Reverberation Chamber System Validation and Verification

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CTL
Communications
Technology Laboratory

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

Outline

- About NIST
- Ideal Reverberation Chamber Characteristics
- Validation and Verification Plan
- Loaded Chamber Uniformity
- Fields and Field Probes
- Empty Chamber Evaluation
- Signal Quality Evaluation

About NIST (Organization)

NIST: National Institute of Standards and Technology

Dedicated to measurement science, rigorous traceability, development and use of standards

CTL: Communications Technology Lab

Advances the measurement science underlying wireless technologies

RF Technology Division

Develops theory, metrology and standards for the technologies upon which the future of wireless communications depends.

RF Fields Group:

Measures, characterizes, and calibrates antennas and radiated fields

NIST CTL

RF Fields Group

Principal traceability path for rf field probe calibration in the US

Over 40 years of experience in reverberation chamber research

Helped establish international standards for calibrating and performing measurements in reverberation chambers

Ideal Reverberation Chamber Characteristics

- Antenna placement unimportant.
- Probe placement unimportant.
- Test artifact/animal placement unimportant.
- Orientation is unimportant

Validation and verification plan

- Uniformity (temperature in phantoms, probe field, antenna power)
- Note: cannot directly measure SAR
- Field probe/chamber calibration
- Signal quality

Validations Performed:

- December, 2007 after initial installation
- April, 2012 after pre-chronic and thermal pilot studies
- May, 2015 well after all tests complete, and system had been off for around 1 year

Loaded Chamber Uniformity

Replace 1 cage with an antenna at random orientation.

Measure average received power during continuous paddle rotation.

Repeat at 20 cage positions.

Standard deviation 1.3 dB

Range 2.5 dB

RF Field Probes and calibration

Calibration Procedure for each axis

1. Generate known signal
   GSM, CDMA, …
2. Measure forward and reflected power.
3. Radiate signal using known antenna.
4. Compute field based on radiated power.
5. Measure probe response
6. Repeat over multiple levels to deal with *nonlinear response*.

Standard uncertainty: 0.4 dB or 10 % in power

IT'IS calibration is very similar.

Types of fields

Electric and Magnetic, also know as E-fields and H-fields. (proportional in RC)

Cartesian components: aligned with x-axis ((E_x)), y-axis (E_y), and/or z-axis (E_z)

Depends on orientation

Total Electric Field = $E_T = \sqrt{(E_x)^2 + \left(E_y\right)^2 + (E_z)^2}$ (independent of orientation)

SAR is proportional to $E_T{}^2 = (E_x)^2 + \left(E_y\right)^2 + (E_z)^2$

Empty Chamber evaluation

Measure received power on NIST antenna and Spectrum Analyzer, field on NIST E probe, IT'IS E probe, and IT'IS H probe at 100 discrete paddle positions.

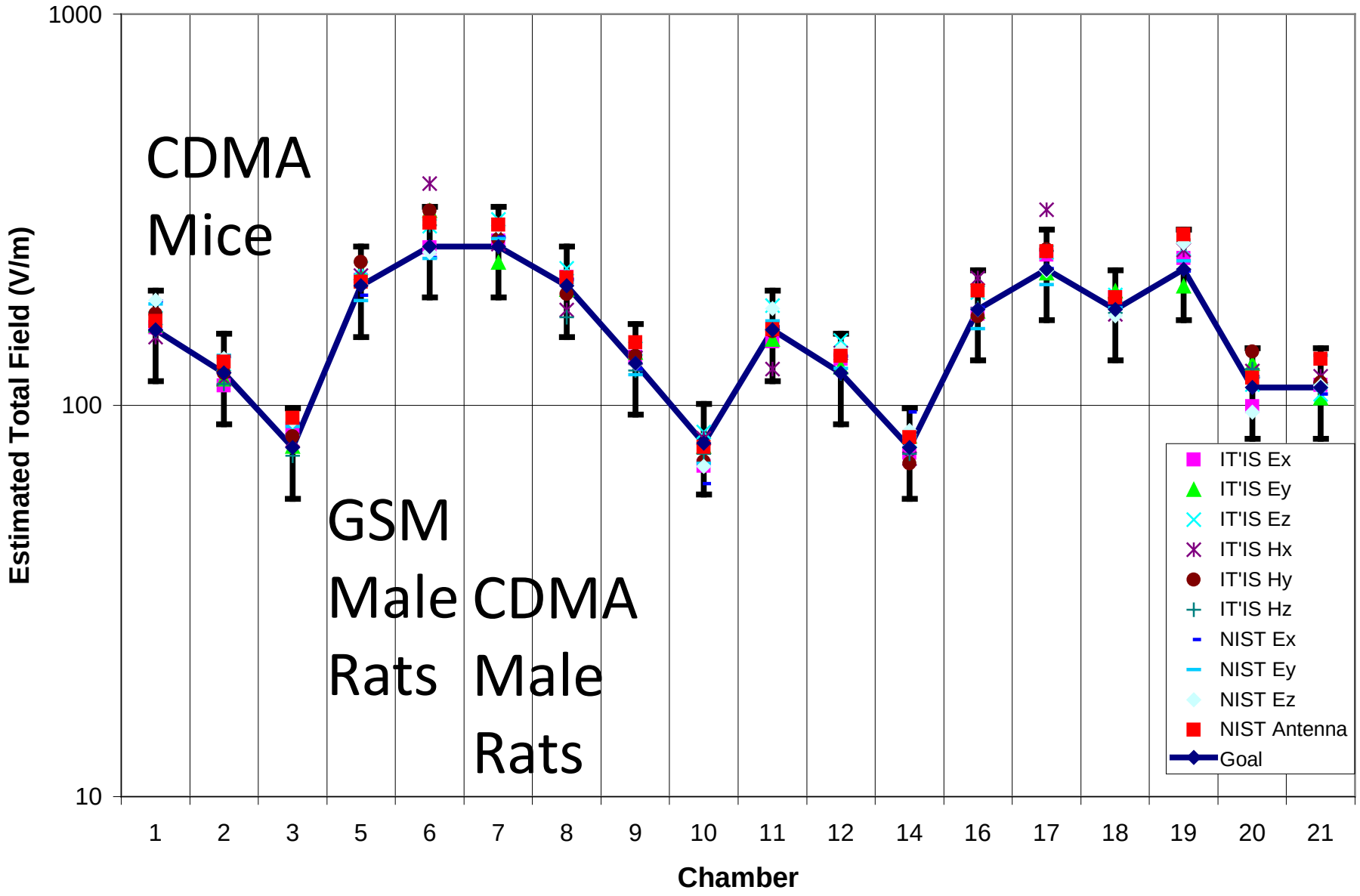
Convert all measurements to squared total E field using known equations.

Compare averages in each chamber with a target field

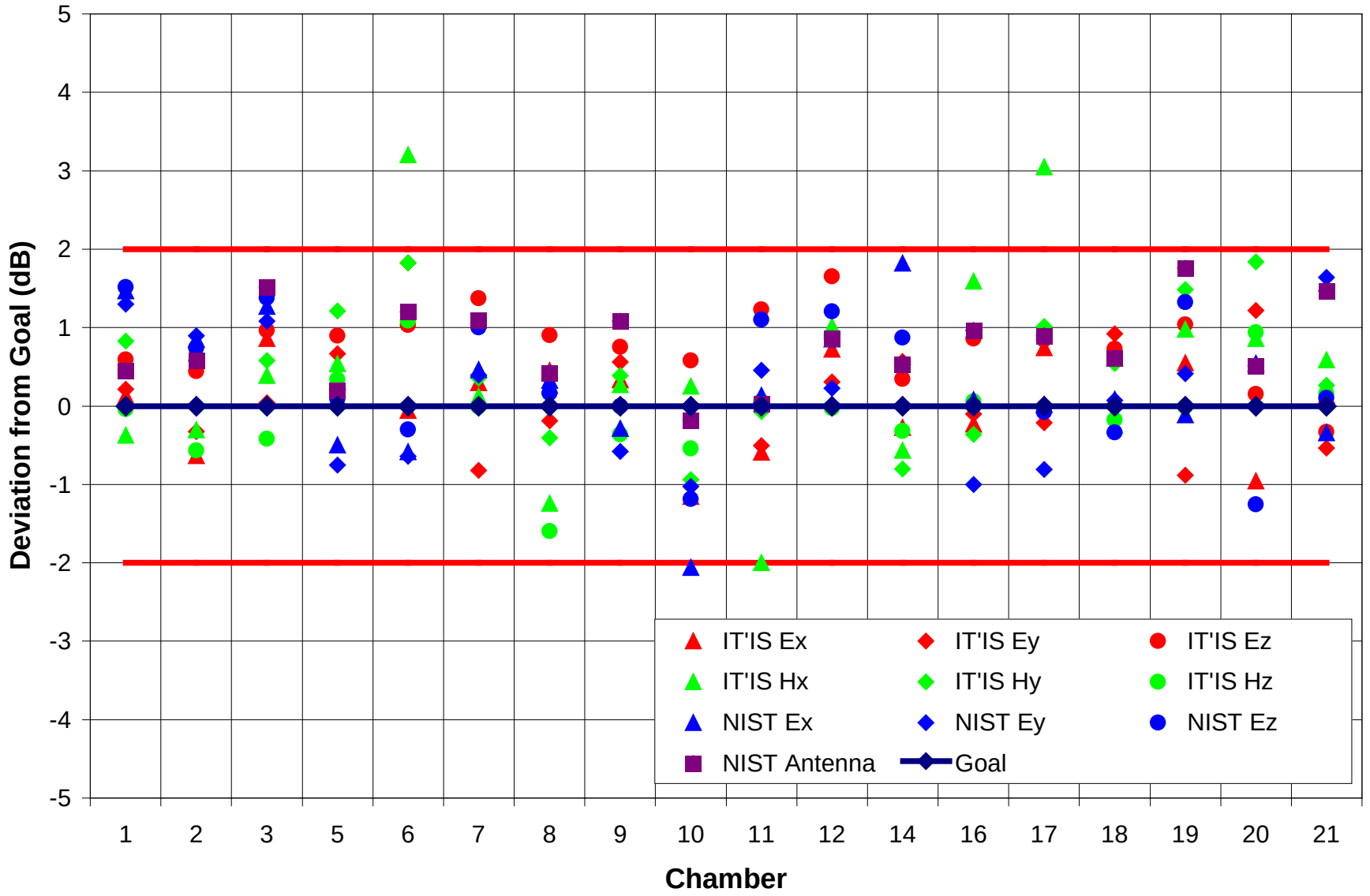
Single-axis field comparison: 2007

Note:
Field levels change over time due to animal growth, although SAR remains constant.

No entries for sham chambers.



Single-axis deviation from goal: 2007



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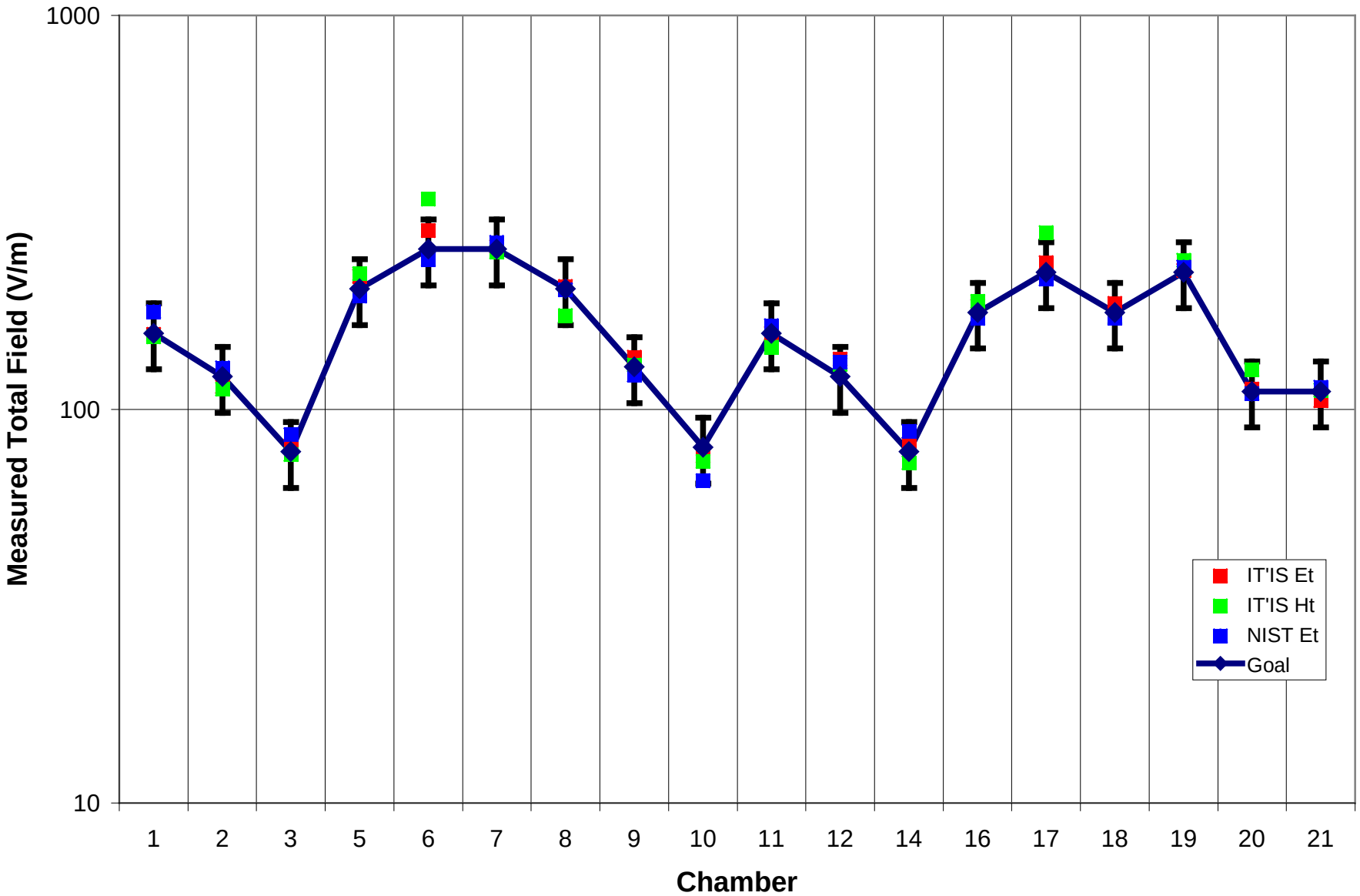

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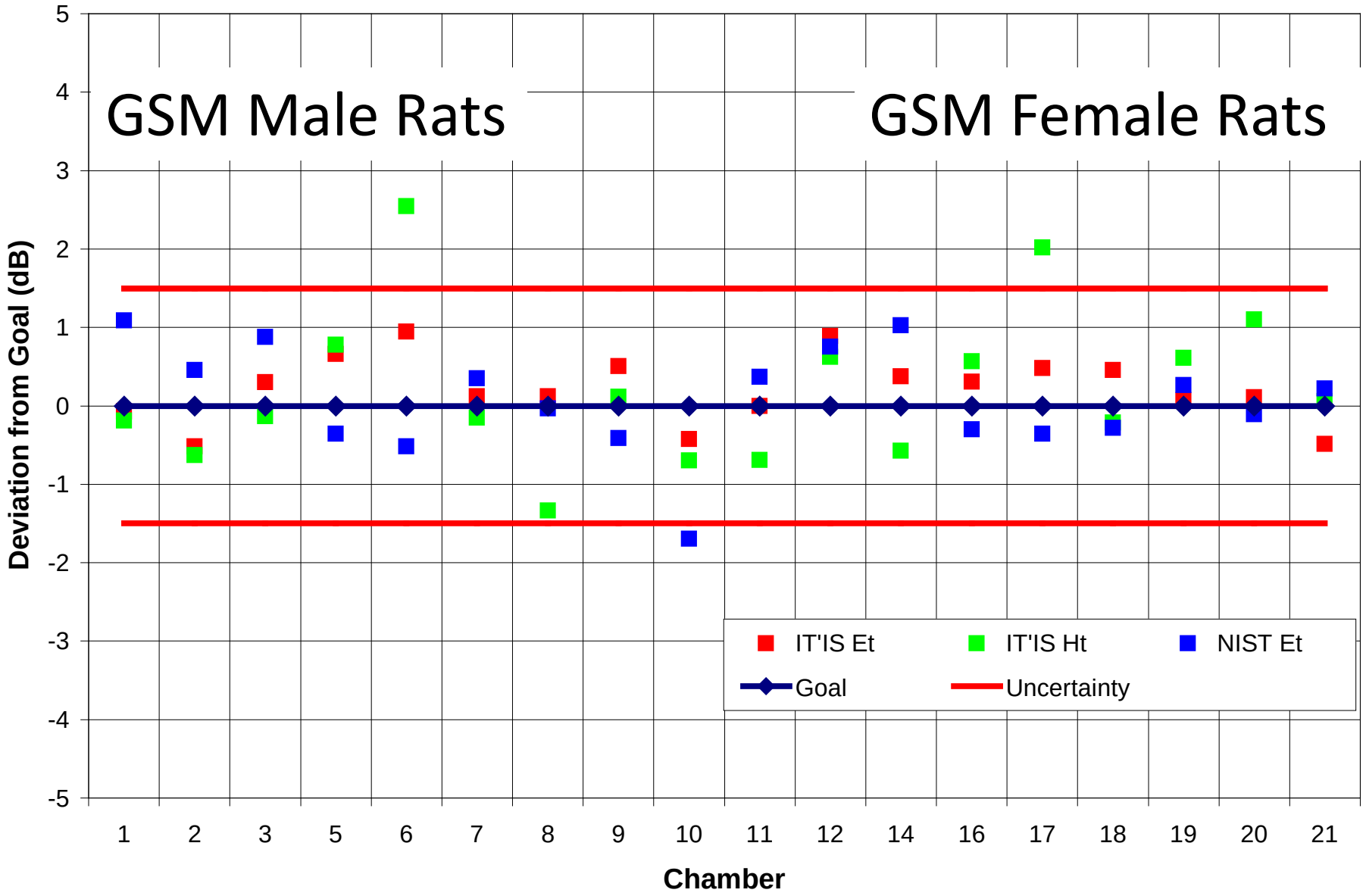
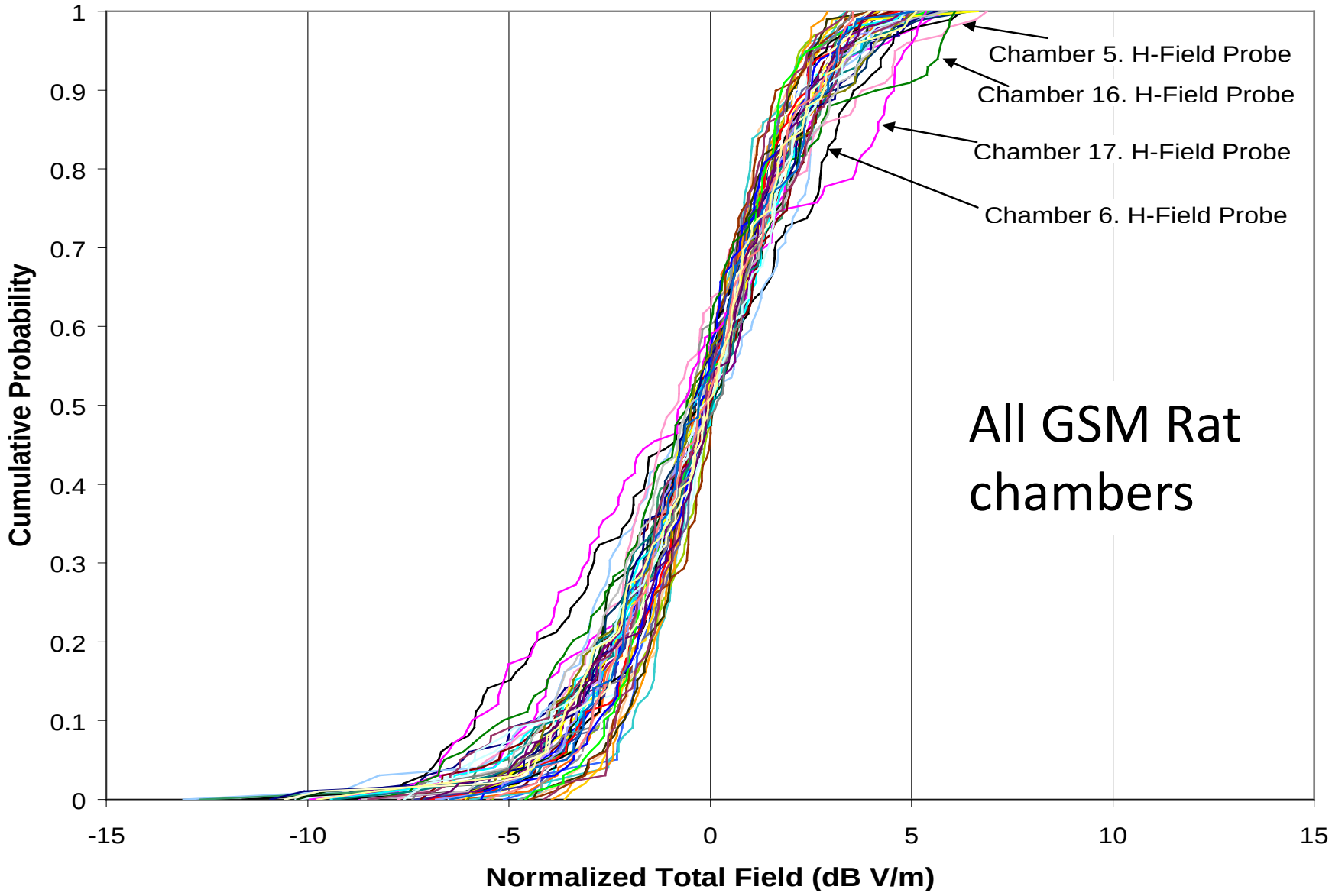
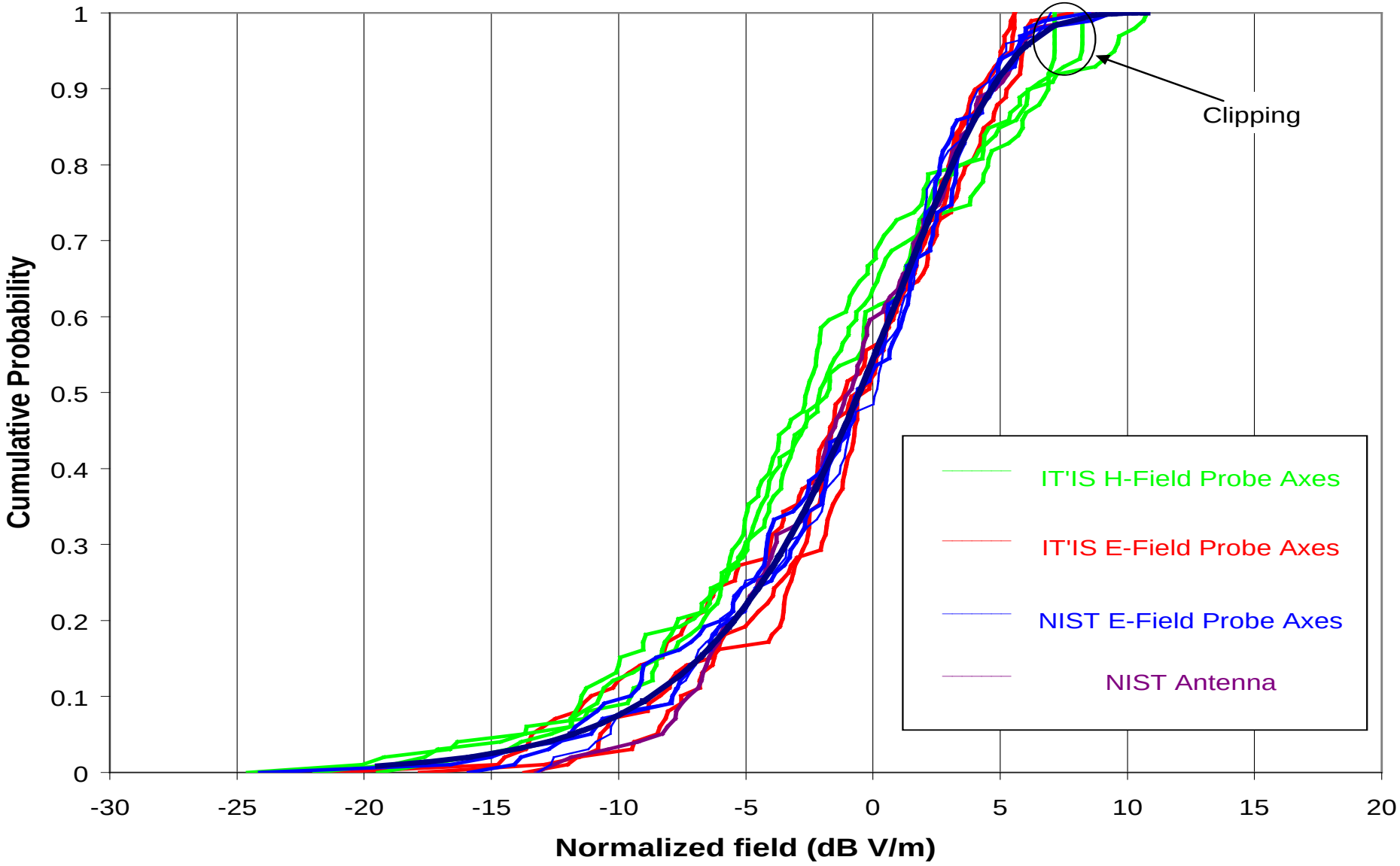


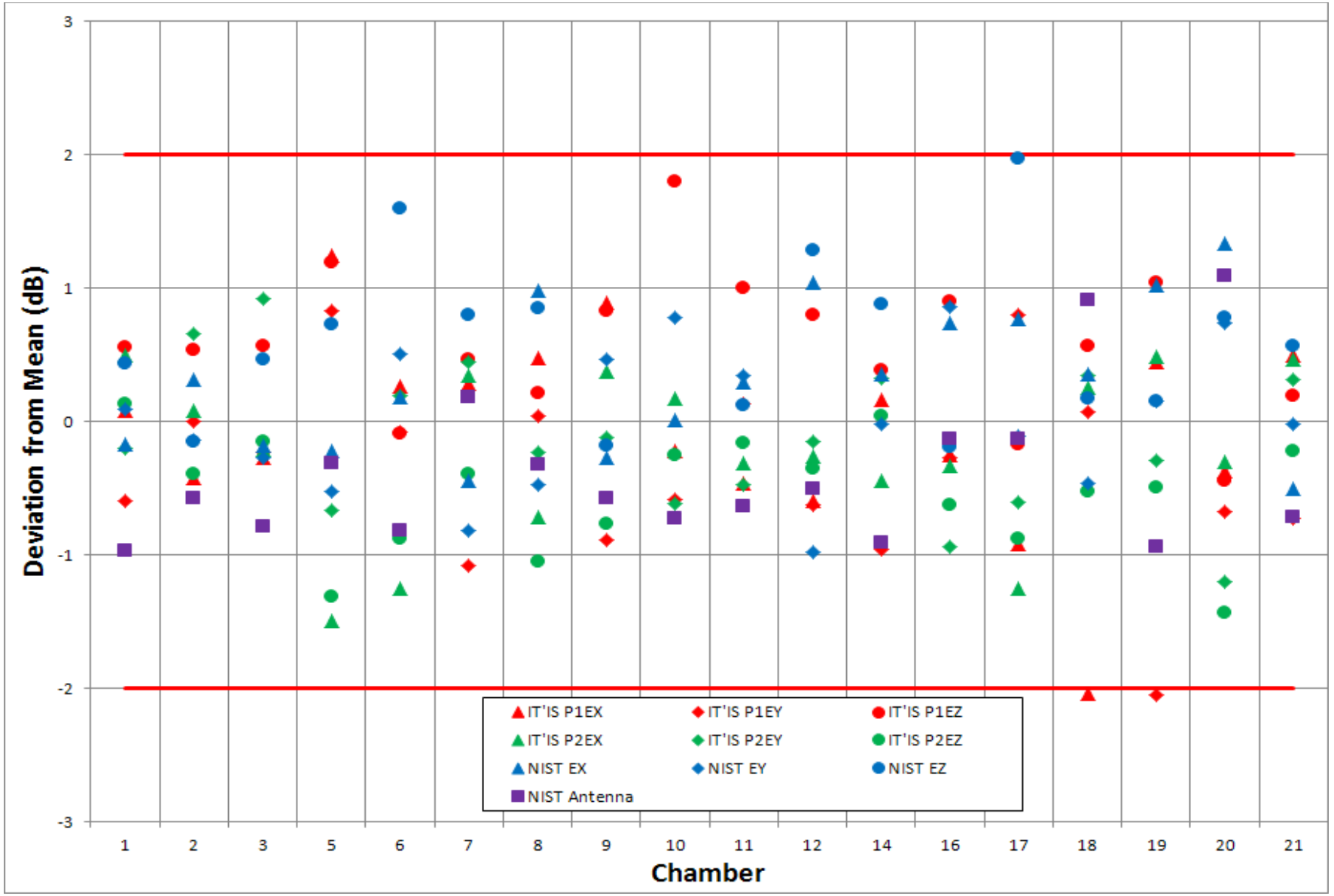
CDF's of single-axis field measurement: 2007



A closer look at Chamber 6: High Male Rat GSM 2007



Single-axis deviation from goal: 2012



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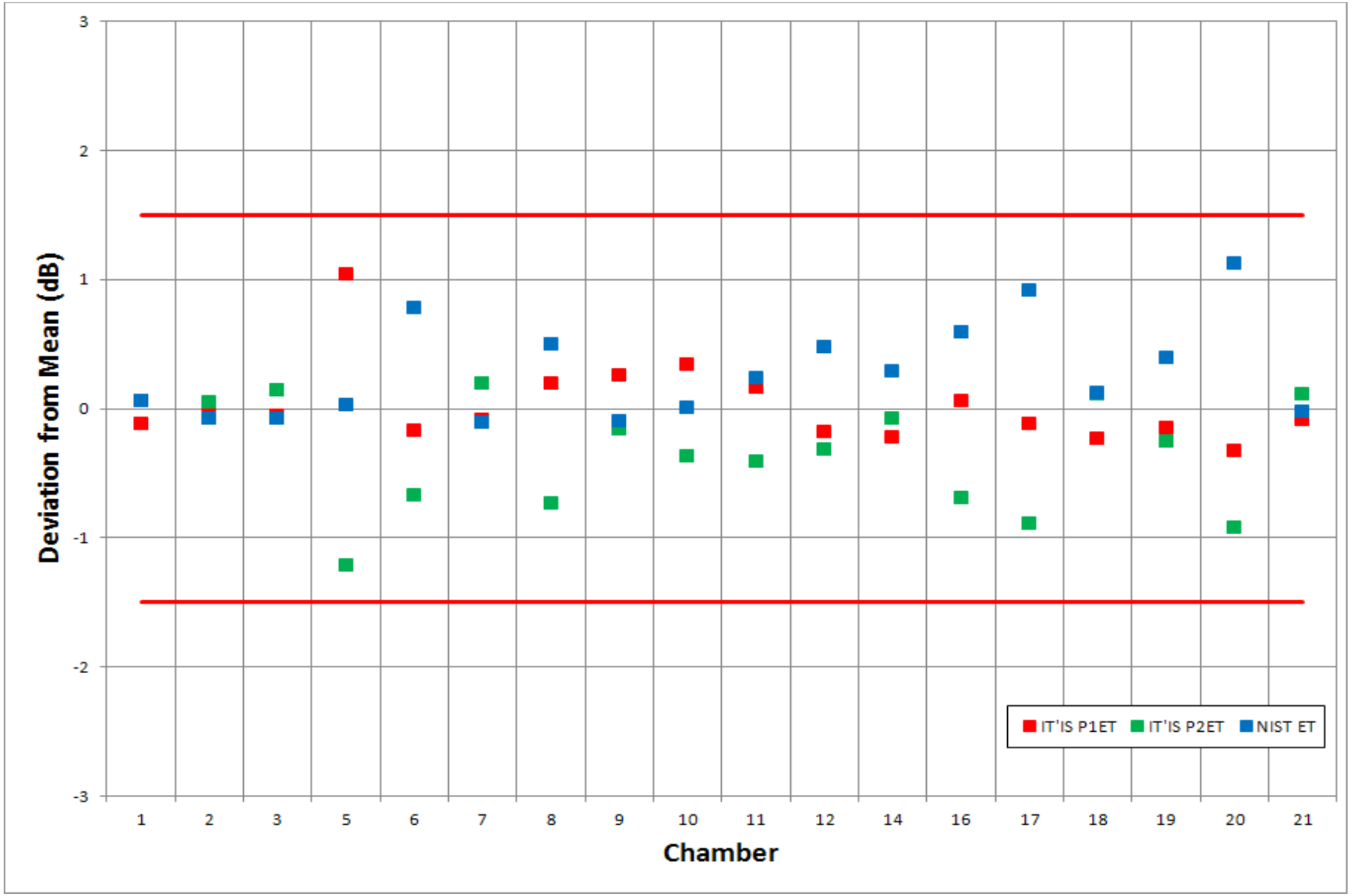
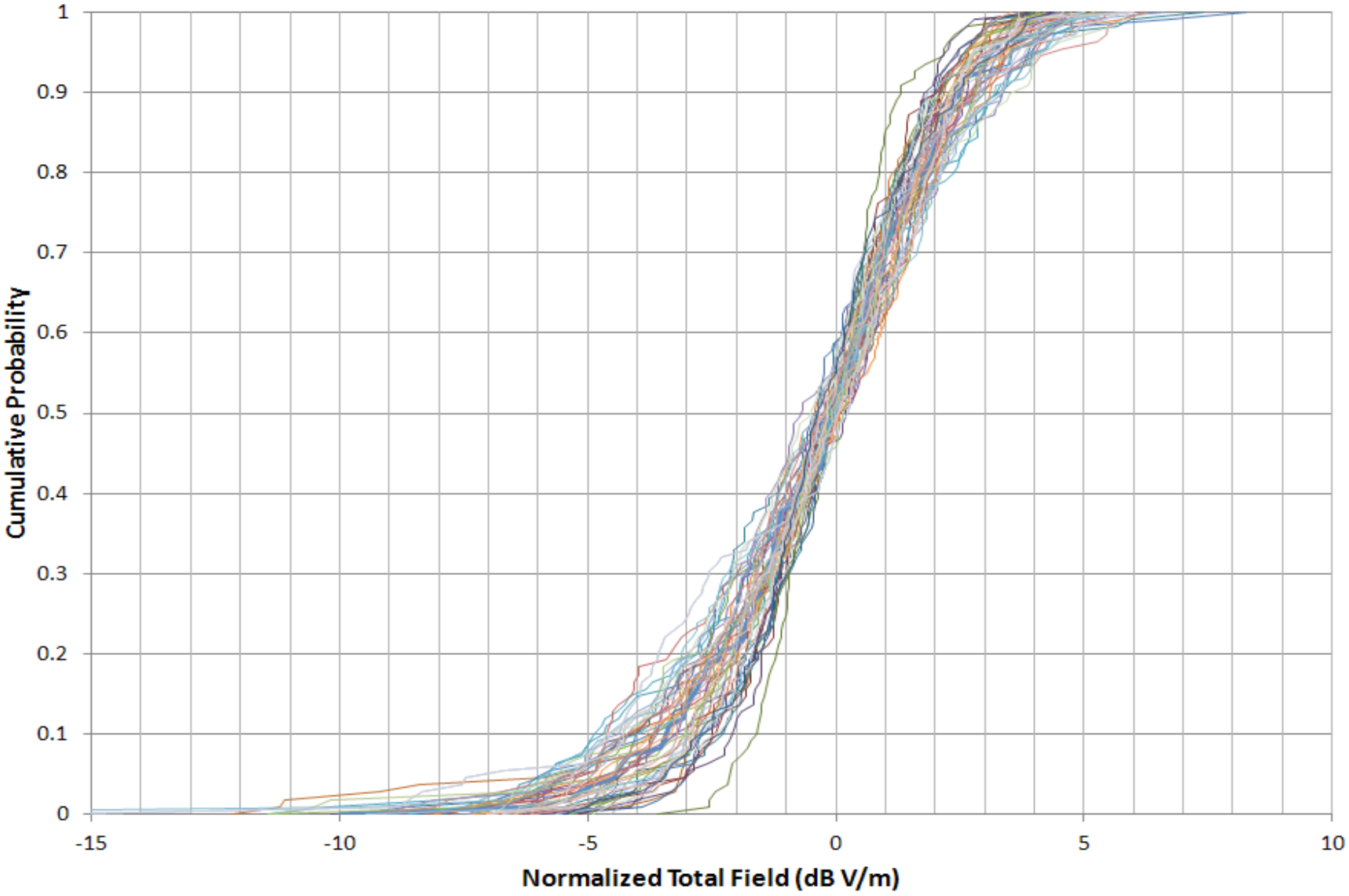


CDF's of single-axis field measurement: 2012



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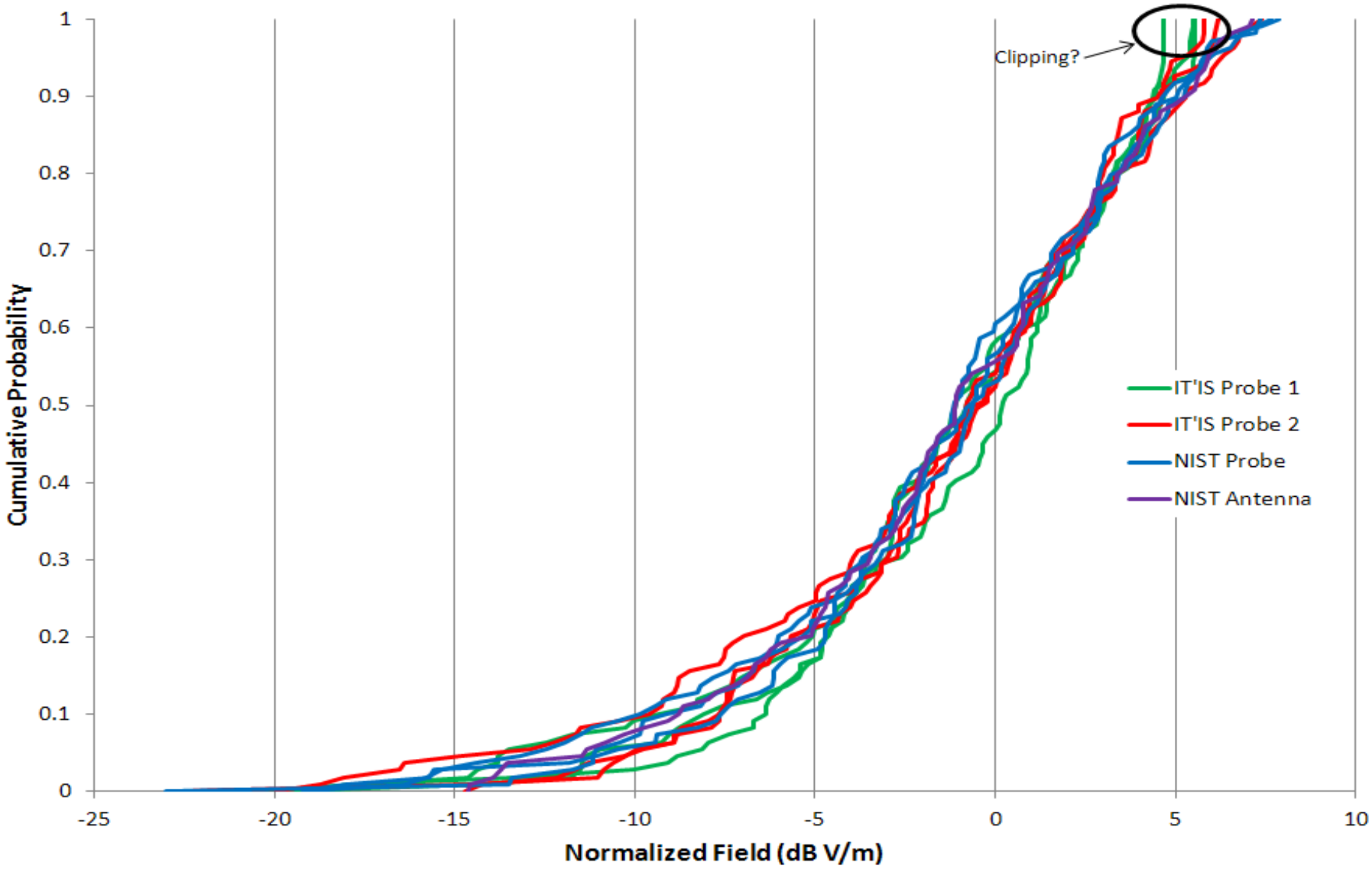
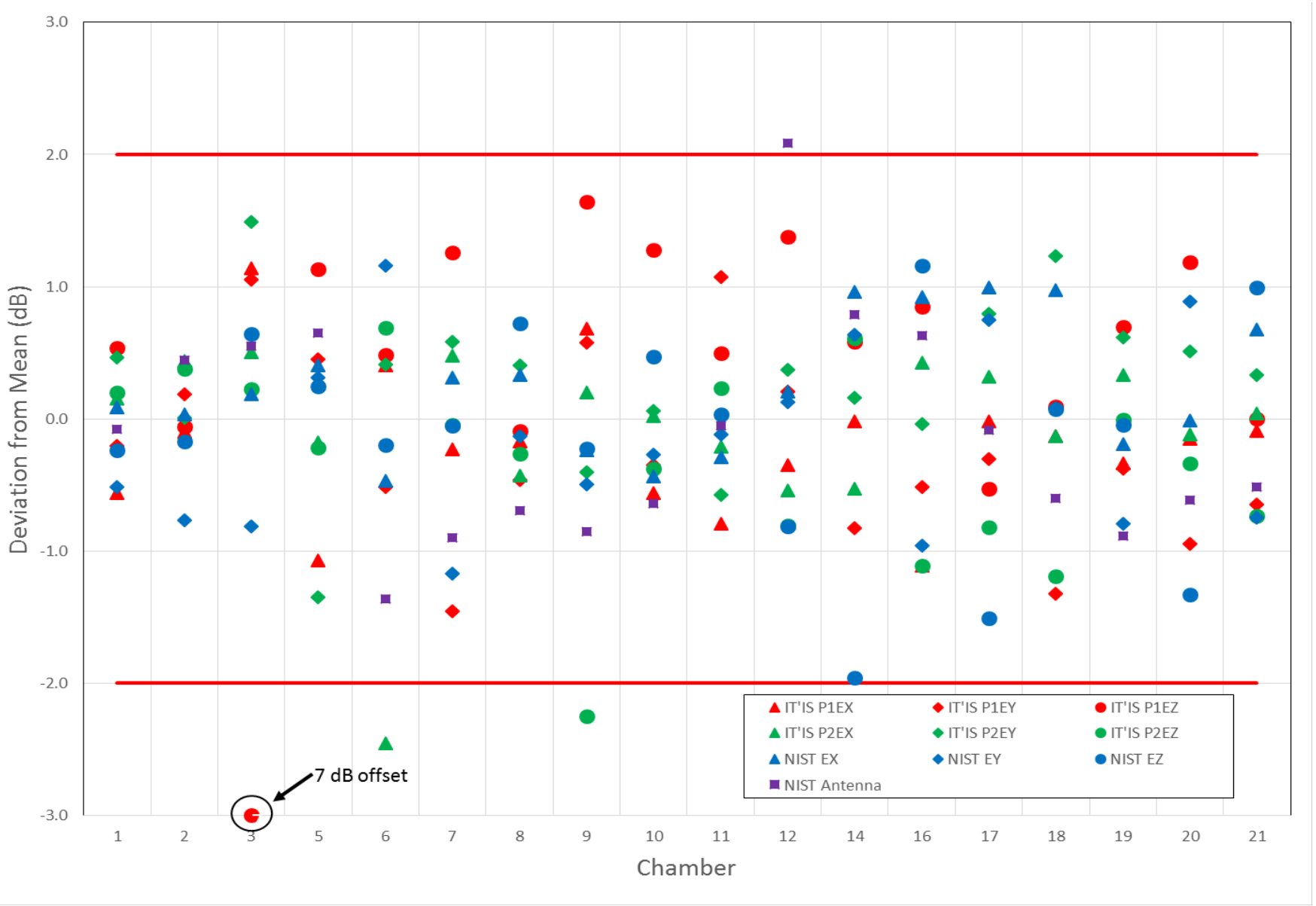


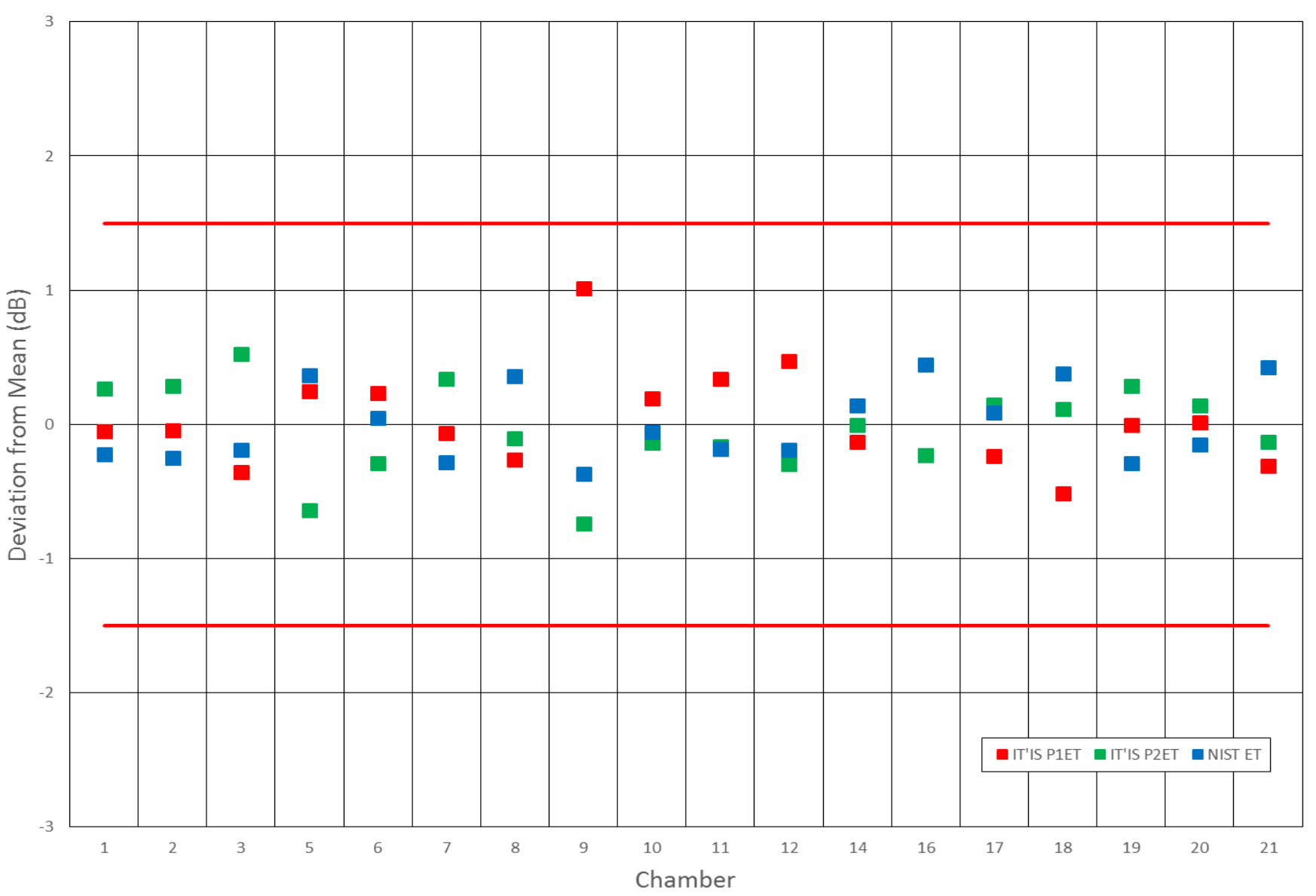
Single-axis deviation from goal: 2015

Zeroing units in chambers 3 and 20 had failed. Data review showed no problems in chamber 20 during tests, but chamber 3 had issues for last 6 months of test.

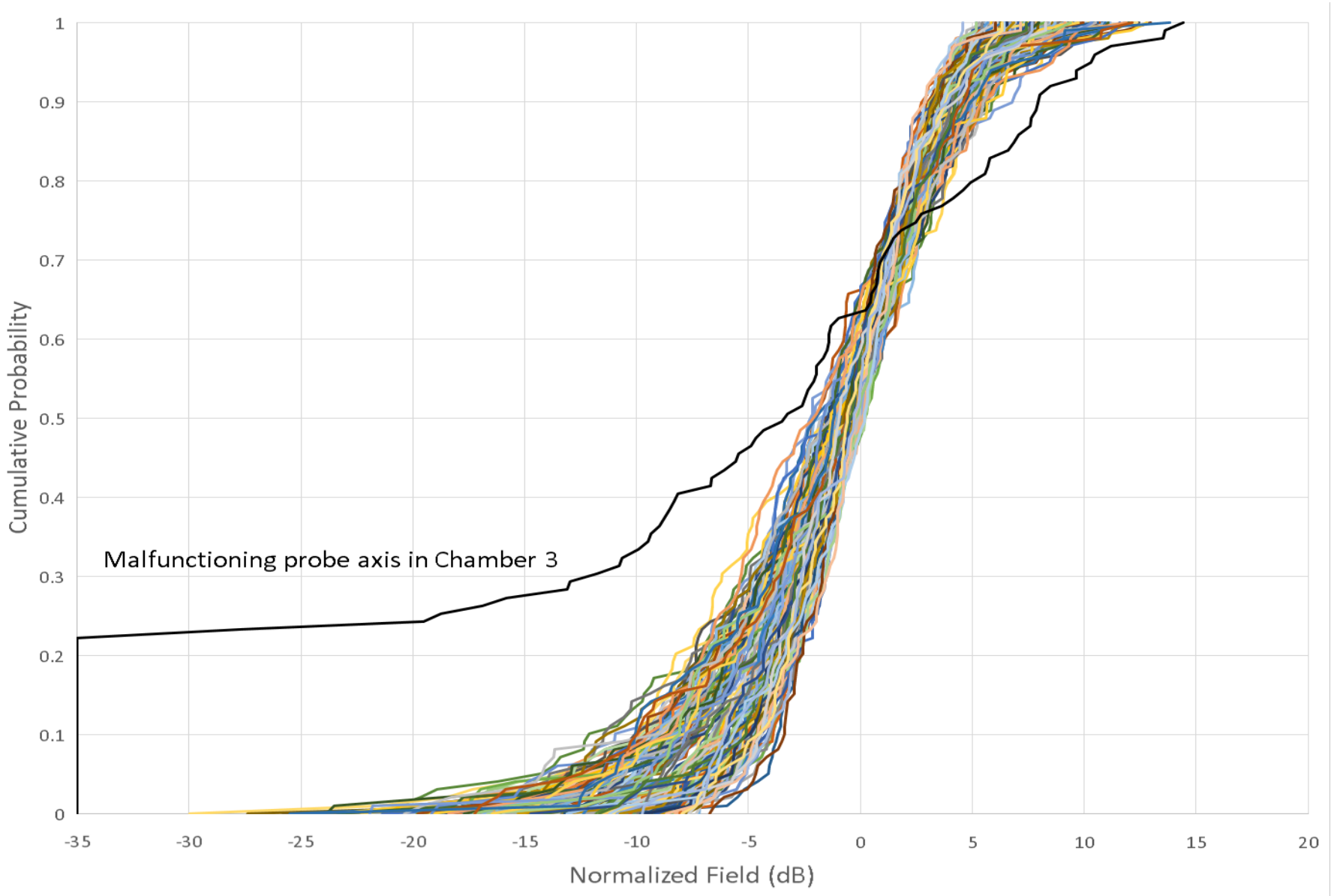


Total field deviation from goal: 2015

No issues seen in measurements of total electric field.



CDF's of single-axis field measurement: 2015



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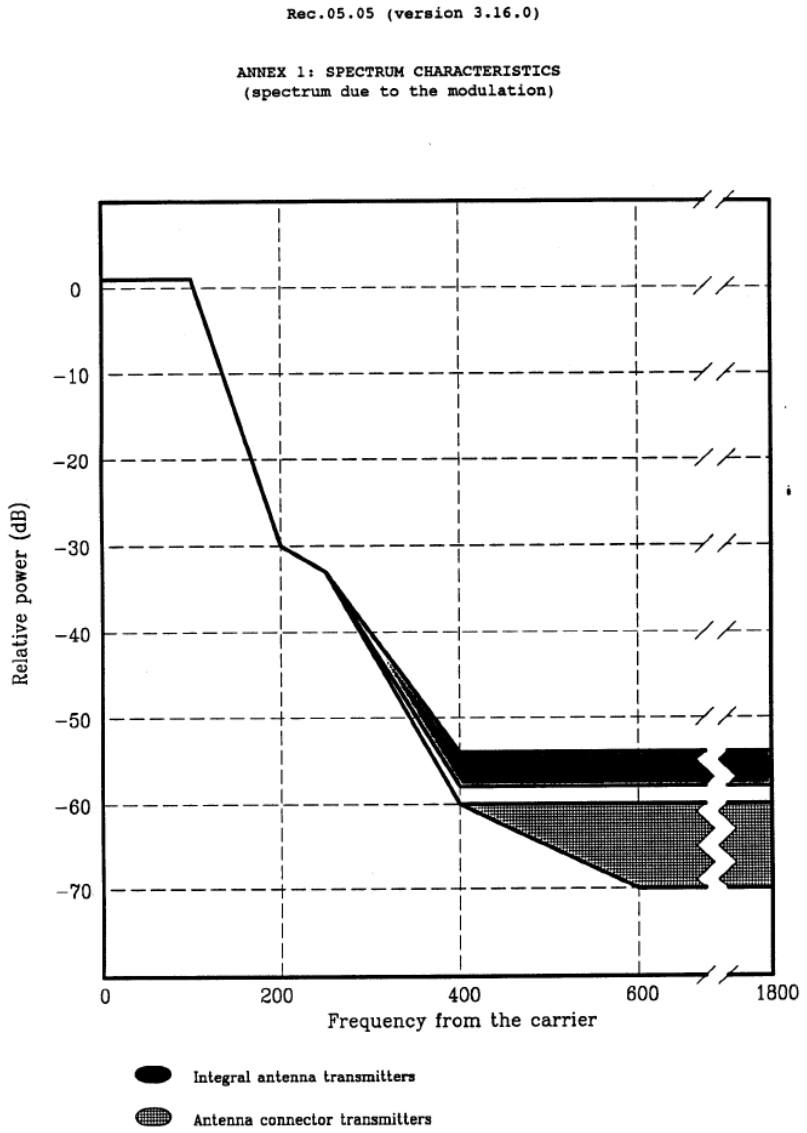
Signal distortion

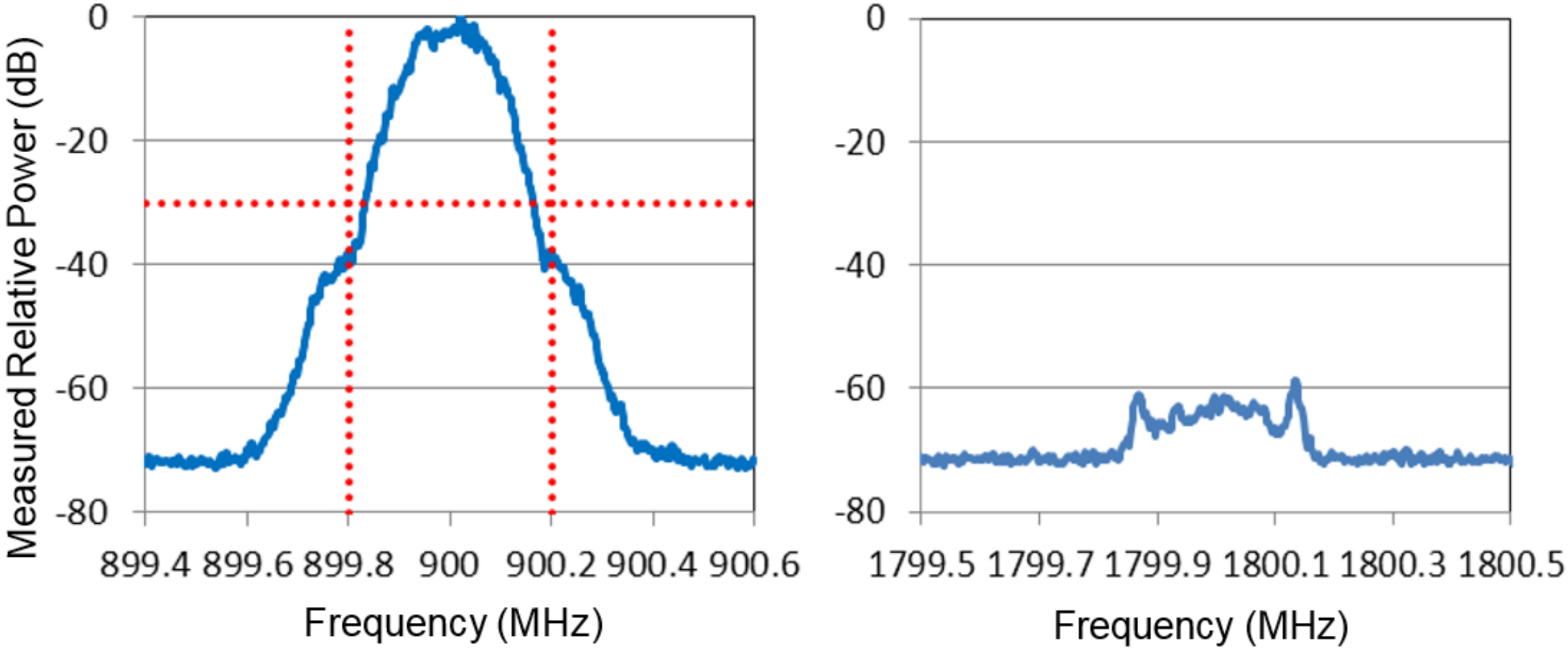
All transmitted signals have *some* distortion

Regulations focused on preventing interference with users of adjacent spectrum.

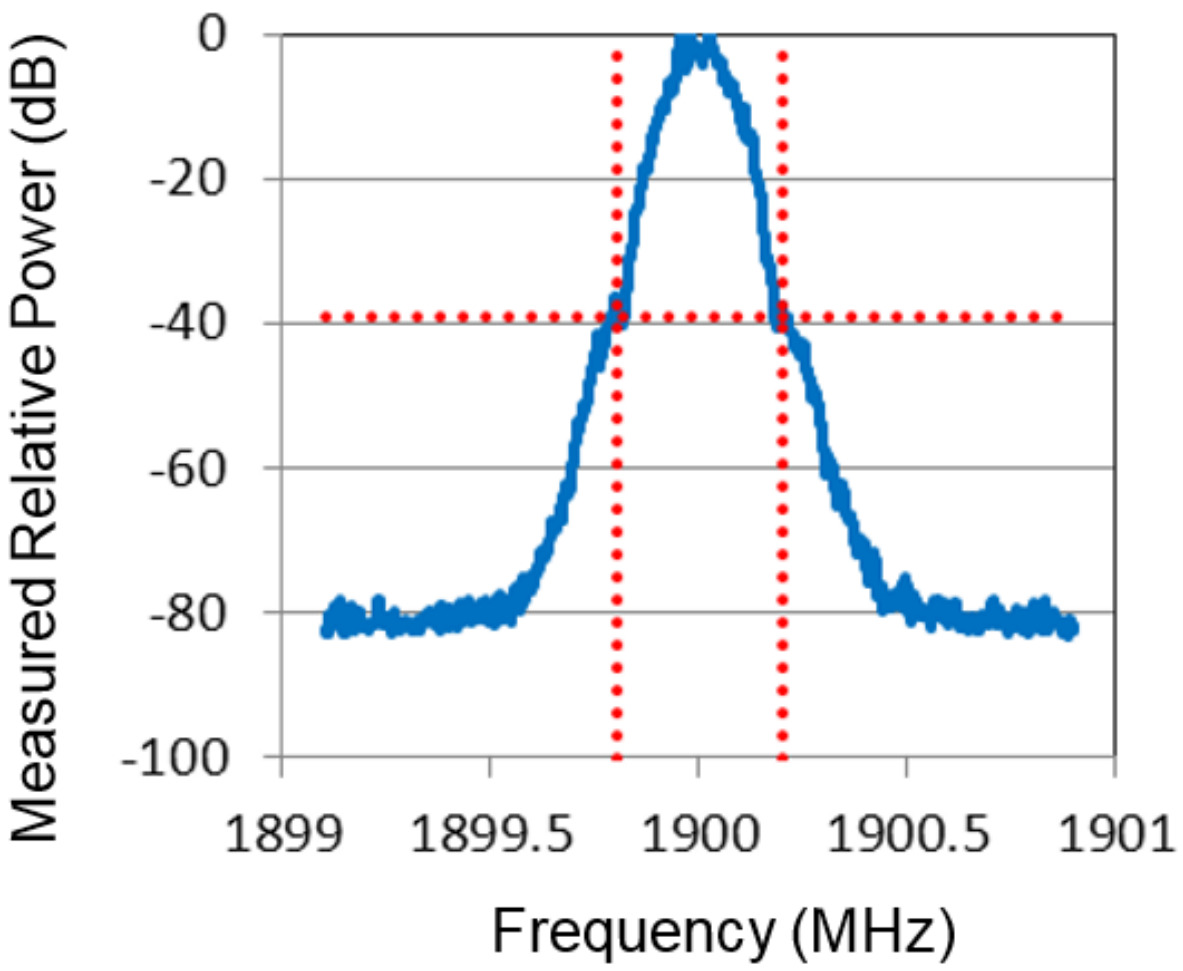
Limited guidance in main signal band.

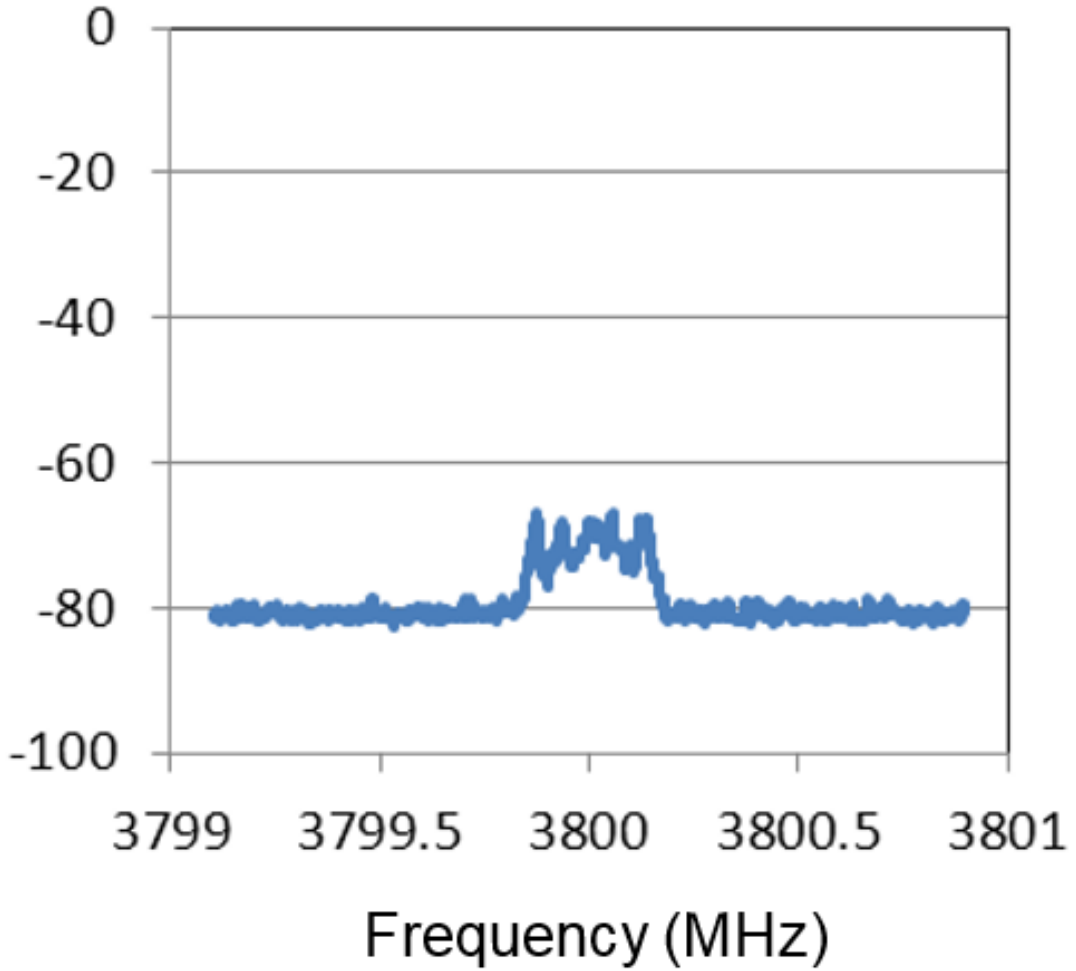


High-power GSM emissions, Chamber 6 (male rat)

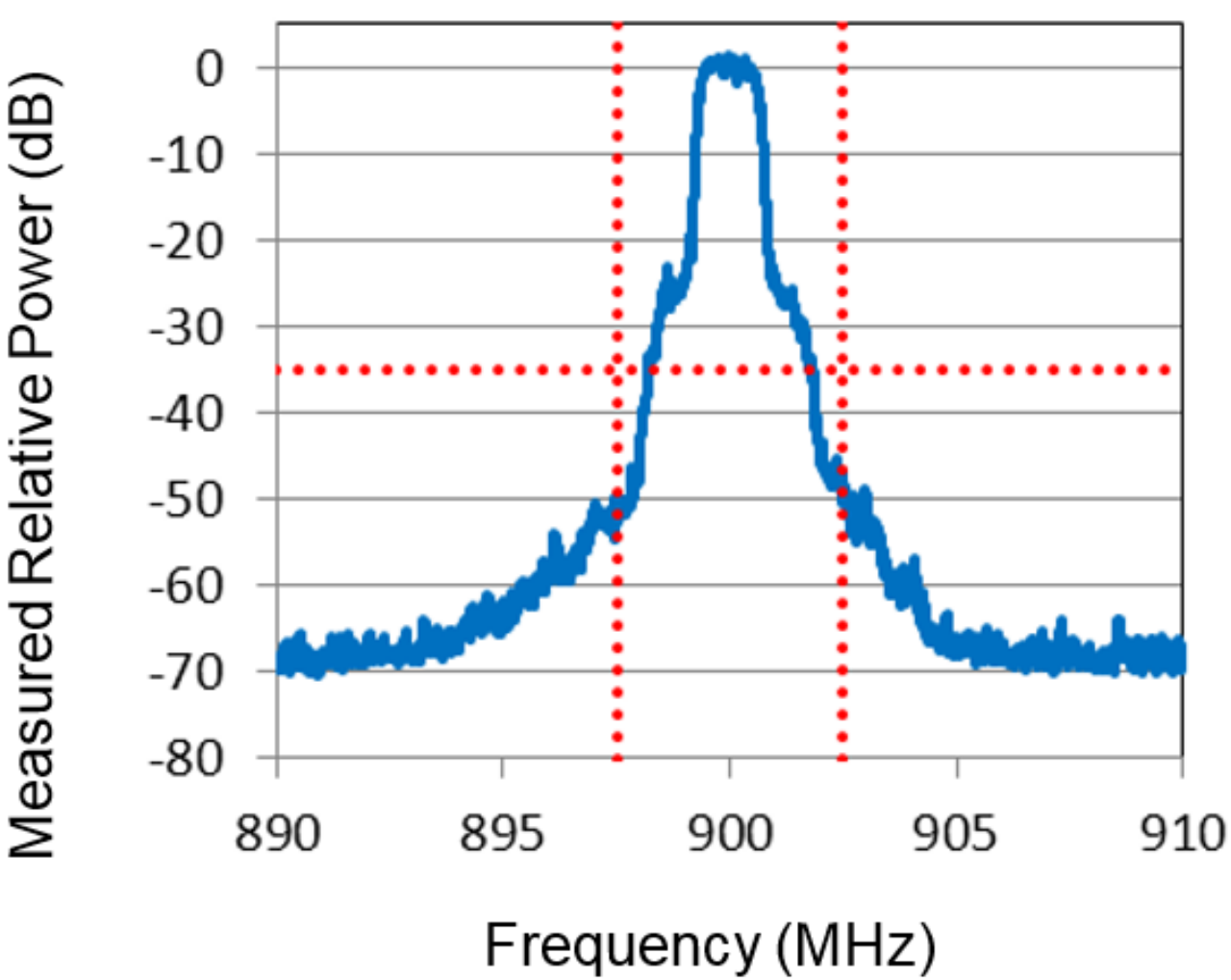


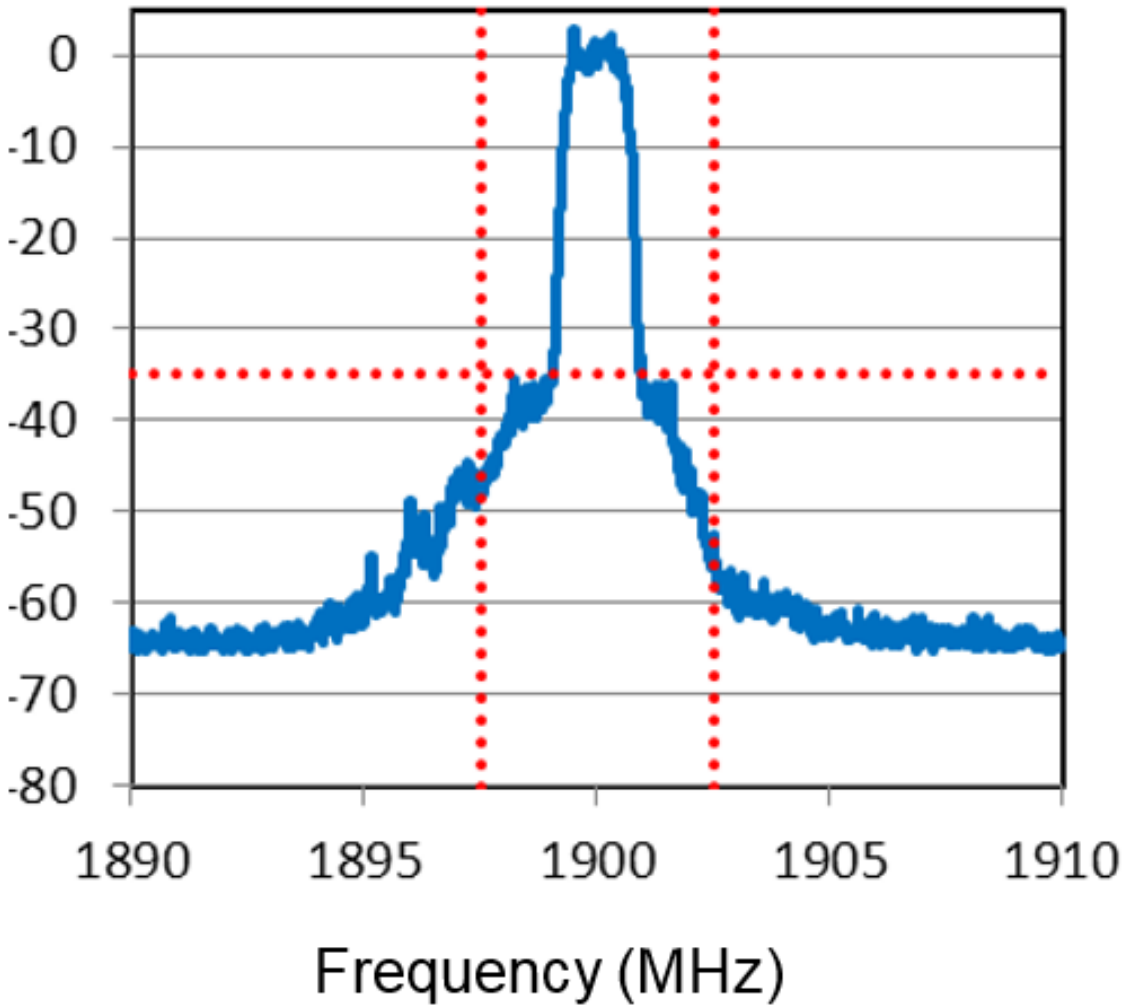
High-power GSM emissions, Chamber 11 (mouse)





High-Power CDMA Spectra Chambers 11 (mouse) and 7 (m rat)





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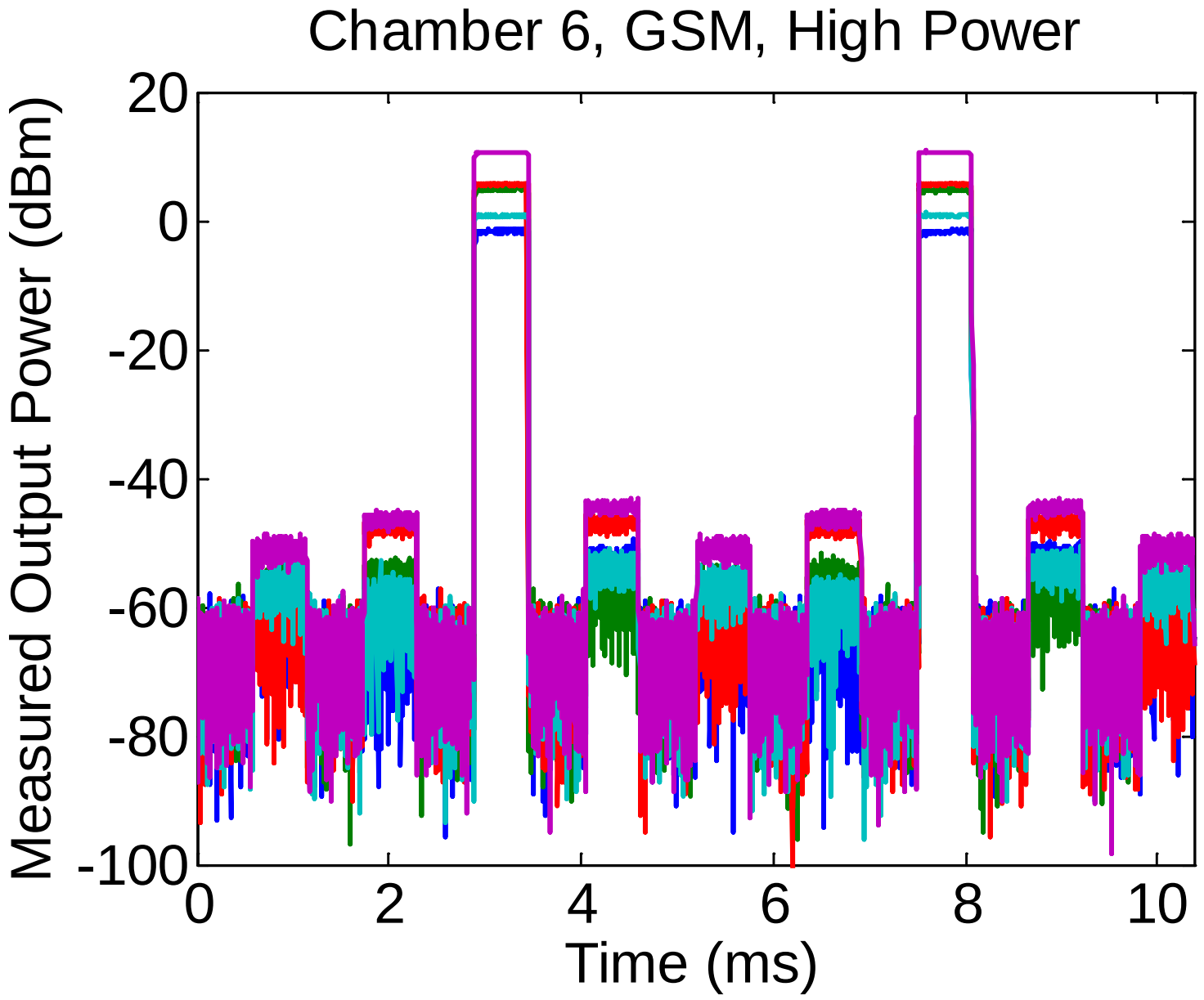
High-power GSM in time domain



Overall Summary

Loaded chamber uniformity: standard deviation of 1.3 dB.

Some unusual probe behavior observed in high-power chambers for H field probes, improved for thermal pilot and prechronic, fixed for chronic tests.

After chronic tests, two zeroing units had failed. One had been working during chronic tests, the other failed approximately 6 months before end of chronic tests. Negligible impact on estimation of the total E field.

Signal quality within standard parameters for communications standards.