Cylindrical Mode Filtered SVSWR – A New ANSC C63 Method Proposed for EMC Site Validation from 18 GHz to 40 GHz

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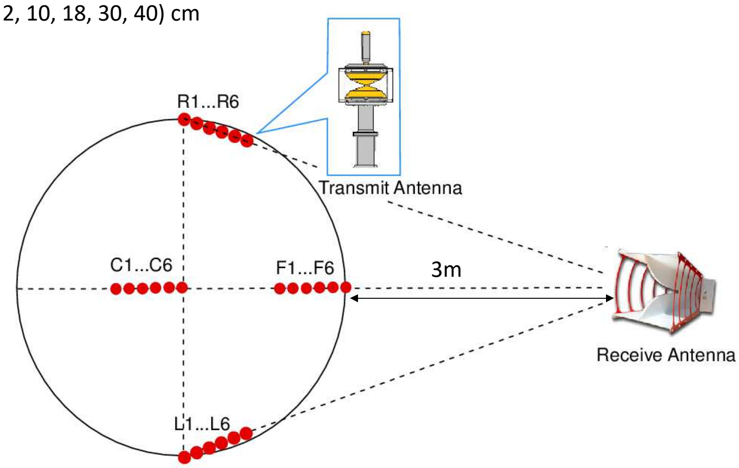
Introduction

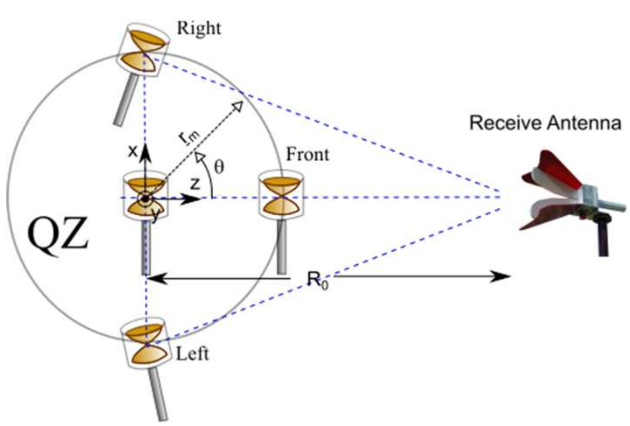
- EMC test sites must meet certain SVSWR requirements. Demarcation @ 1 GHz:
  - < 1 GHz: metal ground plane
  - > 1 GHz: absorber lined ground – "free space"
- For C63 standards, up until 2020, site requirements are specified in C63.4.
- Site requirements have been migrating to C63.25 series
  - C63.25.1-2018 (1 – 18 GHz): Published - Time Domain Site VSWR as an alternative, or the CISPR SVSWR method.
  - C63.25.2 (30 – 1000 MHz): Coming Soon – in ballot forming stage under IEEE Secretariat.
  - C63.25.3 (18 GHz – 40 GHz): Working on a first draft

A Quick Review: Typical SVSWR Test Setup

(0, 2, 10, 18, 30, 40) cm



TD SVSWR as a More Repeatable Alternative



Do we need another SVSWR method?

- Does it make sense to extend the existing methods to higher frequencies, e.g., > 18 GHz?
- Important consideration – must have features:
  - Can't undersample.
  - Need to understand the VSWR in the entire QZ, not a few sampling positions
  - Does it give information about RX pattern coverage?
- What is Cylindrical Mode Filtered SVSWR (CMF SVSWR)?
  - How does it fit in? - C63.25.3 (18 GHz – 40 GHz)
  - Does it address the must haves?

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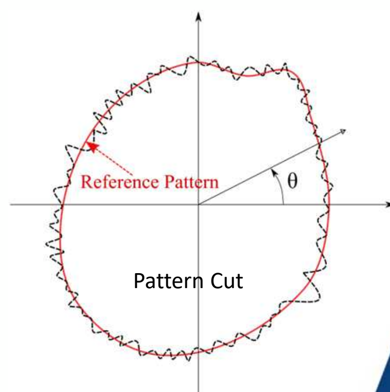
What is Cylindrical Mode Filtered SVSWR

- Similar to the idea of the CISPR SVSWR. Here, we take a circular path around the perimeter of the QZ.
- The measurement is the same as a single cut pattern measurement with an offset TX antenna.
- After a mathematical translation to center, there is a mode separation between the antenna and chamber reflections. This allows extraction of the reference pattern, and the calculation of ripple amplitudes.



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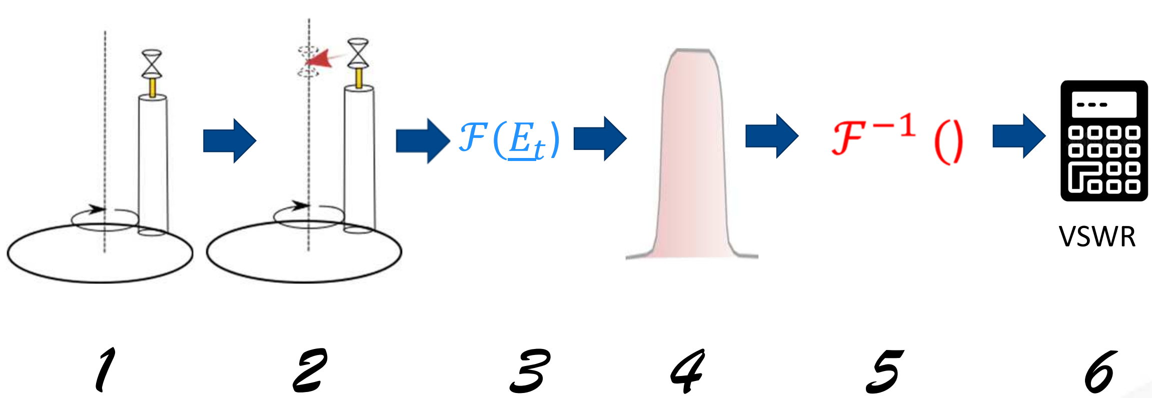
Cylindrical Modal Representation

- Any antenna pattern can be expressed as sum of orthogonal cylindrical modes with varying weights - Cylindrical Mode Coefficients (CMCs).
- The larger the antenna, the more modes it needs, i.e.,

number of modes $\propto$ Maximum Radial Extent of the source.

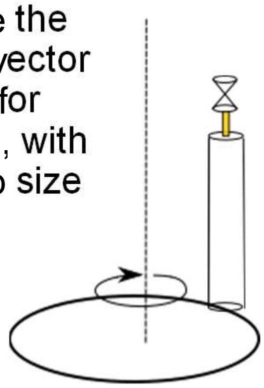
- Measuring antenna with an offset rotation requires more modes to describe the antenna.

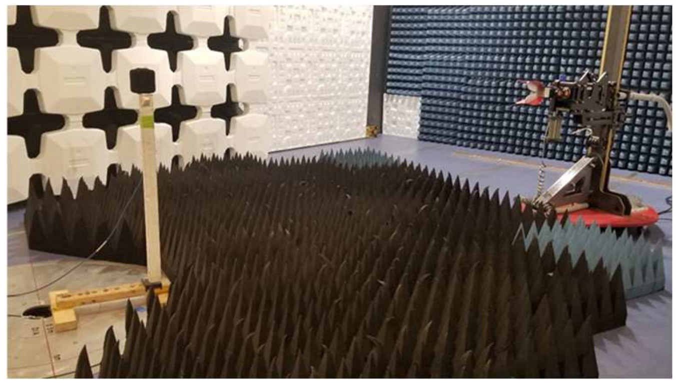
SVSWR 6-Step Process



Step 1

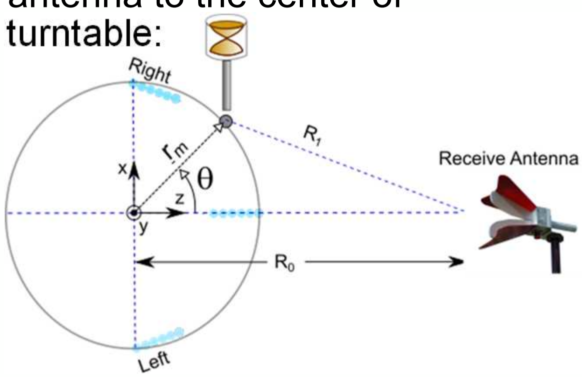
- Measure the full 1-D vector pattern, for example, with a 1° step size



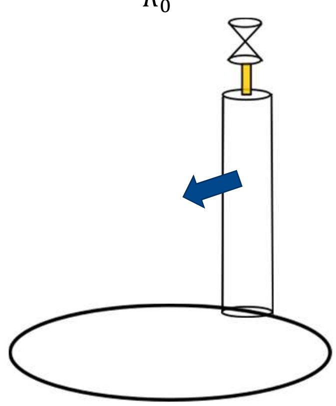


Step 2

- Mathematically translate the antenna to the center of turntable:



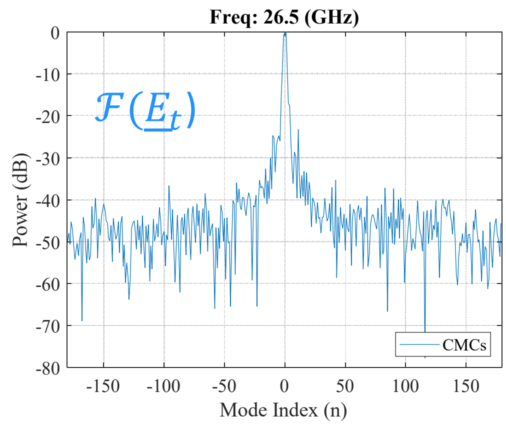
$$\underline{E}_t(\theta) = \underline{E}(\theta)\frac{R_1}{R_0}e^{jk_0(R_1-R_0)}$$



Step 3

- Take a FFT of the translated pattern to compute Cylindrical Mode Coefficients (CMCs)

$$\mathrm{CMC}_n = FFT(\underline{E}_t(\theta))$$



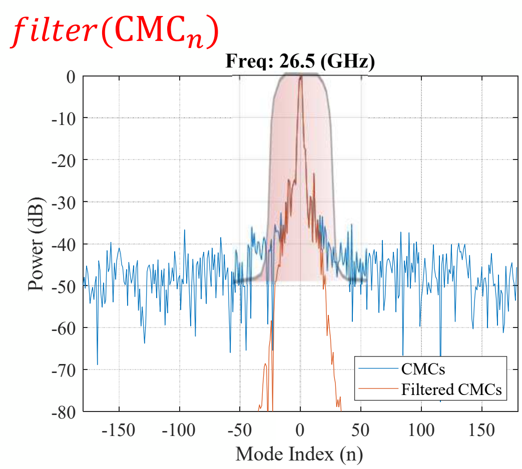
Step 4

- Apply a filter in the spectrum domain to keep only the modes that can be supported by the size of the antenna

$$f = \begin{cases} 0.8^{(|n|-n_{Max})} & \text{when } |n| > n_{Max} \\ 1 & \text{elsewhere} \end{cases}$$

$$n_{Max} = k_0\rho_0 + 2$$

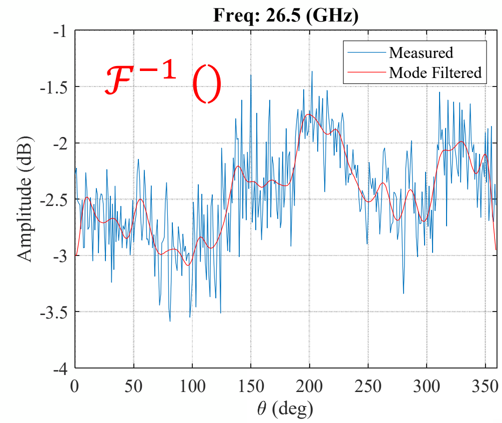
ρ_0 is the MRE of the antenna



Step 5

- Inverse transform the filtered modes to obtain the "clean" pattern

$$\underline{E}_{clean}(\theta) = IFFT(filter(\mathrm{CMC}_n))$$



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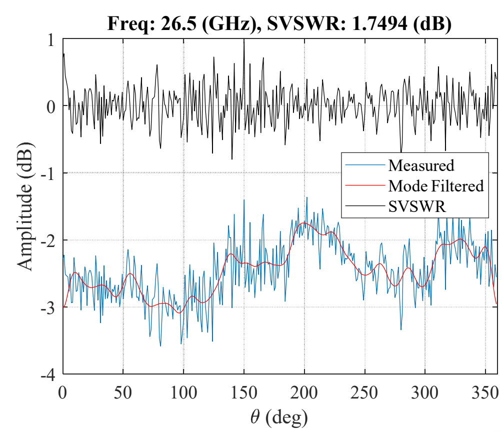
Step 6

- Calculate the standing wave (in dB)

$$Standing\ waves = \underline{E}_t(\theta) - \underline{E}_{clean}(\theta)$$

- Or calculate the VSWR based on the statistical distribution (to be discussed next)



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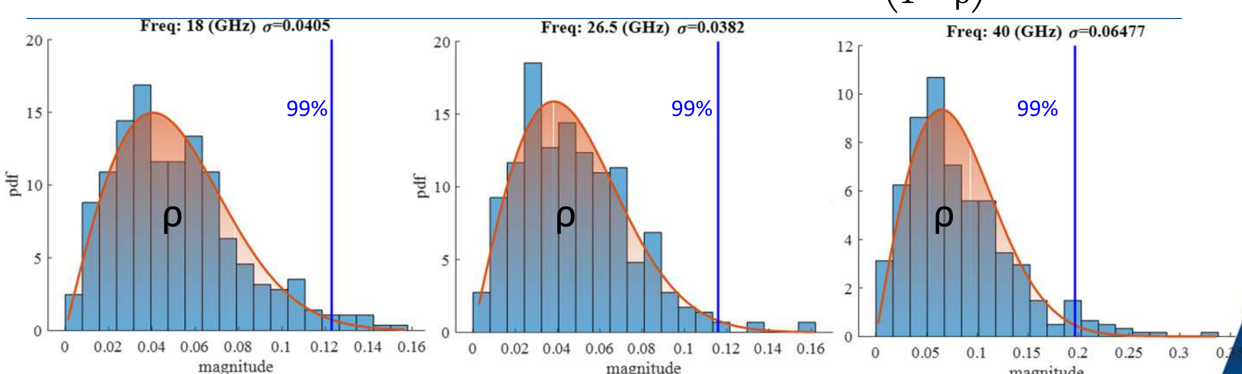
Computing a Meaningful VSWR

- Using the max/min to calculate VSWR can be very erratic because of our sampling.
- However we have obtained enough statistical samples to infer about the population.

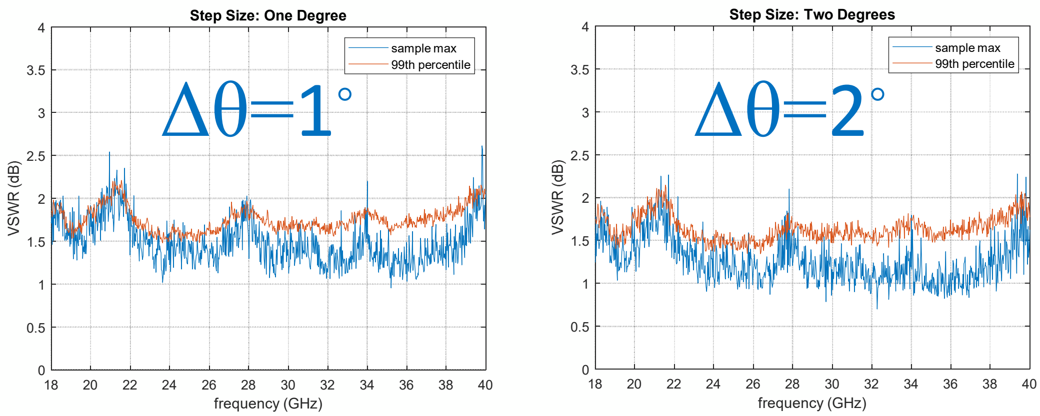
"Data don't make any sense, we will have to resort to statistics."

- Measured relative ripples (ρ) display **Rayleigh** distribution.

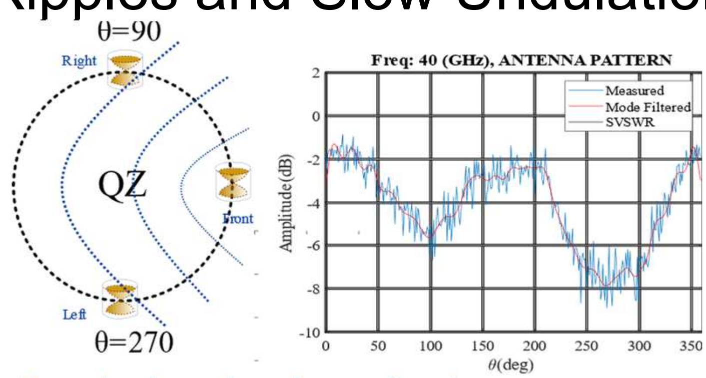
$$\rho = \left|E_{raw} - E_{clean}\right| / \left|E_{clean}\right| \qquad \text{VSWR} = 20\log\left(\frac{1+\rho}{1-\rho}\right)$$



Decreasing Angular Step Size



Fast Ripples and Slow Undulation



1. Fast ripples: chamber reflections
2. Slow undulation: receive antenna pattern

Summary

- CMF SVSWR provides several advantages over the CISPR or TD SVSWR
  - Does not undersample the standing wave at 40 GHz
  - No additional requirements on antennas (e.g., broadband, and fast ringdown)
  - Shows VSWR along the entire QZ perimeter, not just at cardinal points
  - Offers indications on the receive antenna pattern coverage of the QZ
- Test is fast and efficient, < 30 min per geometry.
- The post process can be done in real time, and can be scripted.
- Measurements can be automated using the existing turntables. No need for special positioning equipment.

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