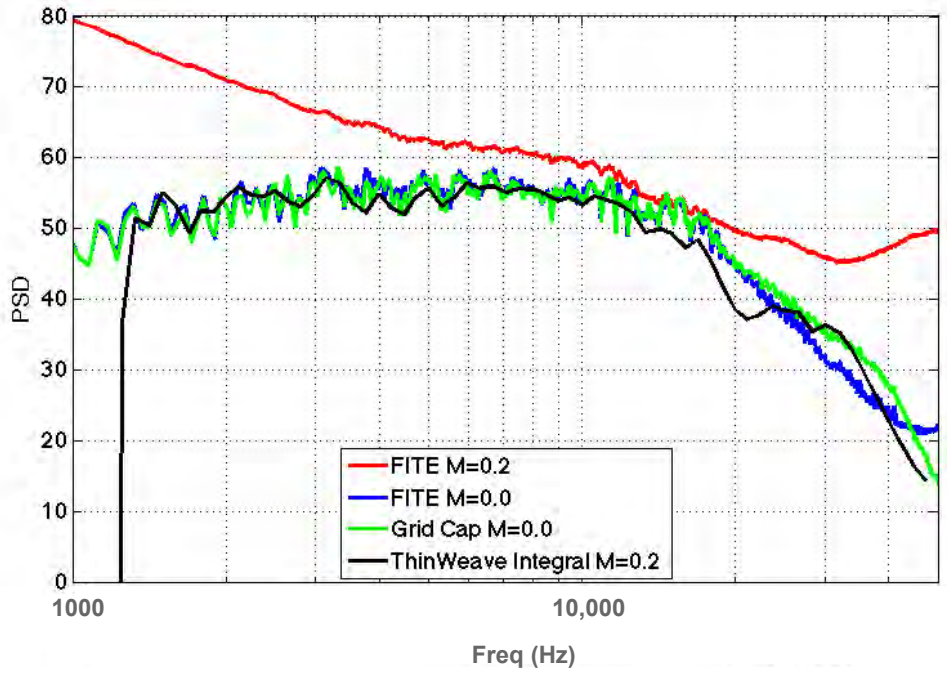
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Freq (Hz)


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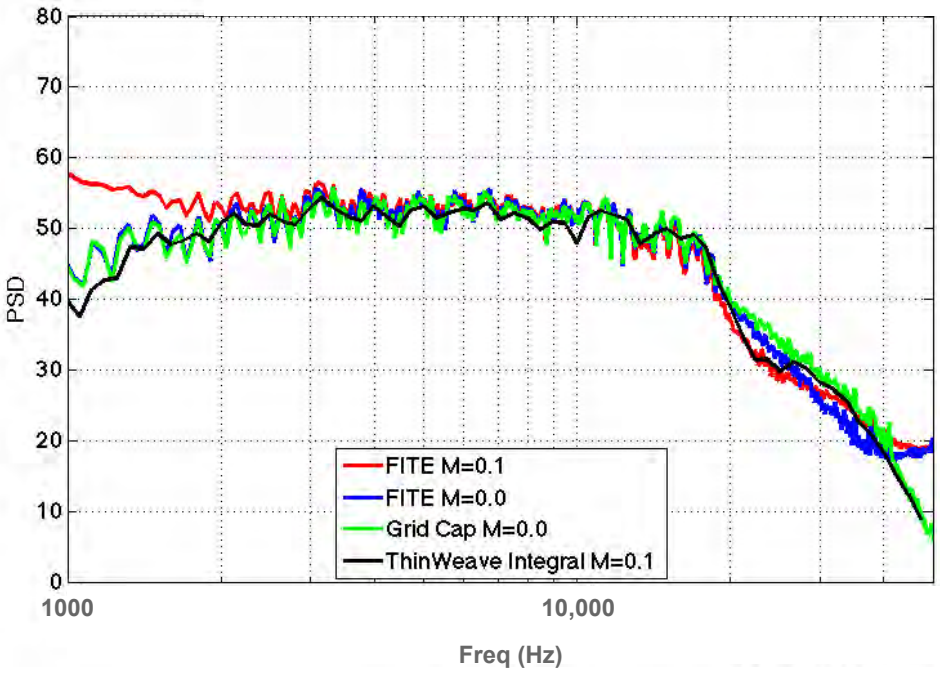
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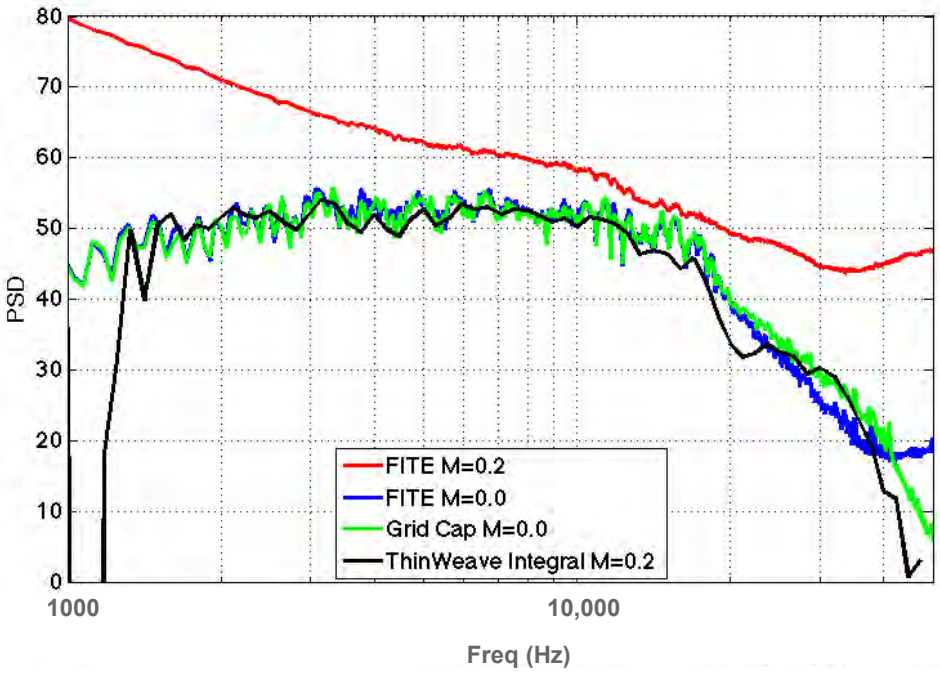
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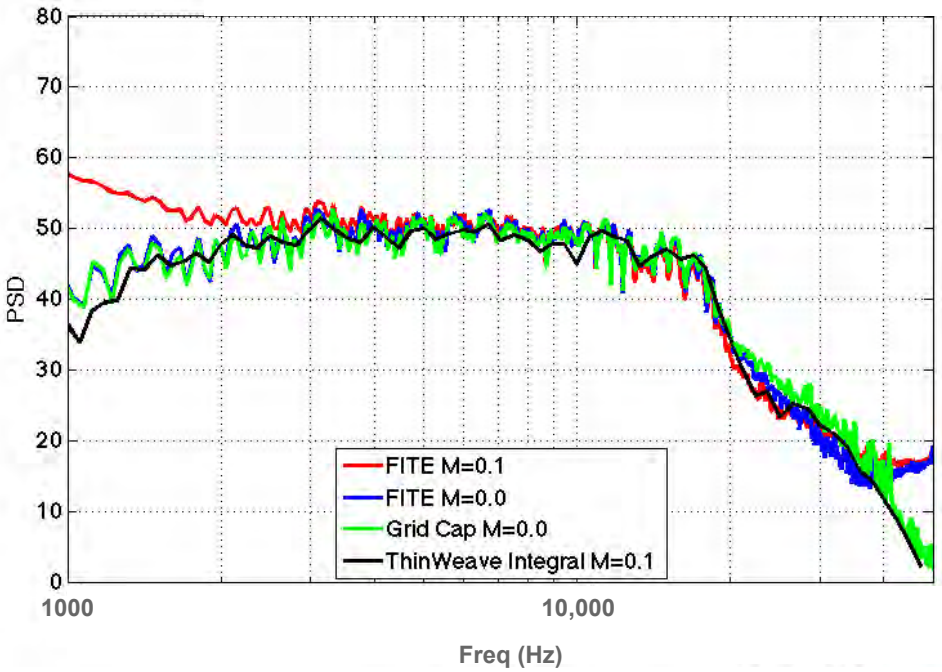
Off
Max-6dB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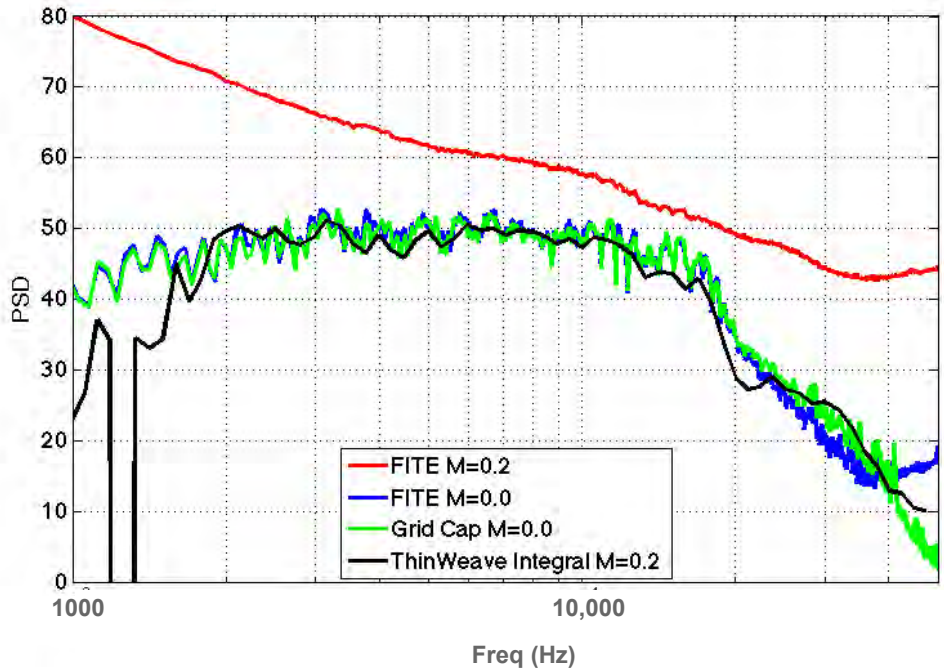
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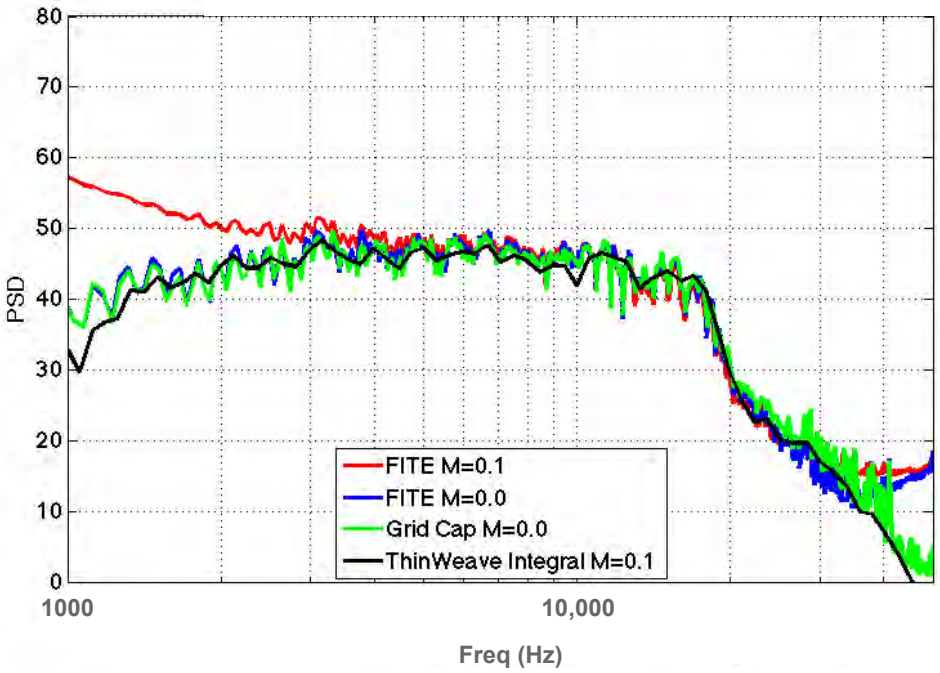
Max-9dB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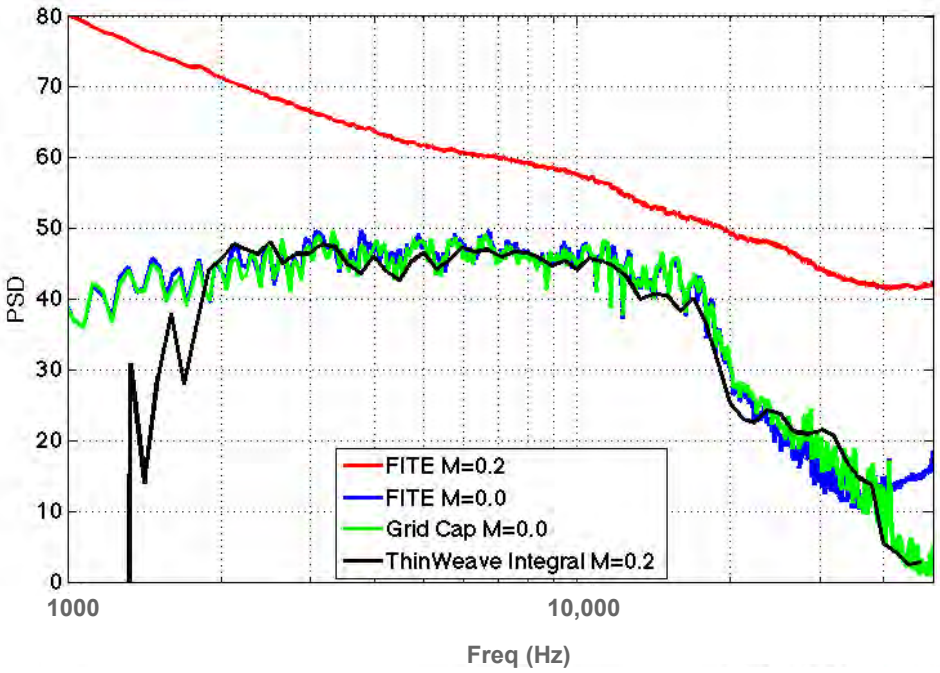
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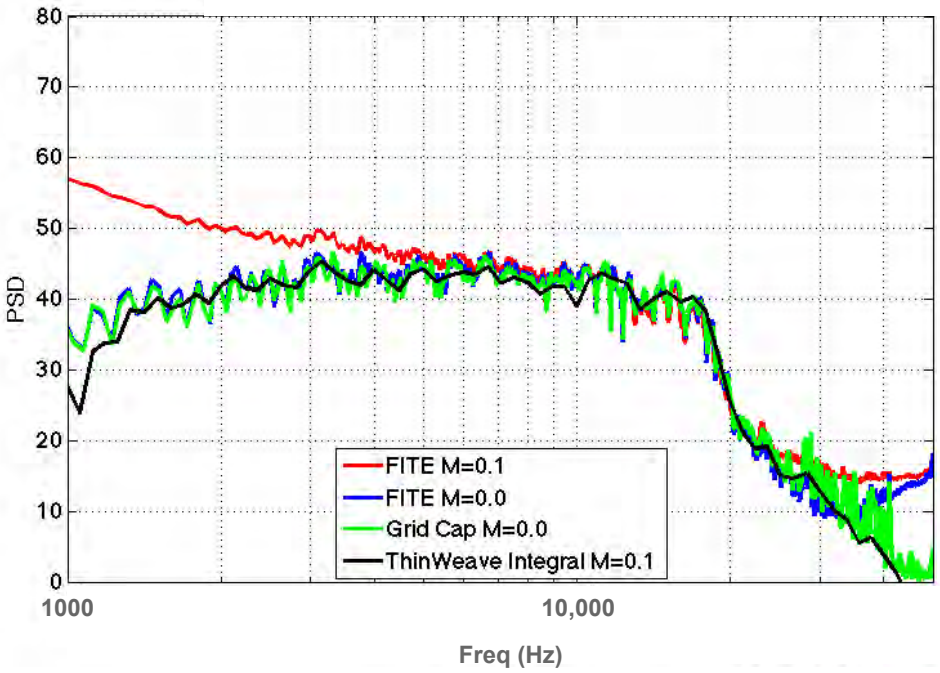
Max-12dB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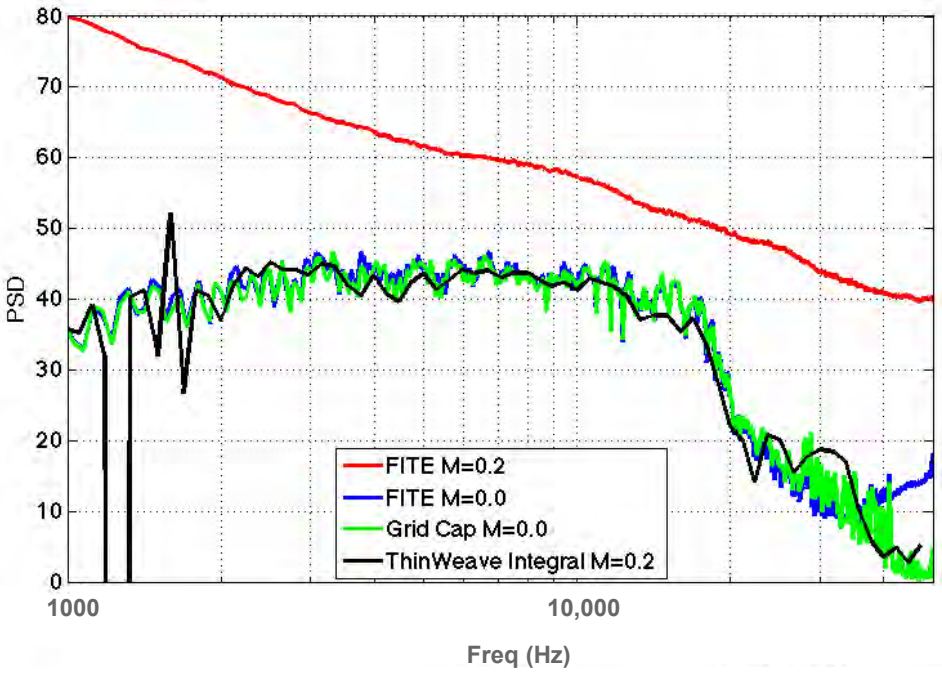
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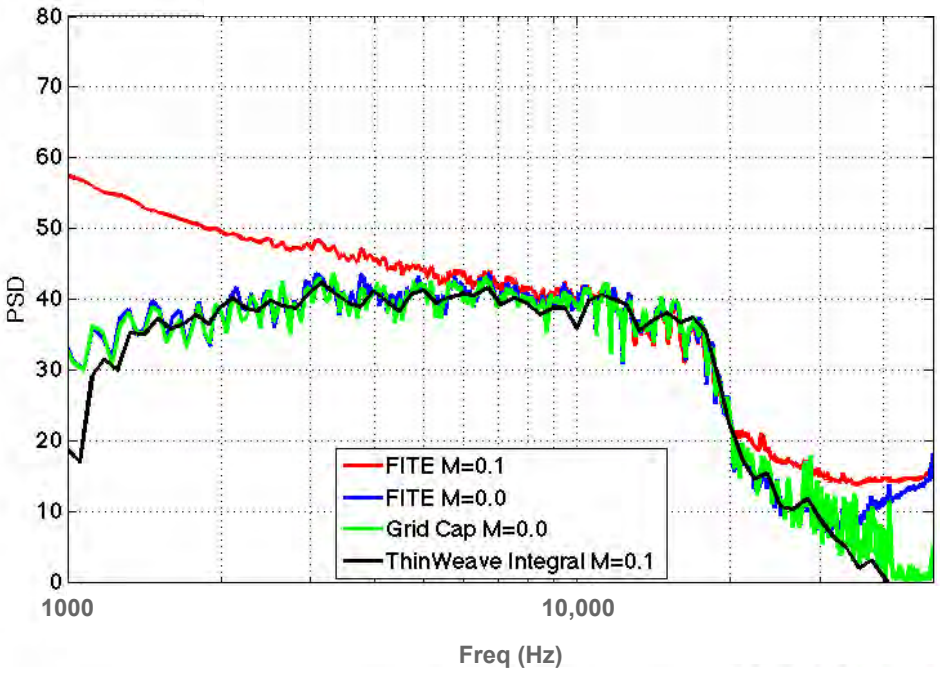
Off
Max-15dB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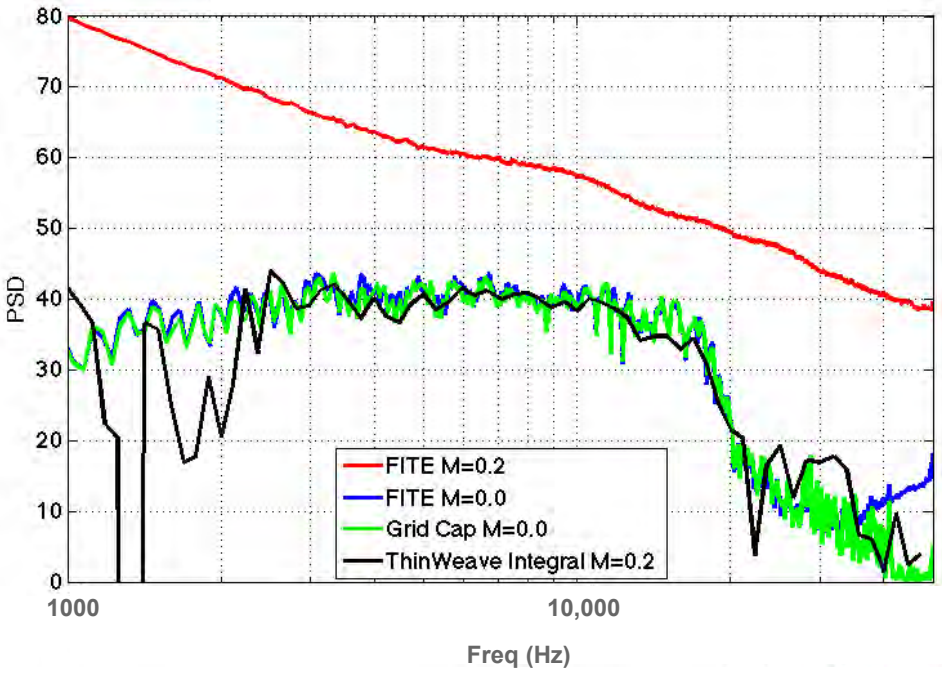
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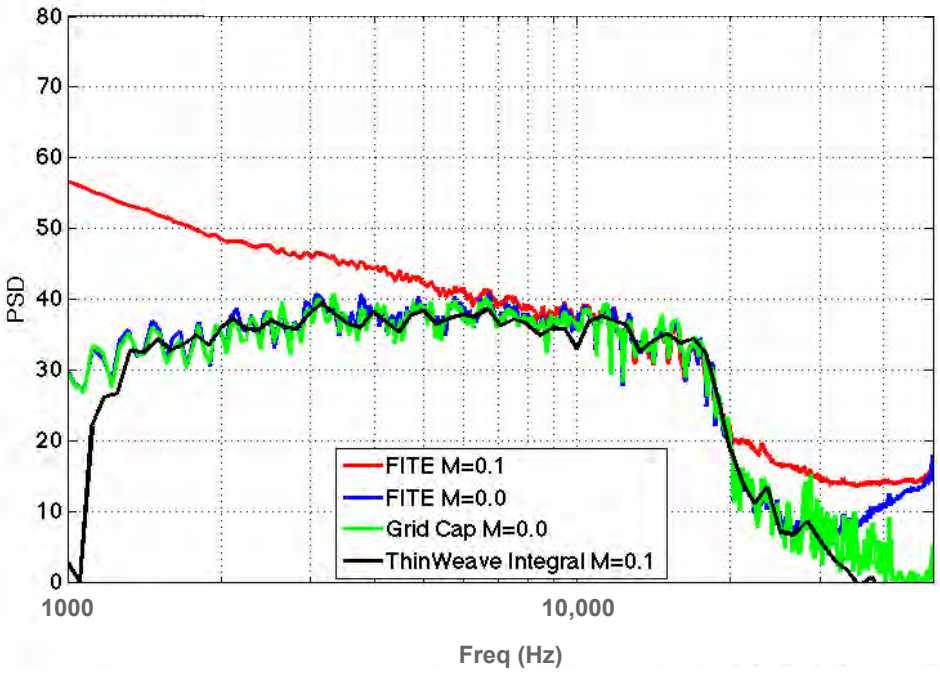
Freq (Hz)


Off
Max-18dB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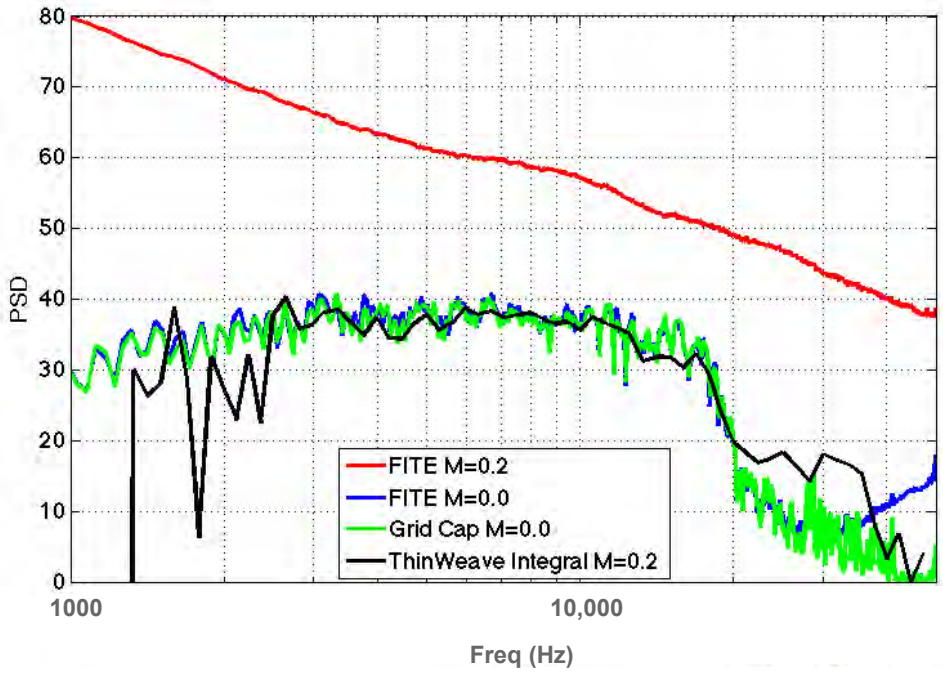
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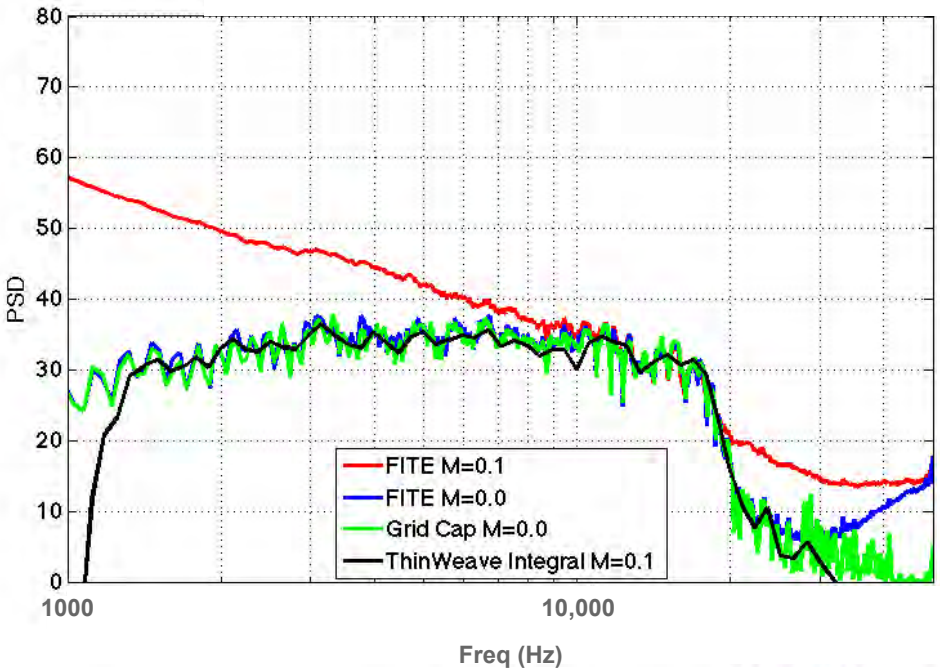
Freq (Hz)


Off
Max-21dB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Freq (Hz)
FITE M=0.1
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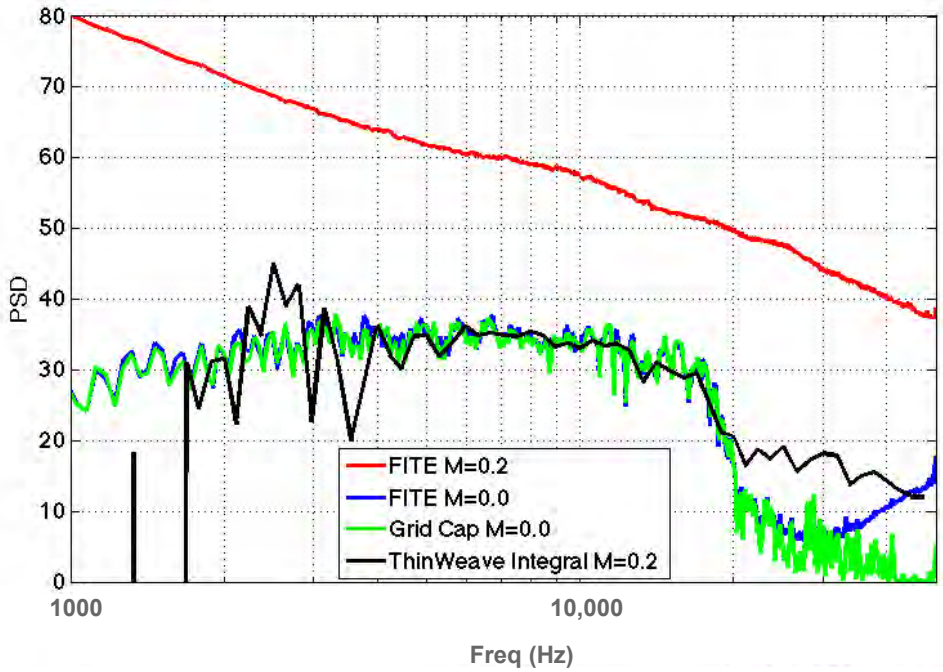
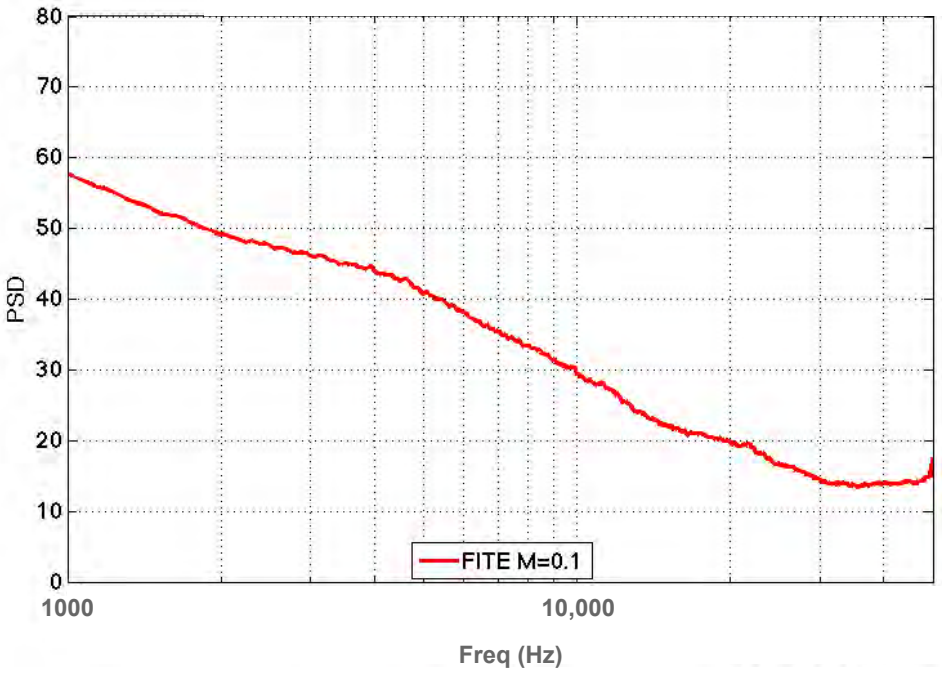
Grid Cap M=0.0
ThinWeave Integral M=0.1


PSD
80
70
60
50
40
30
20
10
0
1000
10,000
Freq (Hz)
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2


Off
Off


80
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60
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40
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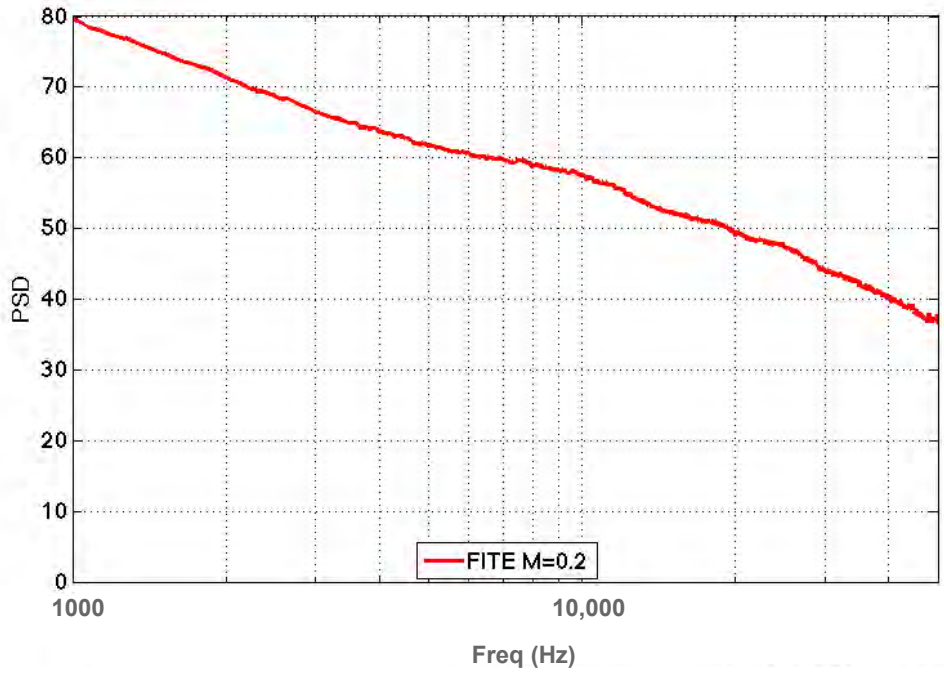
20
10
0
PSD
FITE M=0.1
1000
10,000
Freq (Hz)


80
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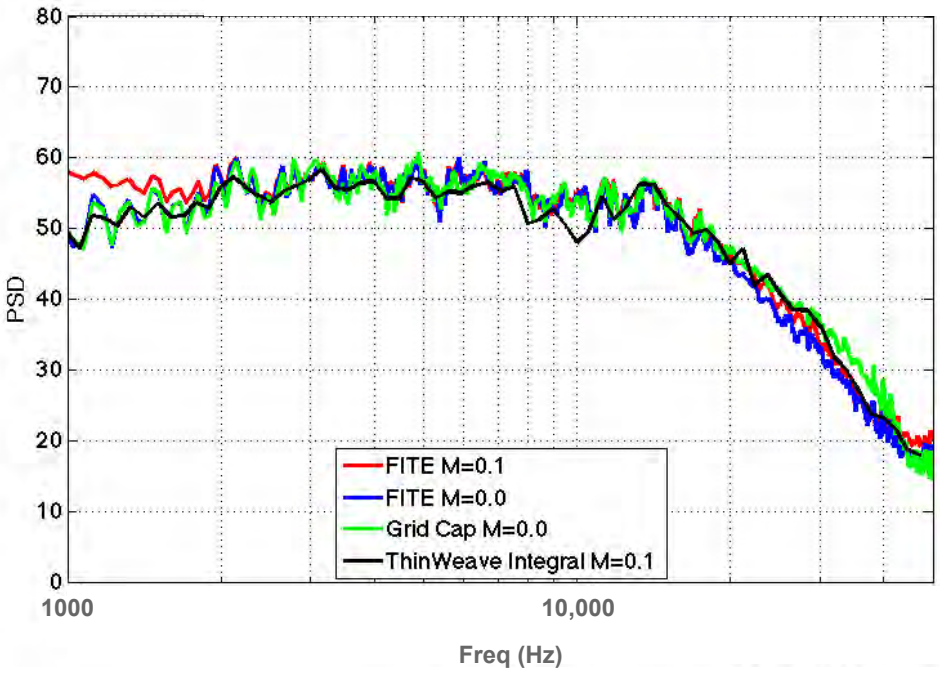
40
30
20
10
0
PSD
FITE M=0.2
1000
10,000
Freq (Hz)

Max

Off


80
70
60
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40
30
20
10
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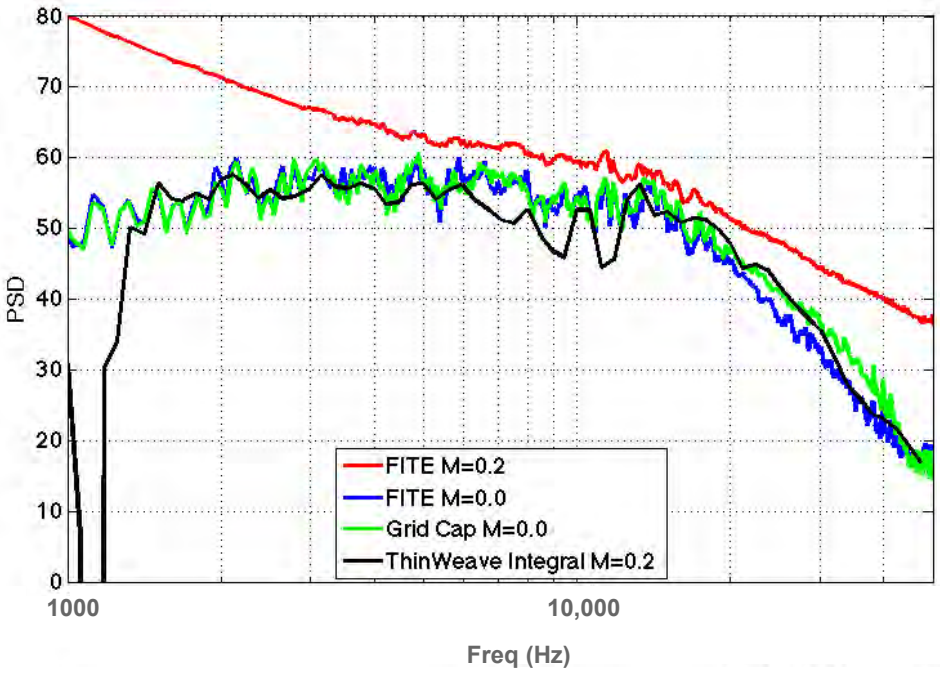
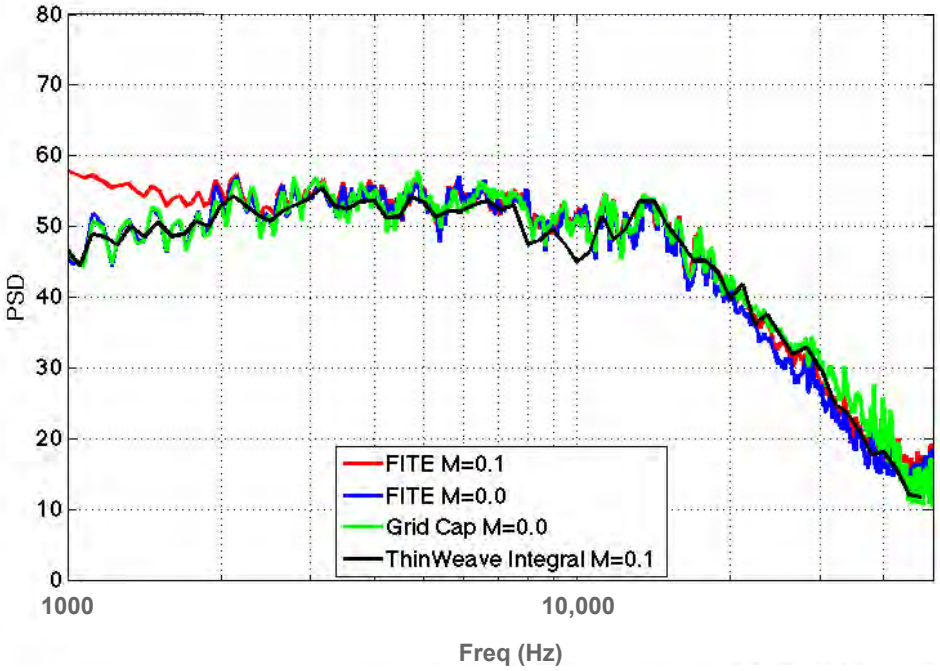
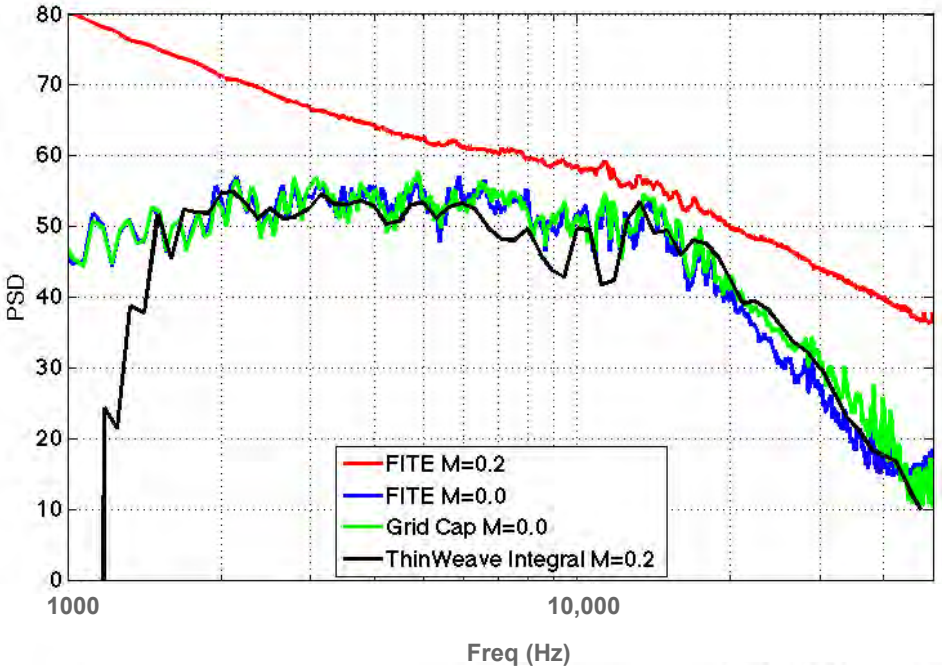
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-3dB

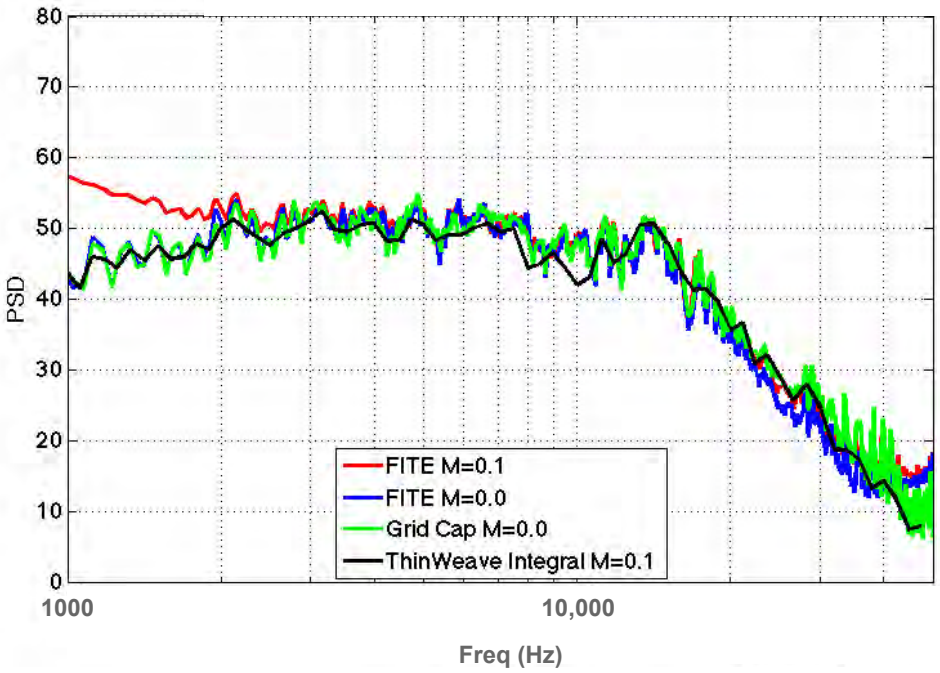
Off

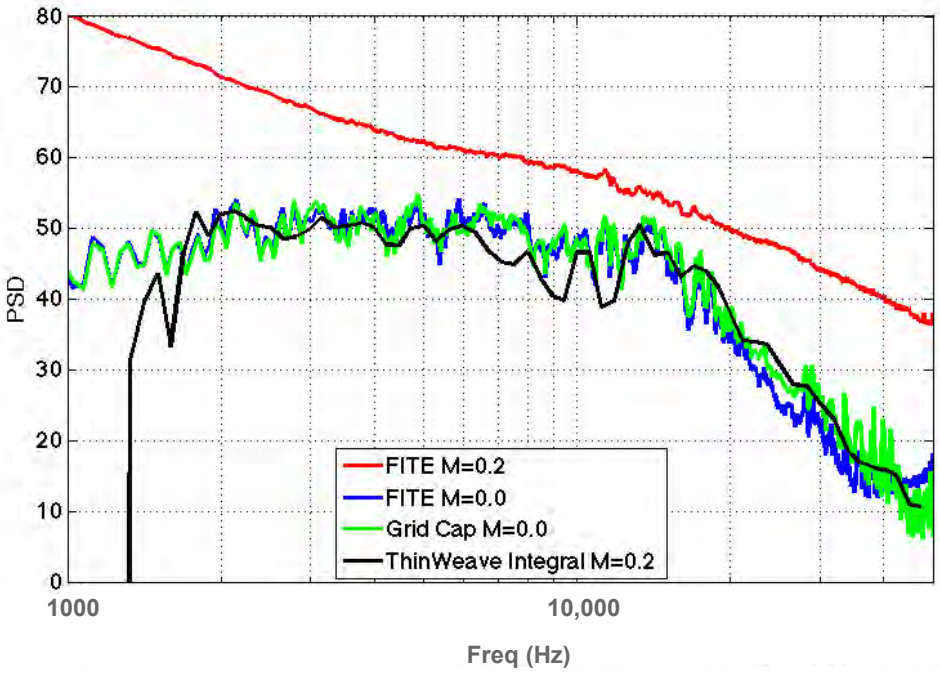

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-6dB

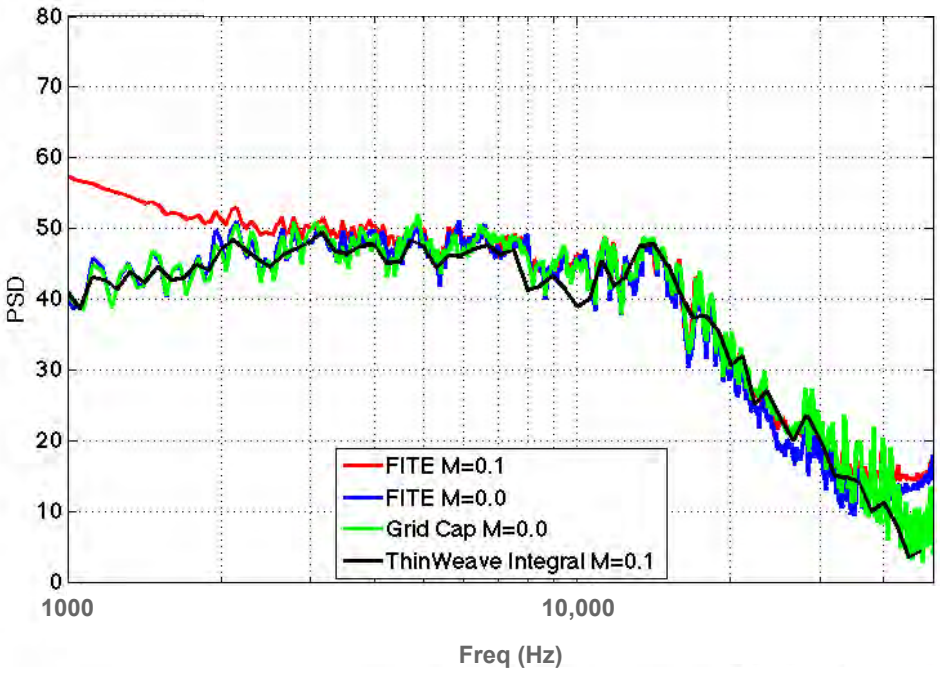
Off

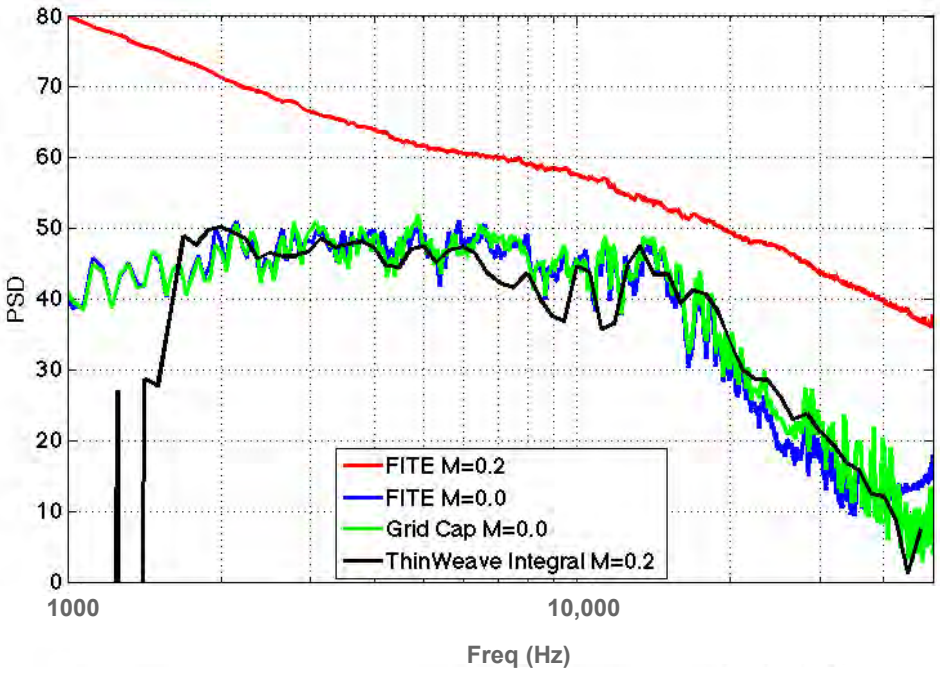

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-9dB

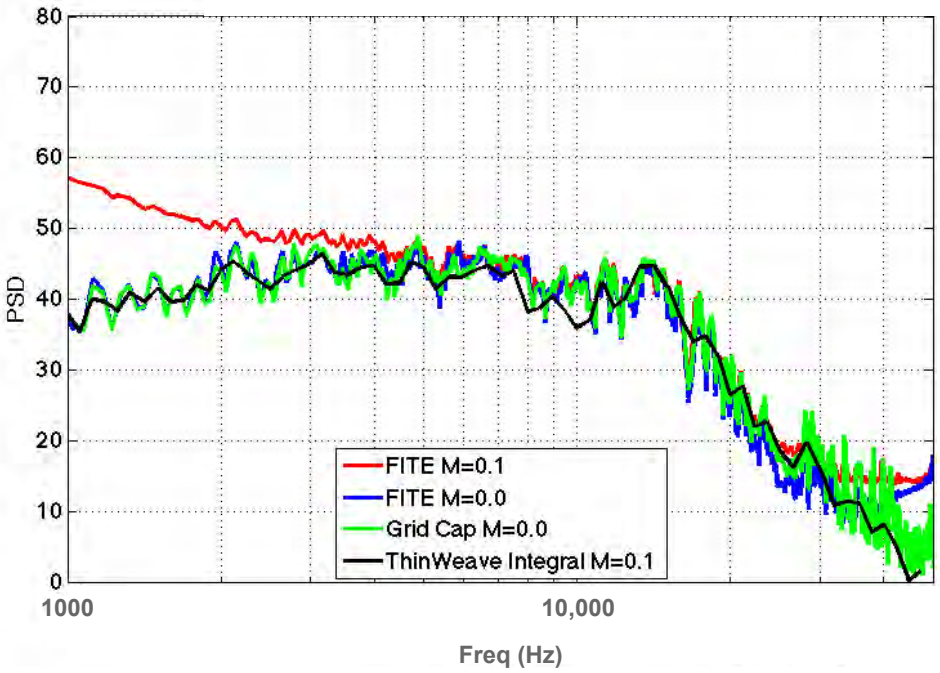
Off

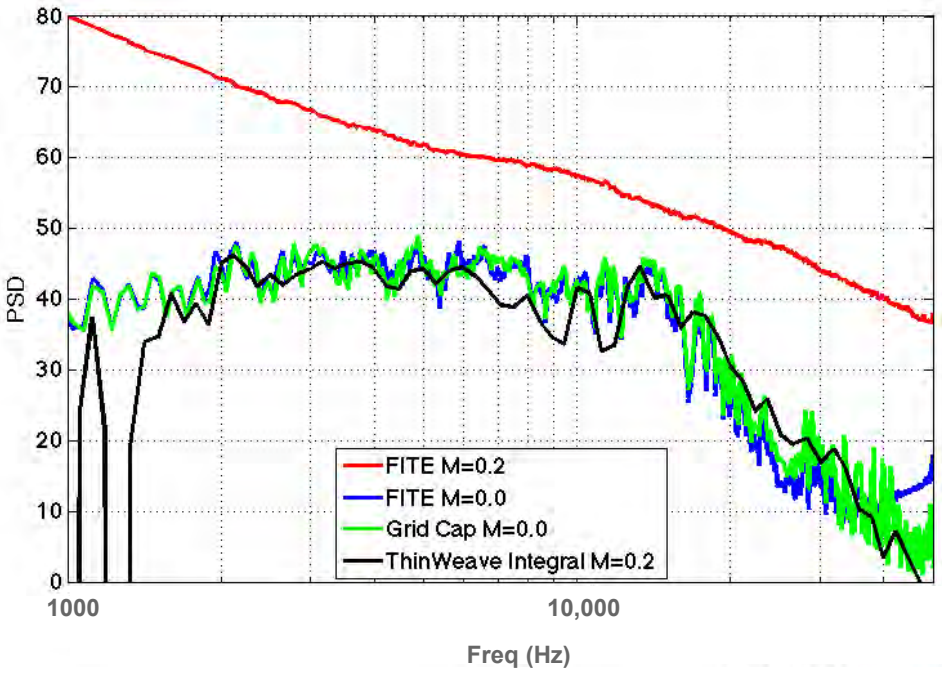

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-12dB

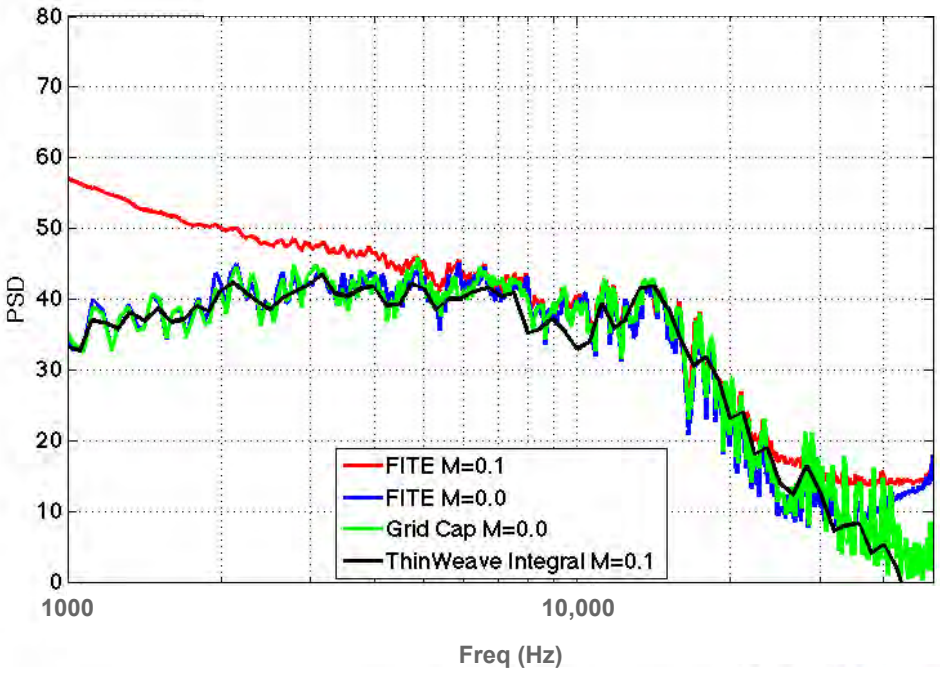
Off

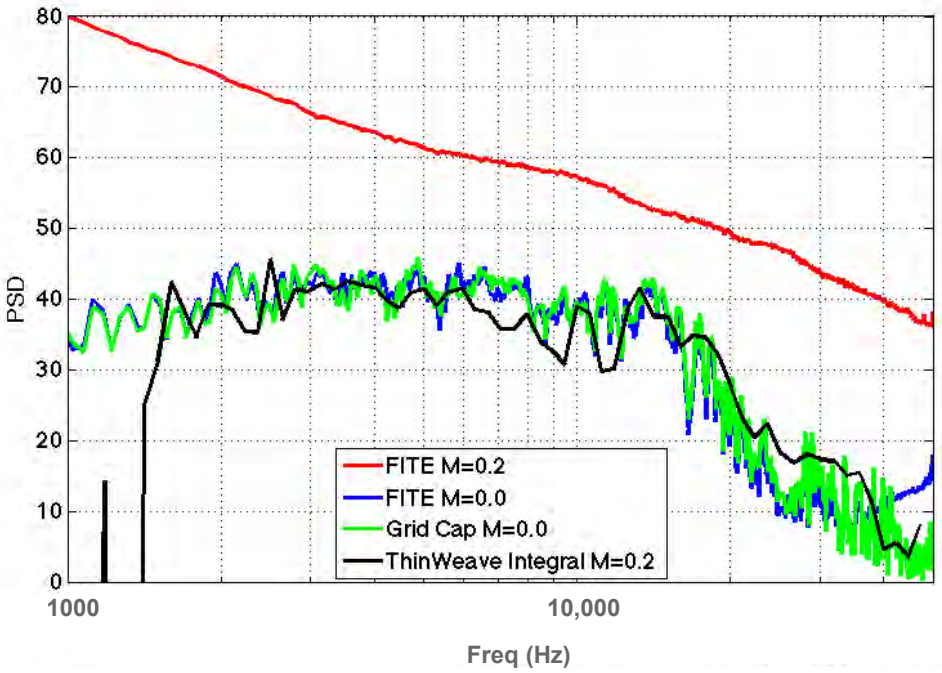

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-15dB

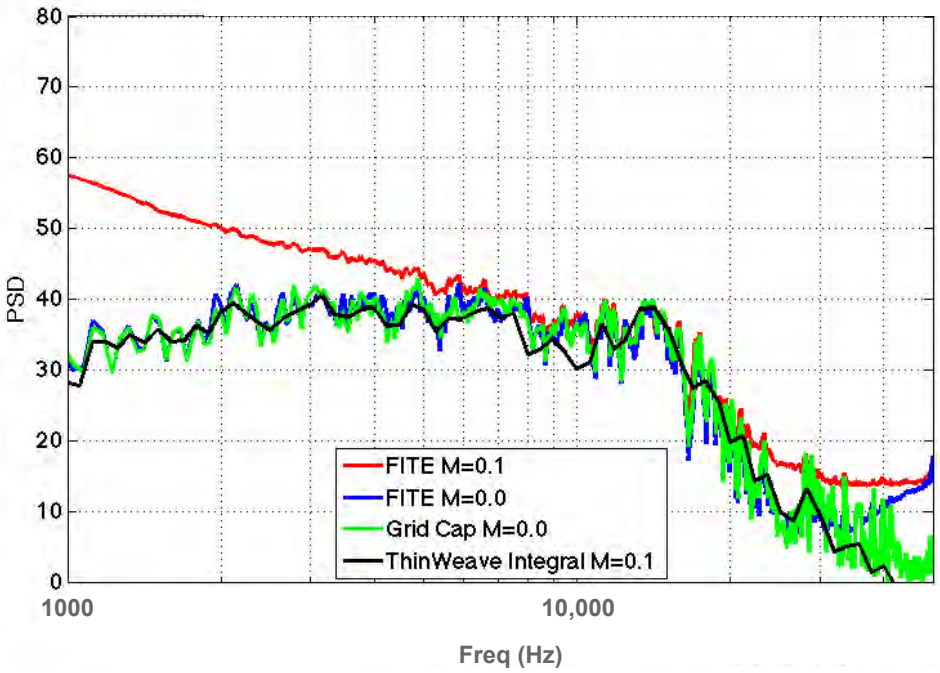
Off

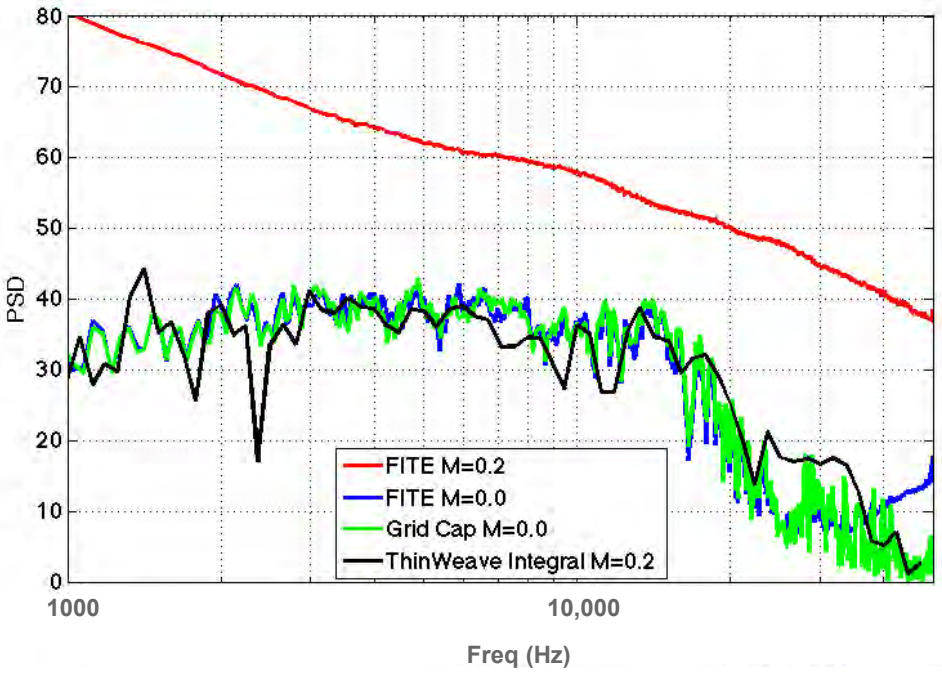

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-18dB

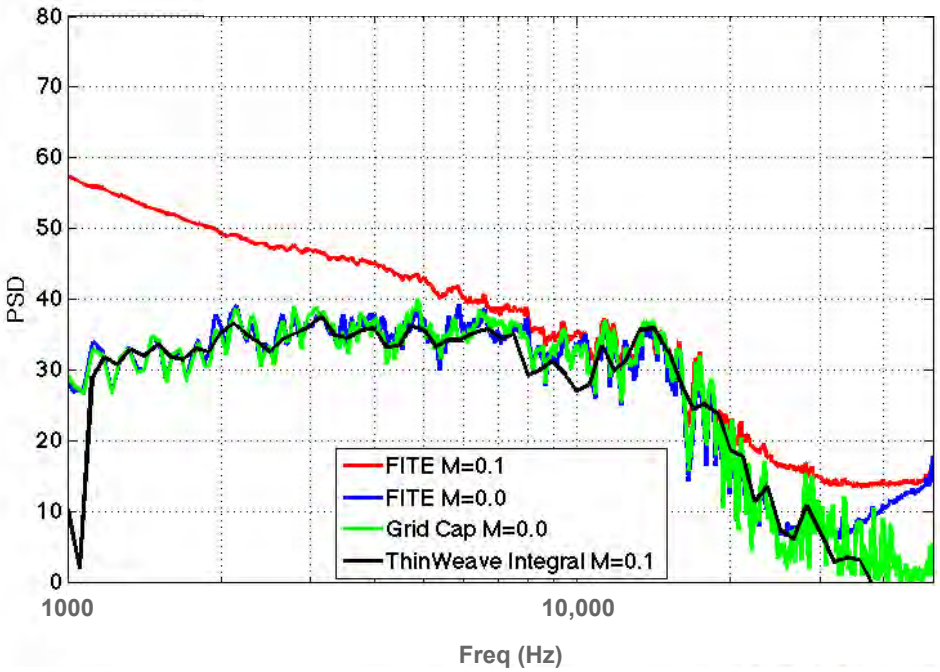
Off

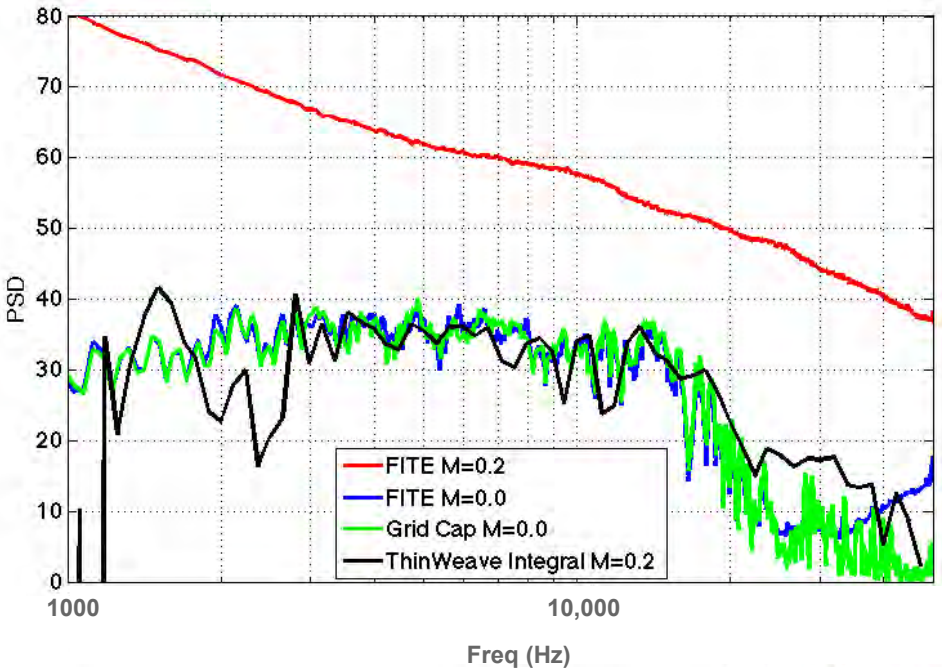

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)

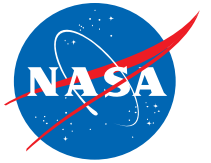

80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)

Max-21dB

Off


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.1
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.1
1000
10,000
Freq (Hz)


80
70
60
50
40
30
20
10
0
PSD
FITE M=0.2
FITE M=0.0
Grid Cap M=0.0
ThinWeave Integral M=0.2
1000
10,000
Freq (Hz)



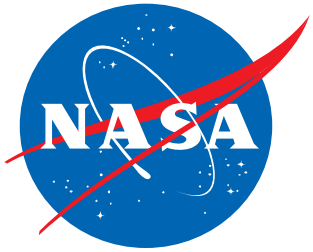
Summary

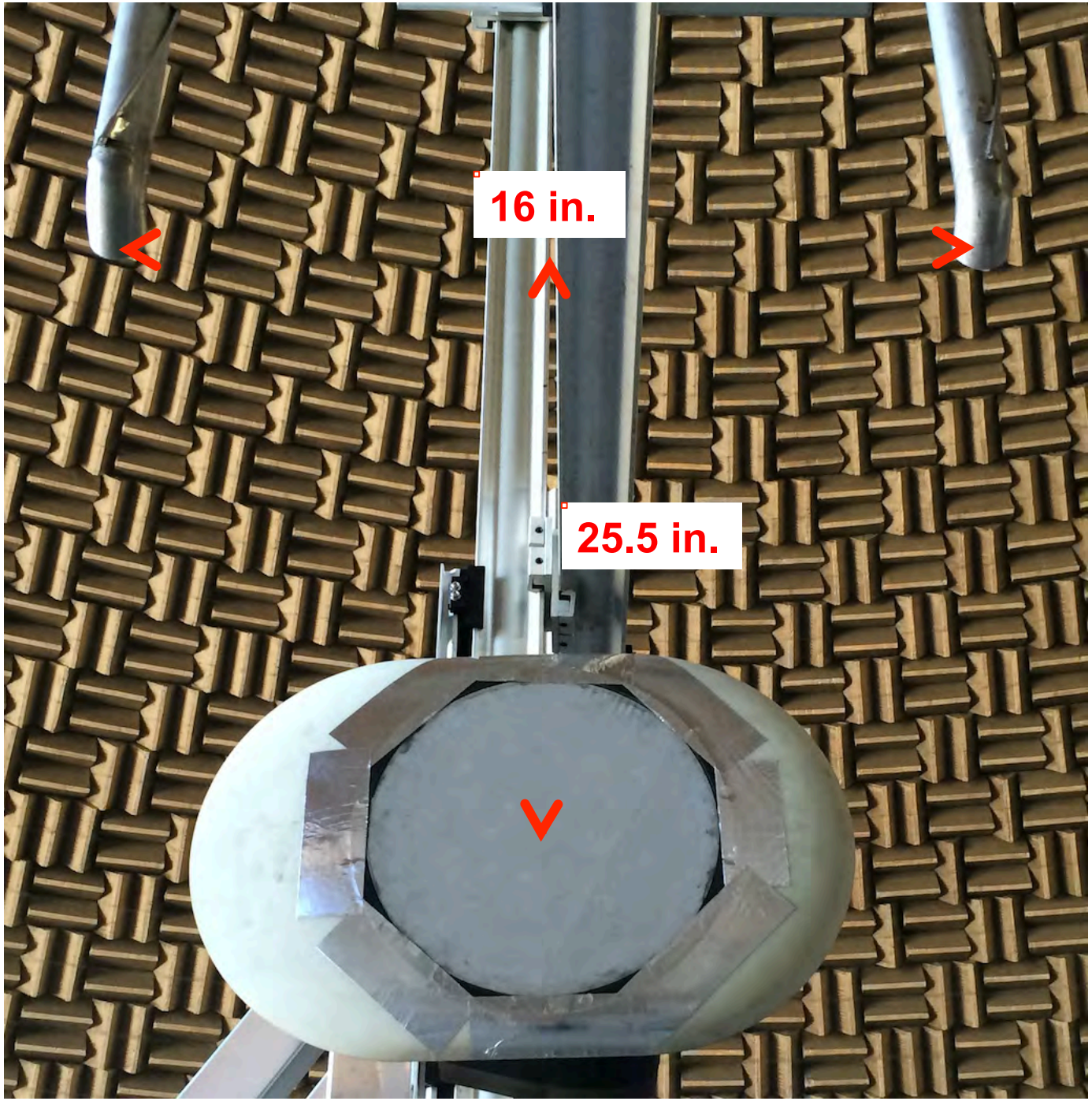
These results are encouraging. They indicate that combining Functional Beamforming with CSM subtraction is an effective method for pulling signals out of background noise.

Future Work

More work needs to be done to understand how the angular position of the source relative to the array impacts the results.

Need to test with a source that extends higher in frequency.


NASA


16 in.
25.5 in.