2009 International Zurich Symposium on Electromagnetic Compatibility

Module Level EMI Measurements and Estimation Workshop

Predicting Module Level RF Emissions from IC Emissions Measurements using a 1 GHz TEM or GTEM Cell – a Review of Related Published Technical Papers

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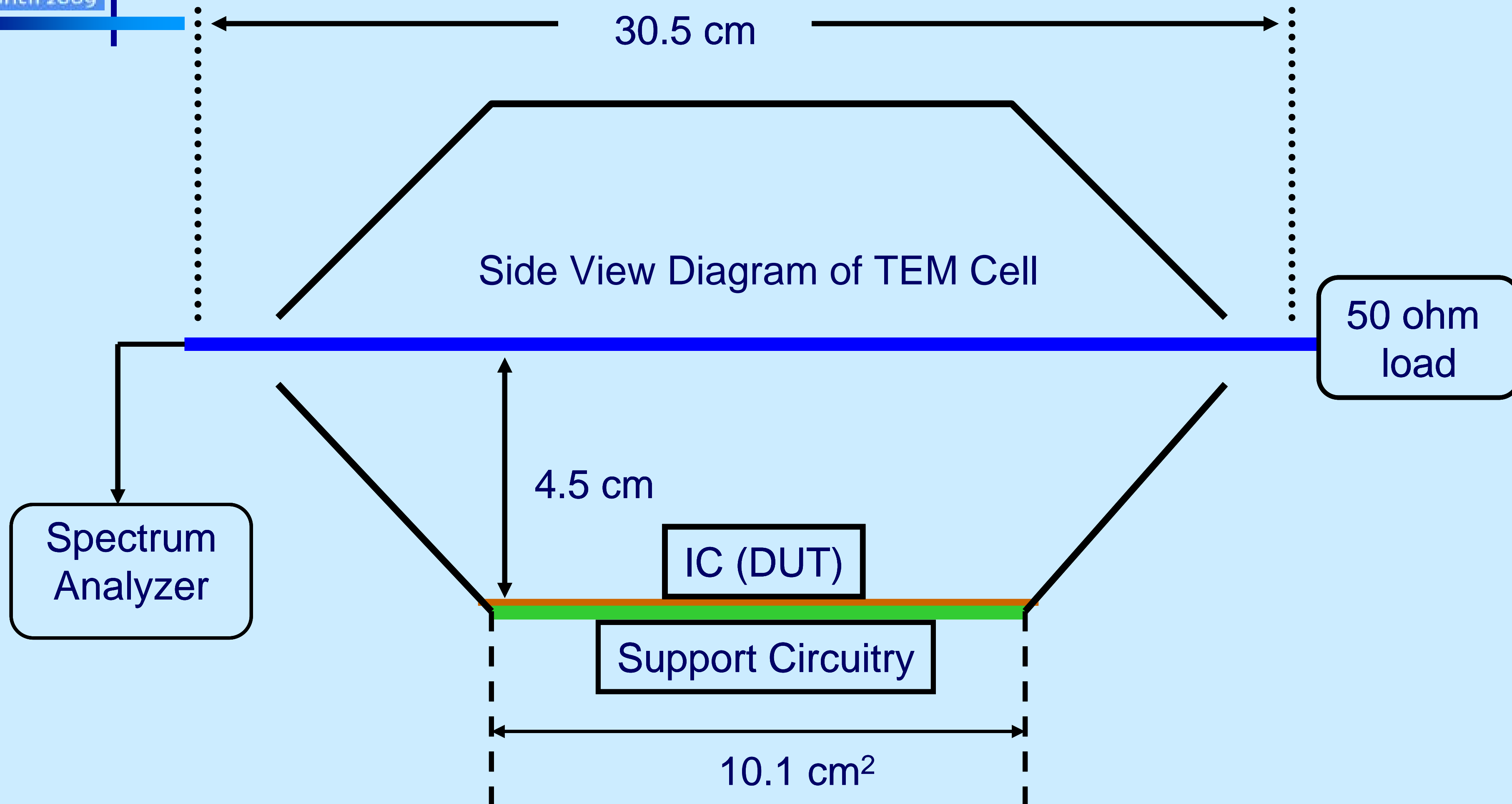
Outline of Topics

- Introduction
- Description of the TEM Cell and IC Test Board
- Development of the TEM Cell Method
- Evaluation of IC Process Variables
- Evaluation of the Effects of IC Internal Structure, Software Level, Environmental Temperature and IC Packaging on Emissions
- Correlation Between IC and Far Field Measurements
- Extension of the 1 GHz TEM Cell Method to Several GHz Using a Small GTEM Cell
- Related IC Emissions Measurement Standards
- Conclusions

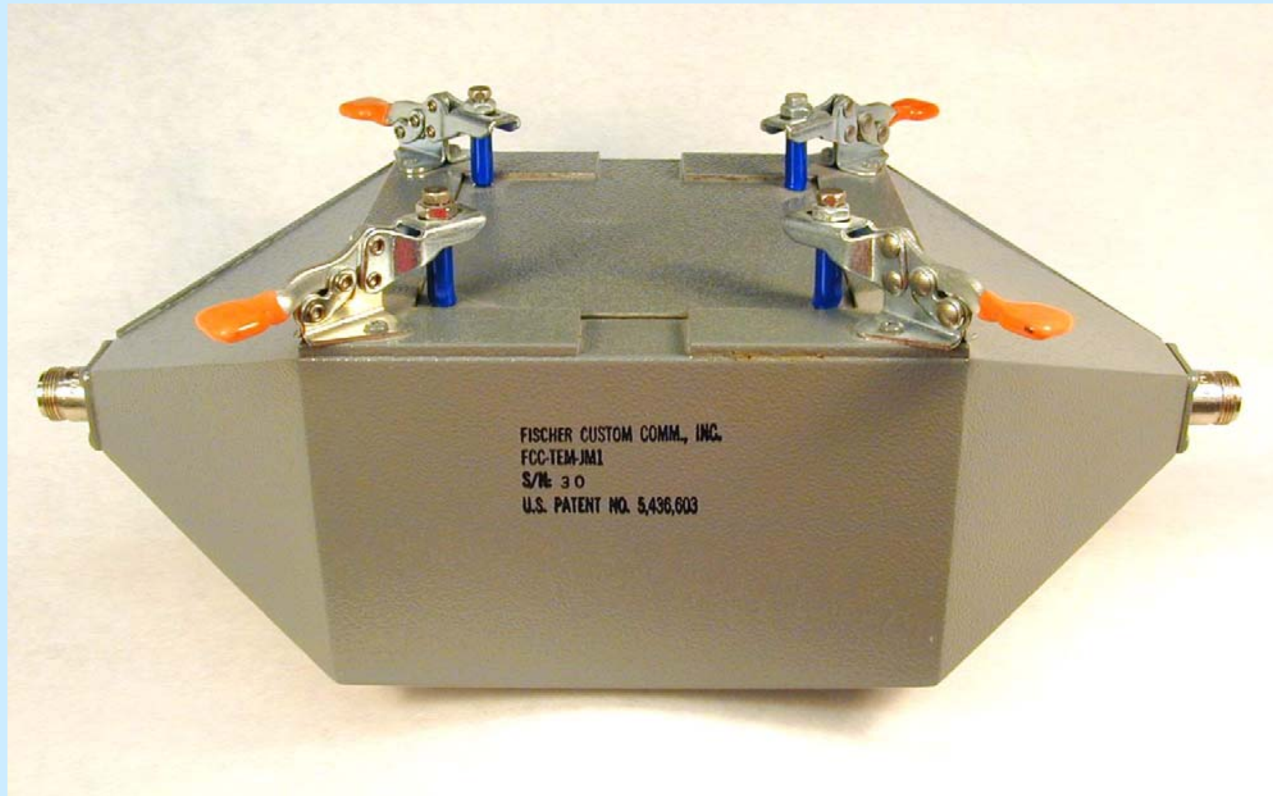
Description of the TEM Cell and IC Test Board

Cross Section Of 1 GHz TEM Cell



In the Fisher TEM Cell, the IC Test Board is actually part of the cell structure.

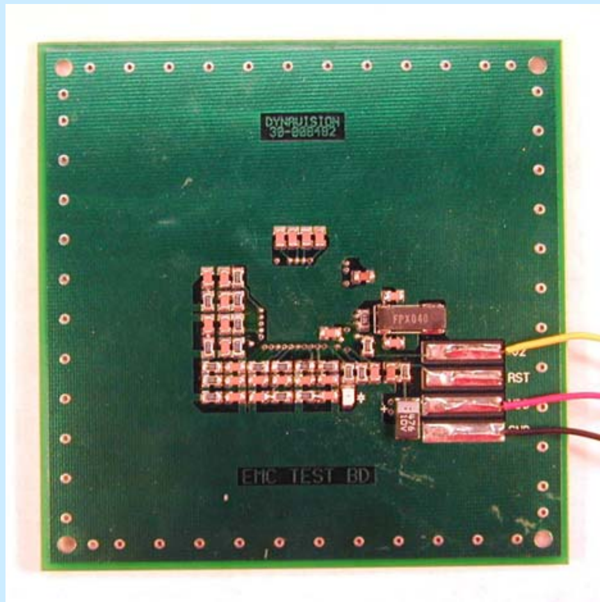
View of 1 GHz TEM Cell

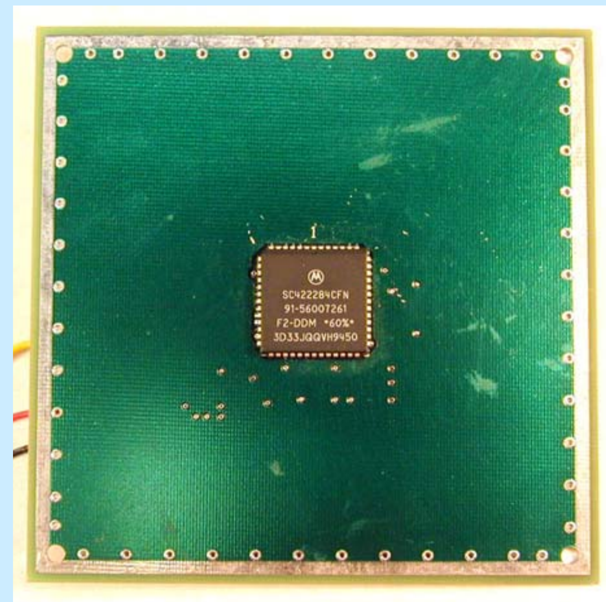


IC Test Board

Left side: support circuitry

Right side: IC under test (facing into TEM Cell)





Development of the TEM Cell Method

Some of the Contributors to the IC - EMC Task Force

Jim Muccioli: Chairman
Mike Catherwood: V. Chair
Scott Lytle: Secretary
Terry North: Editor
Ross Carlton: IEC Liaison
Jerry Meyerhoff
Kevin Slattery
Bob Moeckel
Steven Chybowski
Arnie Nielsen
Ed Bronaugh
Gerald Servais
Tim Harrington
Art Collard
Richard Goulette
Don Seyerle
Joe Fischer
D. W. Elting

Poul Andersen
Mark Steffka
Garth D'Abreu
Jim Rader
Tony Anthony
Paul Cook
Stevan Dobrasevic
Rick Goodwin
William Hutter
Kevin Lavery
Andy Macko
Phil Bator
Dave Pamparo
Ian Morgan
David Meir
Glen Watkins
Rick Goodwin
Robert DeMoor

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Vision and Goal of the IC - EMC Task Force

- To develop a measurement method to characterize the RF emissions from integrated circuits that:
    - Is usable to at least 1 GHz
    - Is able to provide a repeatable "signature"
    - Facilitates emission comparisons between different IC design implementations (layout or die shrink variations)
    - Evaluates the effect of process variations and other critical factors on RF emissions

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Vision and Goal of the IC - EMC Task Force

- The end users require that this method:
  - Provides the capability for IC manufacturers to quickly evaluate the effects of design or process changes to their final product emissions
  - Provides the capability for IC customers to quickly evaluate the potential effect of an IC source or process change on their product RF emissions

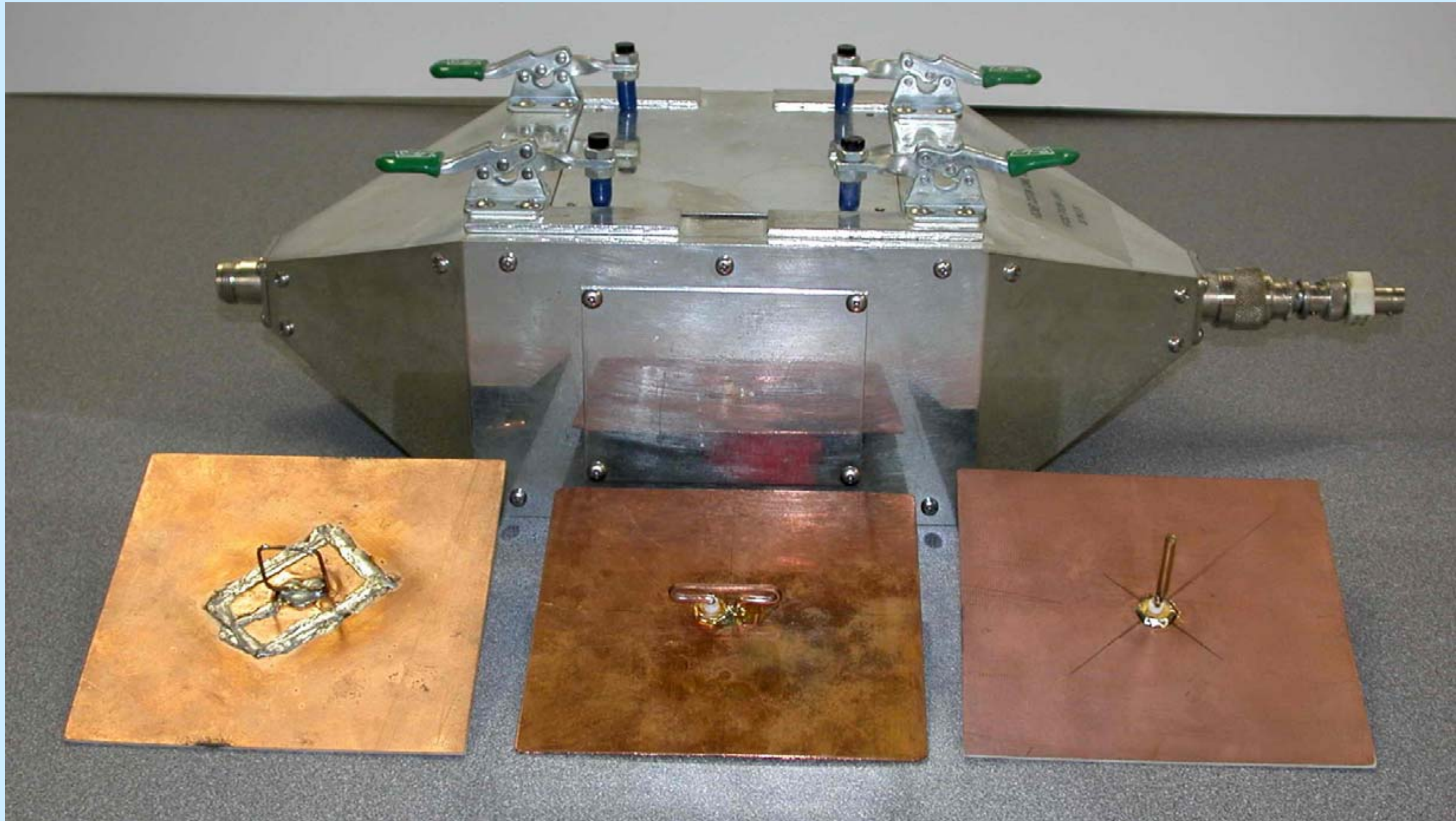
References - Technical Papers on IC Emissions

- [1] Investigation of the Theoretical Basis for Using a 1 GHz TEM Cell to Evaluate the Radiated Emissions from Integrated Circuits, Muccioli, North, Slattery, 1996 IEEE International Symposium on EMC
- [2] Model of IC Emissions into a TEM Cell, Engel, 1997 IEEE International Symposium on EMC
- [3] Characterization of the RF Emissions from a Family of Microprocessors Using a 1 GHz TEM Cell, Muccioli, North, Slattery, 1998 IEEE International Symposium on EMC
- [4] Measuring the Radiated Emissions from a Family of Microprocessors Using a 1-GHz TEM Cell, Slattery, Muccioli, North, 1999 IEEE International Symposium on EMC
- [5] Modeling the Radiated Emissions from Microprocessors and other VLSI Devices, Slattery, Muccioli, North, 2000 IEEE International Symposium on EMC

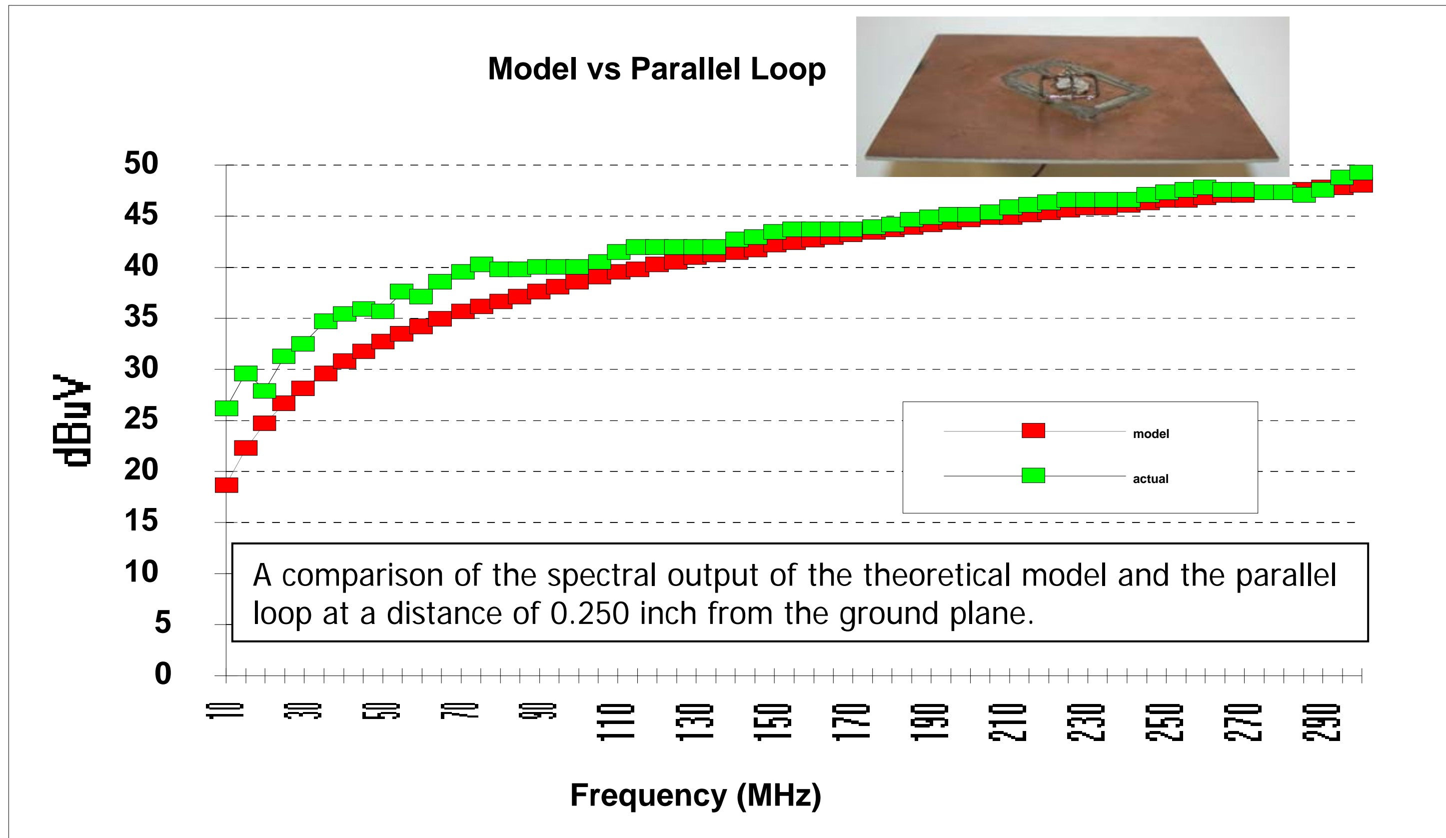
References - Technical Papers on IC Emissions

- [6] Constructing the Lagrangian of VLSI Devices from Near Field Measurements of the Electric and Magnetic Fields, Slattery, Muccioli, North, 2000 IEEE International Symposium on EMC
- [7] Using Near-Field Scanning to Predict Radiated Fields, Shi, Cracraft, Zhang, DuBroff, Slattery, Yamaguchi, 2004 IEEE International Symposium on EMC
- [8] Electromagnetic Emissions: IC-Level versus System-Level, Deutschmann, Winkler, Ostermann, Lamedschwandner, 2004 IEEE International Symposium on EMC
-]9] Predicting TEM Cell Measurements from Near Field Scan Data, Weng, Beetner, DuBroff, 2006 IEEE International Symposium on EMC
- [10] Near field measurements to predict the electromagnetic emission of integrated circuits, Deutschmann, Pitsch, Langer, 5th International Workshop on Electromagnetic Compatibility of Integrated Circuits, November 2005, Munich, Germany

TEM Cell with Cal Antennas



Comparison of Model (Red) vs Measured Parallel Loop (Green)



[1] Investigation of the Theoretical Basis for Using a 1 GHz TEM Cell to Evaluate the Radiated Emissions from Integrated Circuits, Muccioli, North, Slattery, 1996 IEEE International Symposium on EMC

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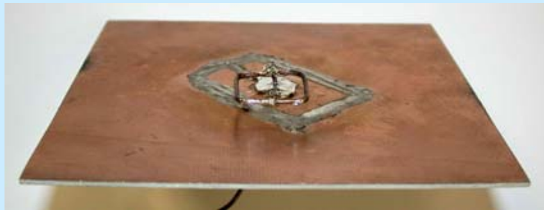
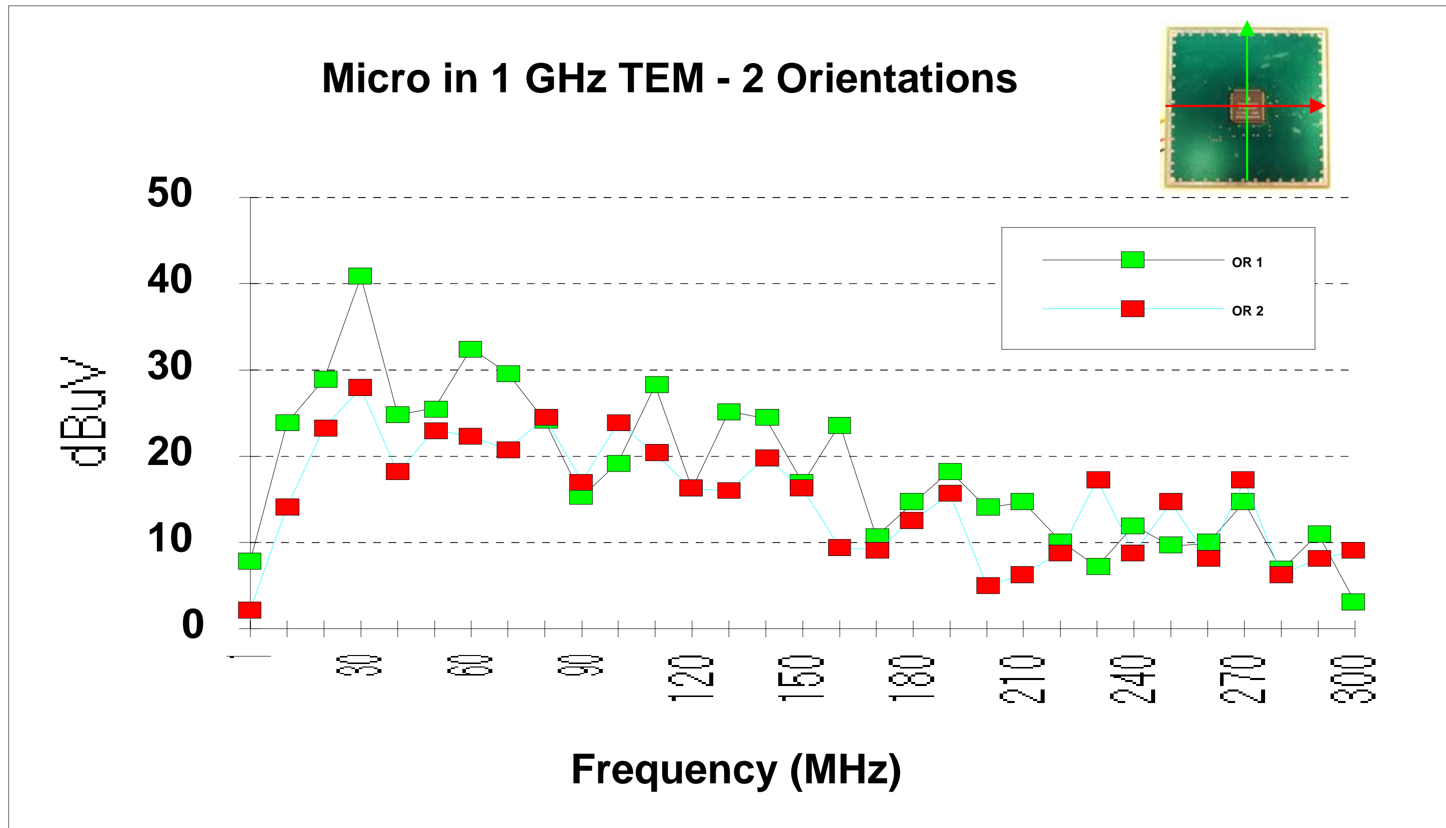
Parallel Loop Output vs Distance & Frequency



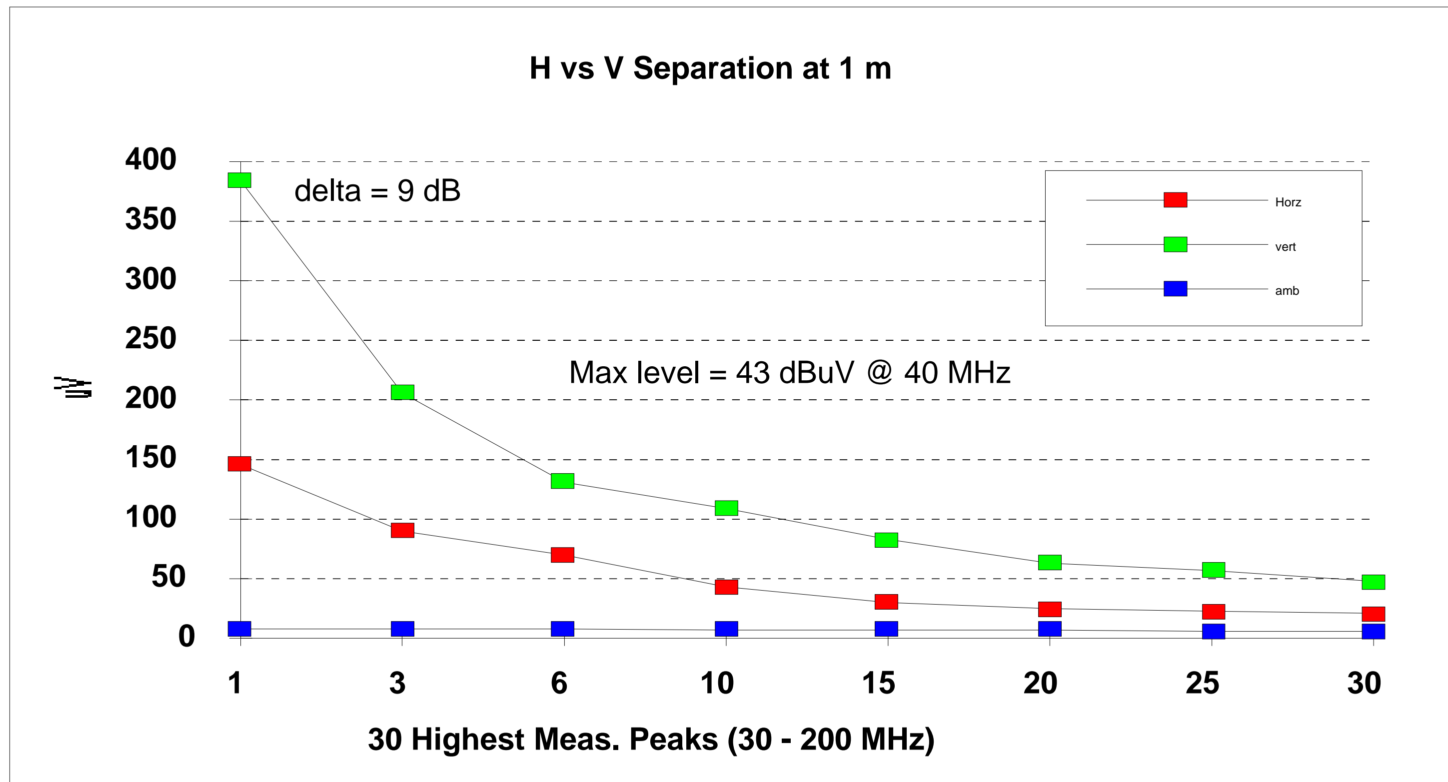
The minimum of this family of curves is in the range of 0.125 to 0.250 inch distance from the ground plane. This suggests that another mechanism is affecting the coupling at very close spacing.

dBuV
60
50
40
30
20
10
0
.028 inches
.062 inches
.125 inches
.250 inches
.375 inches
.50 inches
Distance
300
200
100
1
MHz

Two Orientations of Microprocessor Test Board



Measurement in ALSE with Biconical Antenna of Micro Test Board in H and V Orientations



[2] Model of IC Emissions into a TEM Cell, Engel, 1997 IEEE International Symposium on EMC

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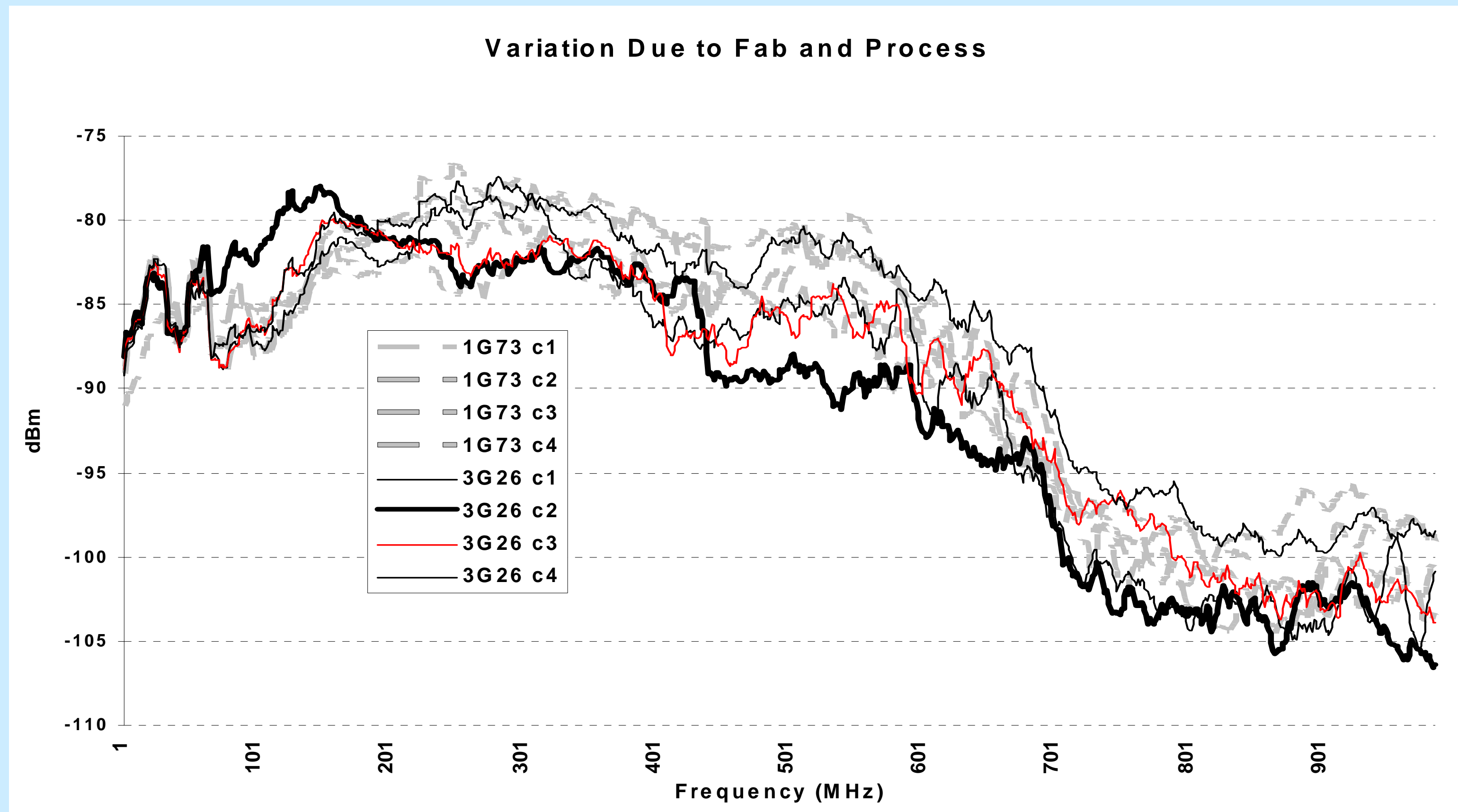
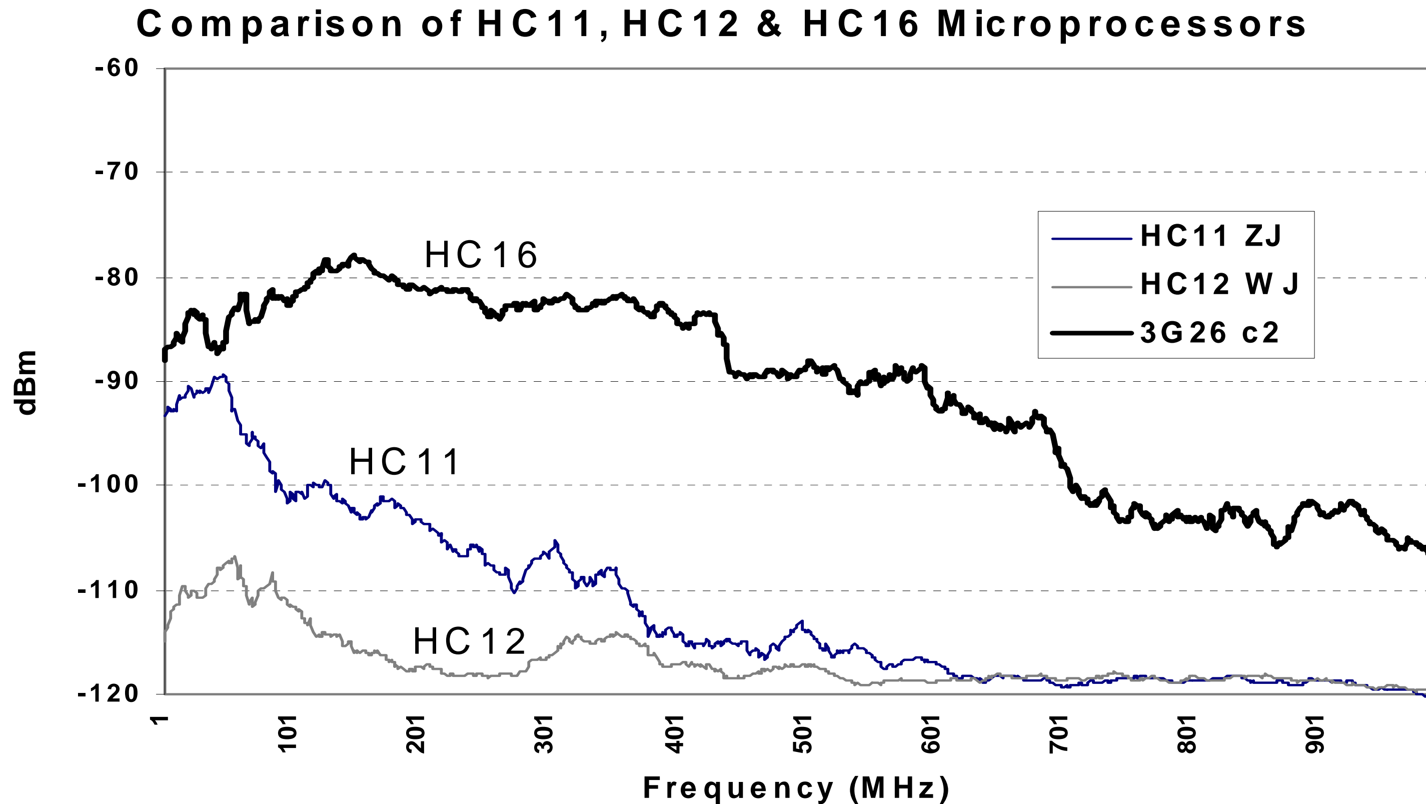
Evaluation of IC Process Variables

IC Emissions Variation Due to Fab and Process Variation



[3] Characterization of the RF Emissions from a Family of Microprocessors Using a 1 GHz TEM Cell, Muccioli, North, Slattery, 1998 IEEE International Symposium on EMC

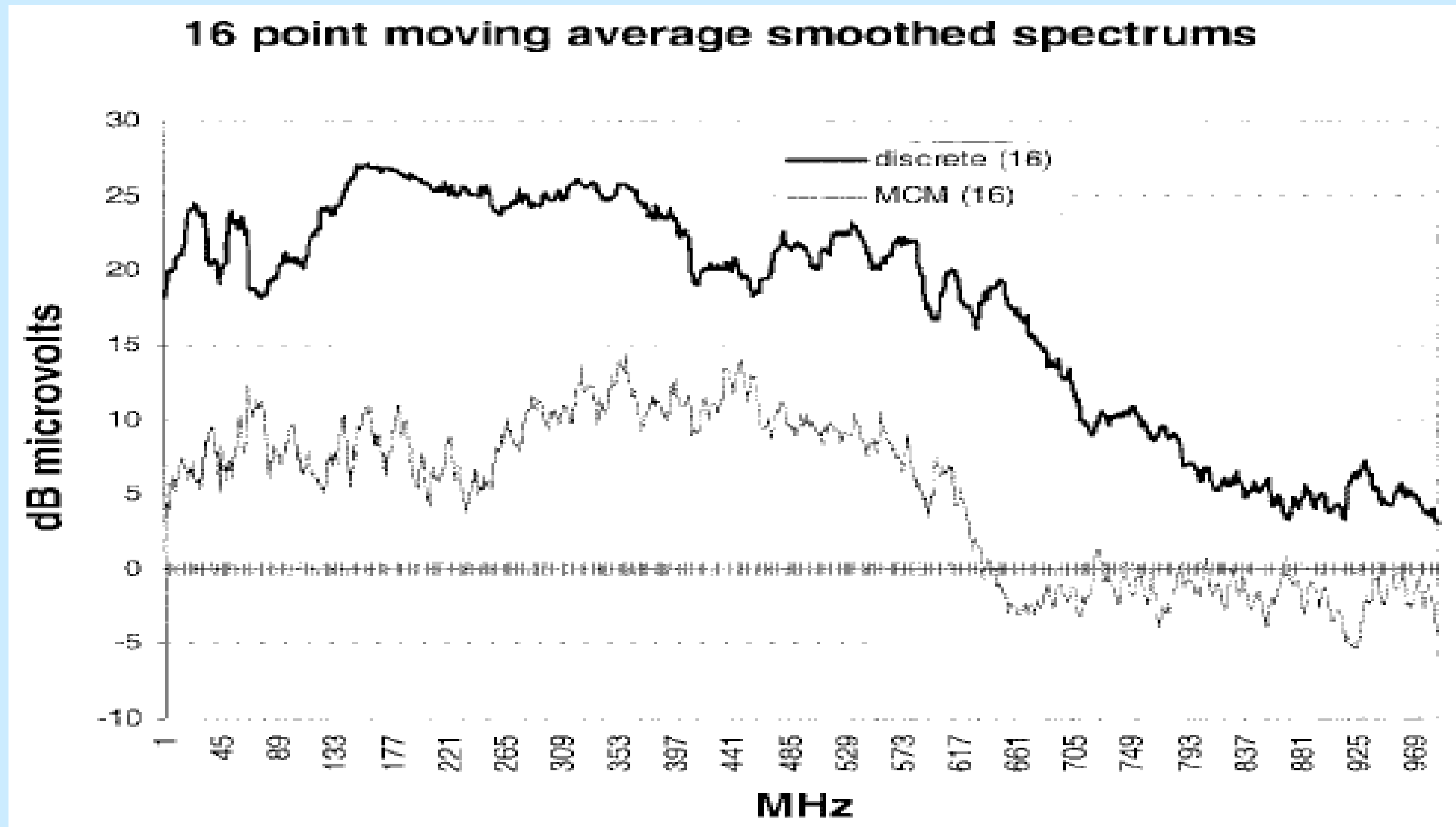
Comparison of a Family of Microprocessors



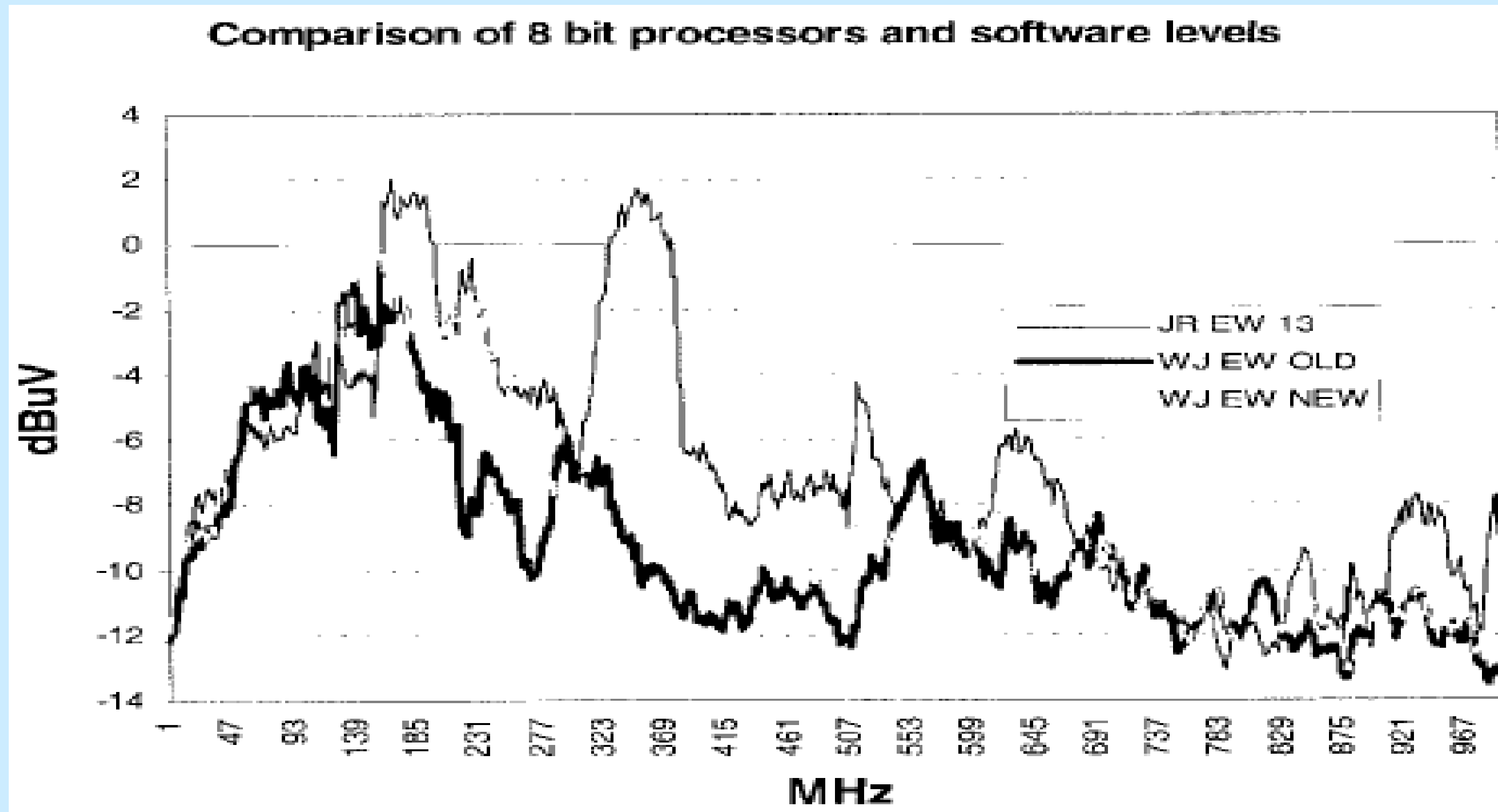
[4] Measuring the Radiated Emissions from a Family of Microprocessors Using a 1-GHz TEM Cell, Slattery, Muccioli, North, 1999 IEEE International Symposium on EMC

Evaluation of the Effects of IC Internal Structure, Software Level, Environmental Temperature and IC Packaging on Emissions

Comparison of Emissions from MCM and Discrete IC Implementations



Spectral Differences due to Software Level



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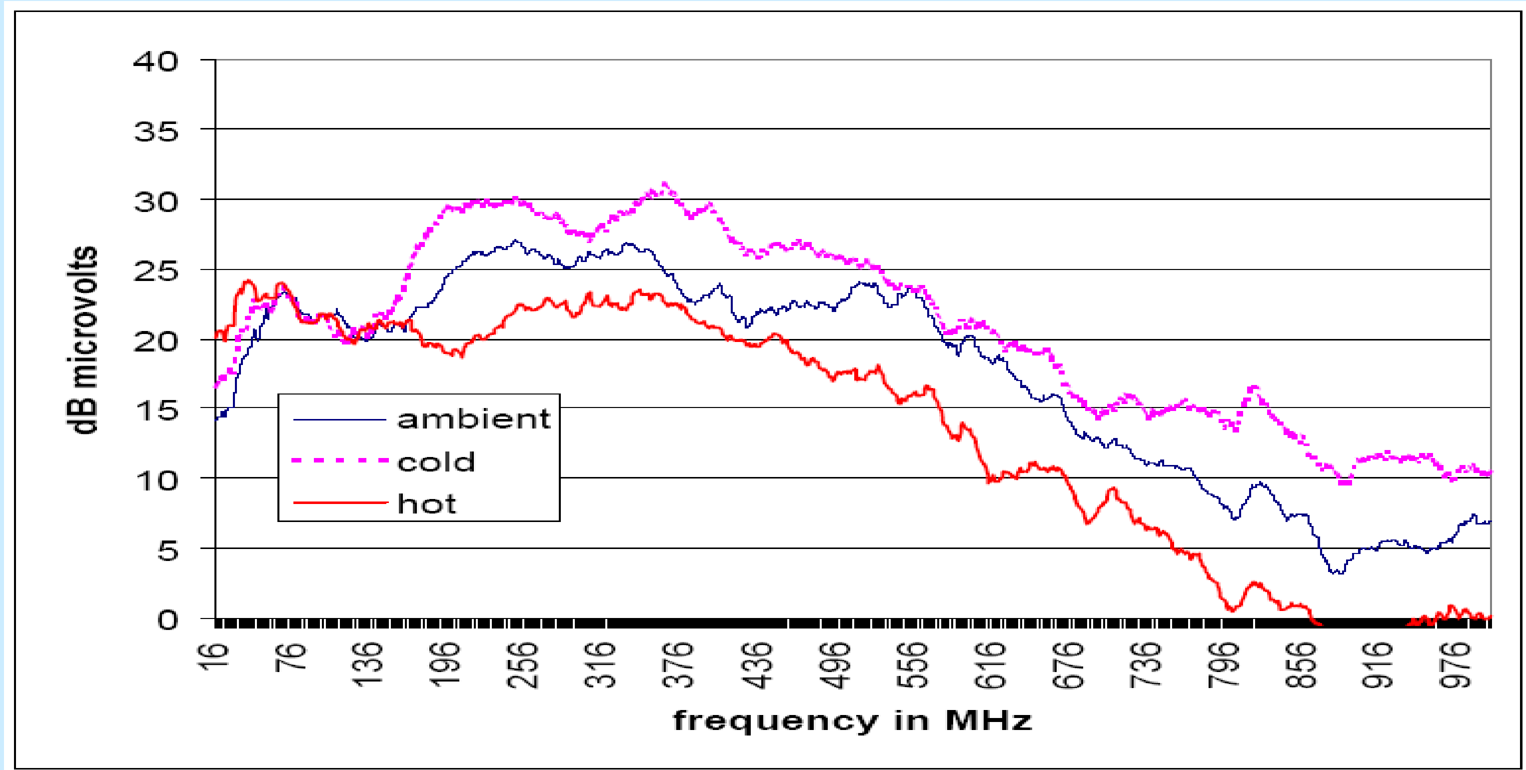
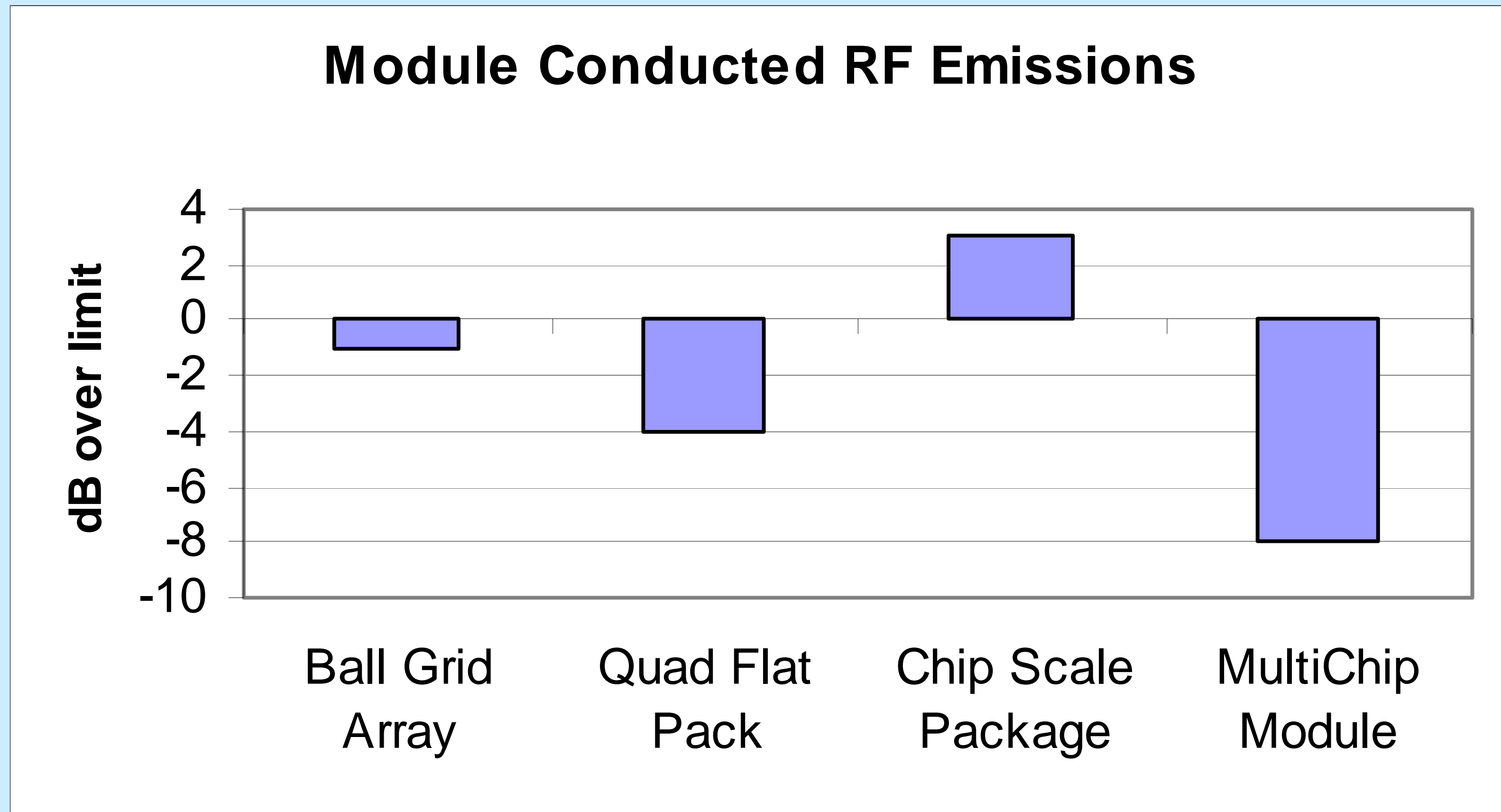
Spectral Emissions as a Function of the IC Environmental Temperature



[5] Modeling the Radiated Emissions from Microprocessors and other VLSI Devices, Slattery, Muccioli, North, 2000 IEEE International Symposium on EMC

Relative Emissions Comparison of Four IC Package Implementations



6] Constructing the Lagrangian of VLSI Devices from Near Field Measurements of the Electric and Magnetic Fields, Slattery, Muccioli, North, 2000 IEEE International Symposium on EMC

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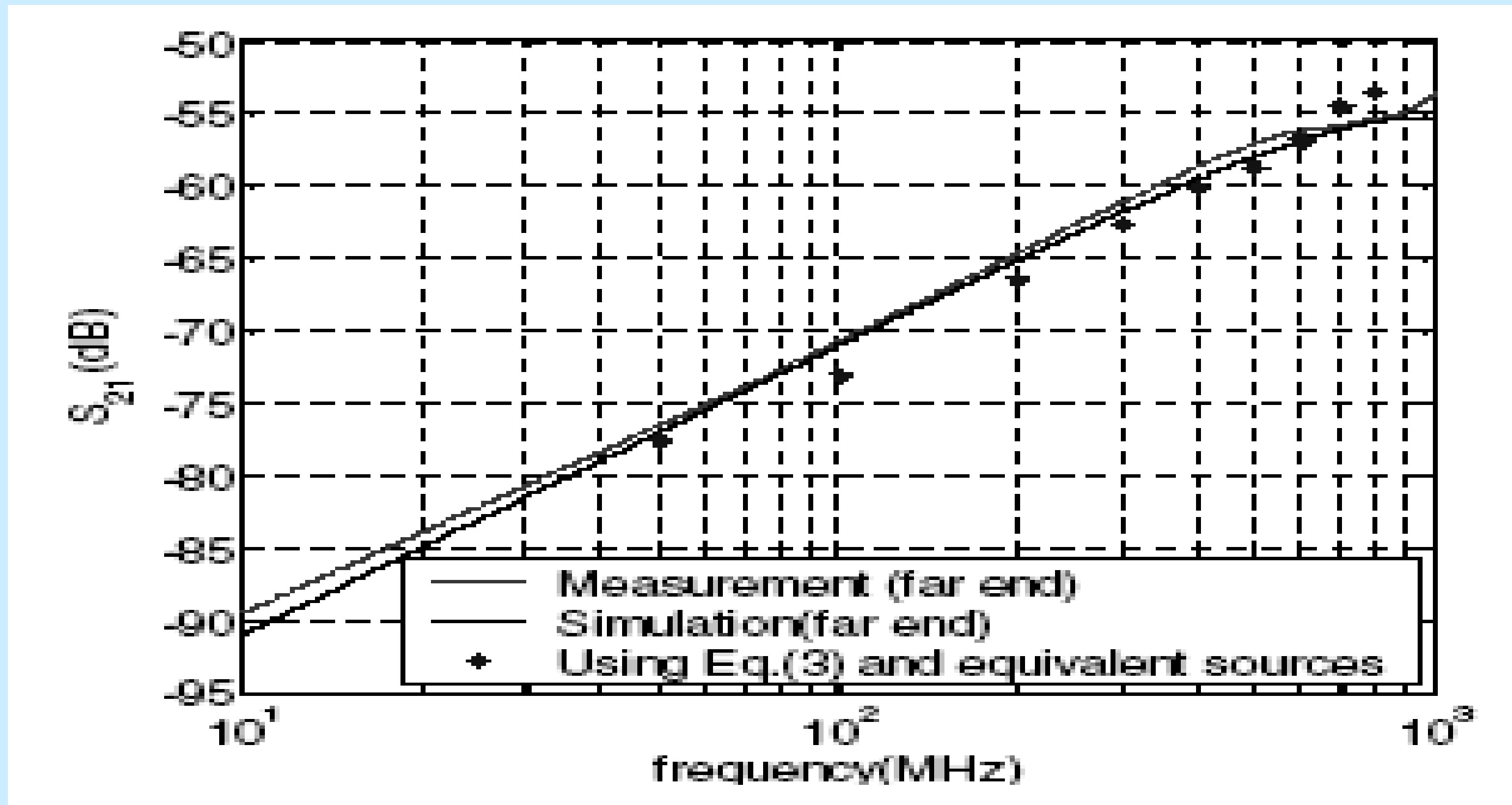
Correlation Between IC and Far Field Measurements

Comparison of TEM Cell Measured Data with Simulation Data and Analytical Formula Calculations both Generated from Near Field Scan Data



[7] Using Near-Field Scanning to Predict Radiated Fields, Shi, Cracraft, Zhang, DuBroff, Slattery, Yamaguchi, 2004 IEEE International Symposium on EMC

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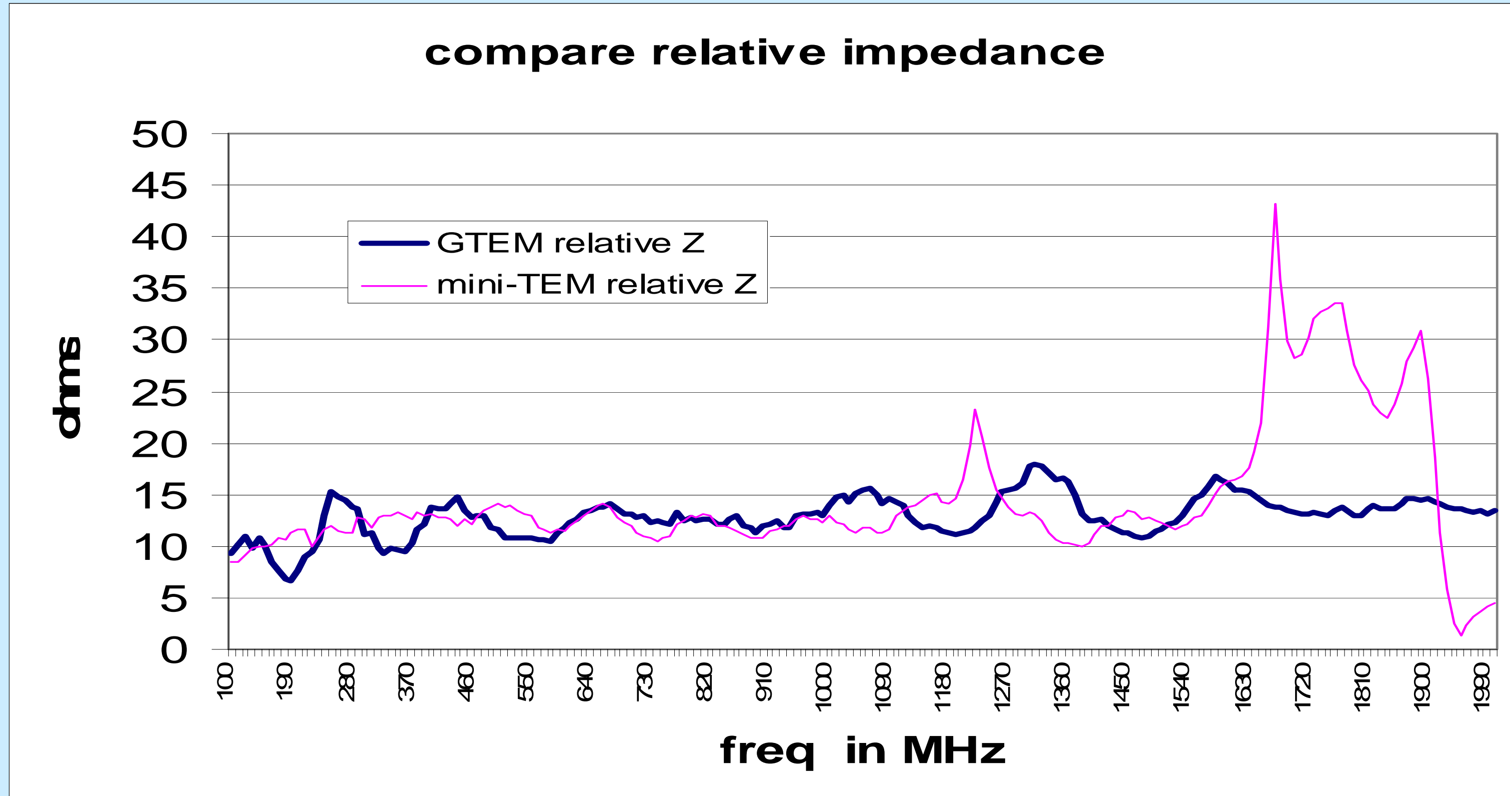
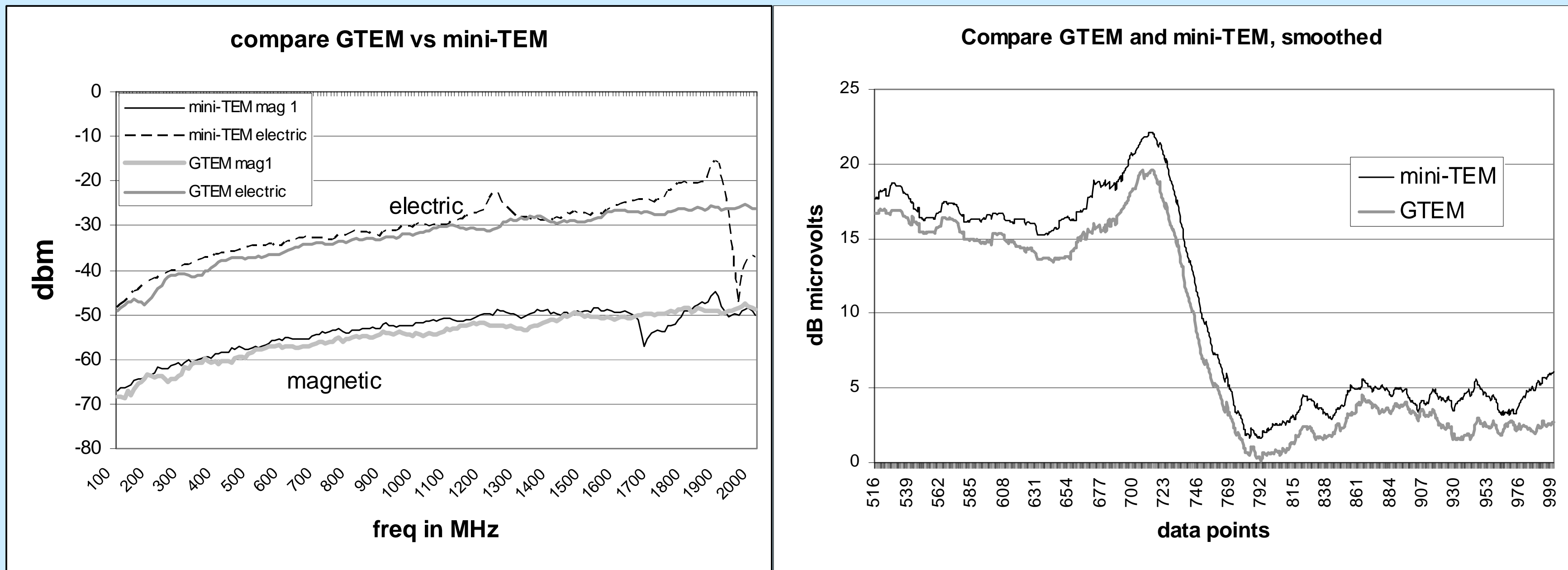
Extension of the 1 GHz TEM Cell Method to Several GHz Using a Small GTEM Cell

Impedance Comparison of Fischer TEM Cell with GTEM

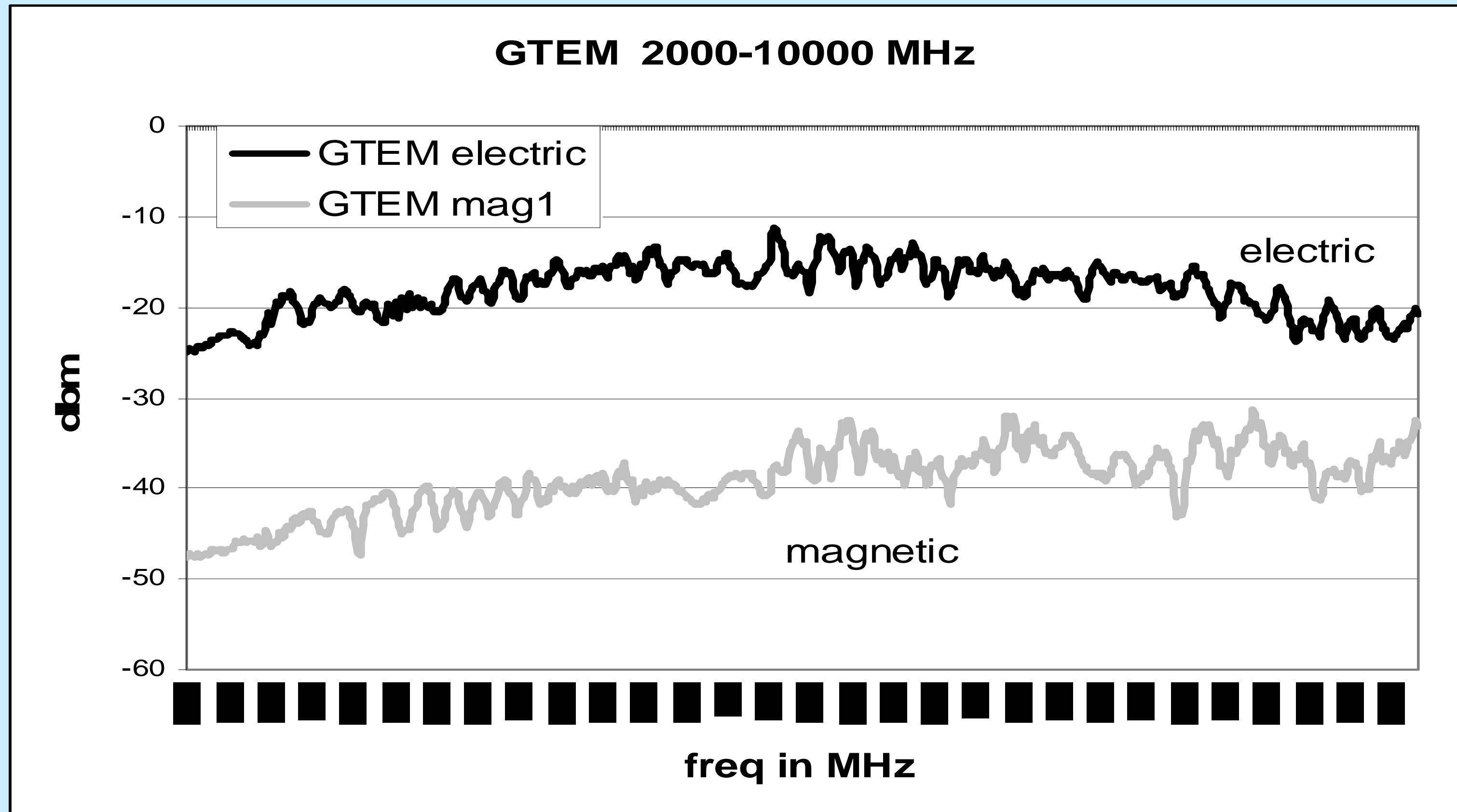


Comparison of Electric and Magnetic Fields as Measured in the TEM and GTEM Cells



IC Data on both the TEM and GTEM Cells

Electric and Magnetic Field Measurements on the GTEM Cell to 10 GHz



Small GTEM Cell with IC Test Board Port

[11] SAE J1752-3 Measurement of Radiated Emissions from Integrated Circuits – TEM / Wideband TEM (GTEM) Cell Method, TEM Cell (150 kHz to 1 GHz), Wideband TEM Cell (150 kHz to 8 GHz) Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA, (412) 776-4841.

[12] IEC 61967-2: Integrated circuits - Measurement of electromagnetic emissions, 150 kHz to 1 GHz - Part 2: Measurement of radiated emissions, TEM Cell and wideband TEM cell method

Conclusions

- We have shown the theoretical basis, numerical modeling and empirical observations that many researchers have developed over the twelve years since the first paper on the topic was presented in 1996
- The repeatability and correlation between these IC emission measurement methods and other methods, including far field measurements, has been well established
- Of particular interest for high frequency applications, this method can utilize a GTEM cell enabling emission measurements up to 10 GHz, which is beyond the current capability of other IC measurement techniques

Conclusions

- Because of the many variables involved in the application of a particular IC in a module, including PCB layout, packaging and cabling, IC measurement methods will never be able to completely eliminate module level EMC measurements
- However, these techniques allow the design engineer to obtain an estimation of resultant module level emissions based on IC level measurements
- This estimation can be made more effective using reasonable assumptions about the effects of application specific variables on the resultant module emissions
- These assumptions can then be pre validated for limiting cases to provide a reasonable range of expected results

Related IC Emissions Measurement Standards

- [11] SAE J1752-3 Measurement of Radiated Emissions from Integrated Circuits – TEM / Wideband TEM (GTEM) Cell Method, TEM Cell (150 kHz to 1 GHz), Wideband TEM Cell (150 kHz to 8 GHz) Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA, (412) 776-4841.
- [12] IEC 61967-2: Integrated circuits - Measurement of electromagnetic emissions, 150 kHz to 1 GHz - Part 2: Measurement of radiated emissions, TEM Cell and wideband TEM cell method

Questions?