SAND2006-4160C

Comparison of Shielding Effectiveness of High Q Canonical Cavities with Thin Slots in a Mode-Stirred and Anechoic Chamber

July 13, 2006

Matthew B. Higgins*, Dawna R. Charley

Sandia National Laboratories, Albuquerque, NM 87123

SAND Number : 2006-XXXX P

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

National Nuclear Security Administration

Sandia National Laboratories

Outline

- Why is this important?
- Current Gain Correction Methods
- Measurement techniques
- Test Objects
- Results
  - 1, 2, and 8 slot cylindrical, high Q cavity (Q ≈ 4000)
  - 1 slot cylindrical lower Q cavity (Q ≈ 800)
- Conclusions

Sandia National Laboratories

Why is this important?

- A gain correction is needed to go from mode-stirred chamber shielding effectiveness data to free-space data
  - For transfer functions
  - For susceptibility testing

Gain Corrections

Gain correction for a single slot (from Warne, et. al at Sandia)

$$D \approx \frac{4\ell}{\lambda} \qquad D_m \approx \begin{cases} 0, & D < 1 \\ D, & D \geq 1, \end{cases}$$

Gain correction for an intentional emitter [1]

$$D_m \approx \begin{cases} 3, & ka \leq 1 \\ (ka)^2 + 2ka, & ka > 1, \end{cases}$$

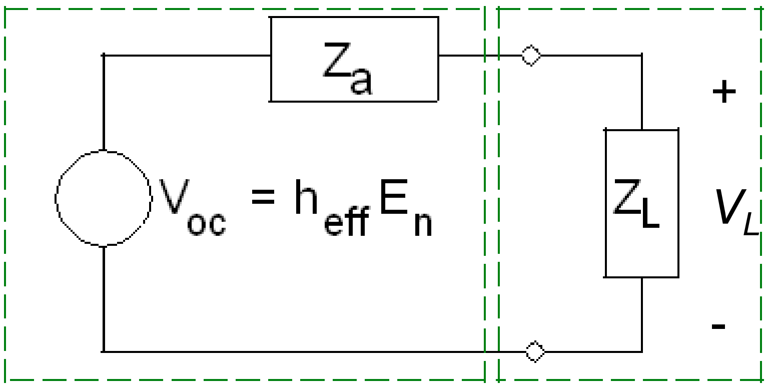
Gain correction for an unintentional emitter for a planar cut [2]

$$D_m \approx \begin{cases} 2.45, & ka \leq 1 \\ 0.577 + \ln(2(2ka+1)) + \dfrac{1}{4(2ka+1)}, & ka > 1, \end{cases}$$

Sandia National Laboratories

Calculating chamber and test object interior fields

Monopole Sensor



The load voltage, V_L, is measured. Use the following values to calculate the normal electric field picked up by the monopole.

Z_L = 50 Ω load
Z_a = monopole radiation impedance
V_{oc} = monopole open circuit voltage
h_{eff} = monopole effective height
E_n = normal electric field (quantity of interest)

Calculation derivation

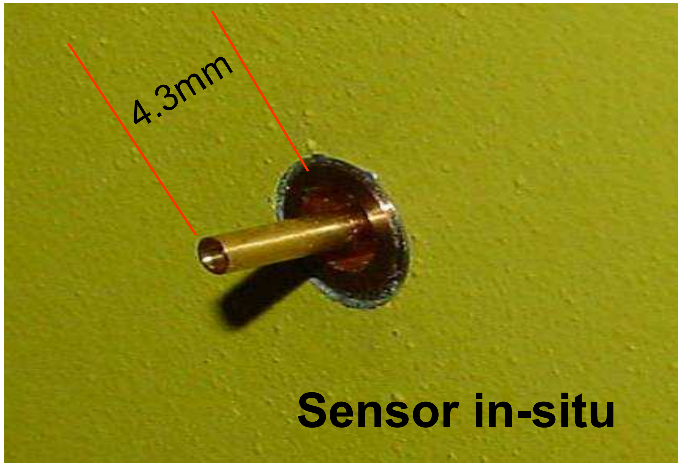
$$V_L = V_{oc} \frac{Z_L}{Z_a + Z_L}$$ from circuit theory

$$V_{oc} = \frac{V_L}{Z_L}\left(Z_a + Z_L\right) = h_{eff} E_n$$

$$E_n = \frac{V_L}{Z_L h_{eff}}(Z_a + Z_L)$$

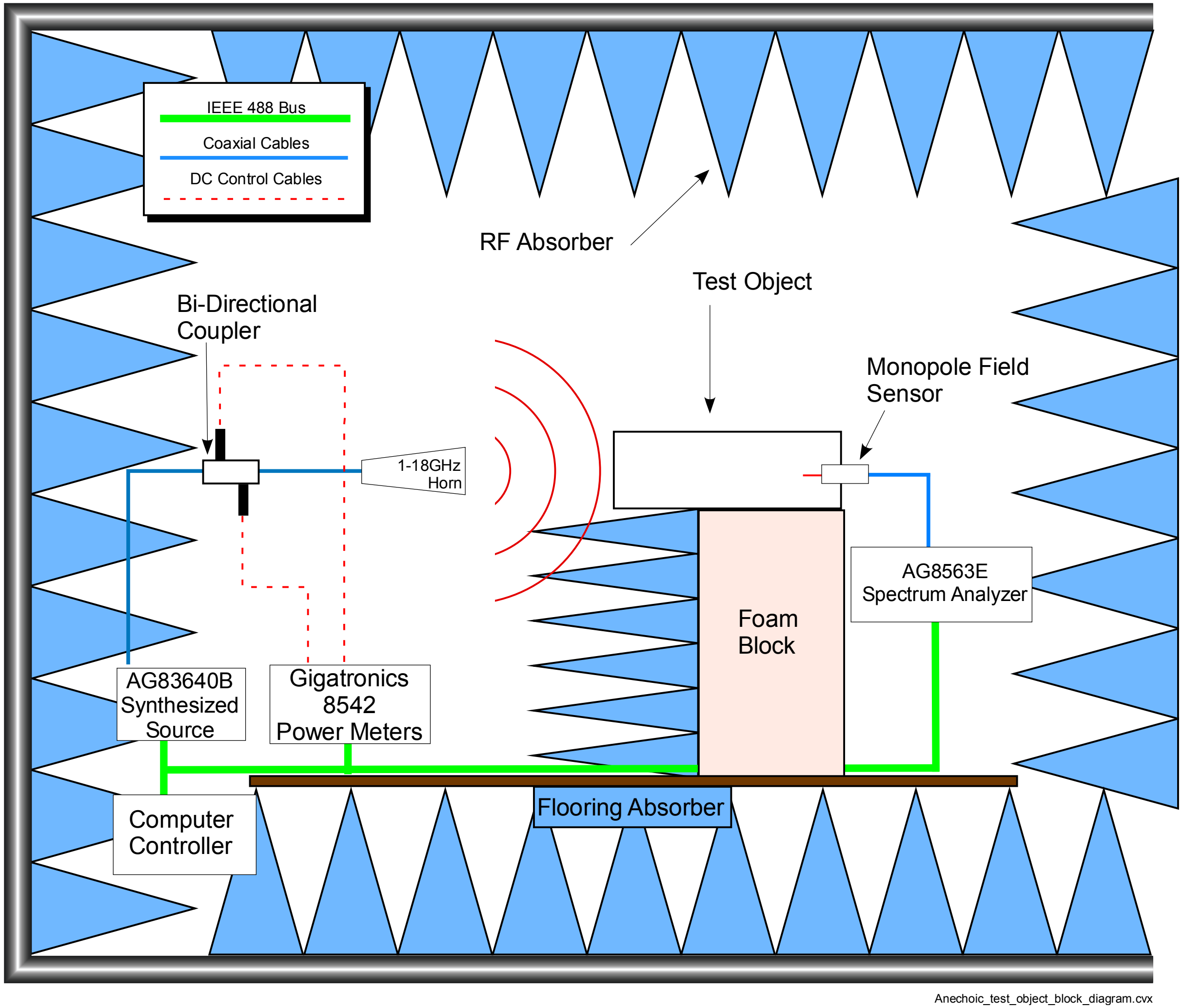
Sandia National Laboratories

Monopole Sensors



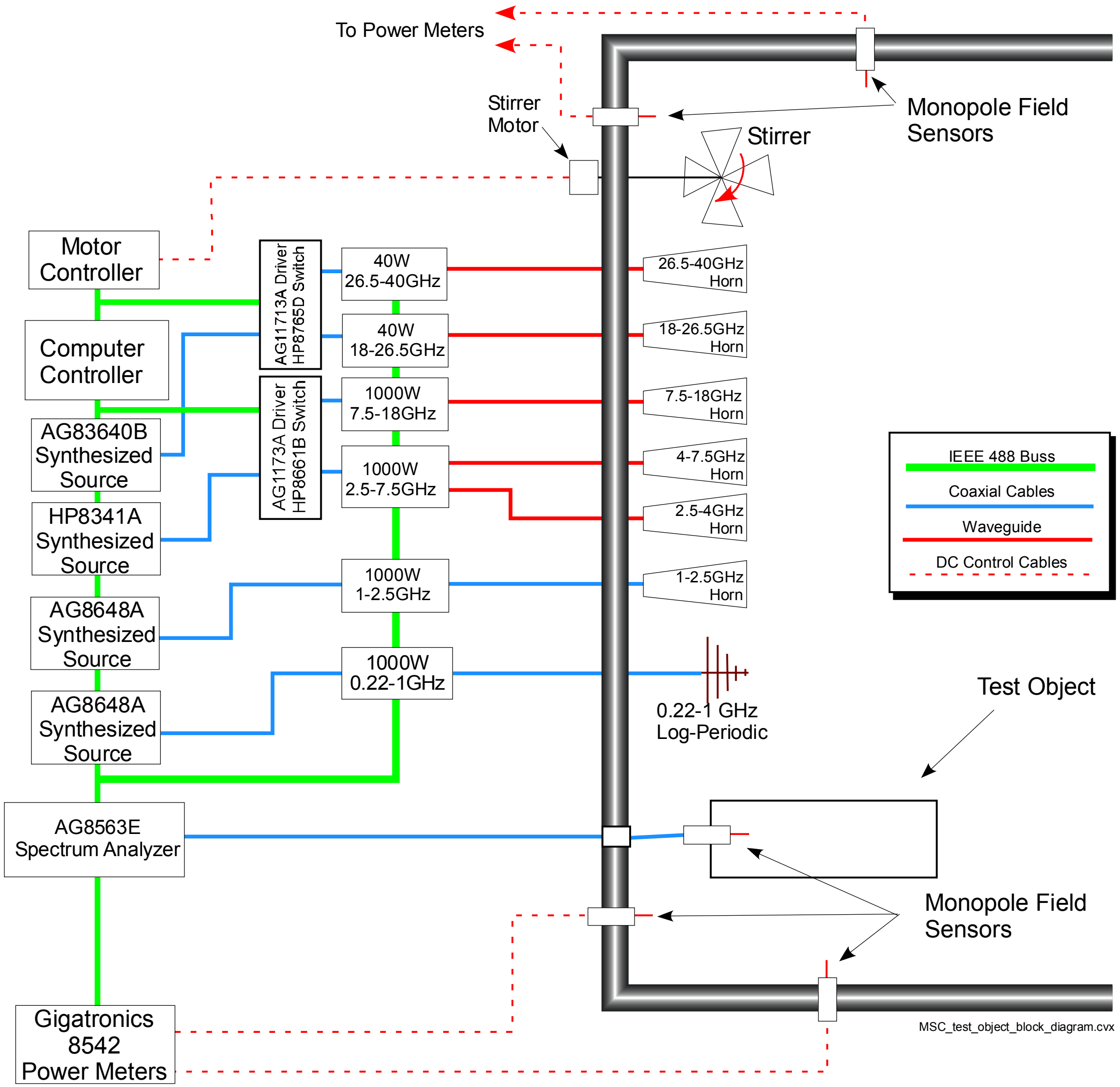
220 MHz – 18 GHz
Monopole sensor

Anechoic Chamber Diagram



Sandia National Laboratories

Mode-Stirred Chamber Diagram



Sandia National Laboratories

Mode-Stirred Chamber (MSC)

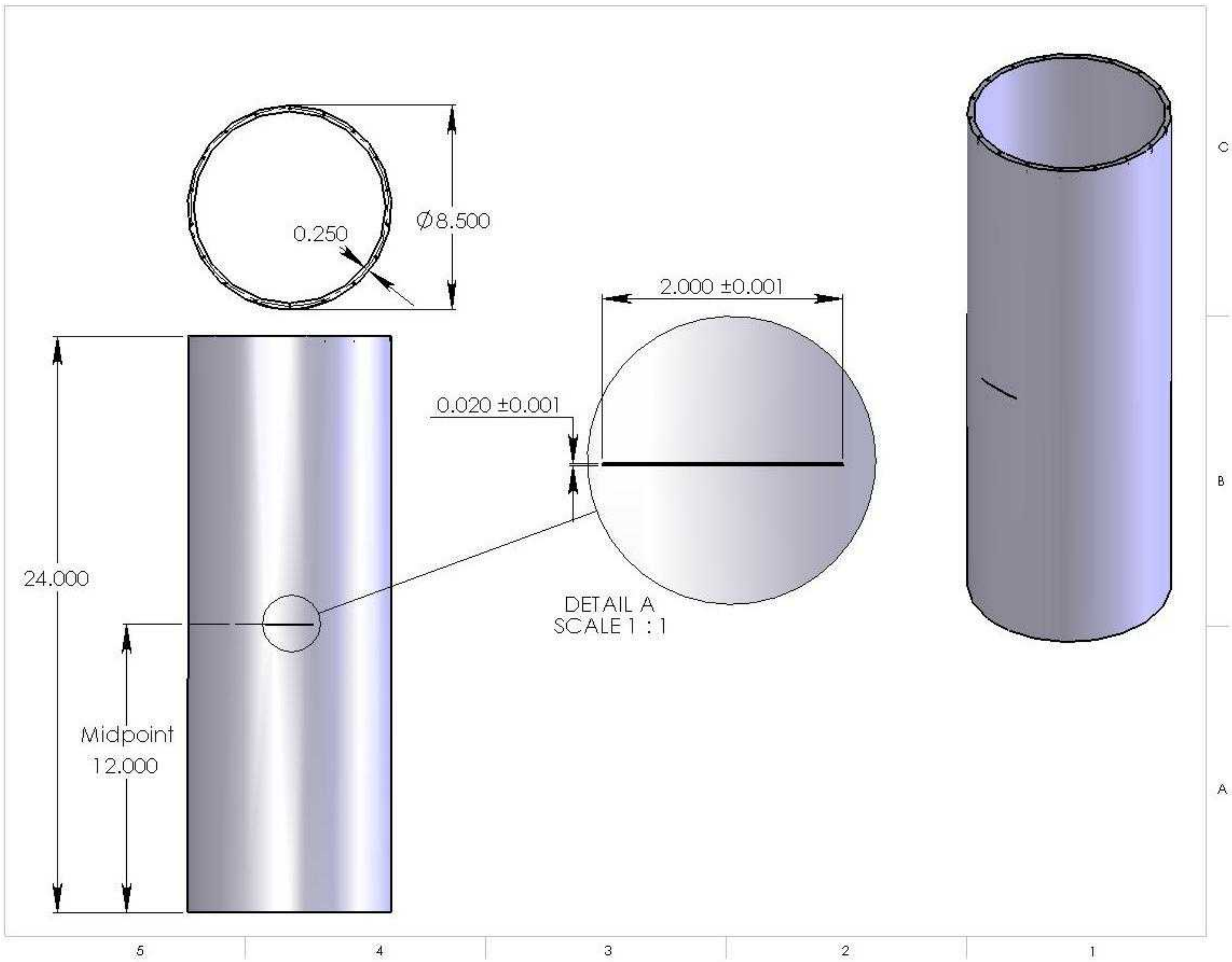
Mode-Stirred Chamber (MSC)

- **MSC provides statistically uniform incident electromagnetic field**
- **A superposition of plane waves**
- **Bathes test object in electromagnetic field, which ensures leaks are found**
- **Cables do not need to be in a specific orientation**

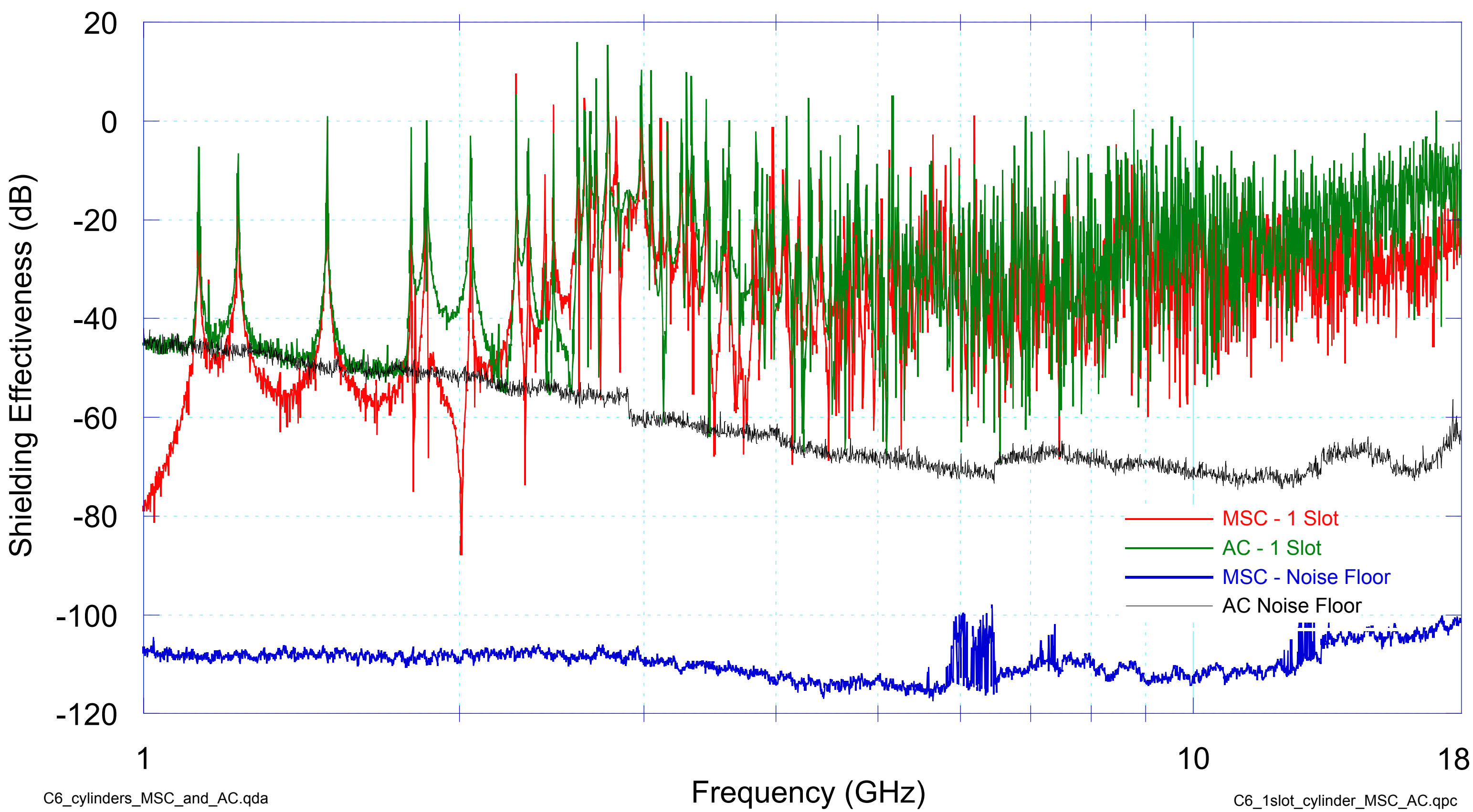
Performance Characteristics of Mode-Stirred Chamber Test Facility

Dimension	**4 x 7 x 11 m (HxWxL)**
Design	**Welded Aluminum**
Entrance Dimensions	**3.7 x 3.7 m**
Frequency	**0.22 – 40 GHz**
Input Power	**Solid State and TWT amplifiers**
	1000 W, 220 MHz – 18 GHz
	40 W, 18 GHz – 40 GHz
Field Strength	**~3000 V/m peak, 220 MHz – 18 GHz**
	~600 V/m peak, 18 – 40 GHz

Cylindrical Test Object

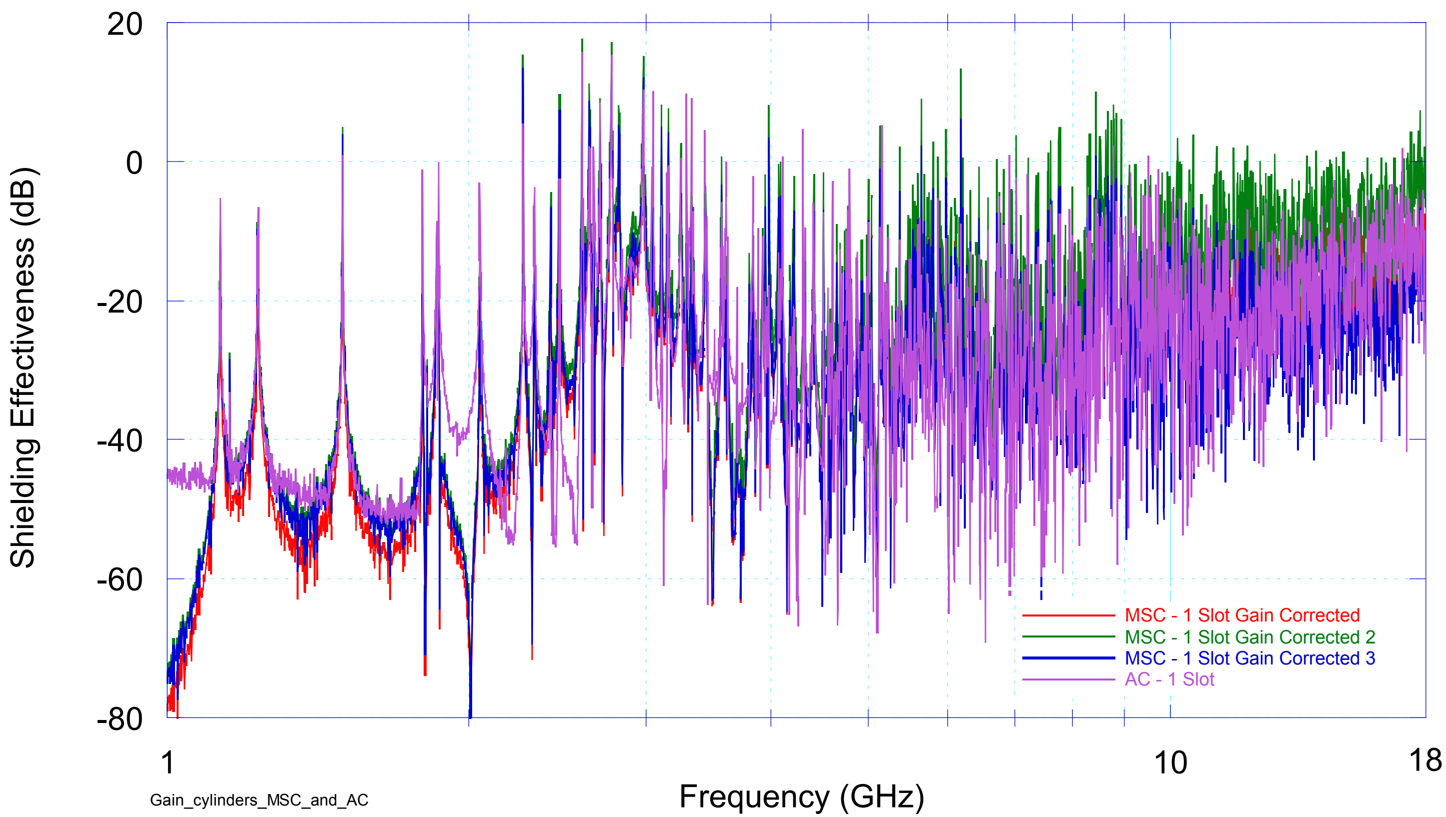


Single Slot Cylinder



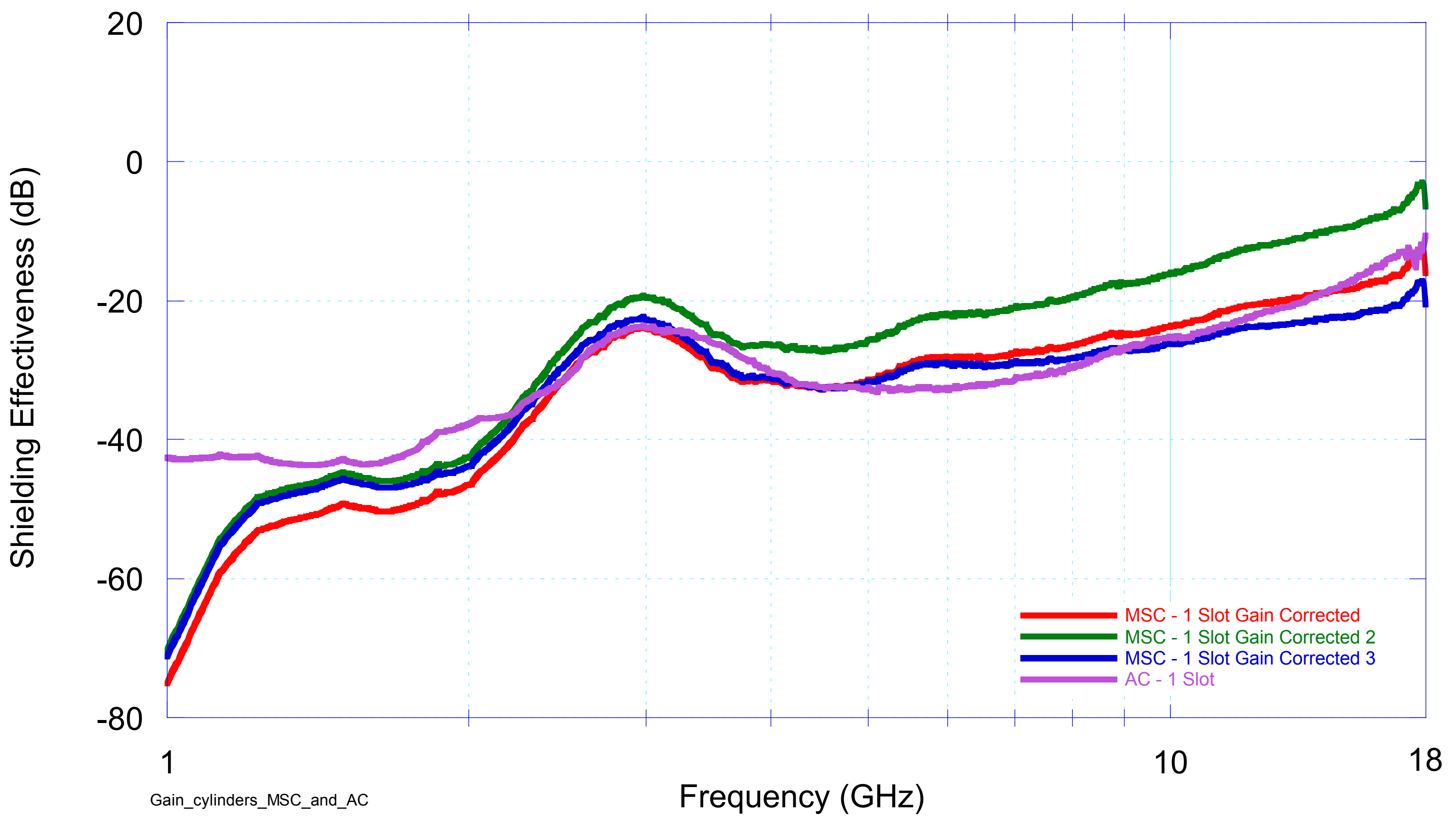
Sandia National Laboratories

Single Slot Cylinder with Gain Correction

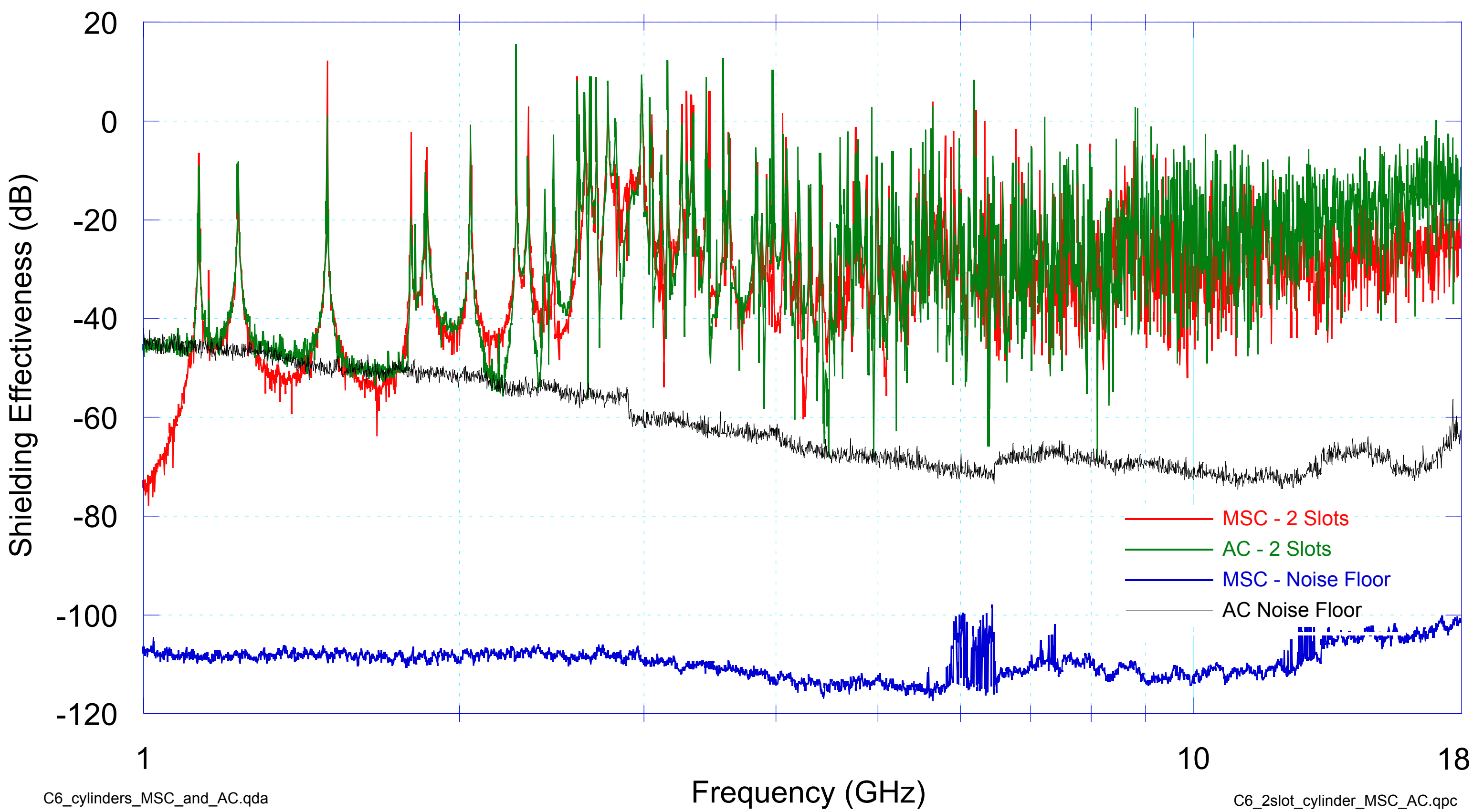


Sandia National Laboratories

Gain Corrected and Smoothed

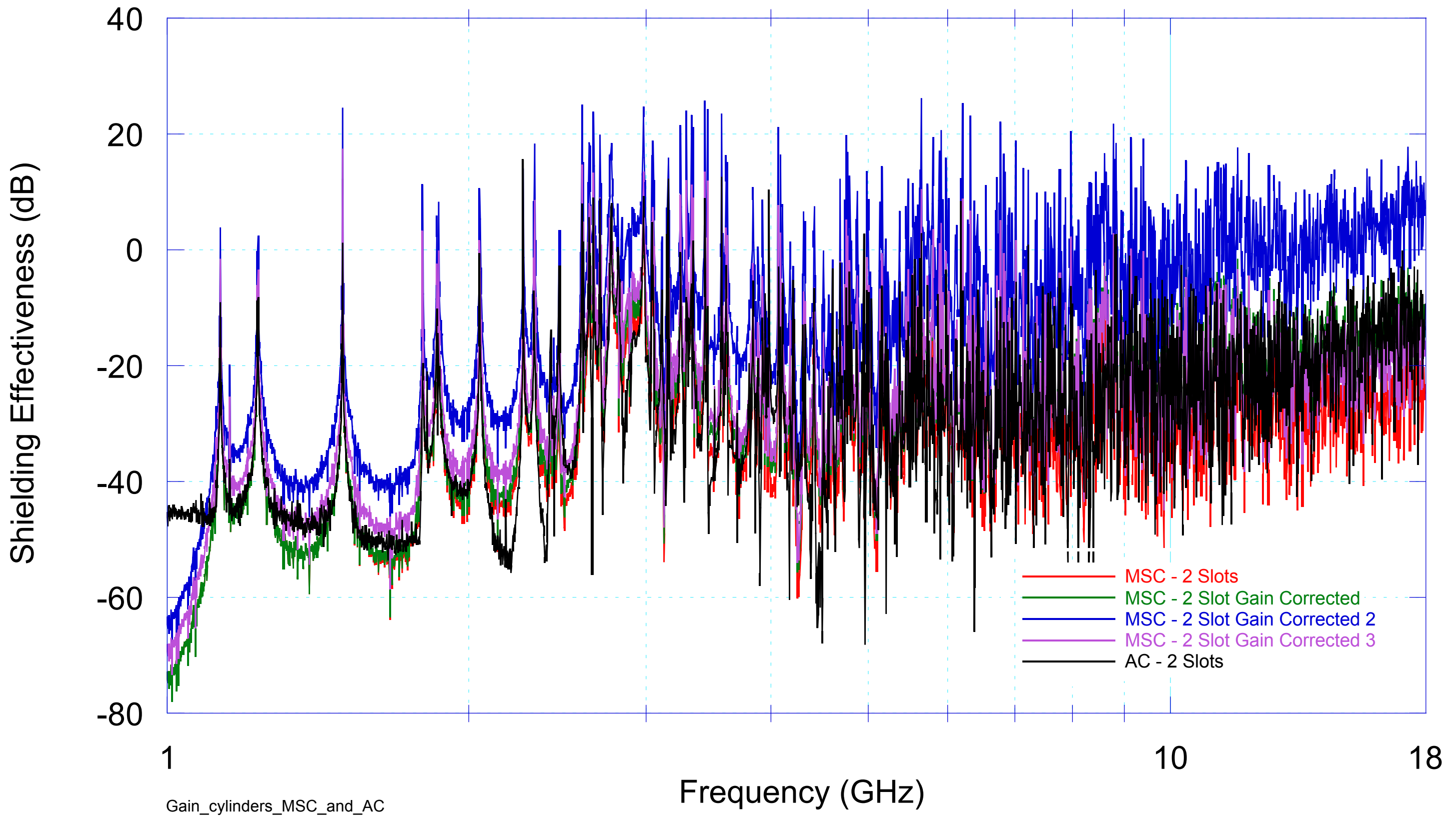


Two Slot Cylinder

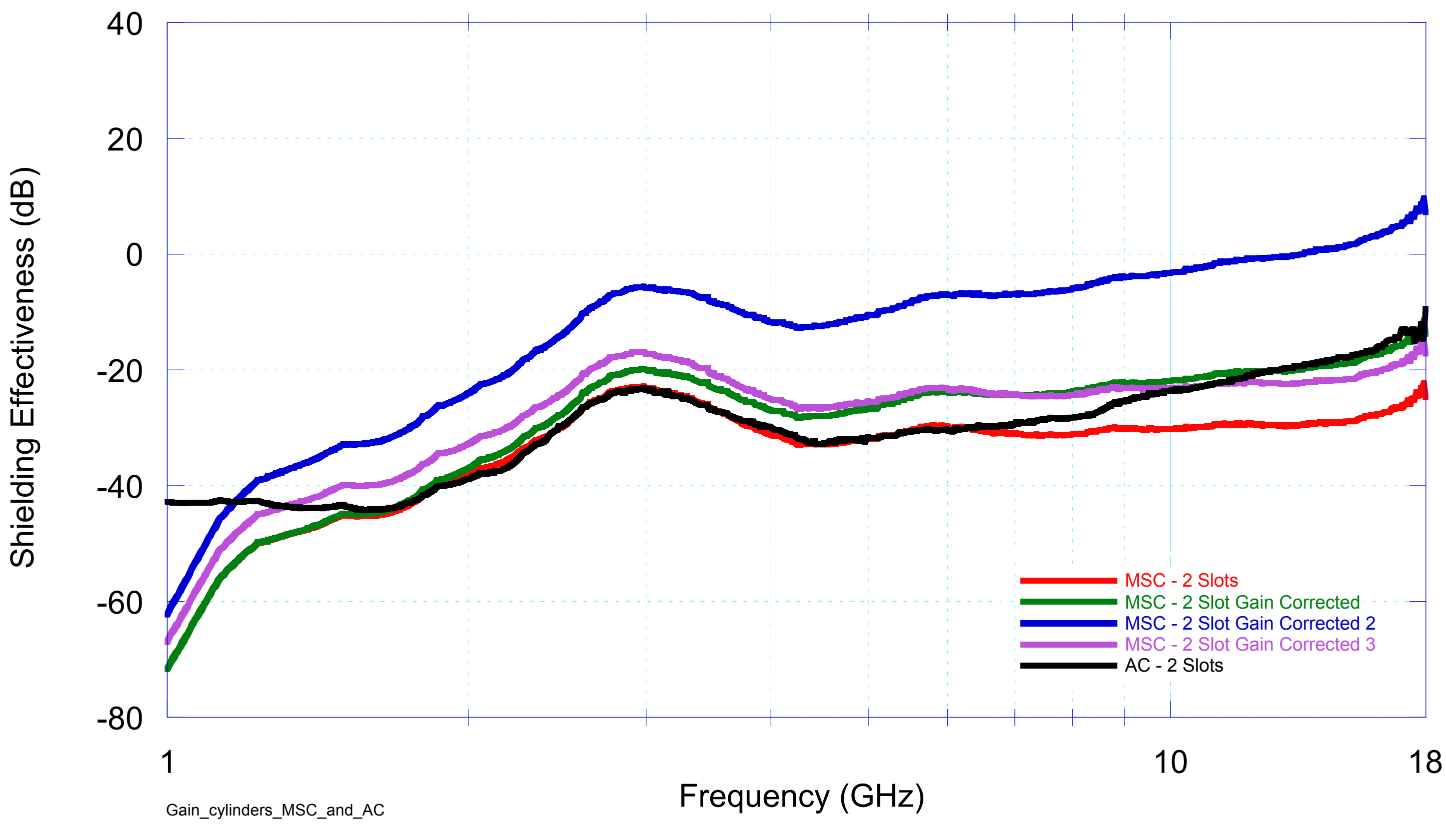


Sandia National Laboratories

Two Slot Cylinder with Gain Correction

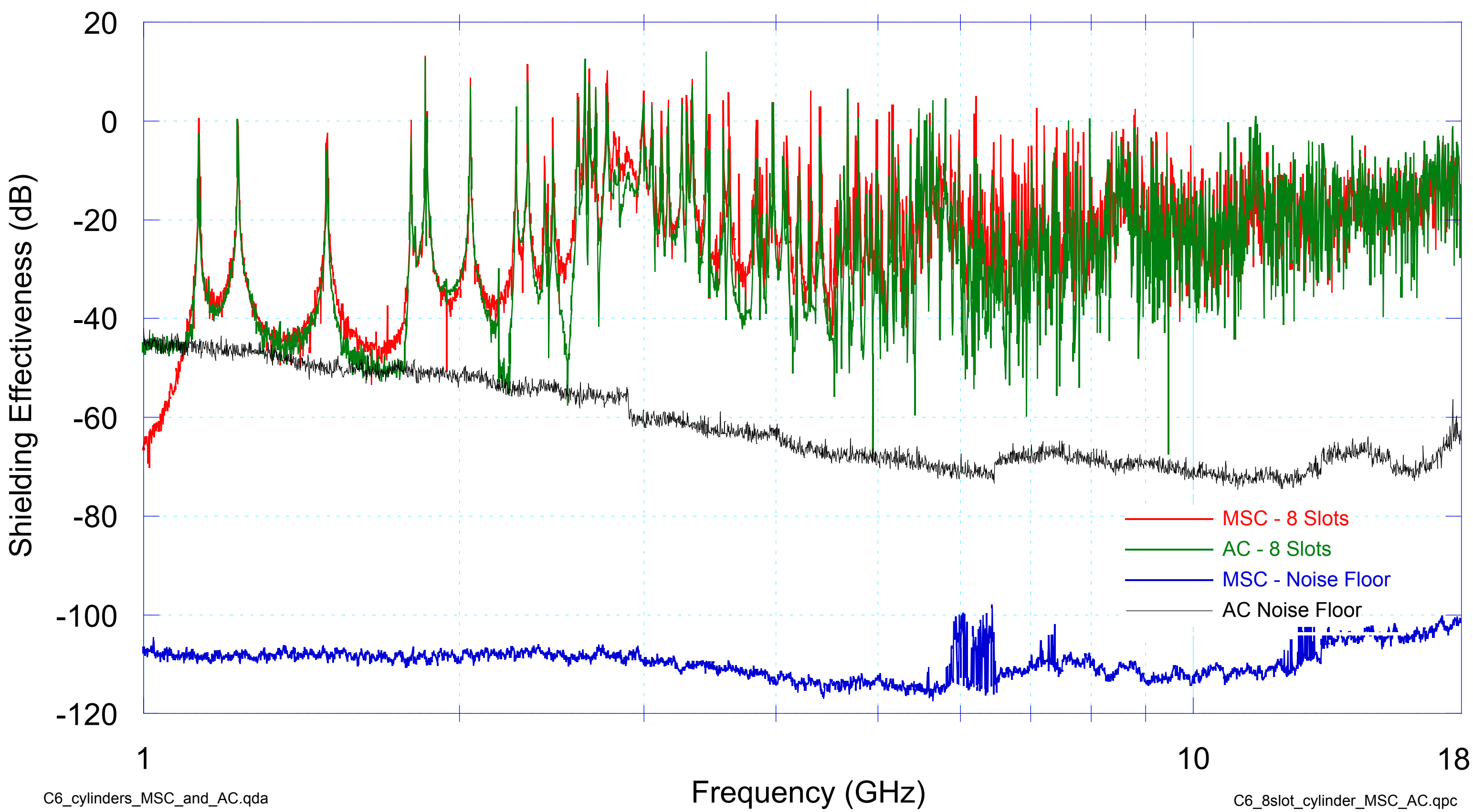


Gain Corrected and Smoothed

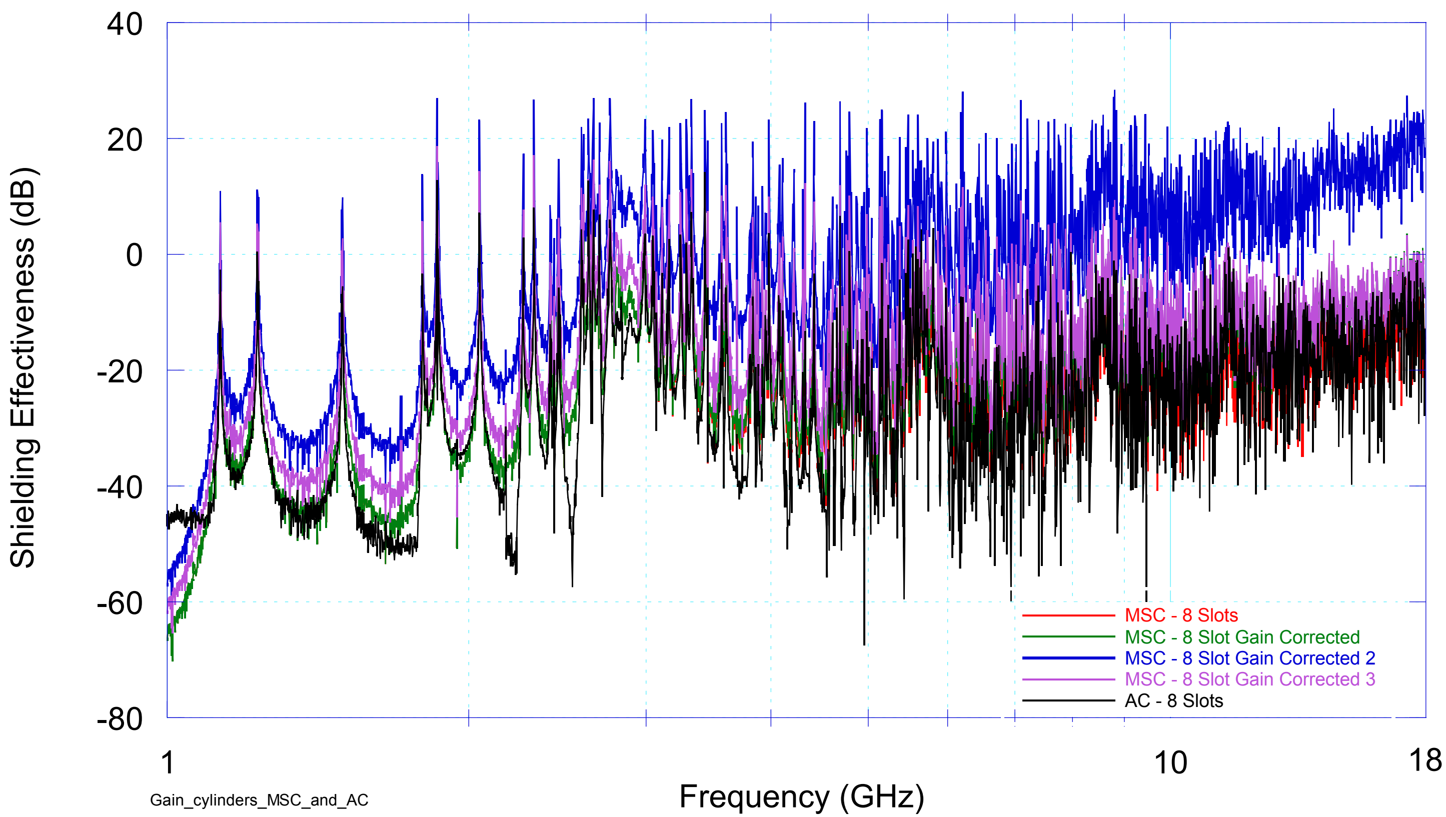


Sandia National Laboratories

Eight Slot Cylinder

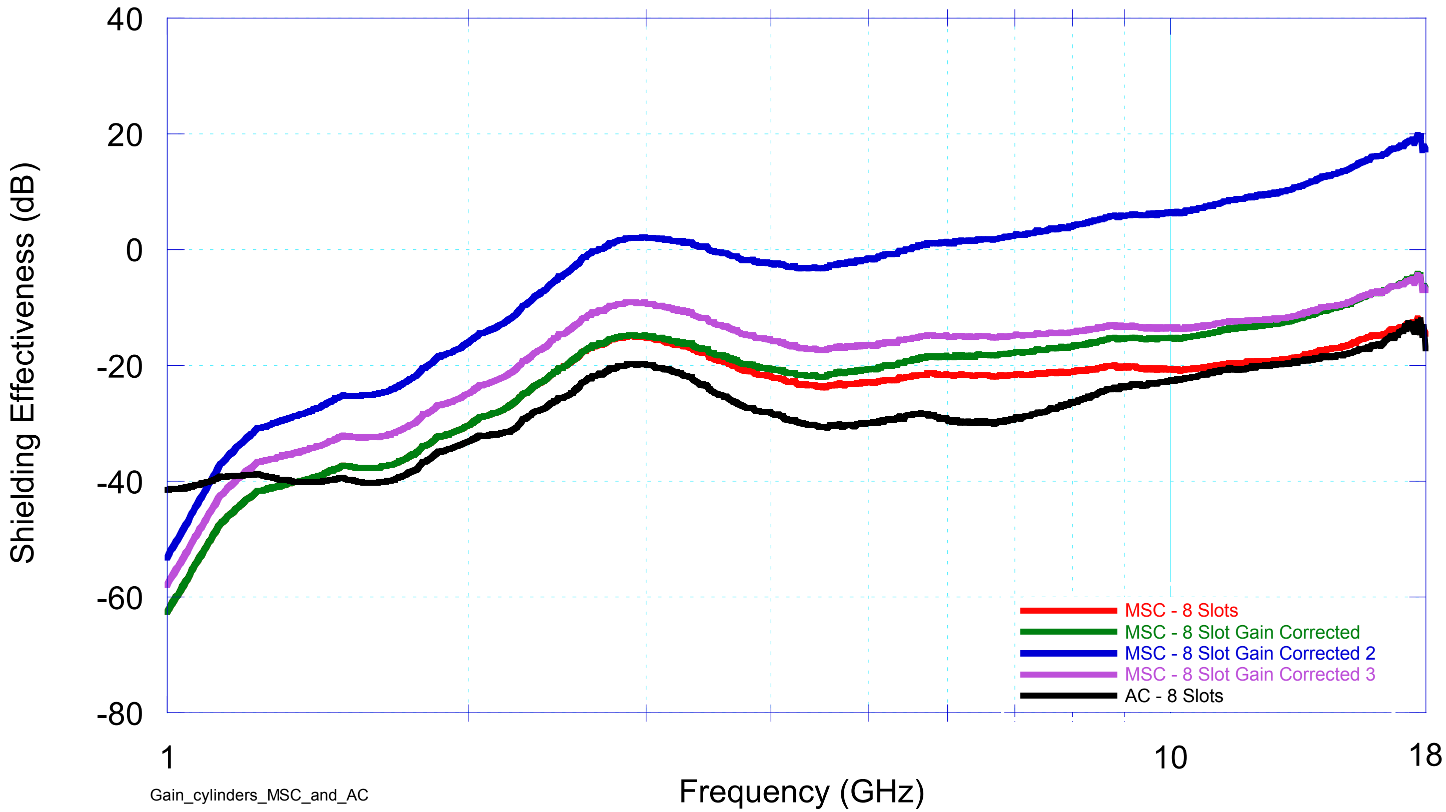


Eight Slot Cylinder with Gain Correction

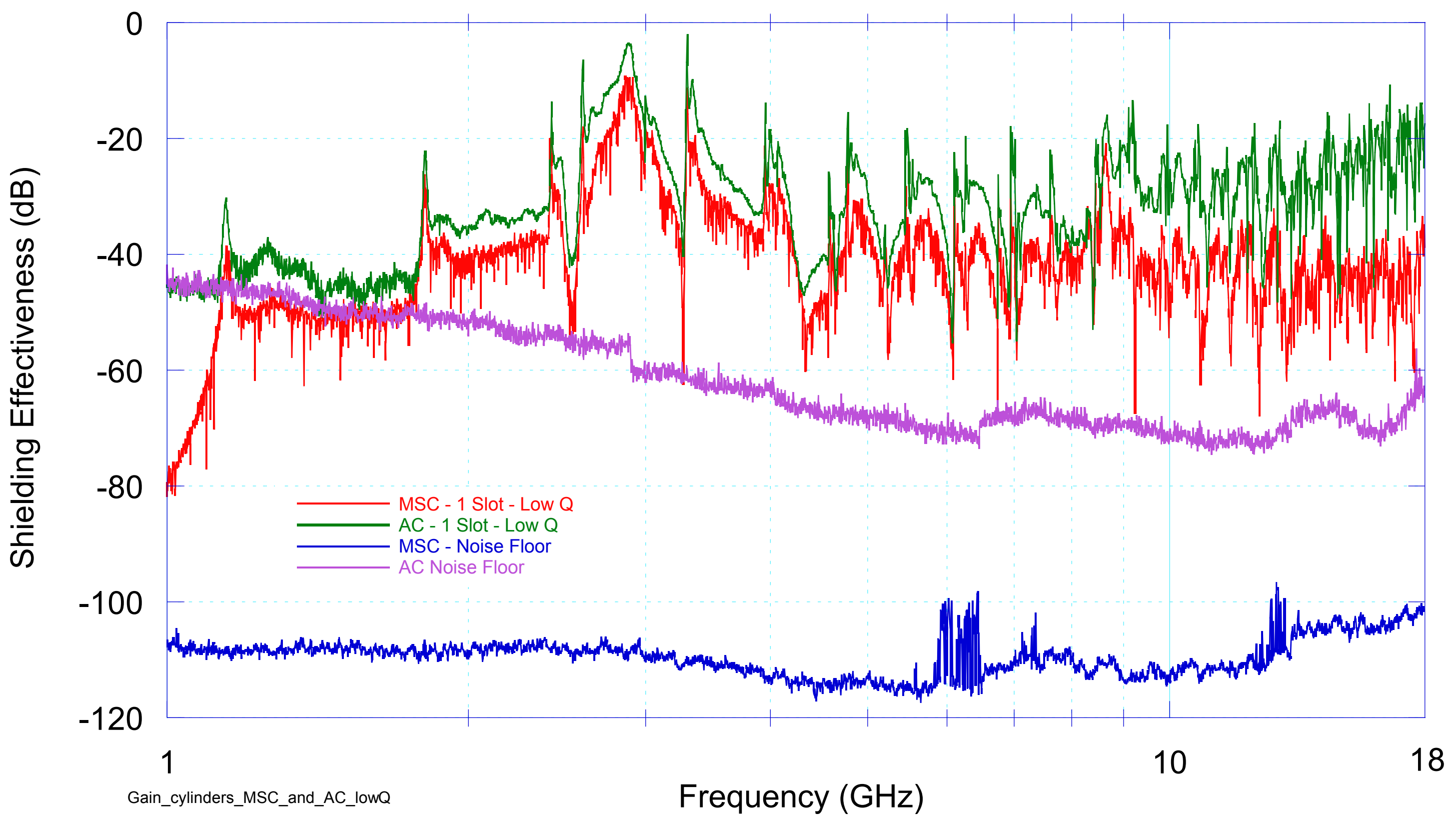


Sandia National Laboratories

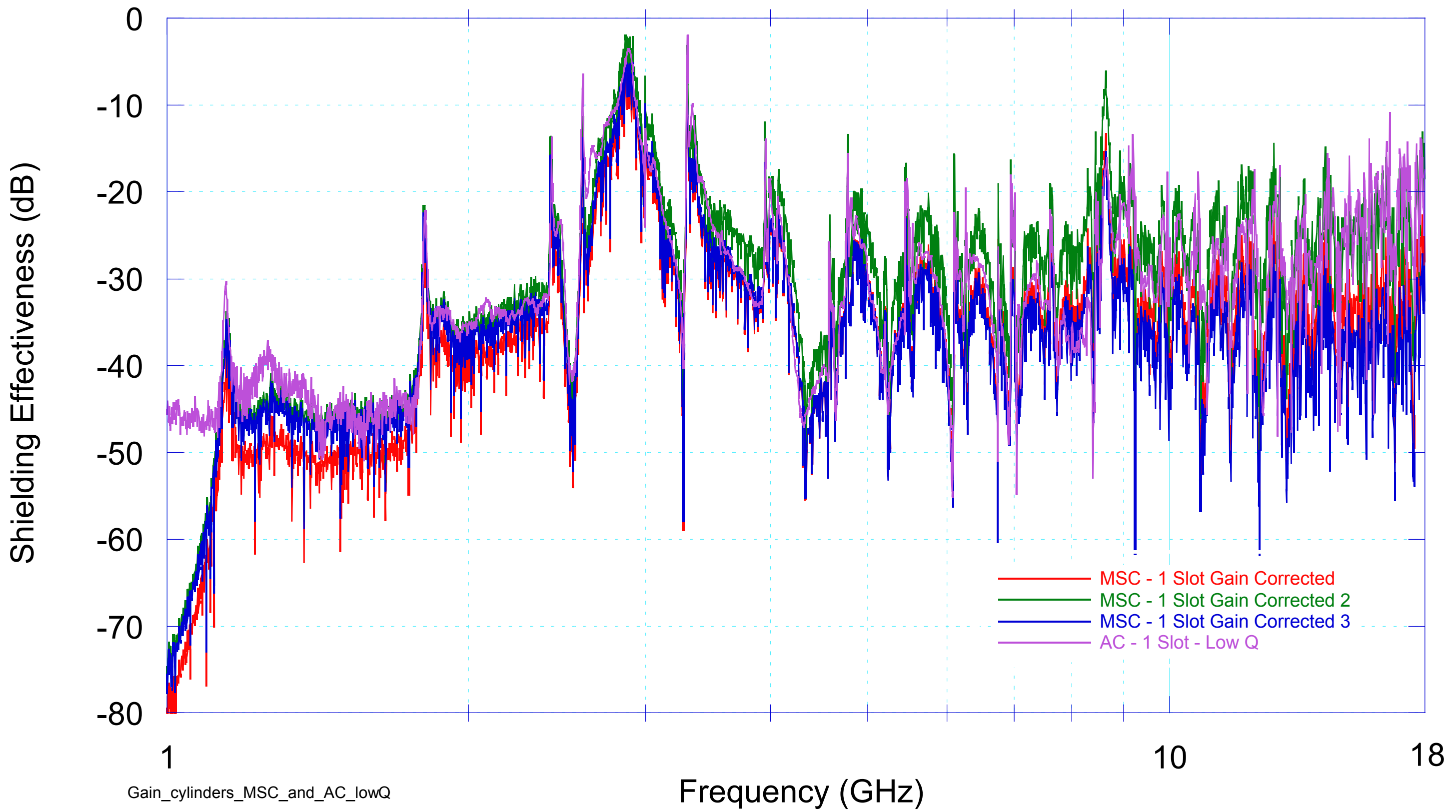
Gain Corrected and Smoothed



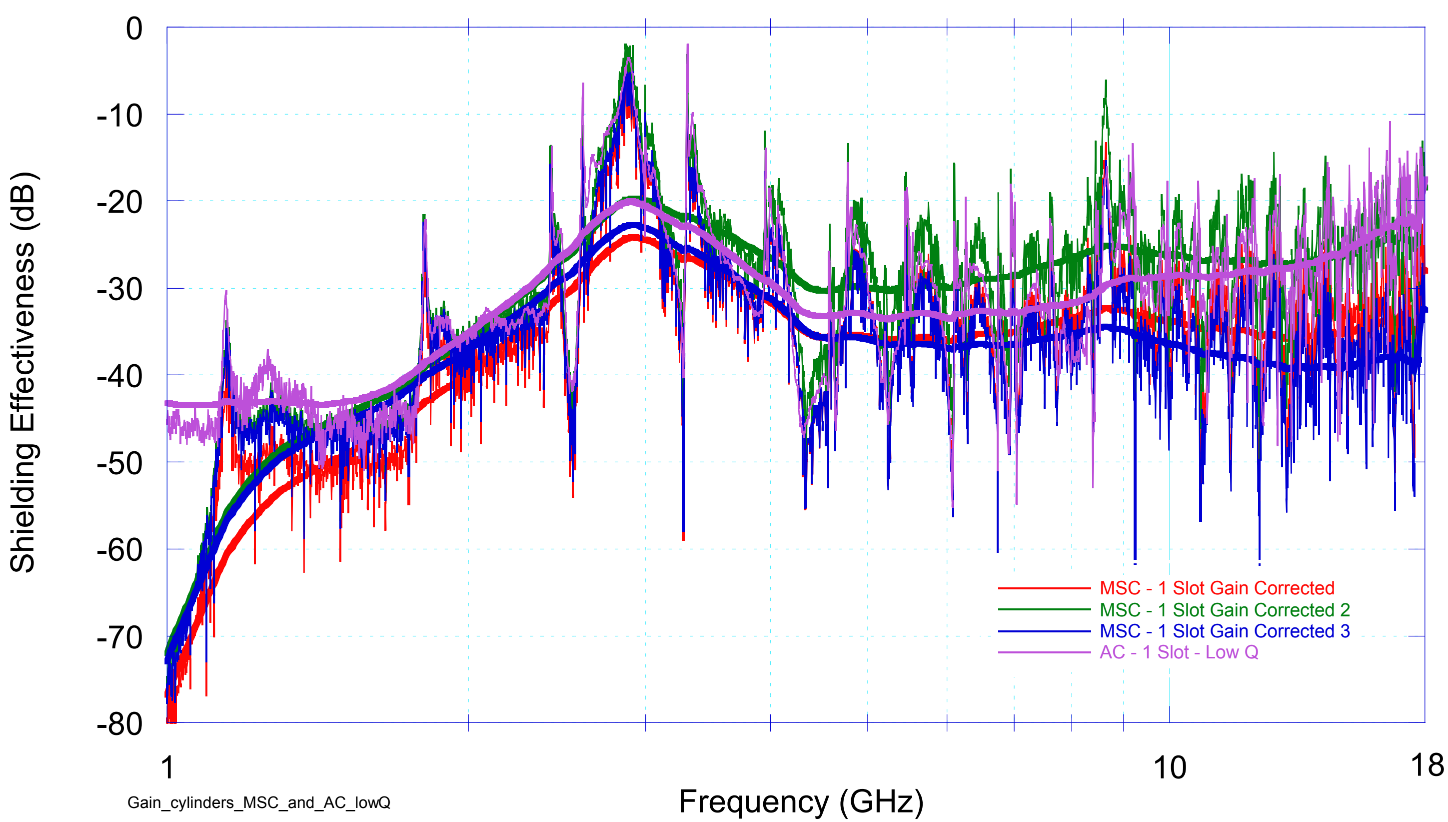
Single Slot Cylinder – Low Q



Single Slot Cylinder (Low Q) with Gain Correction



Gain Corrected and Smoothed



Sandia National Laboratories

Conclusions

- High Q Cavities
  - Single slot
    - Good correlation on average was seen with gain correction at slot resonance and above with the Sandia equation and the equation from Ref #2.
  - 2 slot
    - MSC data appears to not need gain correction below 7 GHz.
    - Above 9 GHz, Sandia equation and Ref #2 equation perform well.
  - 8 slot
    - MSC data appears to not need gain correction.
    - Full pattern of test object needed in Anechoic chamber.

Conclusions (cont.)

- **Low Q Cavities**
  - **Single slot**
    - **Good correlation on average was seen with gain correction below 3.5 GHz and above 10 GHz using the equation from Ref #1. Between 3.5 and 10 GHz the gain was over compensated by less that 5 dB.**
    - **Below 10 GHz Sandia equation and Ref #2 equation under compensated by 2 – 3 dB.**

Sandia National Laboratories

References

1. Hill, D.A.; Camell, D.G.; Cavcey, K.H.; and Koepke, G.H., "Radiated emissions and immunity of microstrip transmission lines: theory and reverberation chamber measurements," *IEEE Trans. Electromag. Compat.*, vol. 38, pp. 165-172, 1996.
2. Koepke, G.H.; Hill, D.A.; and Ladbury, J., "Directivity of the Test Device in EMC Measurements," *IEEE International Symposium on Electromagnetic Compatibility*, vol. 2, pp. 535-539, Aug. 2000.

Sandia National Laboratories