2014 IEEE International Symposium on Electromagnetic Compatibility
August 3-8, Ralieigh NC

Simple Statistical Model to Quantify Maximum Expected EMC in Spacecraft and Avionics Boxes

Workshop Session FR-AM-2
"EMC for Space Applications"

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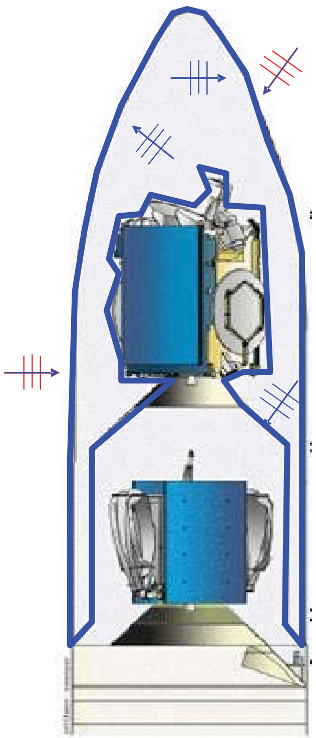
NASA Requirement
Need to know RF environment in large fairings



- **Challenges:**
  1. Interior and exterior sources
     - ***C- S- and X-band transmitters***
     - ***Lightning strike***
     - ***External RF, interference***
  2. Electrically large
     - ***Sensitive to details***
  3. Details only known approximately
     - ***Fairing lining dimensions***
     - ***Payload dimensions***
     - ***Payload surface impedances***

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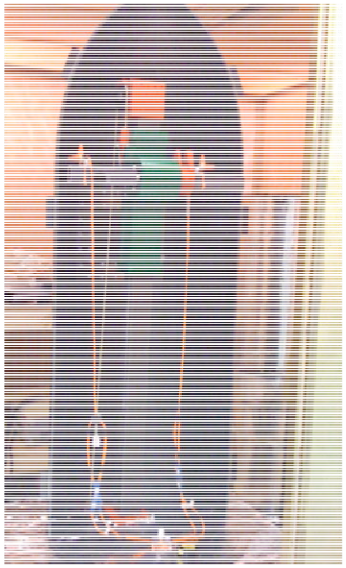
Model scale fairing EM field tests at KSC



inner probe placement

Composite fairing half test set-up with fiberglass mount - outer probe positions

- Fiber optic sensors to on a fiberglass mount used in 56 location within the fairing to measure the distribution.
- Spatial and frequency variation used.

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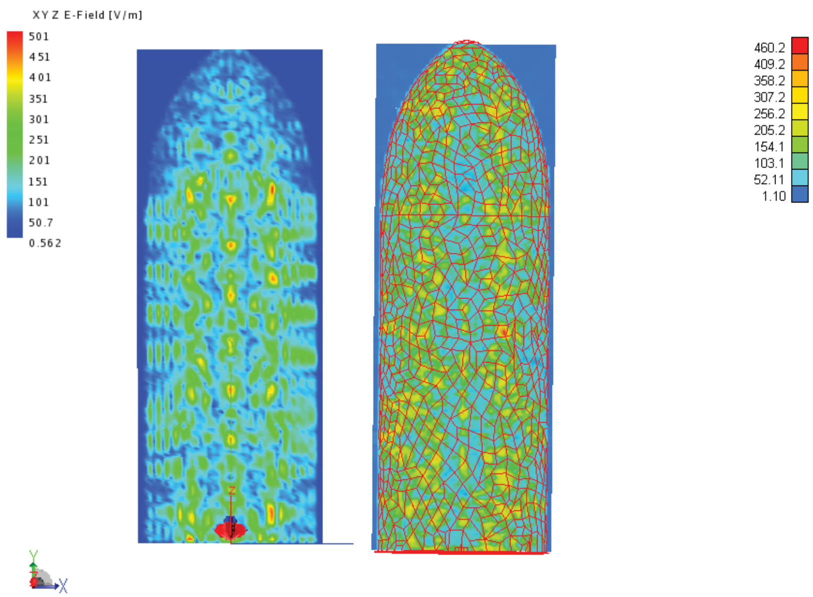
3D EM Wavefield modelers



Field distribution of lossless fairing model at 5.65 GHz of small composite model MLFMM (FEKO) and MoM (WIPL-D)

Rotational model of a typical large fairing with size of lab model fields shown for comparison

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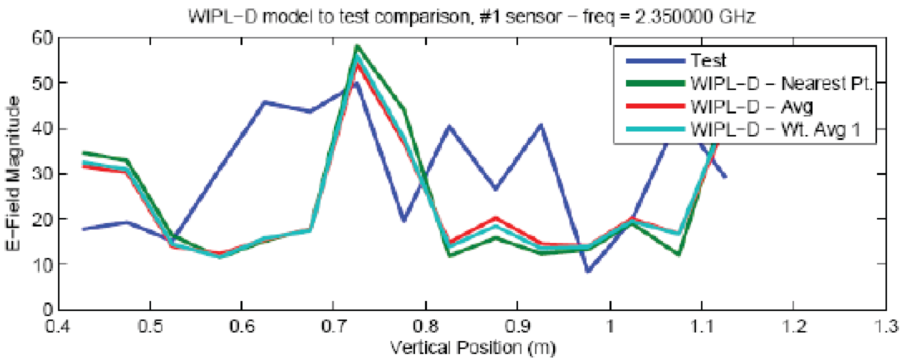
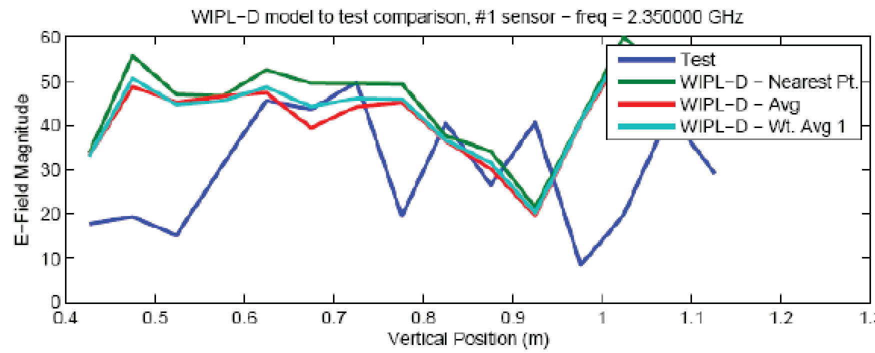
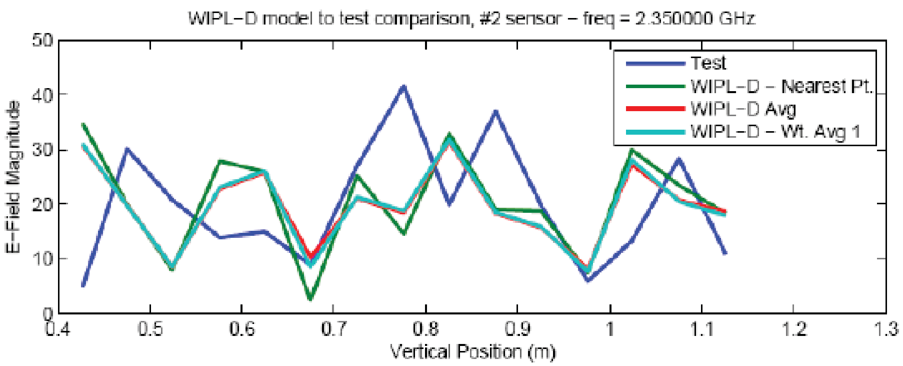
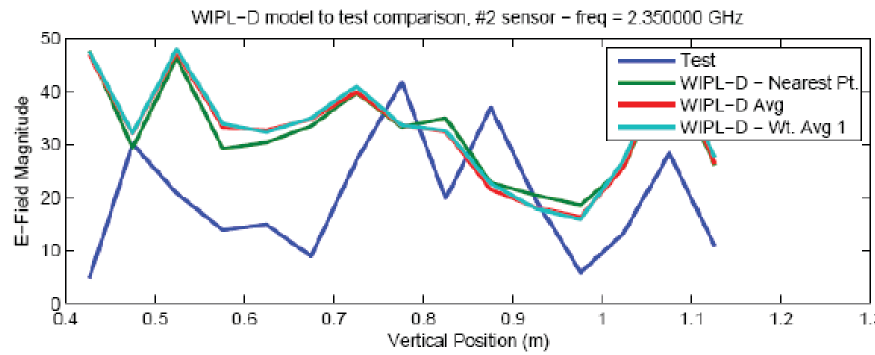
Models have not correlated well with test









Magnitude of 3 axis E-field comparison for composite three layer model

Without fiberglass mount

With fiberglass mount

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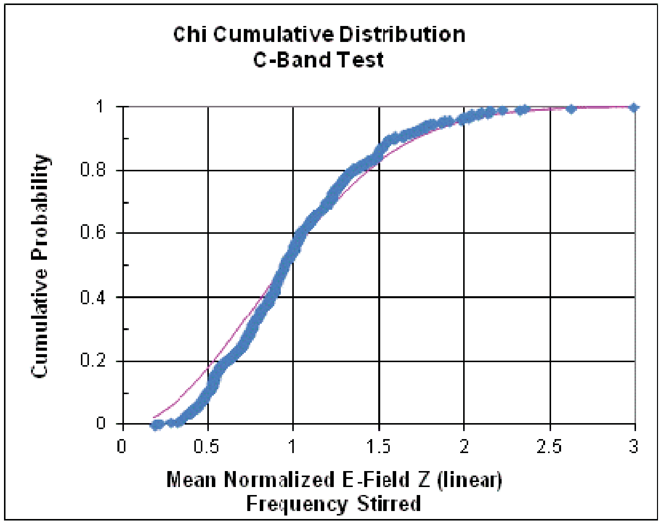
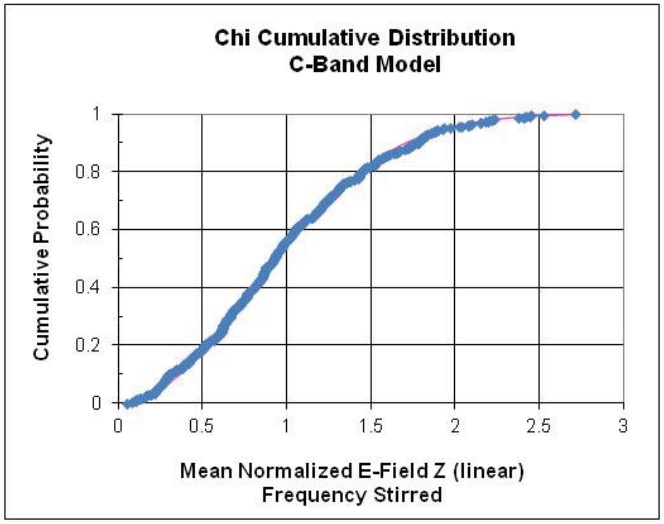
However, both model AND test show EM filed collapses to 2 parameter PDF





C-Band composite fairing position and frequency stirring test and model data following Chi distribution.

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Power balance (PWB)method
Recently extended to predict Variance & Max Expected E-field

An electronic enclosure of volume V has EM modal density $$n = \frac{8\pi V f^2}{c^3}$$

The asymptotic statistical mean EM field energy in the enclosure is governed by the excitation source power and enclosure Q factor $$E[U] = \frac{Source\ power}{\omega\eta}$$

Hill (2009) has shown that: $Q = 1/\eta$ $\quad Q = \dfrac{3V}{2\mu_r \delta S}$, $\quad \delta = \sqrt{\dfrac{1}{\pi f \mu_w \sigma_w}}$

where S is the surface area of the cavity walls μ_r, μ_w, and σ_w are respectively the relative permeability, the permeability, and the conductivity of the cavity walls.

Langley [2004] has shown the asymptotic relative variance of the cavity energy is:

$$\mathrm{RelVar}[U] = \frac{1}{\pi m}\left\{\alpha - 1 + \frac{1}{2\pi m}\left[1 - e^{-2\pi m}\right] + \mathrm{E}_1(\pi m)\left[\cosh(\pi m) - \frac{1}{\pi m}\sinh(\pi m)\right]\right\}$$

where m is the EM modal overlap factor: $m = f\eta n = fn/Q$,

The relative variance of a field component at a point is: $1 + 2\,\mathrm{RelVar}[U]$

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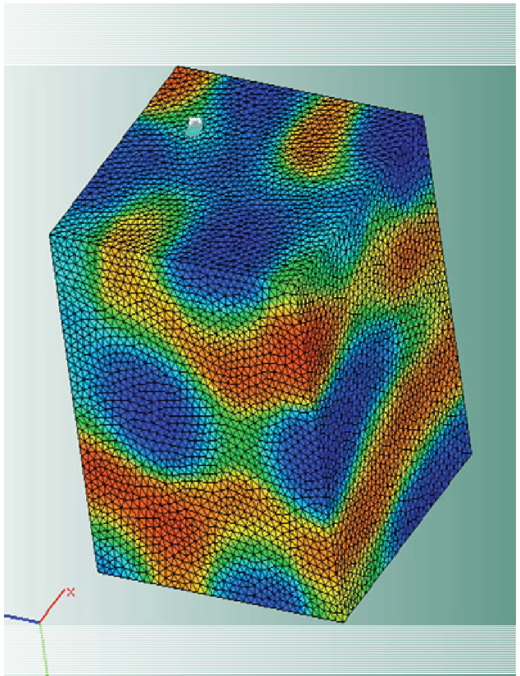
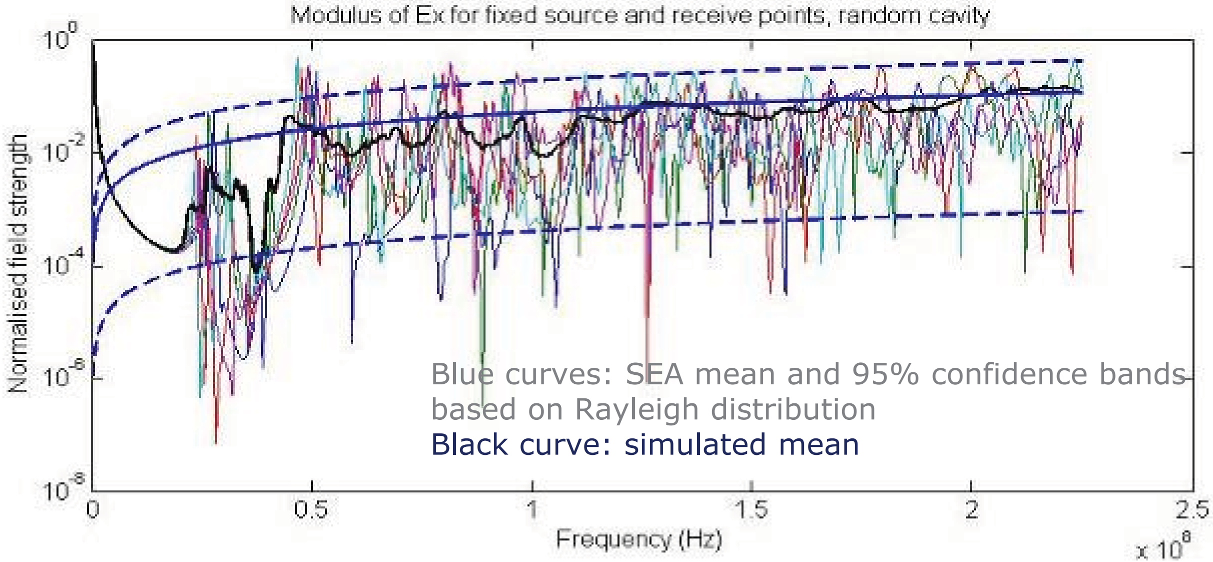
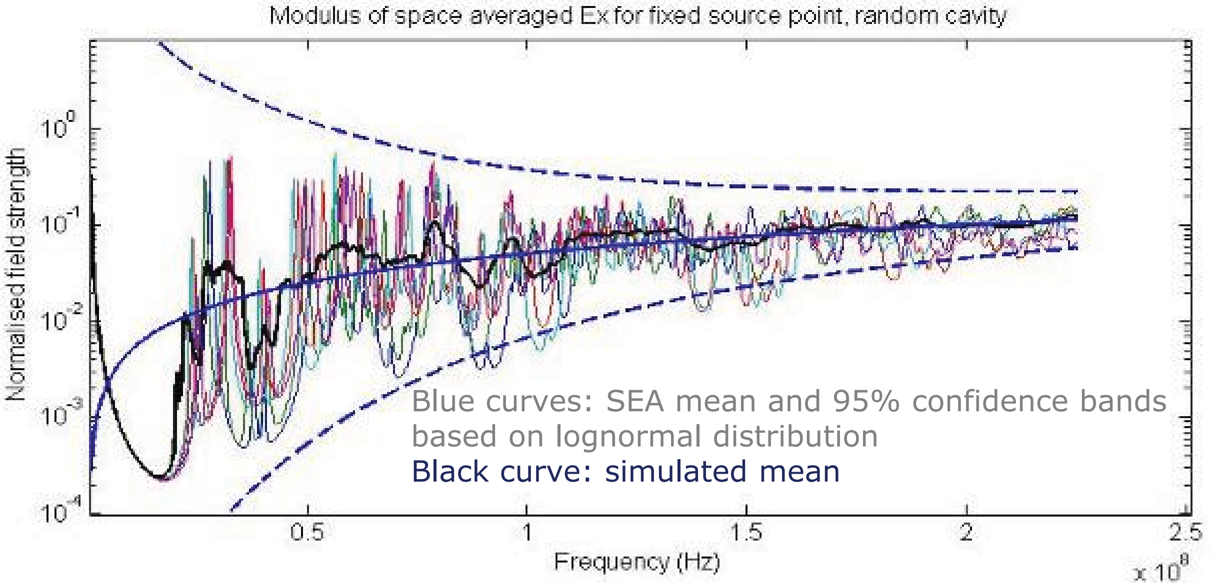
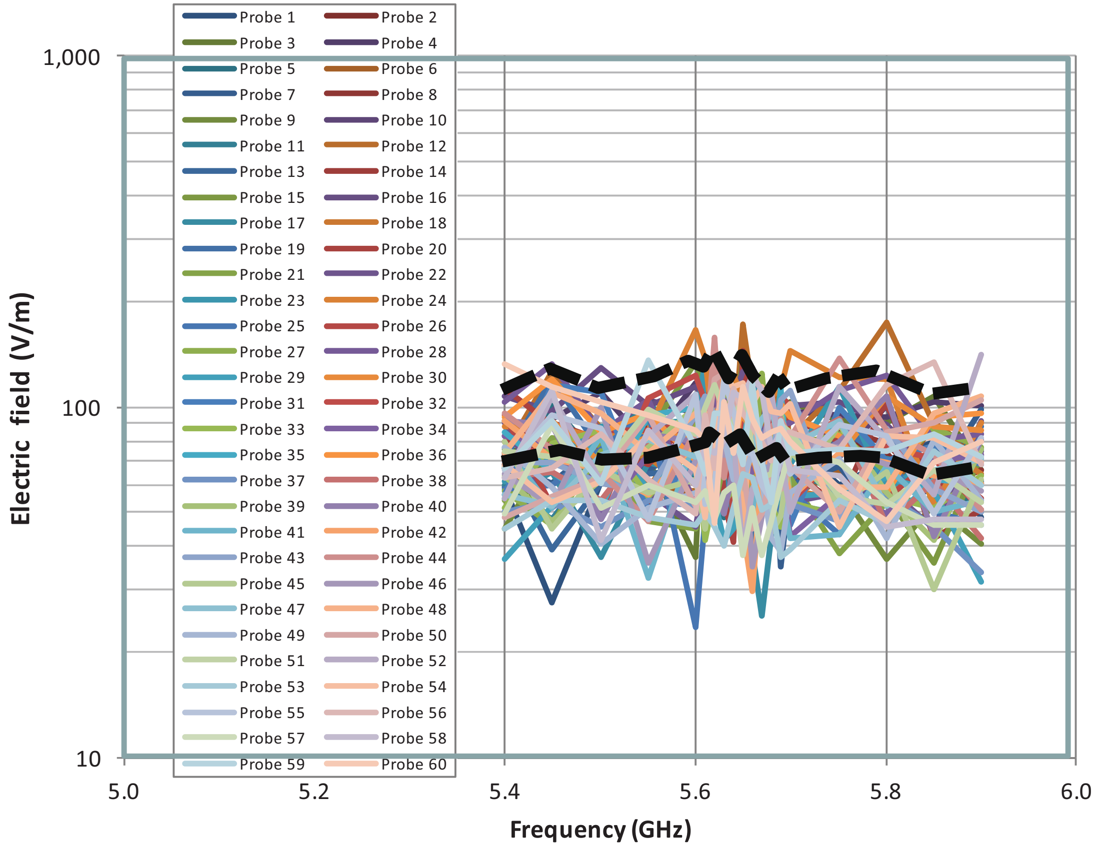
New Variance & Max Expected
checked on modes of rectangular cavity







EM field Mean & Max Expected **Measured**



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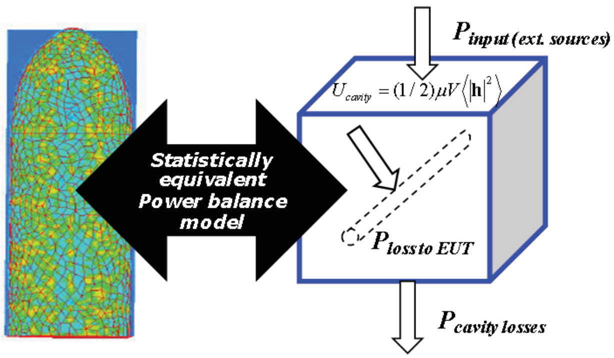
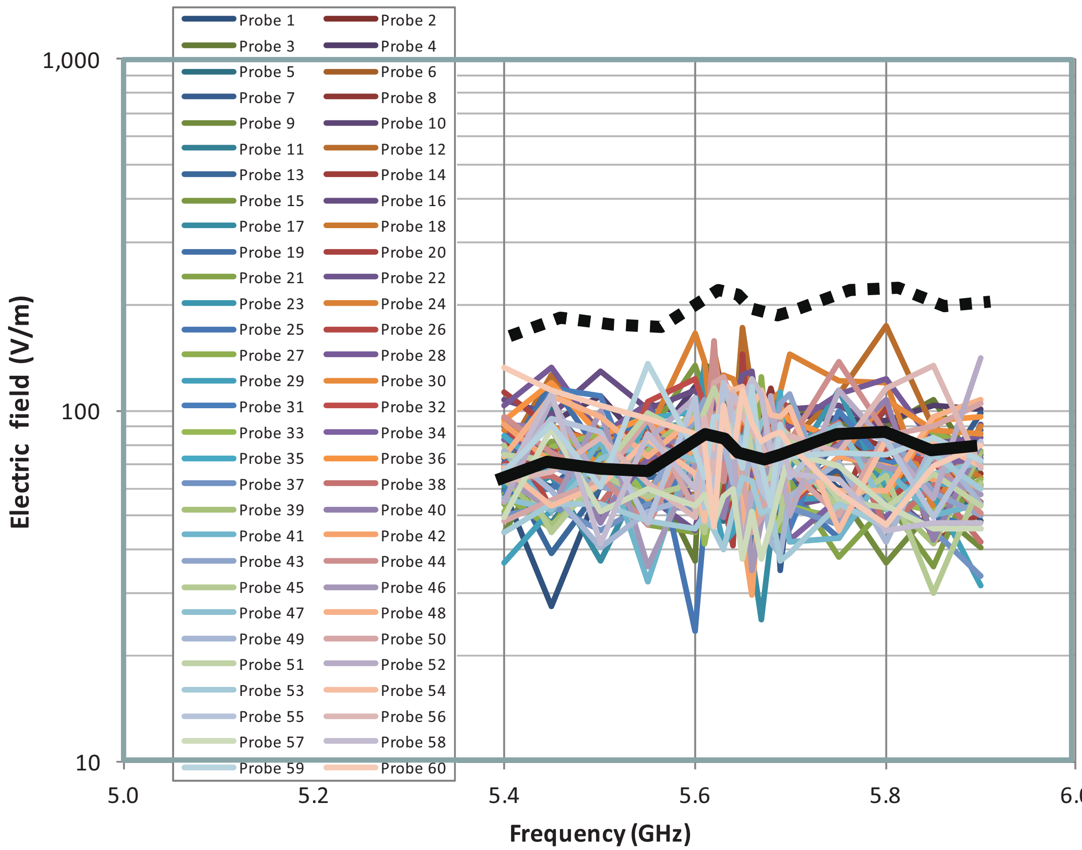
EM field Mean & Max Expected
Predicted with simple PWB statistical model





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Conclusions

- **Statistical PWB models look promising**
  - Ideal for complex payloads in fairings when EM design parameters are only ever known approximately
  - Statistical model predicts:
    - ***Mean***
    - ***Standard deviation***
    - ***Max expected (eg 97.5% quartile)***
  - No time wasted meshing details
  - PWB model solves in seconds on laptop computer

  - Can also predict induced current & voltages in wiring harnesses