# Investigation of Sampling Geometry for Simultaneous Emissions / Immunity Calibration of Free Space Chambers

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# Overview

- History : What’s wrong with Normalized Site Attenuation Criteria of +/- 4 dB ?
- Background : Proposed Method of Simultaneous Emissions/Immunity Calibration in Free Space Chambers
- Calibration Geometry : Uniform Plane vs. Volumetric Sampling
- Experimental Results for a typical chamber
- Conclusions

# Radiated Emissions Model

Emissions Source
(dBuV/m)

↓

+Ideal Site Attenuation (dB)

↓

+Non-Ideal Site Attenuation
(+/- 4 dB to Ideal)

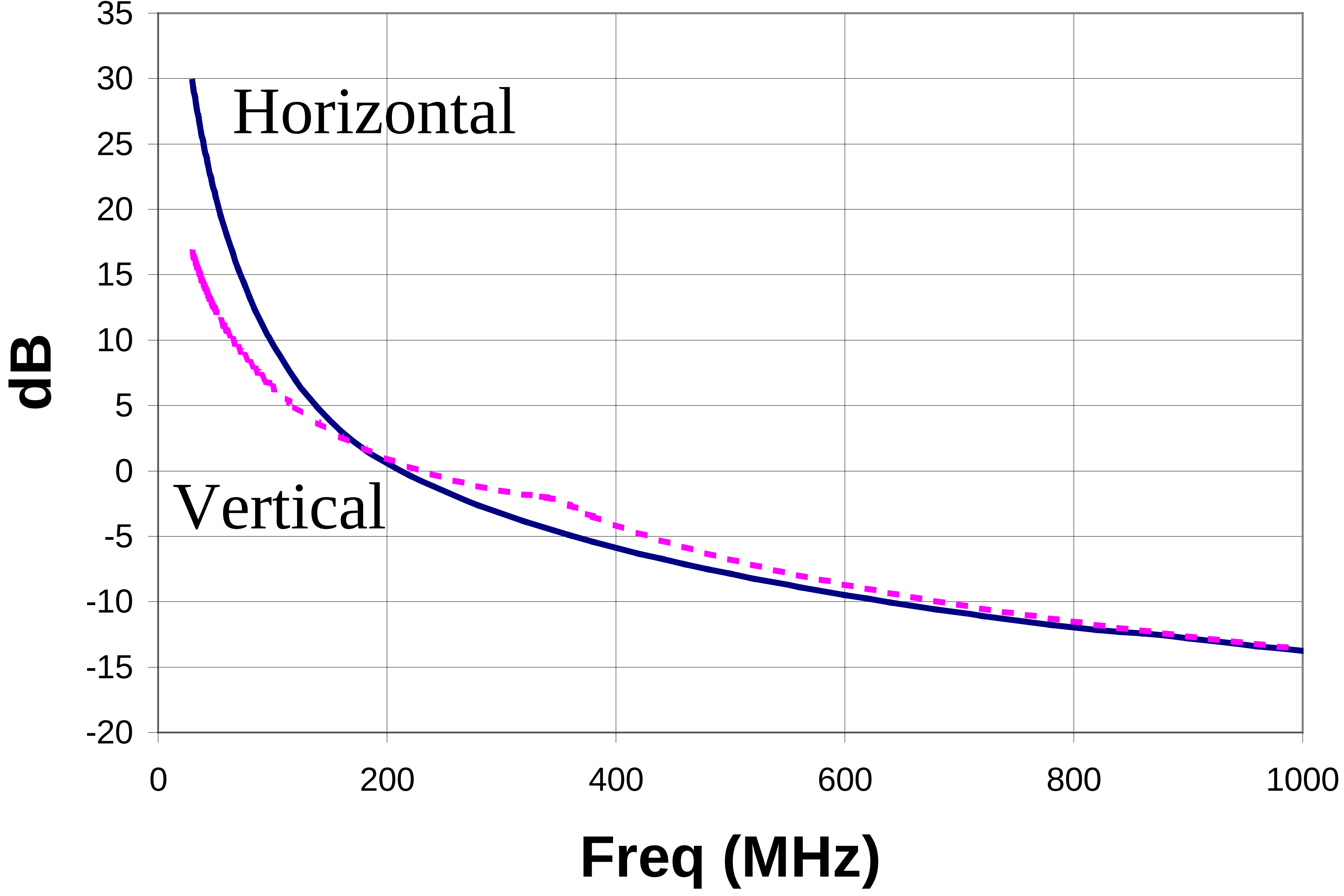
↓

+Other Transducers
(antenna, cables, pre-amp, +/- dB)

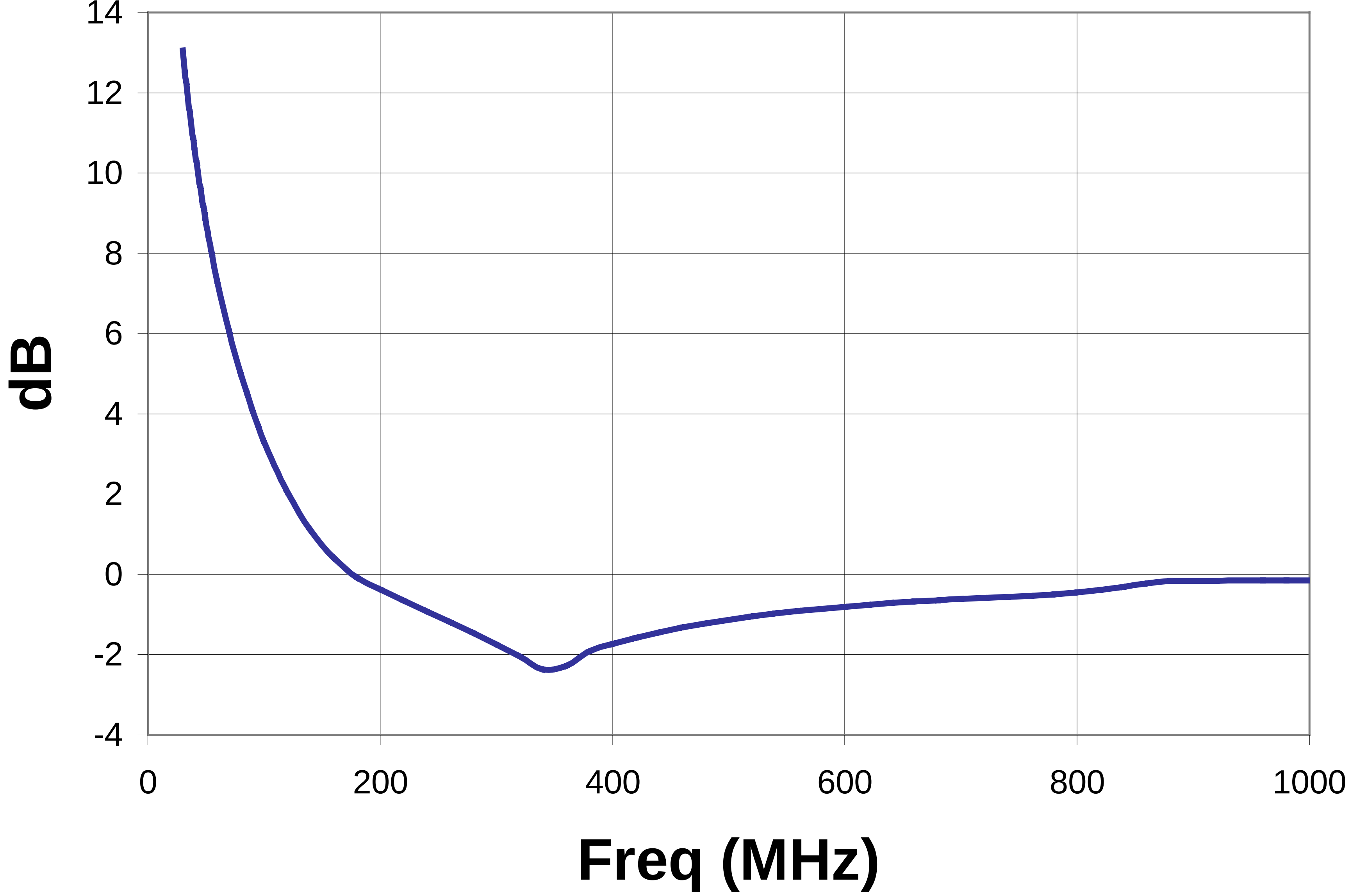
↓

Measurement (dBuV/m) → Compare to Limit

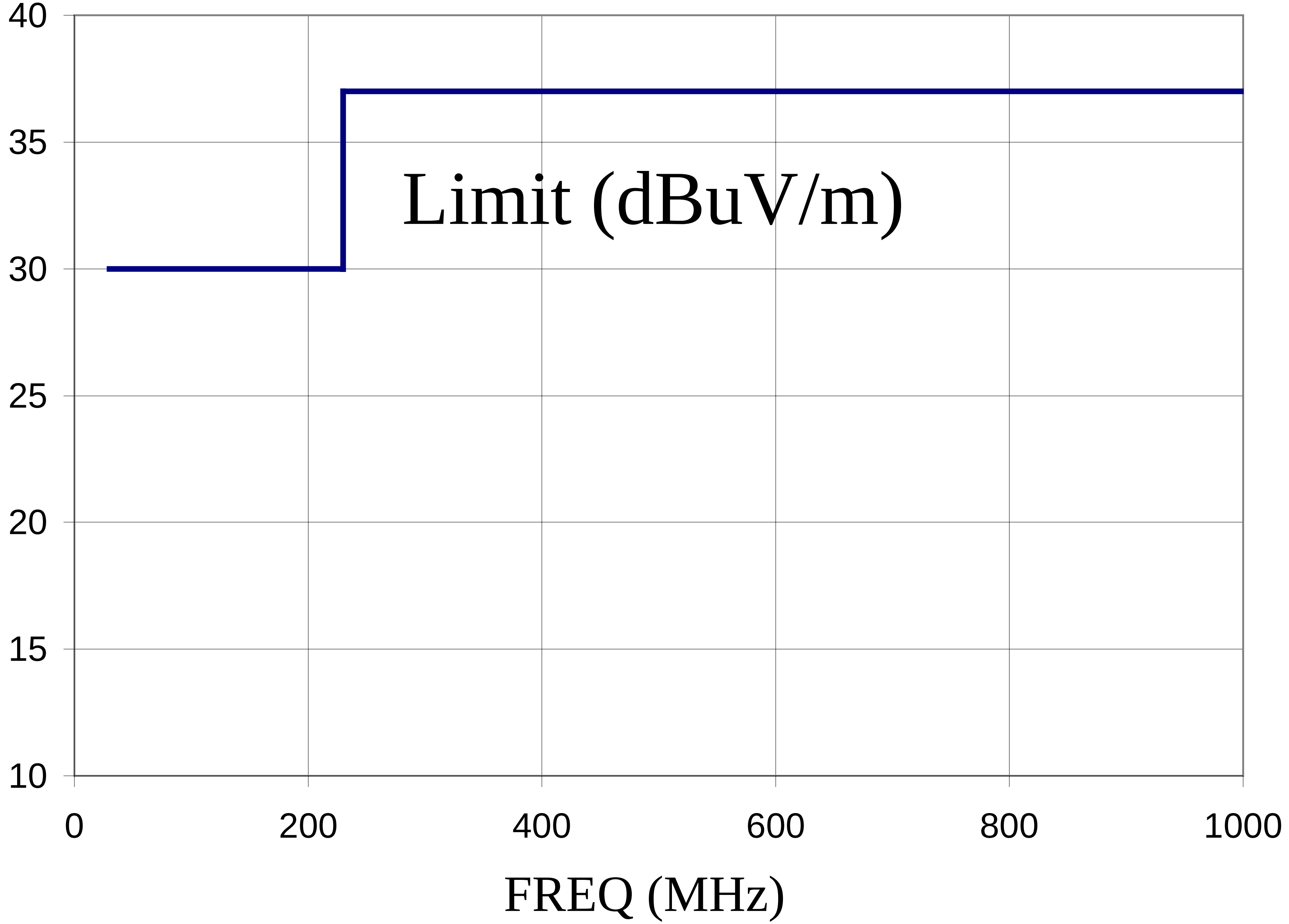
# Ideal 10m OATS Site Attenuation (source ANSI C63.4, Table 1, 1m source height)



# Difference In Ideal 10m OATS Site Attenuation (Horiz/Vert, dB)



# CISPR 22 Specification Limit (dBuV/m at 10 meters, Horiz or Vert)



# Site Attenuation on OATS : What’s Wrong?

- The IDEAL 10m OATS site attenuation produces large differences in actual measurements (H vs. V) even for the very basic example of a 1 meter source height above ground.
- But Limits for Horiz or Vert are the same!
- Application of Limits is not the same due to the IDEAL characteristics of the chosen model test facility (the OATS).
- Problem is even worse when different source locations are considered.

# Why Free Space?

- Free space methods solve the inconsistencies in the IDEAL site model : Ideal Site Attenuation is the same regardless of polarity and independent of emissions source location in the test volume.
- Why not just use Free Space NSA of +/-4 dB to ideal for validation of free space chambers? (McConnell and Vitek, IEEE 1996 EMC Symposium, also prEN50147 part 3)

# Free Space NSA Validation?

- Deviation from Ideal NSA (ΔNSA) is required to be within +/- 4 dB to ideal model.
- Consider NSA results for the following two sites :
  - Site 1 : All positions = +4 dB +/- 0.2 dB
  - Site 2 : All positions = - 4 dB +/- 0.2 dB
- Thus, 8 dB Error still exists in Site to Site Measurements between validated sites!

# Problems with NSA +/- 4 dB methods

- Deviation from ideal NSA (ΔNSA) is an error term not an uncertainty. Error terms require determination and compensation in subsequent measurements.
- The Type A uncertainty component (the +/- 0.2 dB in this example) is presently unused.
- Result: NSA validation methods are not consistent with *NIST Technical Note 1297* or ISO Guide for expression of Uncertainty in Measurement (ISO GUM).

# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

- Key Proposal :
  - Use a single procedure to simultaneously calibrate facility, antenna, and cabling for emissions and immunity.
  - Results traceable to National Reference (NIST) through reference instrumentation : error and uncertainty calculated in accordance with ISO guide.

# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

- Requirements
  - Must use single facility (Free Space Chamber) and equipment set (antenna, cables) as a system.
  - Must harmonize the calibration geometry (plane vs. volume) to enable a single procedure to be used.

# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

- Relationship between NSA (emissions) and IEC 61000-4-3 (immunity) Calibration :

$$NSA = \frac{Vdirect}{Vsite} \cdot \frac{1}{AF_1} \cdot \frac{1}{AF_2}$$

$$Vdirect = \sqrt{P_F \cdot R_L}$$

# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

And,

$$Vsite = \frac{E}{AF_2}$$

Substitute for Vdirect and Vsite :

$$NSA = \frac{\sqrt{P_F \cdot R_L}}{E \Big/ AF_2} \cdot \frac{1}{AF_1} \cdot \frac{1}{AF_2}$$

# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

If ideal NSA is used as the reference, no previous AF’s are needed ($AF_1$ is determined by measurement of E and $P_F$).

$$AF_1 = \sqrt{50 \cdot P_F} \Big/ E \cdot NSA_{Ideal}$$

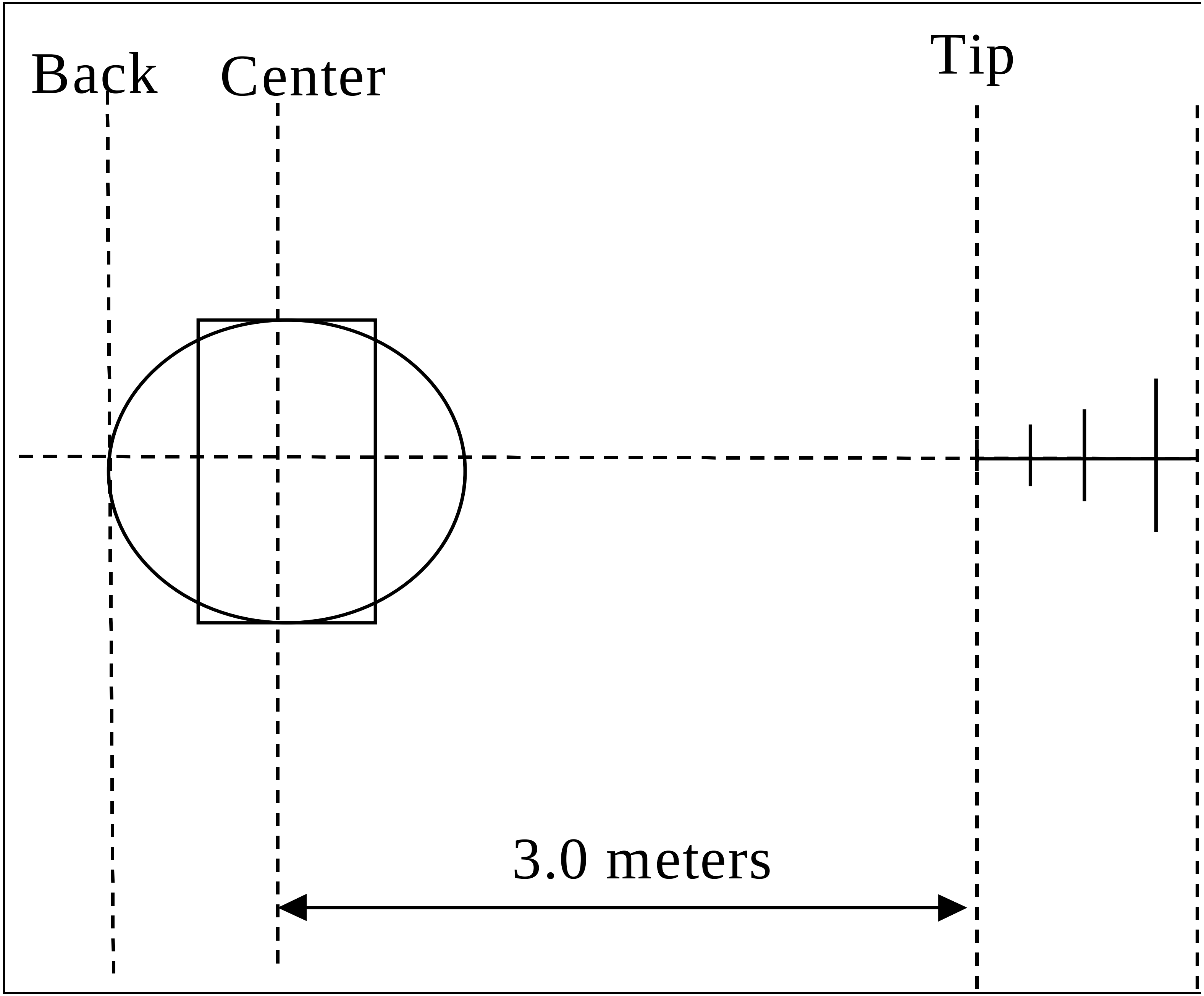
# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

- When measured values of E and $P_F$ are used , $AF_1$ will include full transducer error of antenna, facility and cables.
- Problem? No. This is exactly what we want (the error term for the system).
- Rename $AF_1$ the “combined correction factor”, in dB = $C_{dB}$ to clearly indicate a system combined factor, not just an antenna factor anymore.

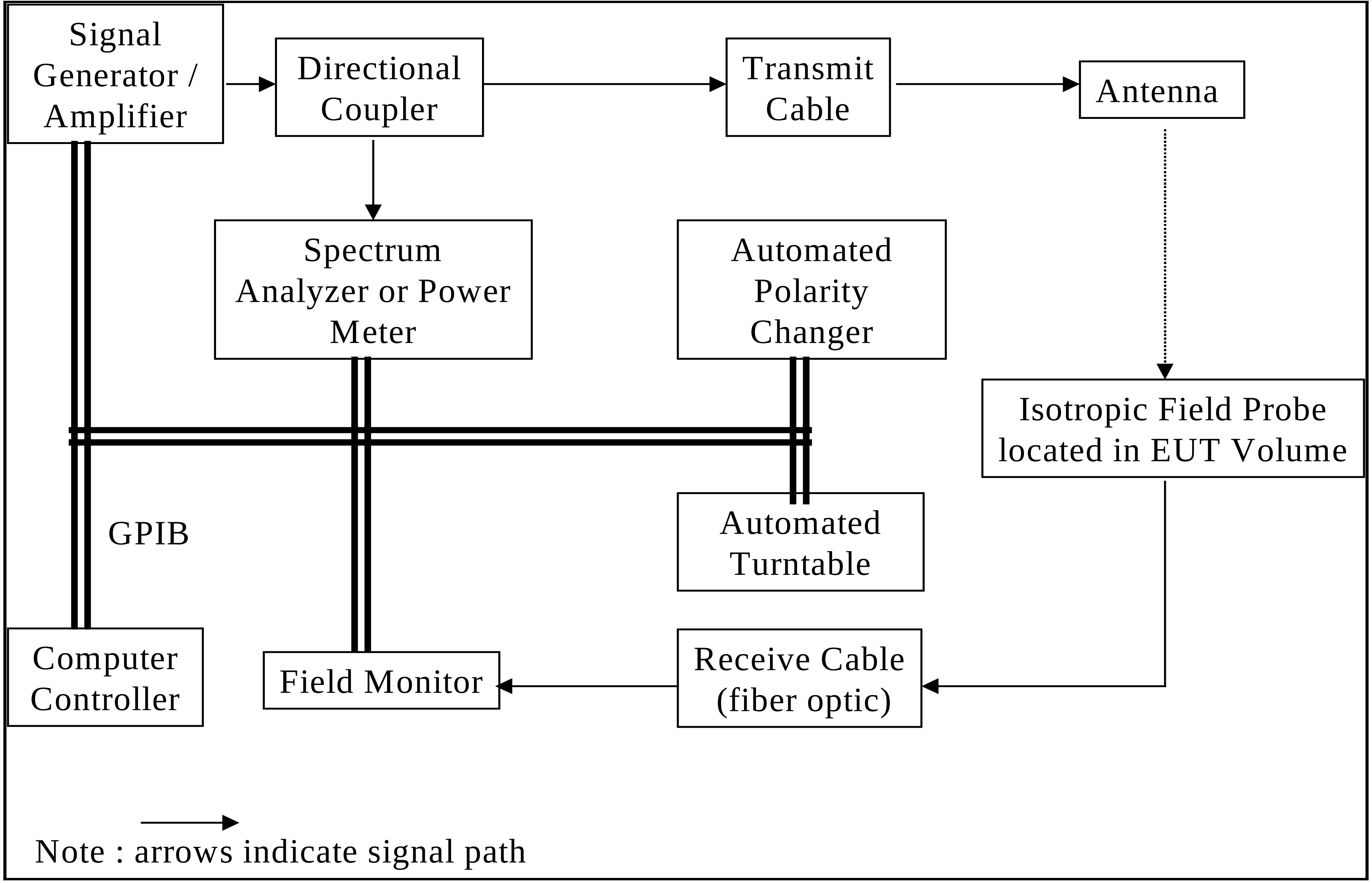
# Simultaneous Emissions/Immunity Calibration of Free Space Chambers

- Preceding is valid for a single point. What about sampling over a plane or a volume?
- Proposal : compute average $C_{dB}$ and uncertainty from a population of sample points.
- Use a Plane similar to IEC61000-4-3 or a volume similar to ANSI C63.4?

# Simultaneous Emissions/Immunity Calibration Procedure


Back
Center
Tip
3.0 meters

# CALIBRATION PROCEDURE
# (Figure 1)



Signal Generator / Amplifier

Directional Coupler

Transmit Cable

Antenna

Spectrum Analyzer or Power Meter

Automated Polarity Changer

Isotropic Field Probe located in EUT Volume

GPIB

Automated Turntable

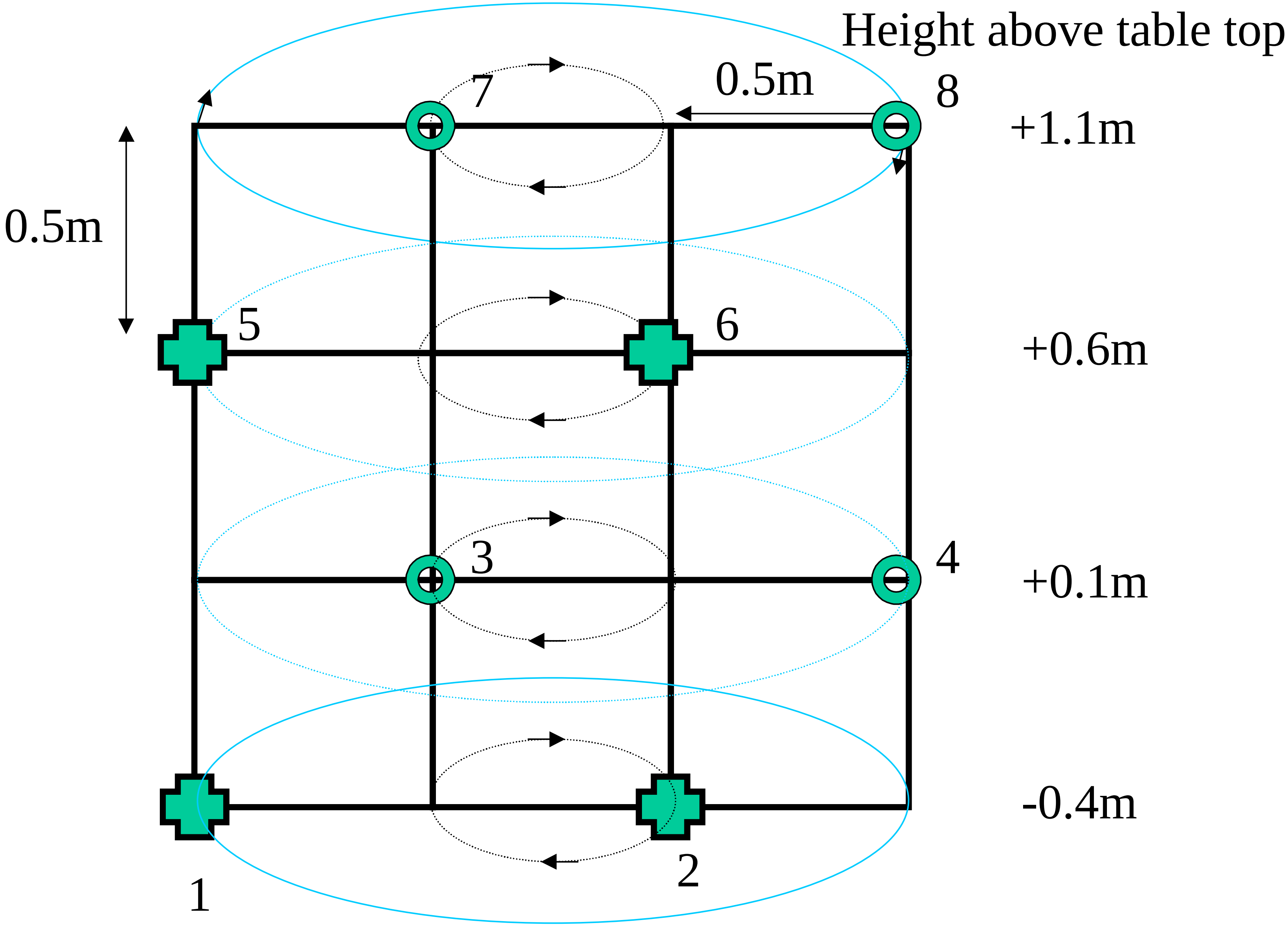
Computer Controller

Field Monitor

Receive Cable (fiber optic)

Note : arrows indicate signal path

# SAMPLING GEOMETRY (FIGURE 2)



# RESULTS FOR A TYPICAL CHAMBER

## Plane vs. Volume

- System Gain
- System Transducer (CdB)
- Uncertainty over Plane or Volume

# Multiple Samples

See Symposium Record (SR), Equations 1 - 5 :

Average Forward Power (normalized to 1 V/m)

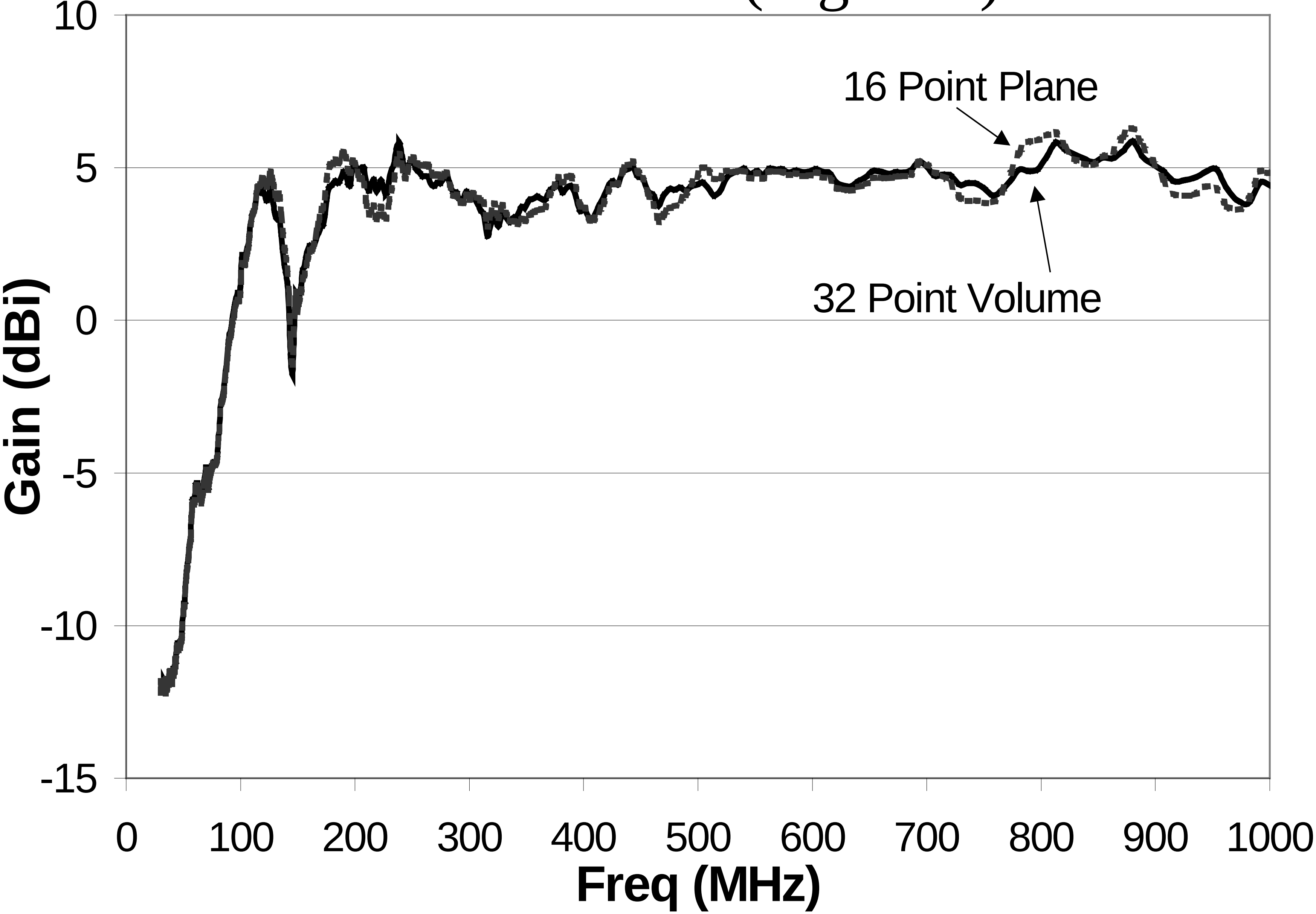
$$\overline{P_f}(watts) = \sum_{i=1}^{n} \frac{Pf_i(watts)}{n} \qquad (1)$$

Average System Gain over isotropic :

$$\overline{G}_{dBi} = 10 \cdot \log\left( \frac{E^2 \cdot d^2}{30 \cdot \overline{P_F}} \right) \qquad (4)$$

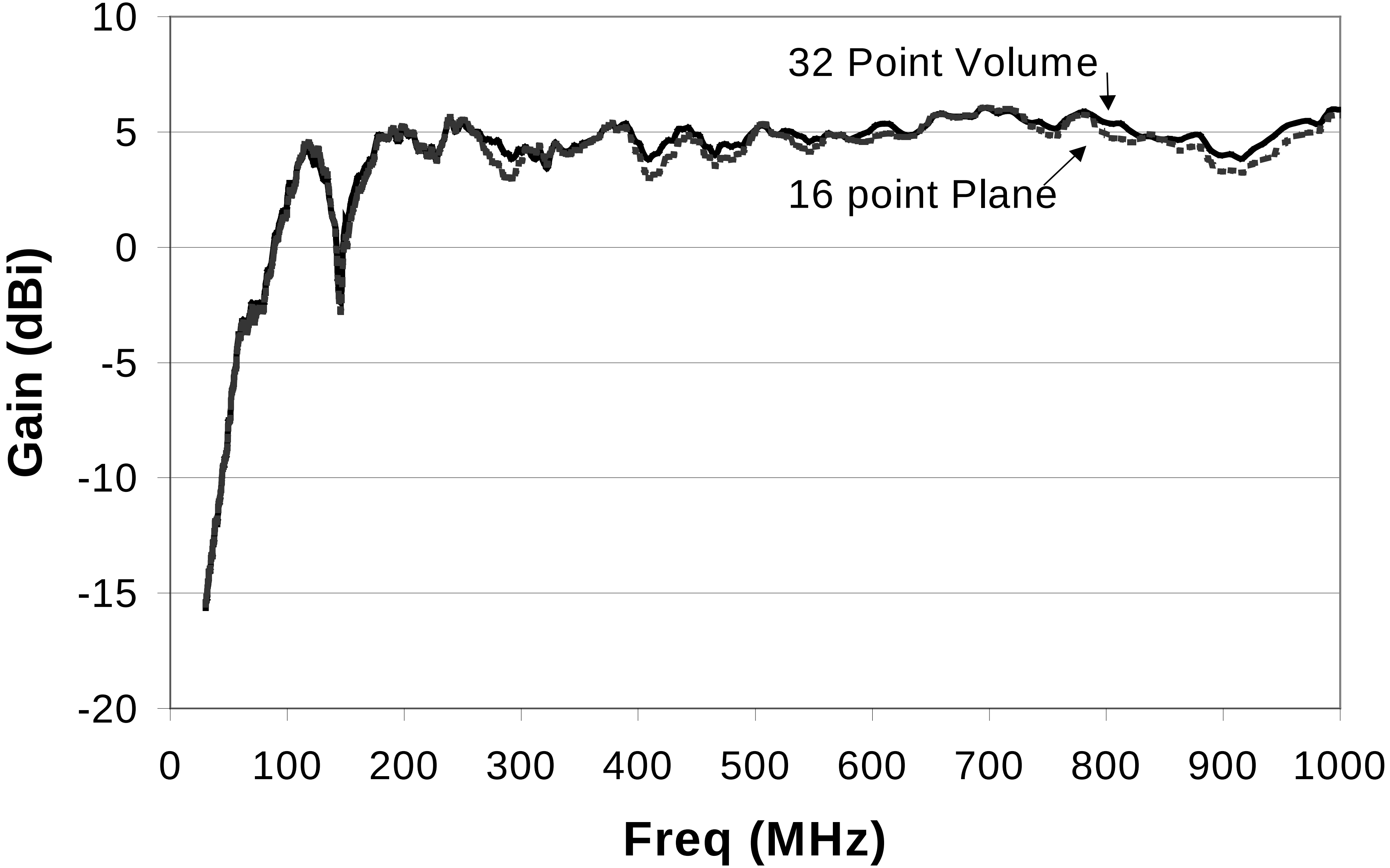
# RESULTS FOR A TYPICAL CHAMBER : GAIN

## Antenna Vertical (Figure 5)



# RESULTS FOR A TYPICAL CHAMBER : GAIN

## Antenna Horizontal (Figure 6)



Average System Transducer Factor ($C_{dB}$) :
(computed from Gain, in decibels)

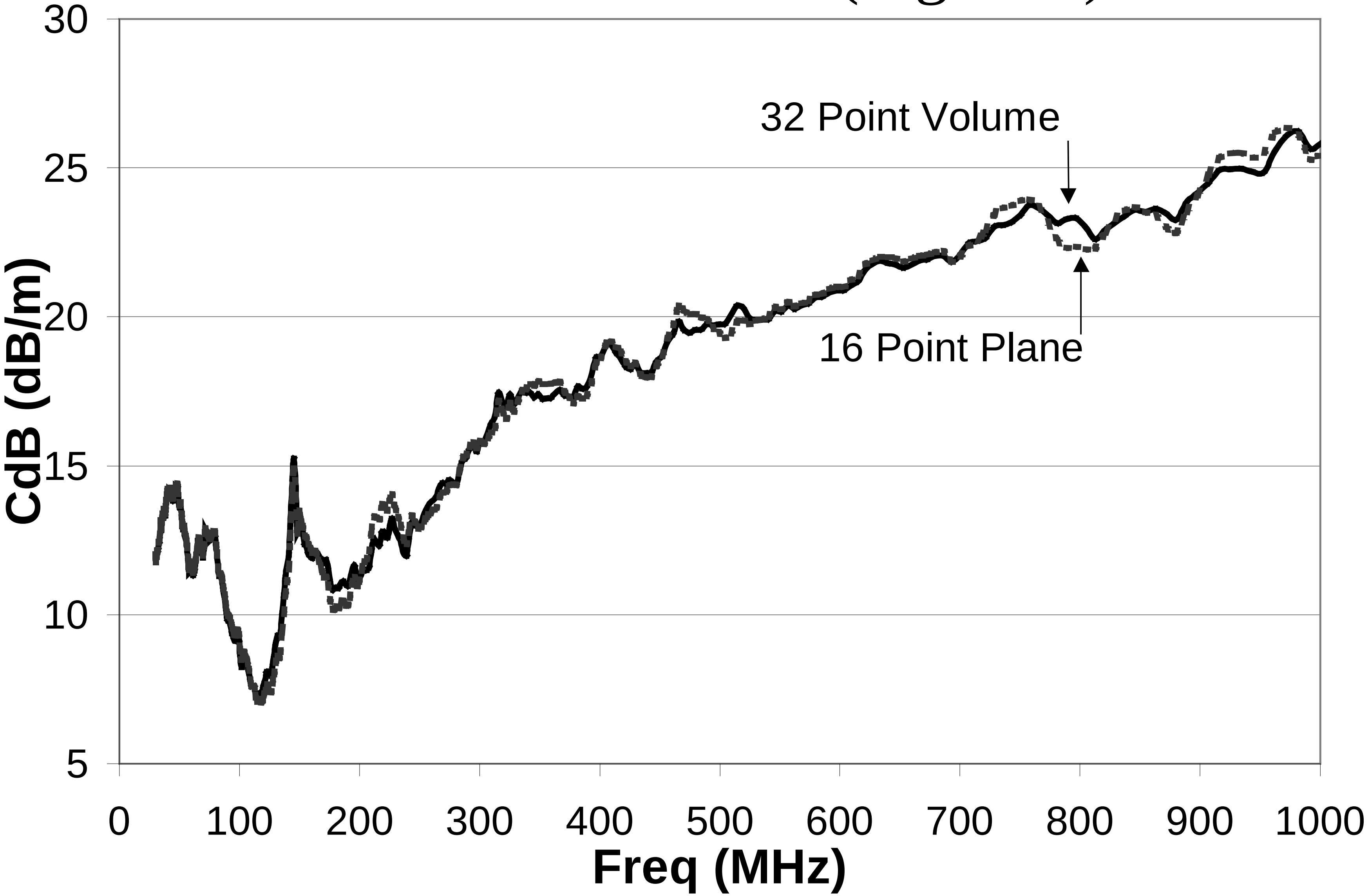
$$\overline{C}_{dB} = 20 \cdot \log(f_{MHz}) - 29.77 - \overline{G}_{dBi} \quad (5)$$

Or, as shown before $C_{dB}$ can also be written in terms of ideal NSA :

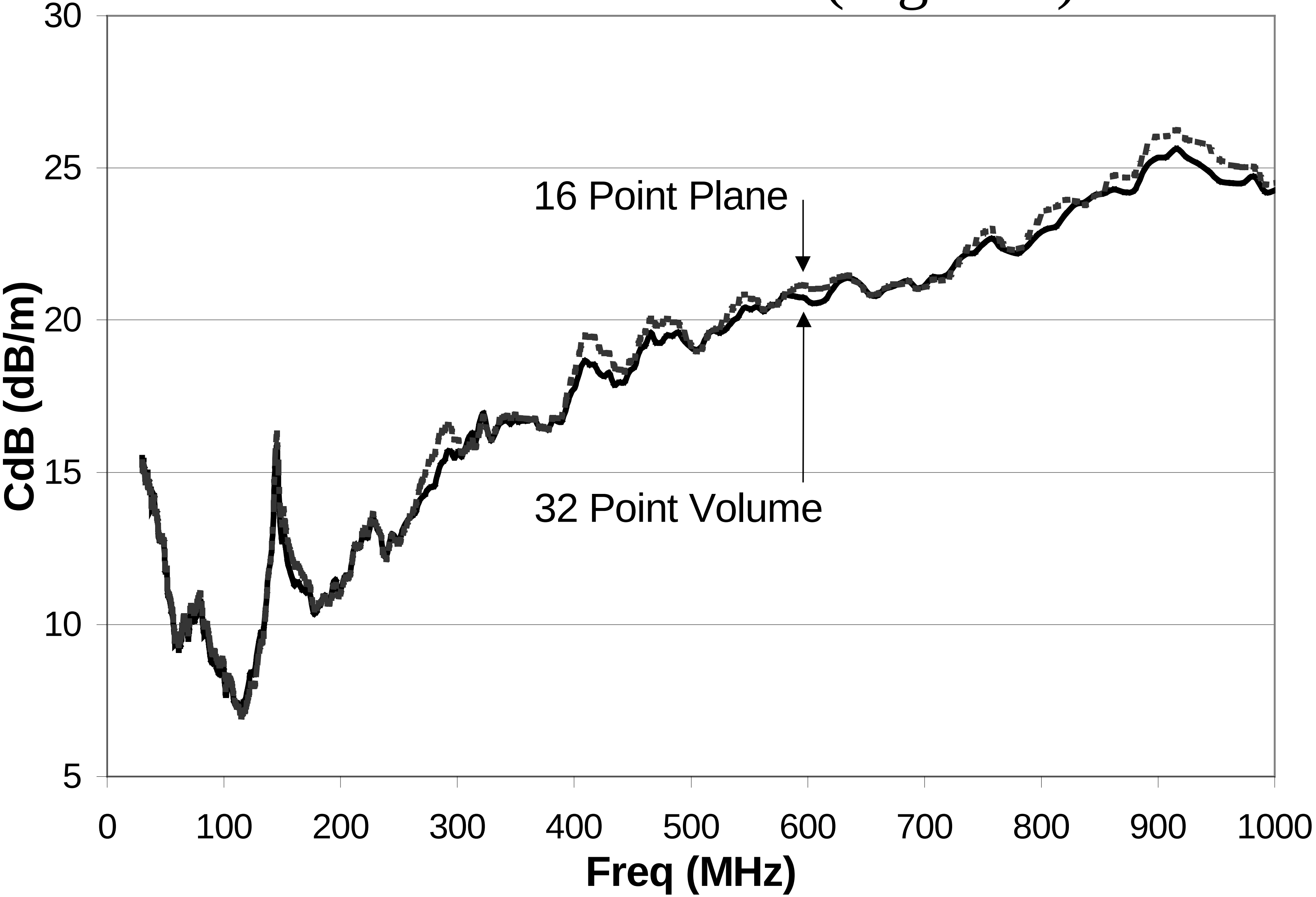
$$\overline{C}_{dB} = 20 \cdot \log\left( \sqrt{50 \cdot \overline{P}_F} \middle/ E \cdot NSA_{Ideal} \right)$$

# RESULTS FOR A TYPICAL CHAMBER : $C_{dB}$

# Antenna Vertical (Figure 7)



# RESULTS FOR A TYPICAL CHAMBER : $C_{dB}$
## Antenna Horizontal (Figure 8)

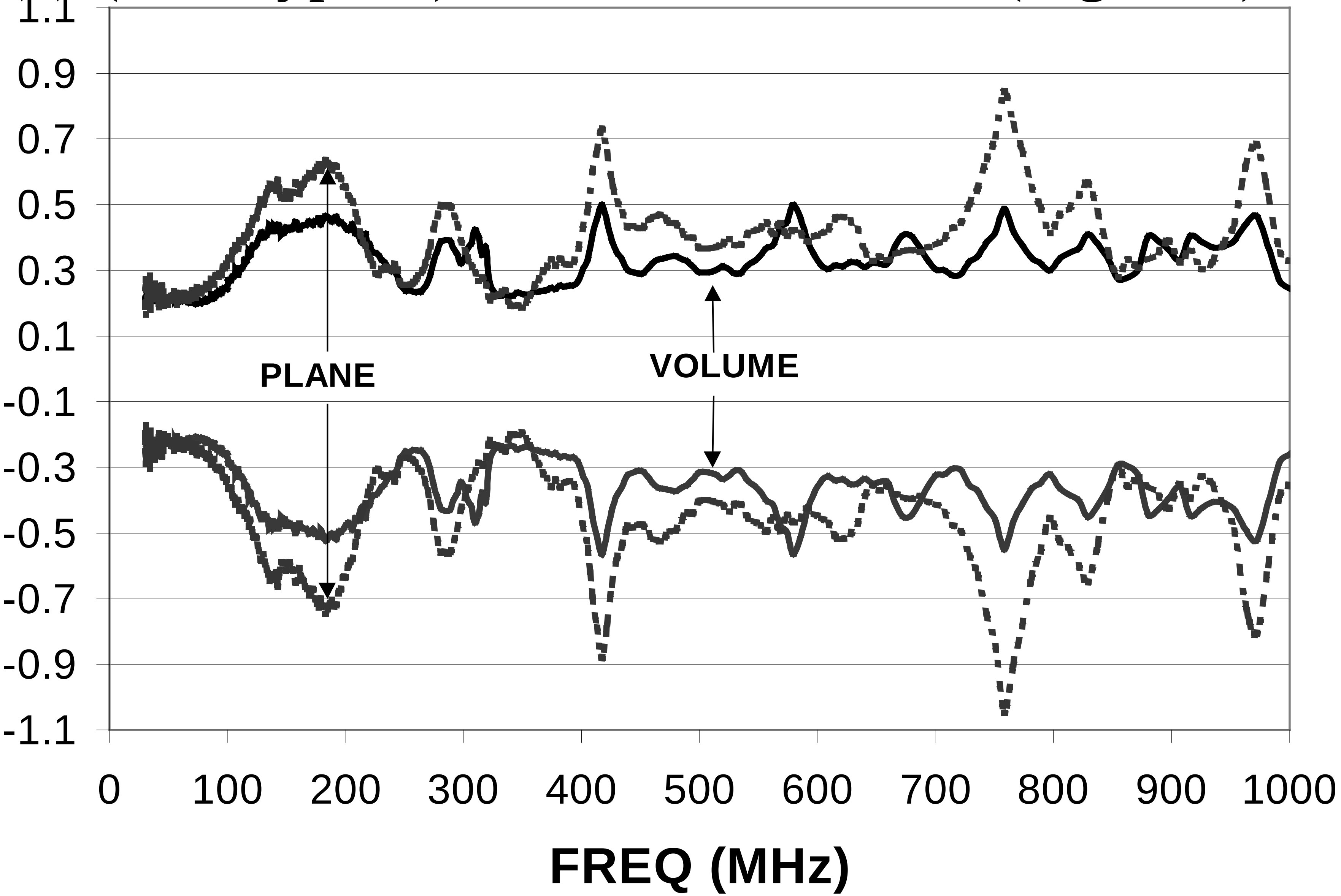


# Standard Deviation and Uncertainty in Average Values (example : $P_F$)

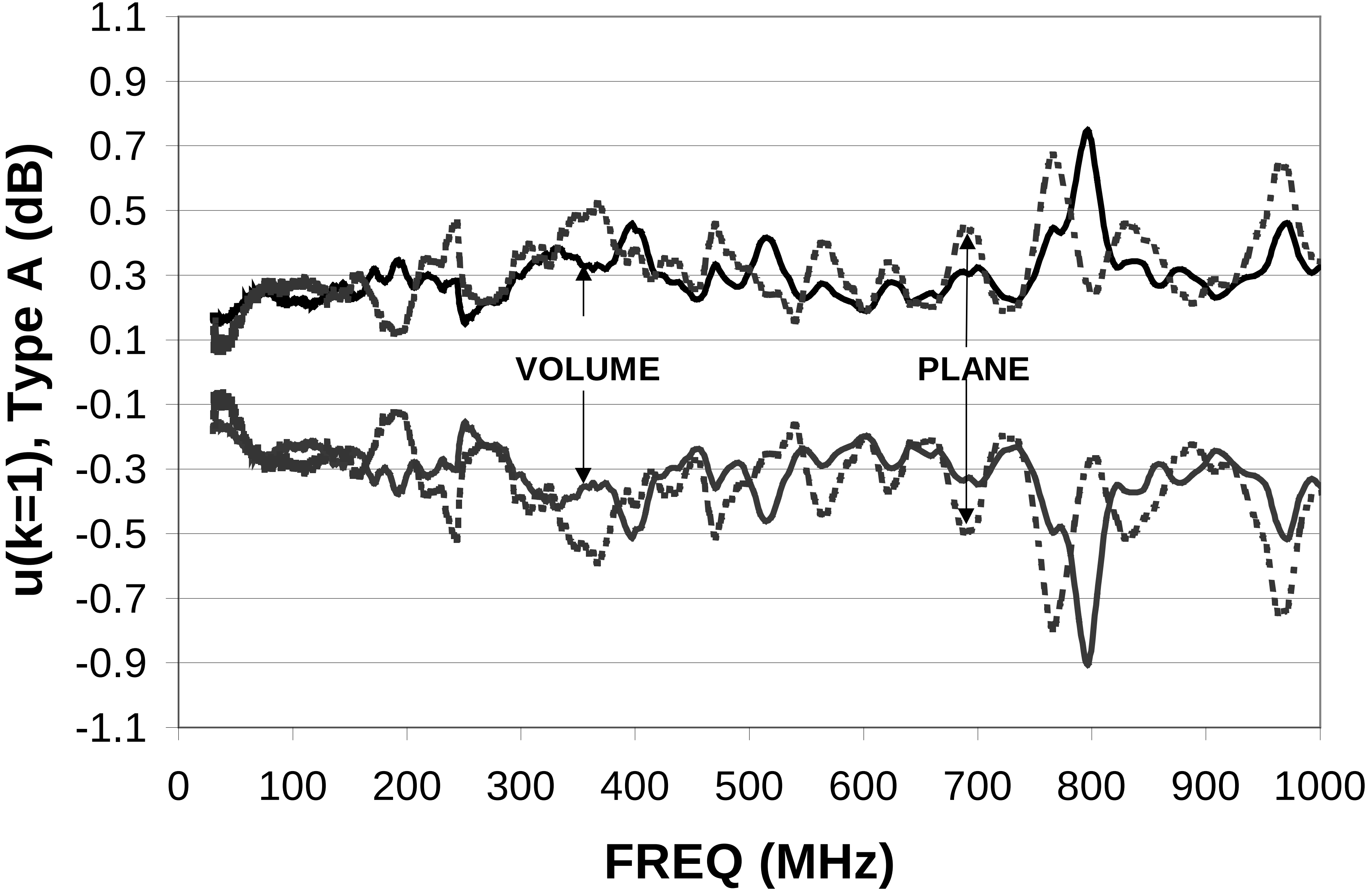
$$s = \sqrt{\frac{n \cdot \sum_{i=1}^{n} P_{f_i}{}^2 - \left( \sum_{i=1}^{n} P_{f_i} \right)^2}{n \cdot (n-1)}} \qquad (2)$$

$$u = \frac{s}{\sqrt{n}} \qquad (3)$$

# Uncertainty Results for Typical Chamber : $u_{dB}$ (k=1 Type A) Antenna Horizontal (Figure 9)



# Uncertainty Results for Typical Chamber : $u_{dB}$ (k=1 Type A) Antenna Vertical (Figure 10)



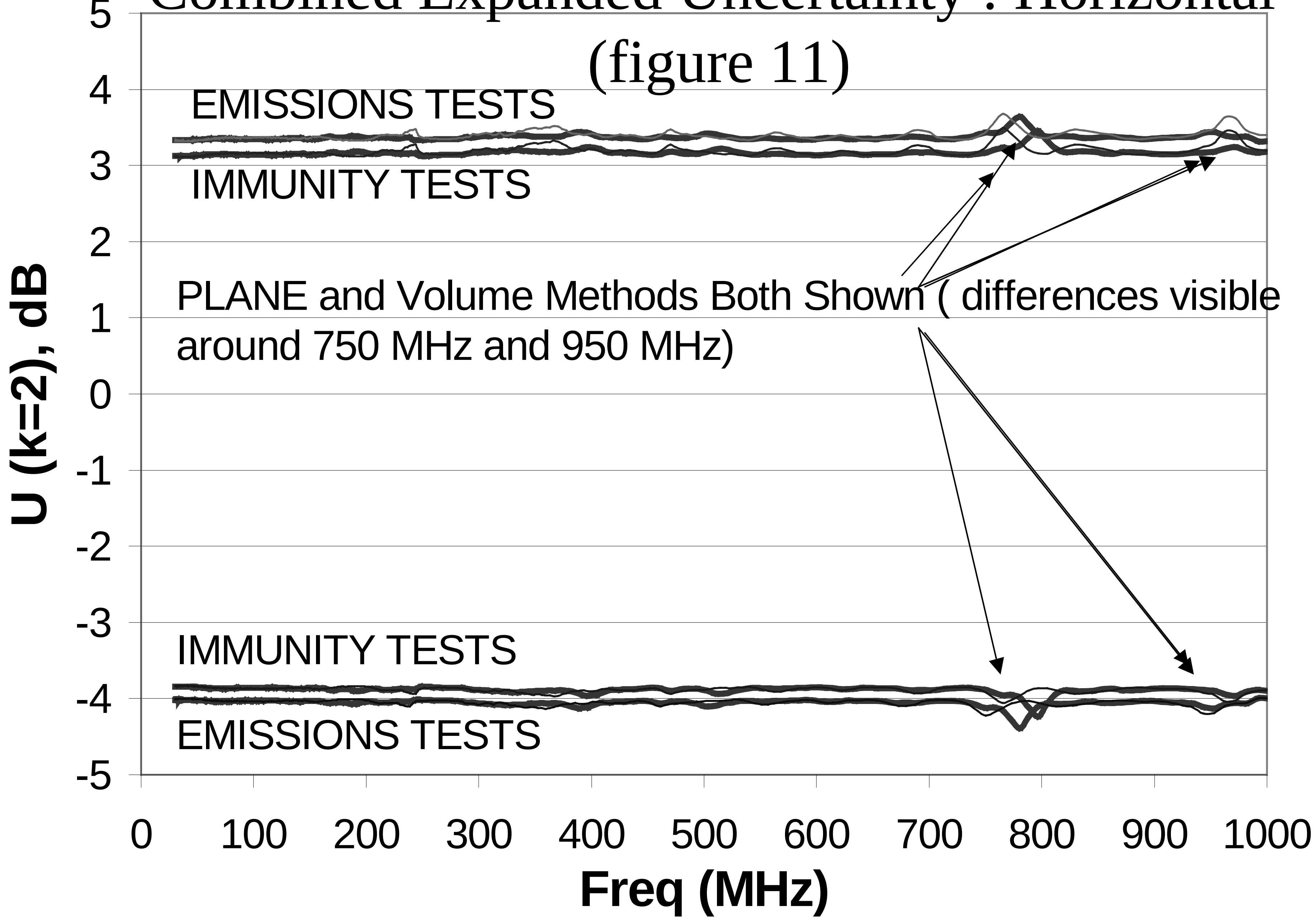
Total, combined expanded uncertainty of instrumentation and facility is Root Sum Squares (RSS) combined Type A and Type B uncertainties (equation 6):

$$U = 2 \cdot \sqrt{u_{probe}^2 + u_{dircoupler}^2 + u_{meter}^2 + u_{preamp}^2 + u_{typeA}^2}$$

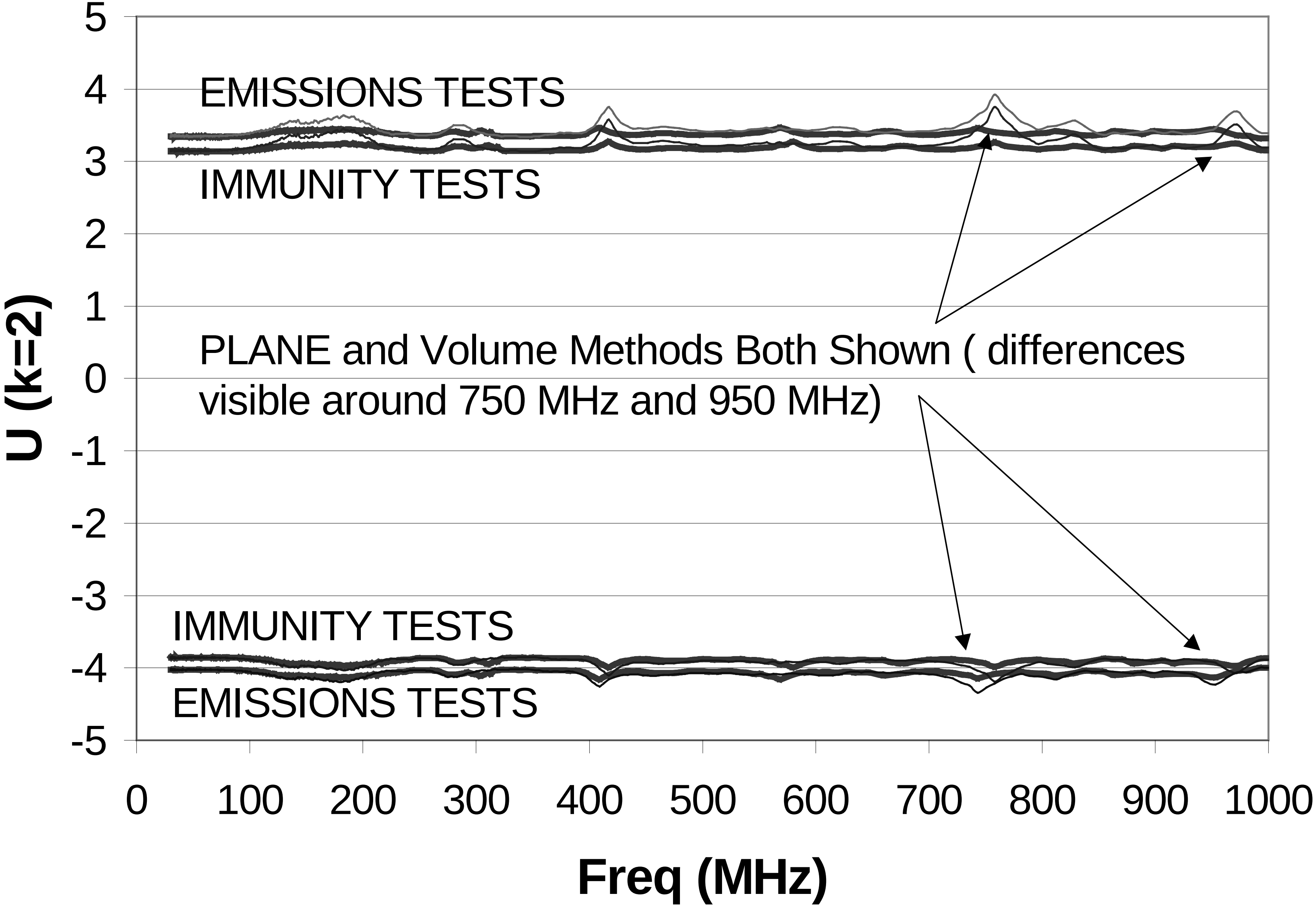
# Uncertainty : Type B (instrumentation) Factors (Table 1)

| Device | Type | Standard Value (k=1) |
|---|---|---|
| Field Probe | Normal(k=2) | +1/-1.5 dB |
| Meter | Rectangular(k=1.73) | +/- 1.15 dB |
| Dir. Coupler | Rectangular(k=1.73) | +/-0.289 dB |
| Pre-Amplifier | Rectangular(k=1.73) | +/-0.577 dB |

# Combined Expanded Uncertainty : Horizontal (figure 11)



# Combined Expanded Uncertainty : Vertical (figure 12)



EMISSIONS TESTS

IMMUNITY TESTS

PLANE and Volume Methods Both Shown ( differences visible around 750 MHz and 950 MHz)

IMMUNITY TESTS

EMISSIONS TESTS

# CONCLUSIONS

- Proposed procedure provides NIST traceable (and ISO Guide compliant) error and uncertainty information not possible with NSA methods.
- A single, harmonized calibration procedure could be used for a free space chamber for emissions and immunity tests.
- Proposed procedure provides simultaneous calibration of chamber, antenna, and cables.

# Conclusions

- PLANE vs. Volume? Little real difference (<0.6 dB) observed in error and uncertainty terms for typical free space chamber.
- Proposal : Just use a 16 point plane sampling geometry for up to 1.5m diameter test volume. Results valid for emissions and immunity chamber validation.

# Acknowledgements

- Patrick Andre - CKC Redmond, WA Lab Manager for assistance in data collection.
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- Martin Alexander, NPL, U.K. - For his helpful comments in our many free space (FAR) chamber discussions.