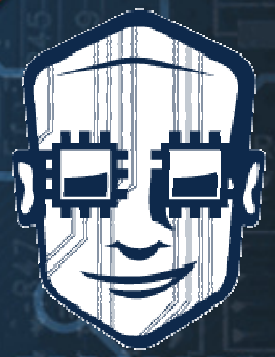
DESIGNCON® 2013

JANUARY 28-31, 2013
SANTA CLARA CONVENTION CENTER



# Effects of Nearby Ground Vias on High Speed Single-ended and Differential Signals

**Alma Jaze, IBM**

ajaze@us.ibm.com

**Bruce Archambeault, IBM**

barch@us.ibm.com

**Samuel Connor, IBM**

sconnor@us.ibm.com

UBM Tech

# Single Ended Signals

- Location of ‘ground’ via can affect return current path
  - Cause noise between the planes which can couple to other vias and/or connector pins
  - Noise from external sources can couple onto signal vias affecting data quality

# Differential Signal Vias

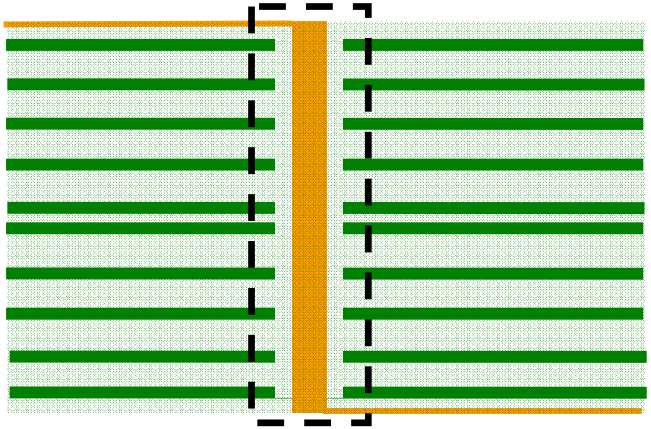
- 'Ground' vias nearby can cause asymmetries which convert intentional signal energy to common mode noise
  - Possible EMC issues
- Same amount of conversion from common mode to differential mode can cause data problems from external noise sources

# Modeling Process

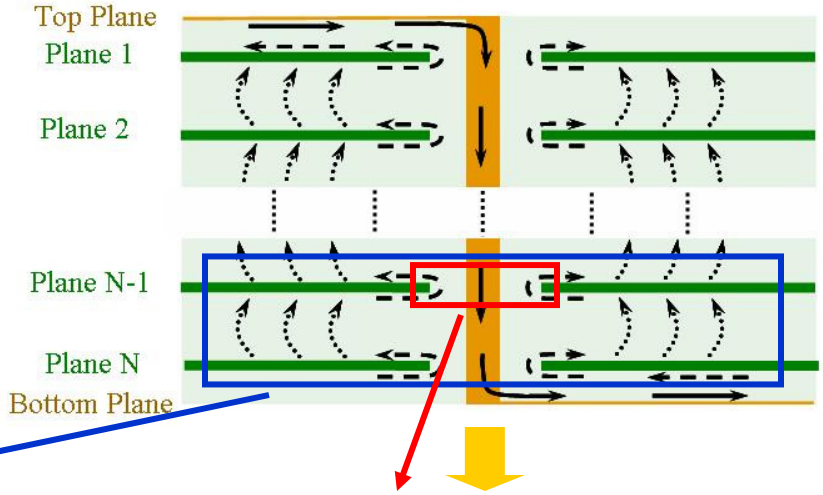
- Cavity resonance approach to find the effect between planes
  - Different distance to ‘ground’ via
- Capacitance from via barrel to via keep out
- Through and shorted vias
- S parameters for each block for multi layered problems
- Everything assembled for final circuit simulation

# Breaking the Problem

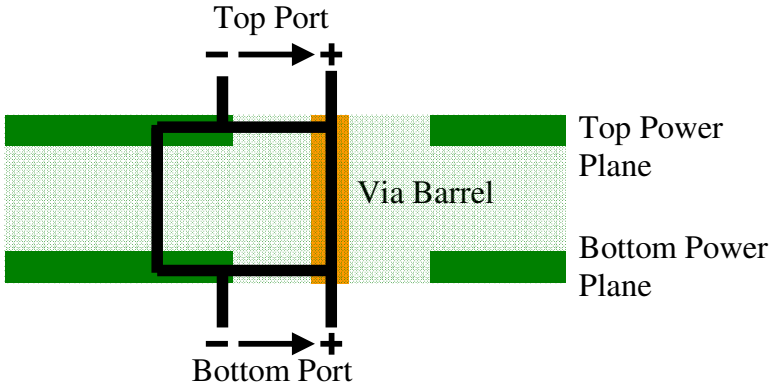
Multilayer via transition geometry



Field mapping and current path identification



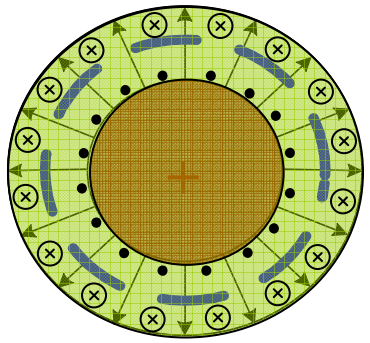

One via between a power plane: 2-port network



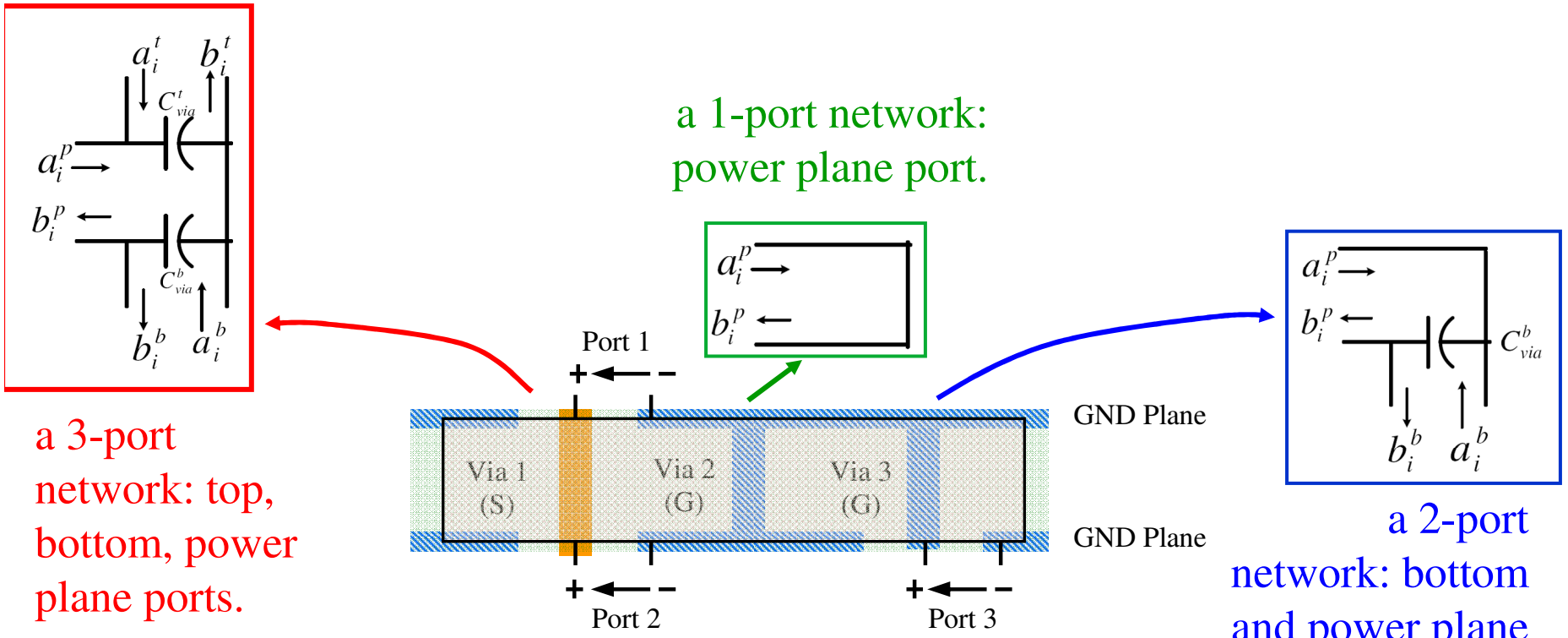

Coaxial field distribution: TEM mode

$$I = \hat{n} \times H$$

$$V_\rho = \int_+^- E_\rho \cdot dl$$



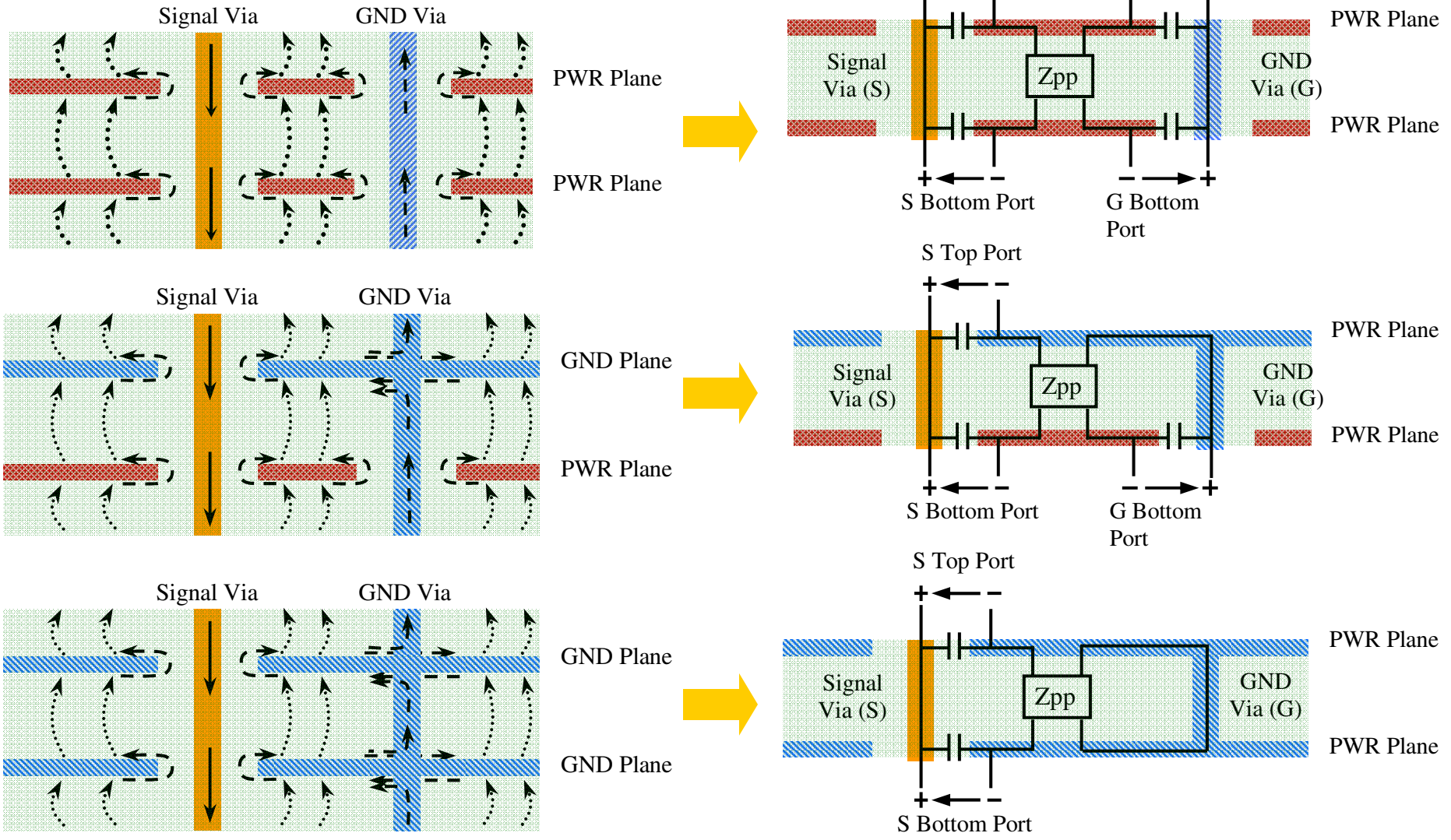
# One Plane Pair: Via Networks



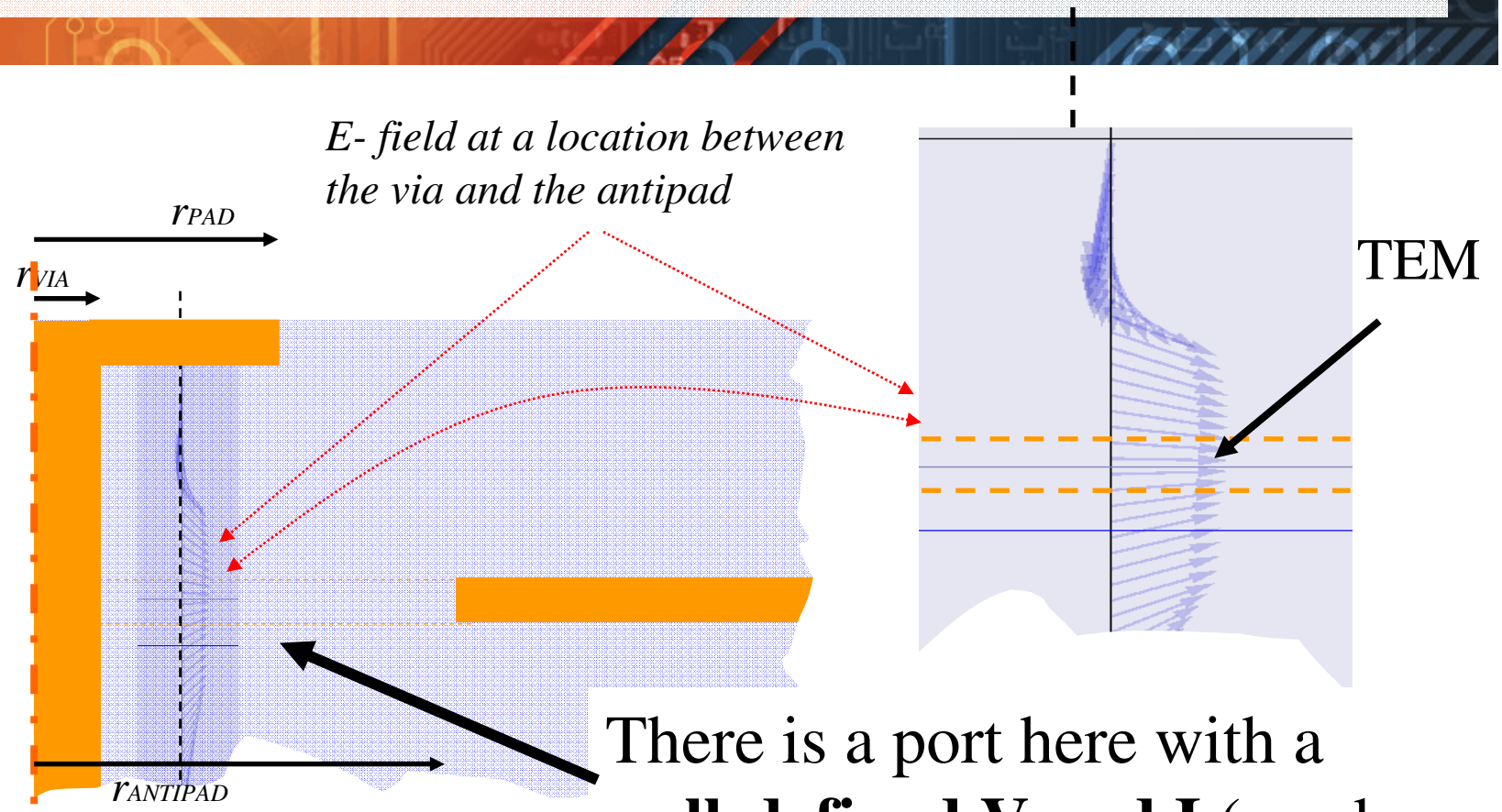

a 3-port network: top, bottom, power plane ports.

a 2-port network: bottom and power plane ports.

# Via Configurations



# TEM Field Between the Via and Antipad

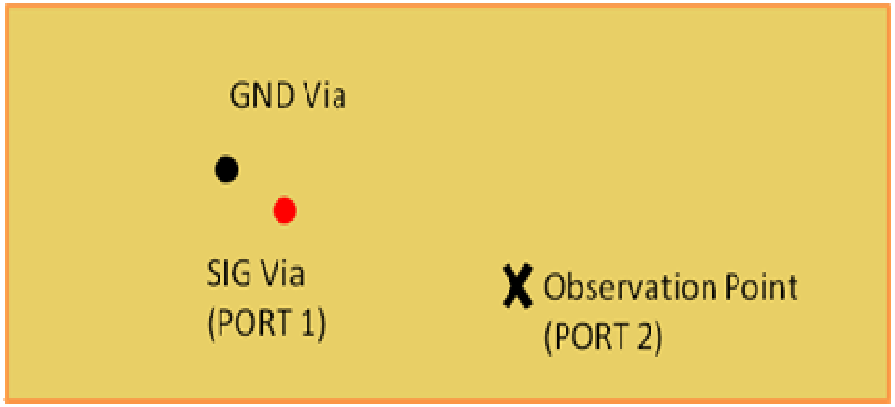



Monitoring the electric field @10 GHz

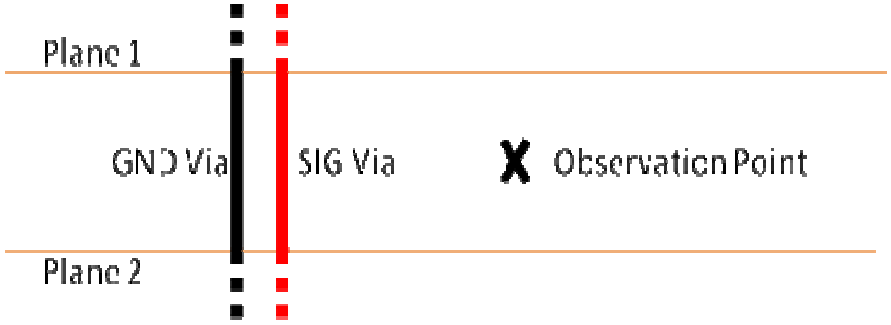
There is a port here with a **well-defined V and I** (need 2 terminals)

# Single Ended Via Configuration
## One 'Ground' Via

TOP VIEW



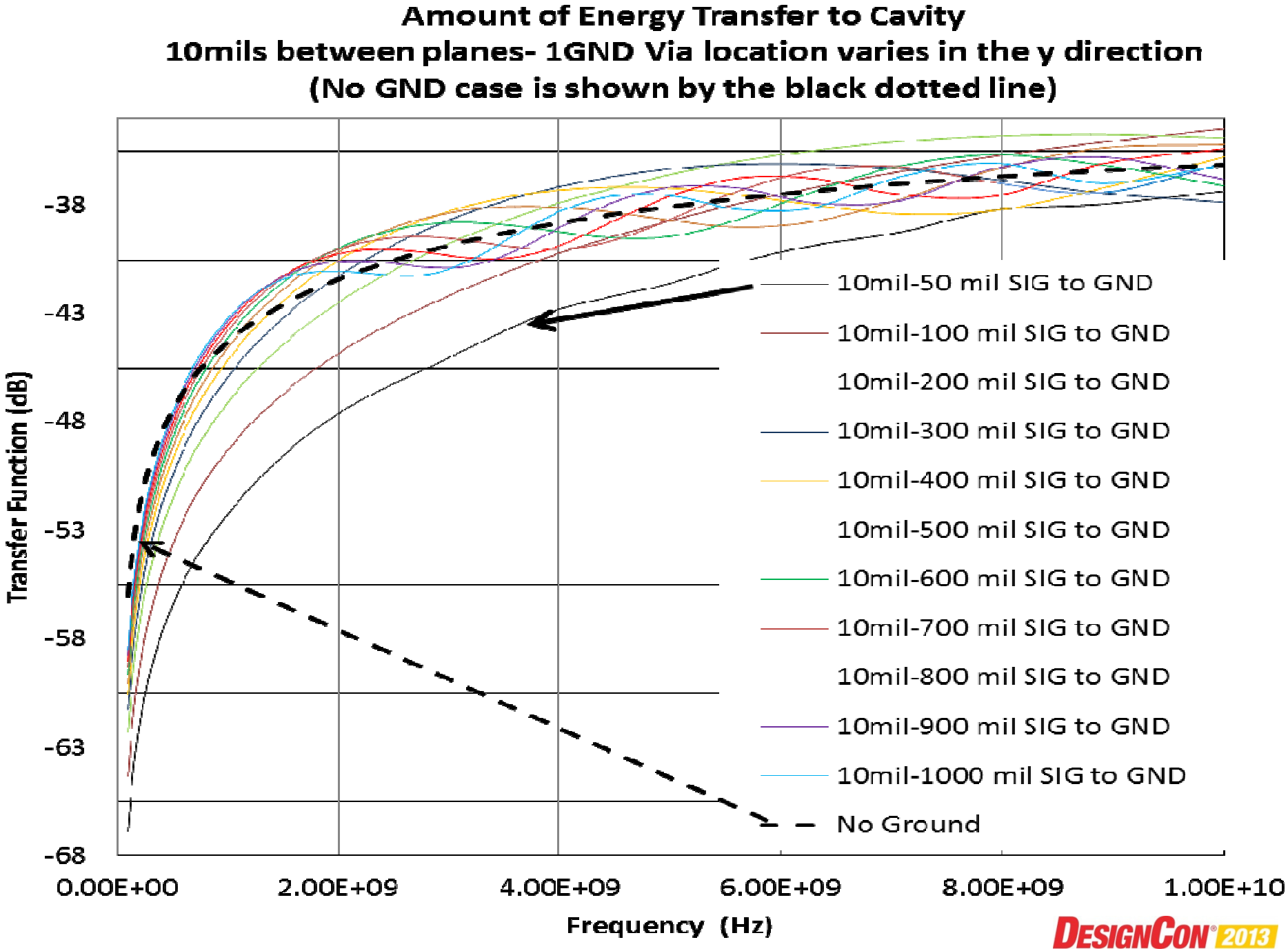

PROFILE VIEW



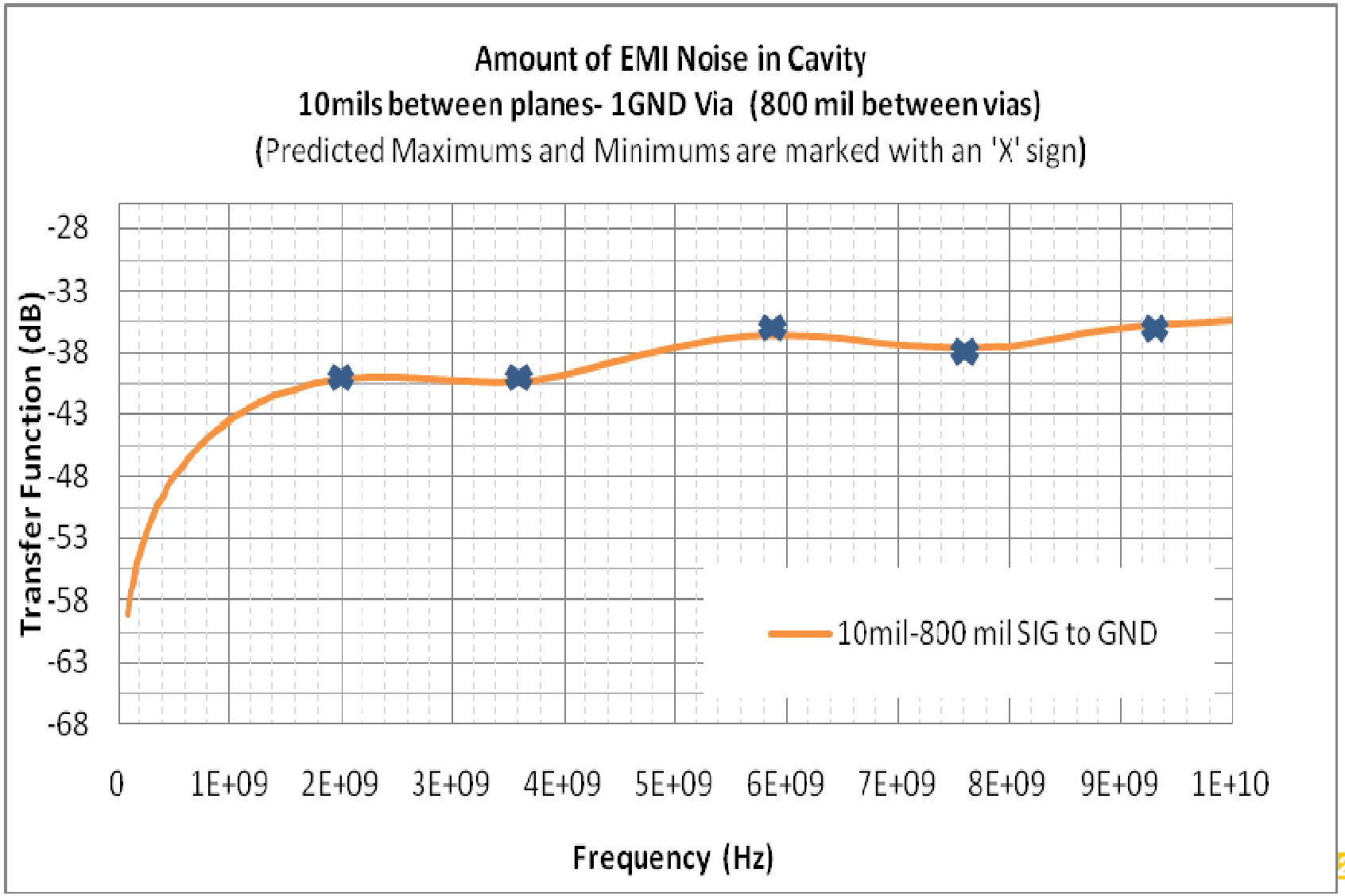

Dielectric, Meta Thickness. 4.3 mil, 1mil
Antipad, Pad, Via Drill Diameter: 35 mil, 20mil, 12 mil

-- Spacing between planes varied

-- Distance between vias varied

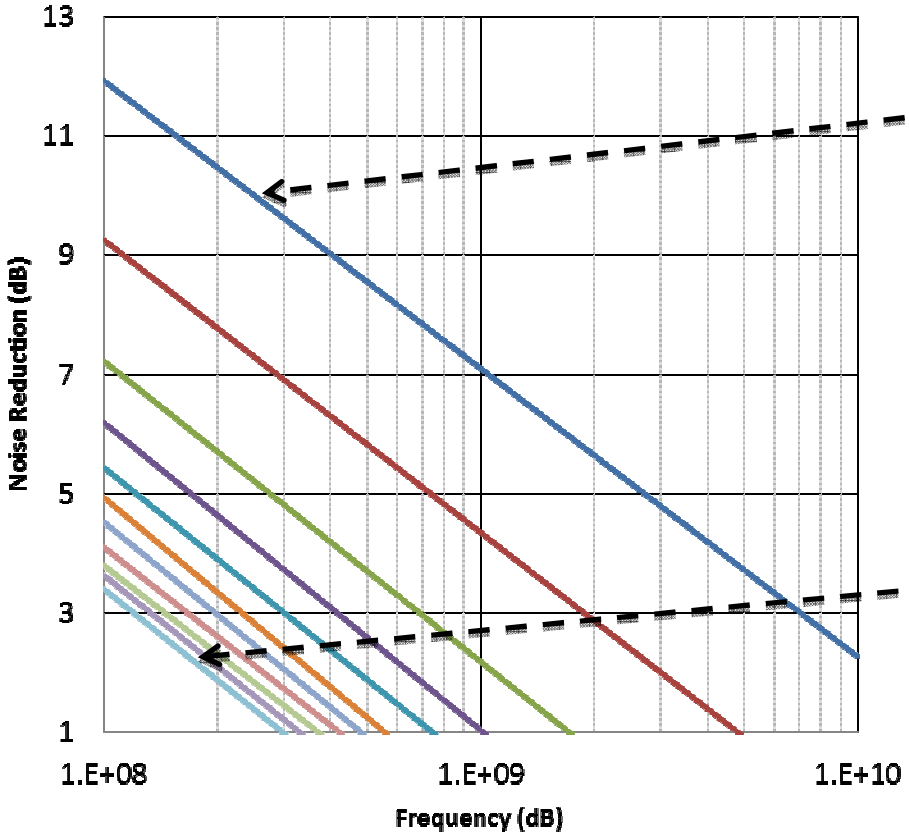

Amount of Energy Transfer to Cavity
10mils between planes- 1GND Via location varies in the y direction
(No GND case is shown by the black dotted line)
Transfer Function (dB)
-38
-43
-48
-53
-58
-63
-68
0.00E+00
2.00E+09
4.00E+09
6.00E+09
8.00E+09
1.00E+10
Frequency (Hz)
10mil-50 mil SIG to GND
10mil-100 mil SIG to GND
10mil-200 mil SIG to GND
10mil-300 mil SIG to GND
10mil-400 mil SIG to GND
10mil-500 mil SIG to GND
10mil-600 mil SIG to GND
10mil-700 mil SIG to GND
10mil-800 mil SIG to GND
10mil-900 mil SIG to GND
10mil-1000 mil SIG to GND
No Ground

# Effect of Positive & Negative Reinforcement Due to Multi-Path

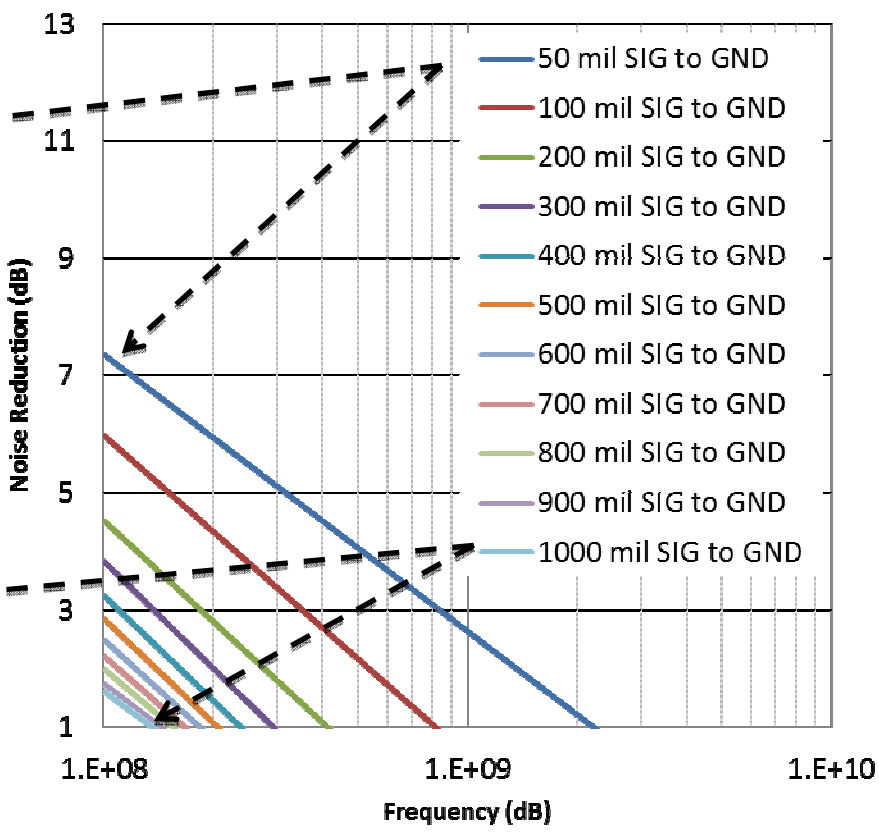


# Maximum Noise Reduction
## Vs. Distance and Frequency

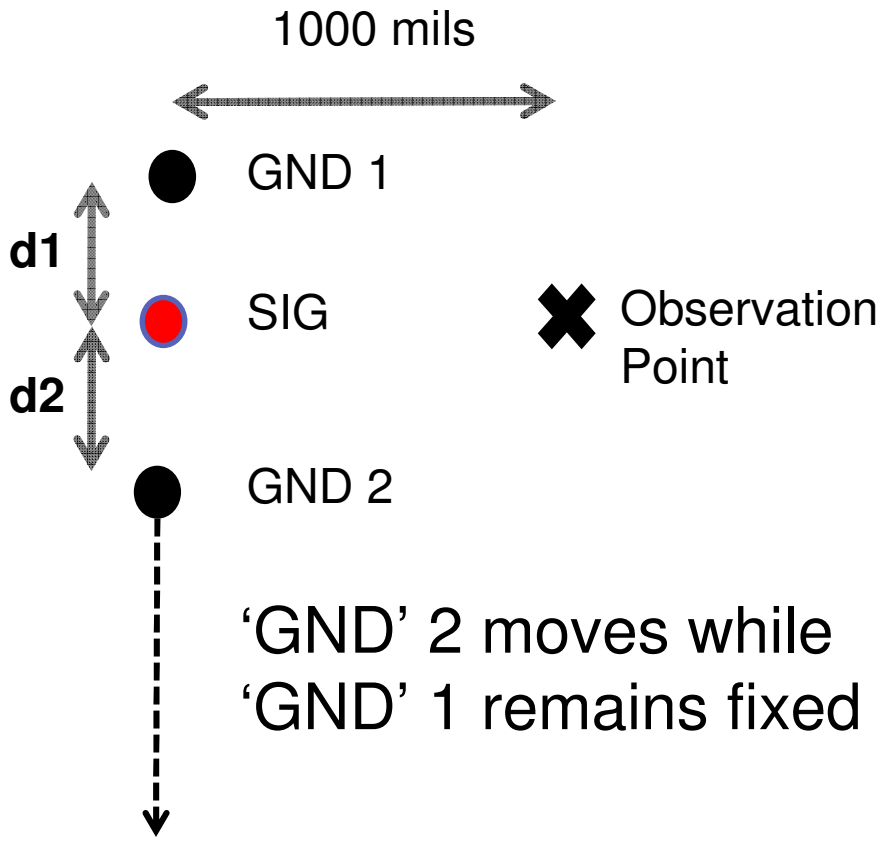
**Noise Reduction in Cavity**
**10mil Dielectric Thickness**




**Noise Reduction in Cavity**
**35mil Dielectric Thickness**

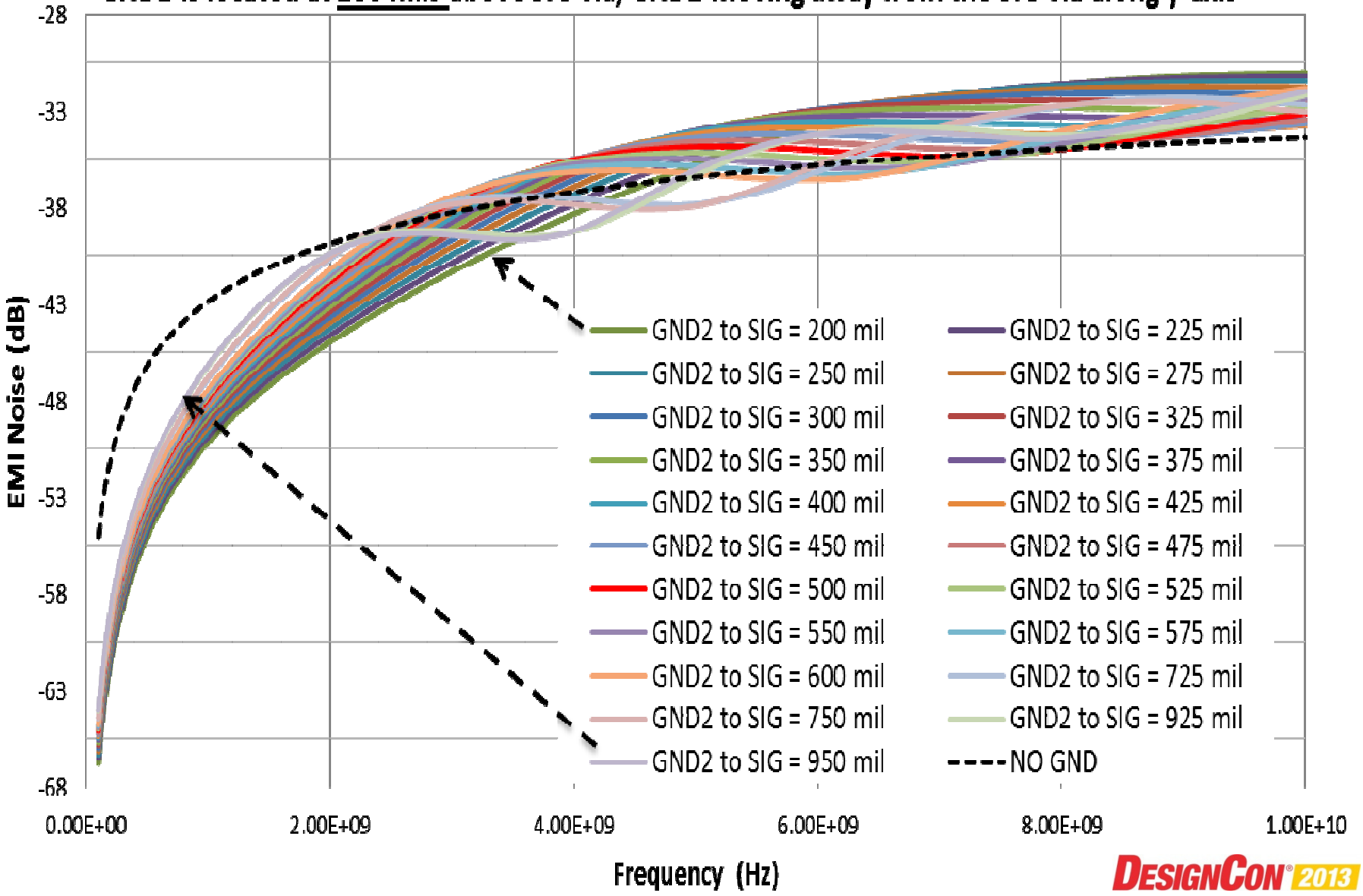


# Single Ended Via Configuration
## Two 'Ground' Vias

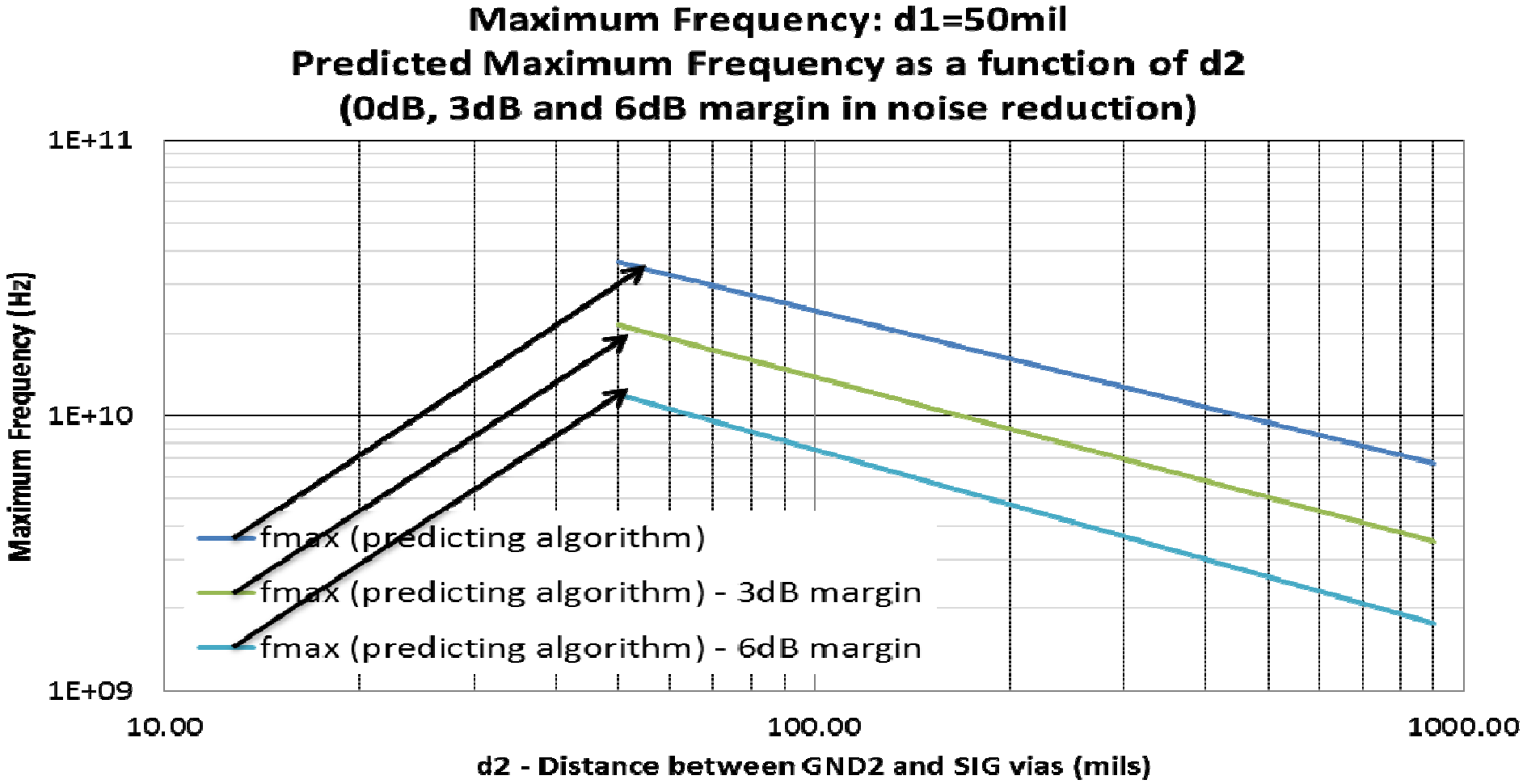



D1 set to 50, 100, 150, 200 mils

## Amount of EMI Noise in Cavity
## 10mils between planes - 2 GND Vias
## GND1 is located at 200 mils above SIG via, GND2 moving away from the SIG via along y-axis



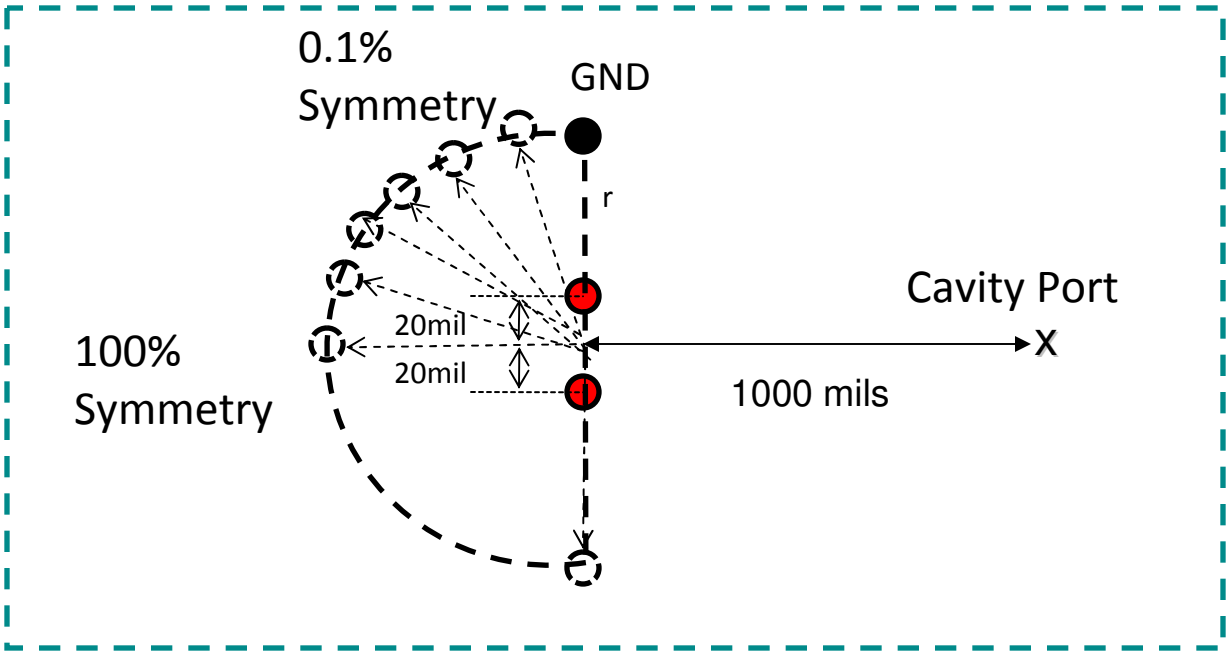
# Maximum Frequency of Benefit Vs. Distance



# Differential Via Configuration
## One 'Ground' Via

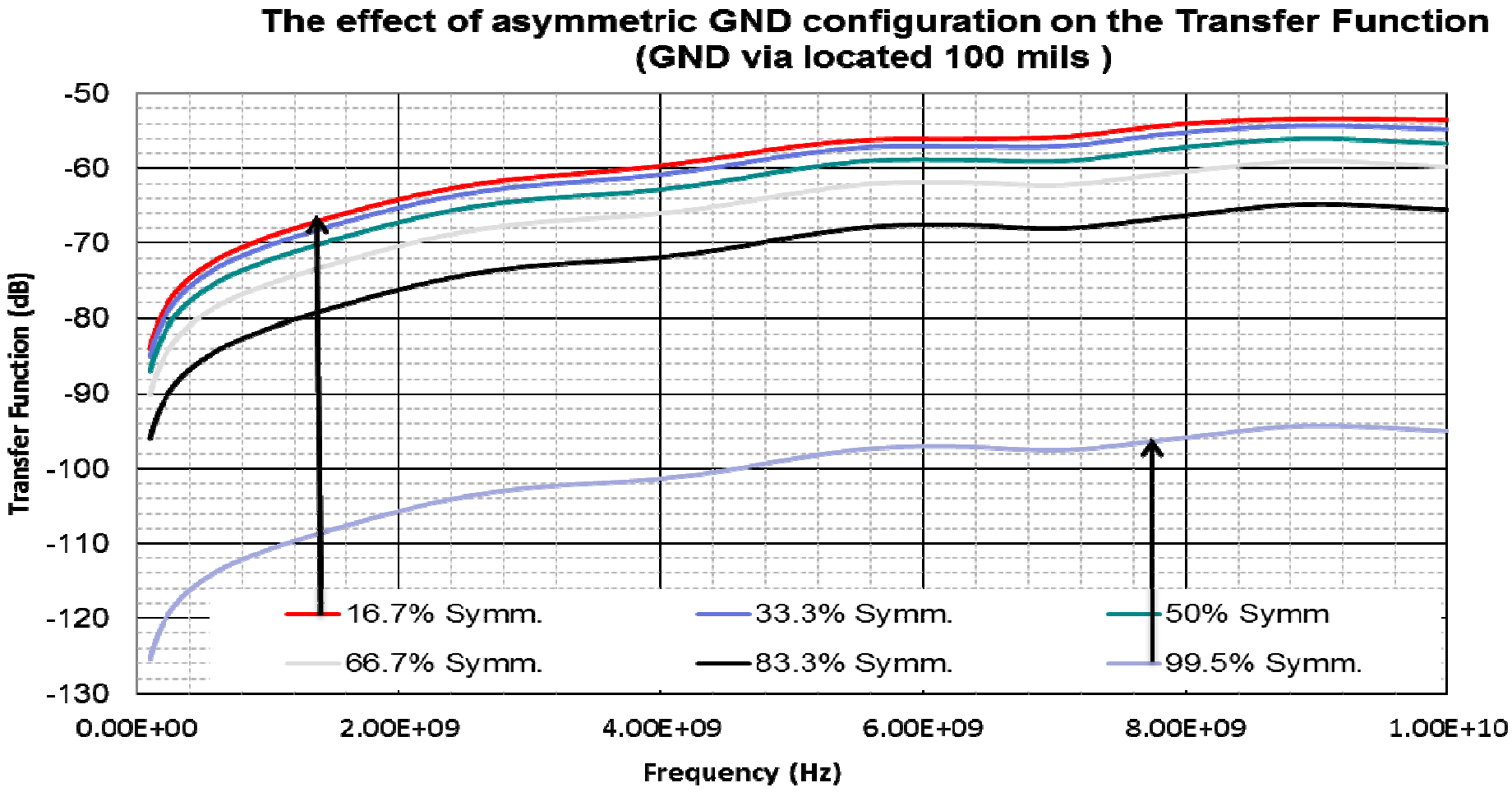
TOP VIEW

**r = 50 mils**
**r = 100 mils**
**r = 150 mils**
**r = 200 mils**
**r = 300 mils**
**r = 400 mils**

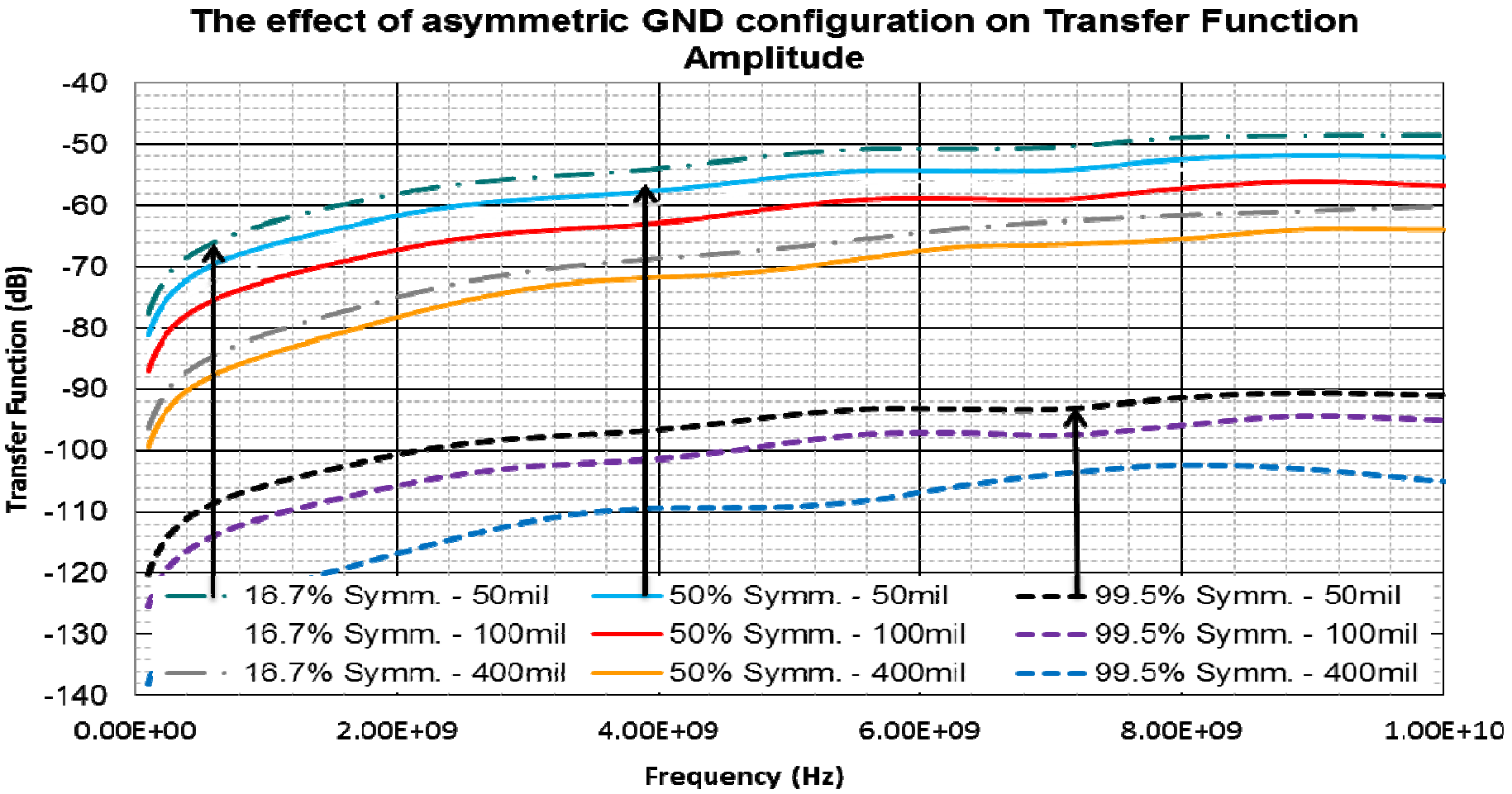



Dielectric Constant, Metal Thickness: 4.3, 1mil
Antipad, Pad, Via Drill Diameter: 35 mil, 20mil, 12 mil

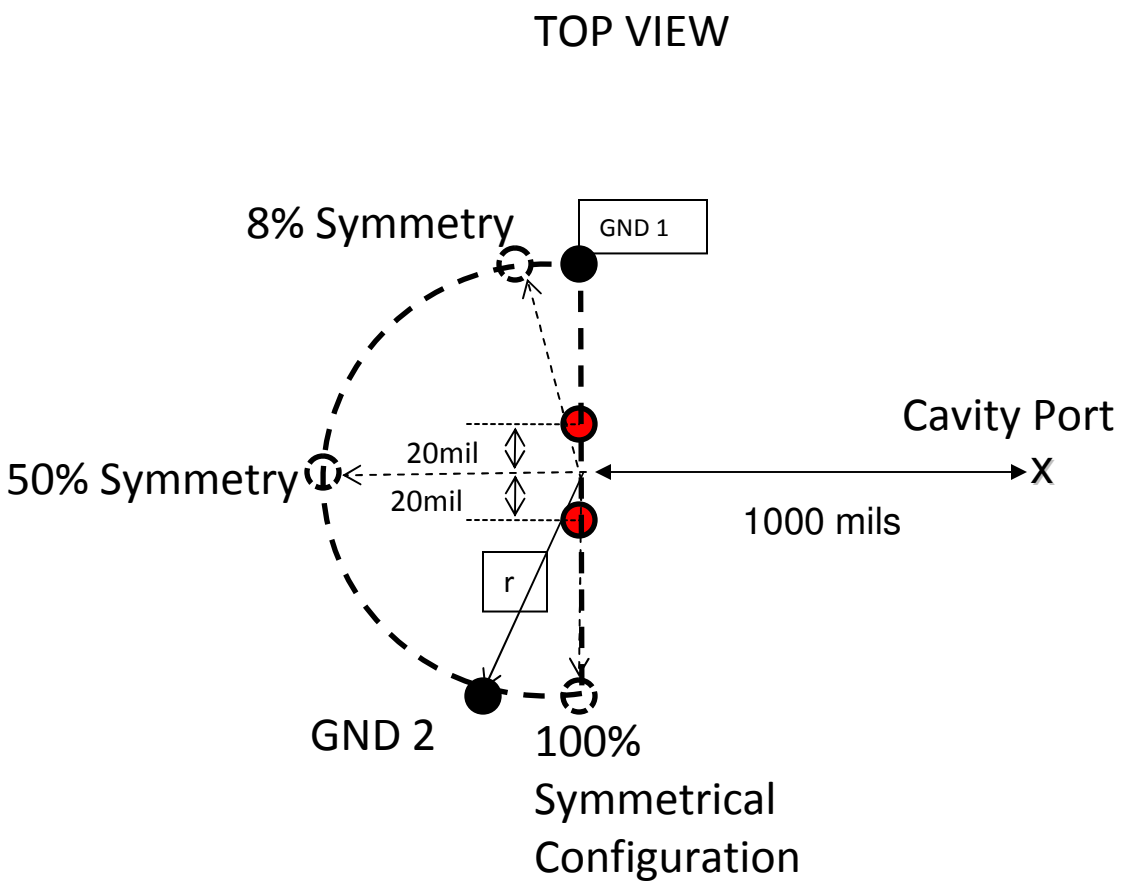
# Noise Between Planes Due to Asymmetrical GND @ 100 mils



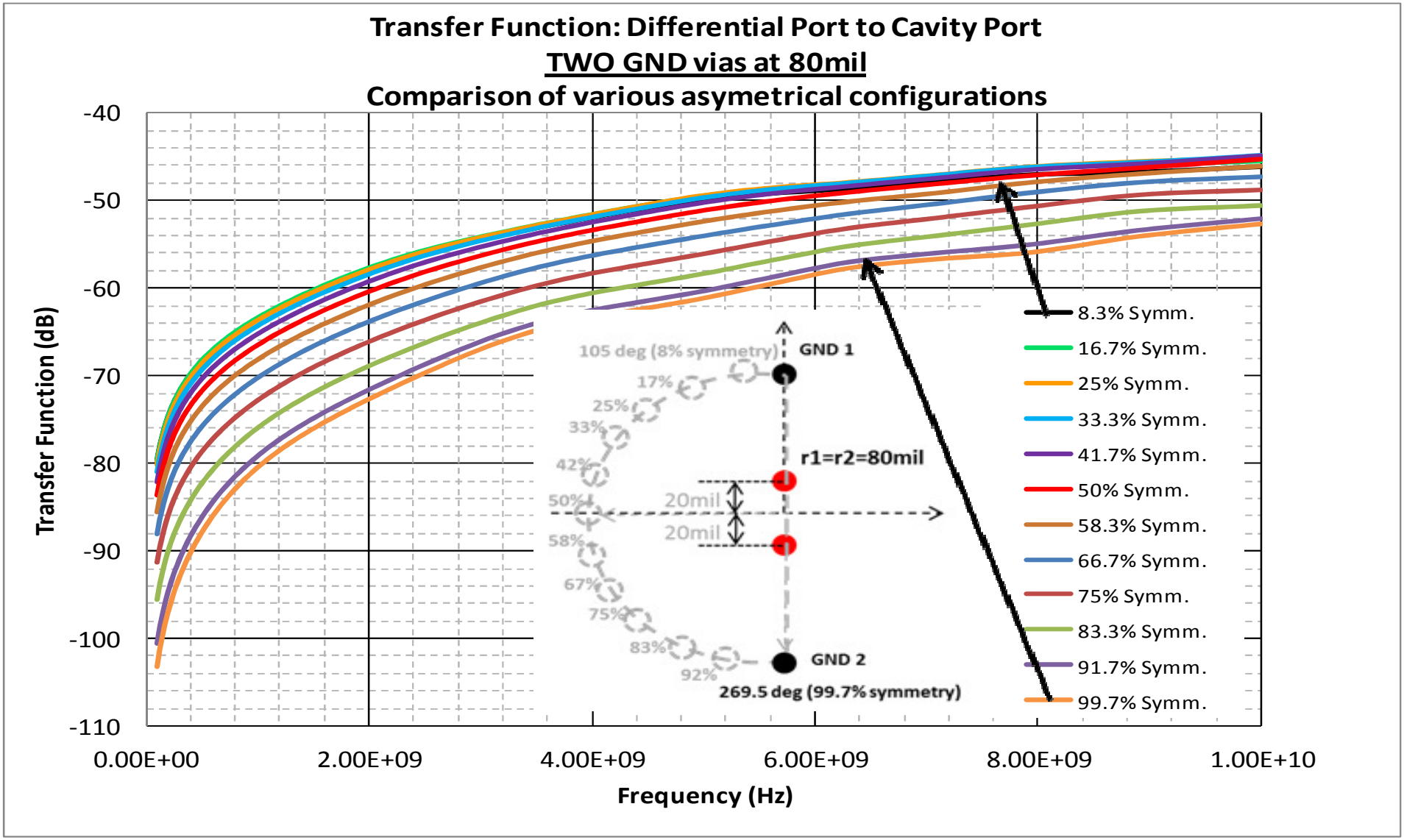
# Noise Between Planes Due to Asymmetry and Various Distances



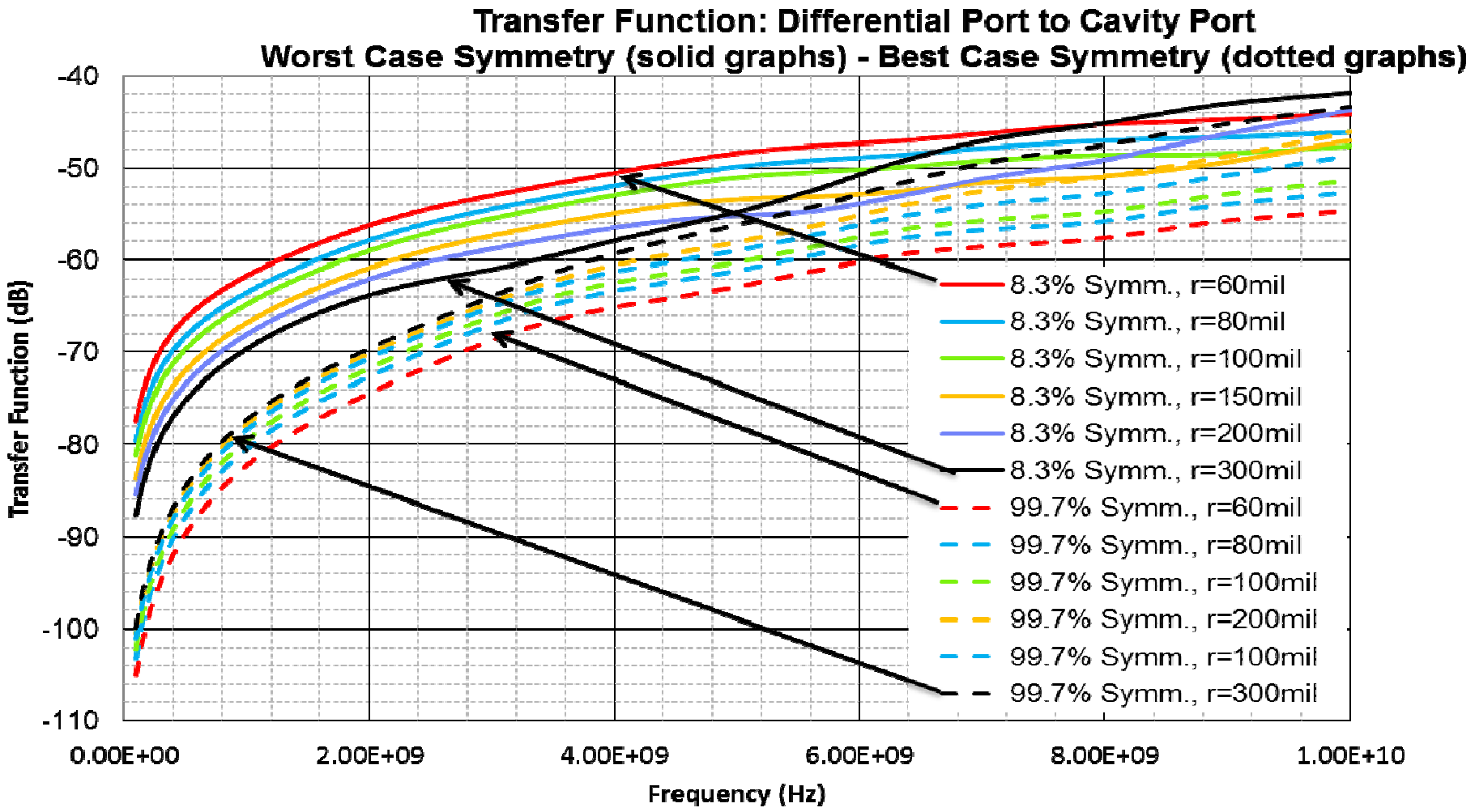
# Differential Via Configuration
## Two 'Ground' Vias



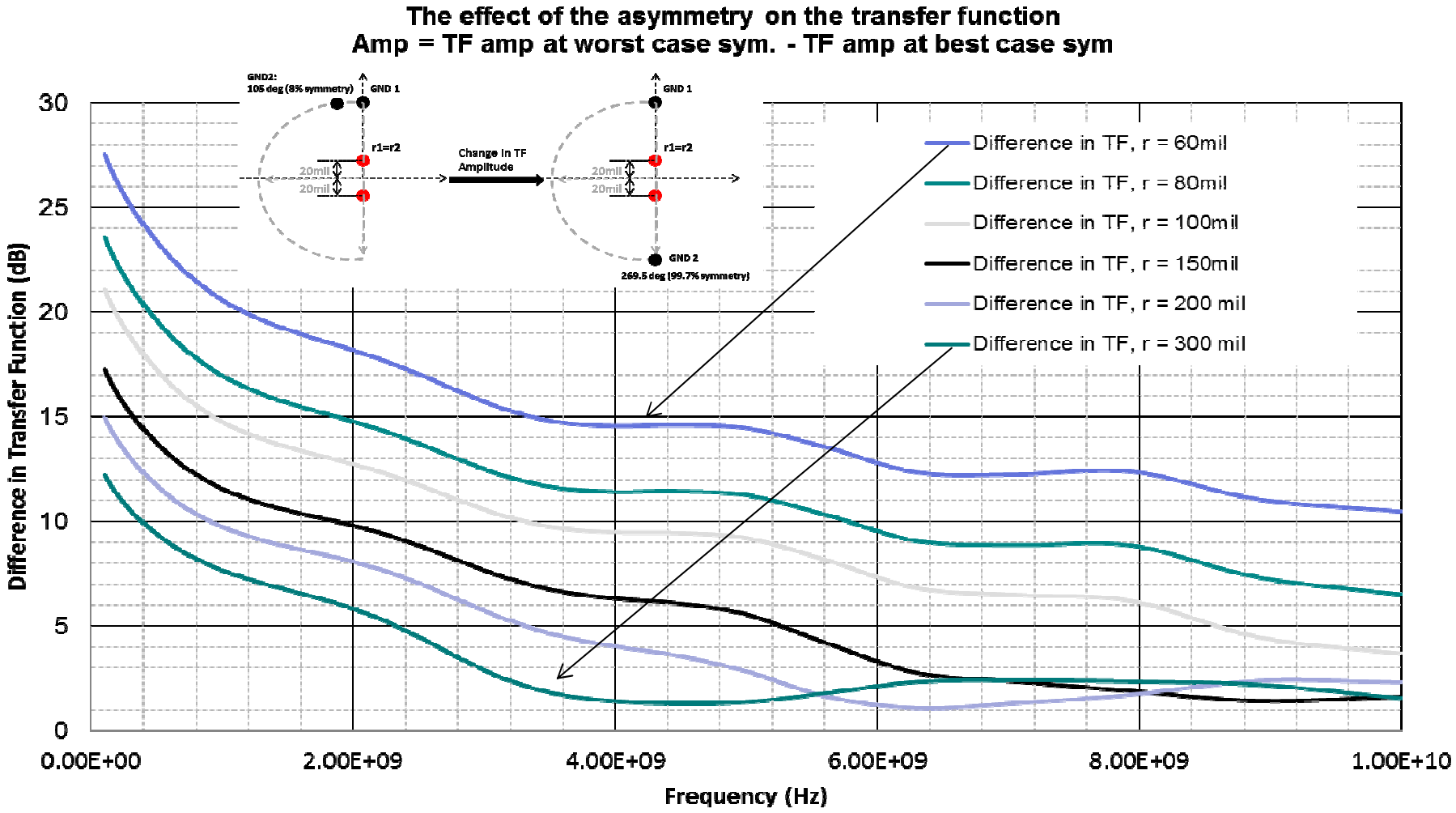
# Noise Between Planes Due to Asymmetrical GND @ 80mils



# Noise Between Planes Due to Asymmetry and Various Distances

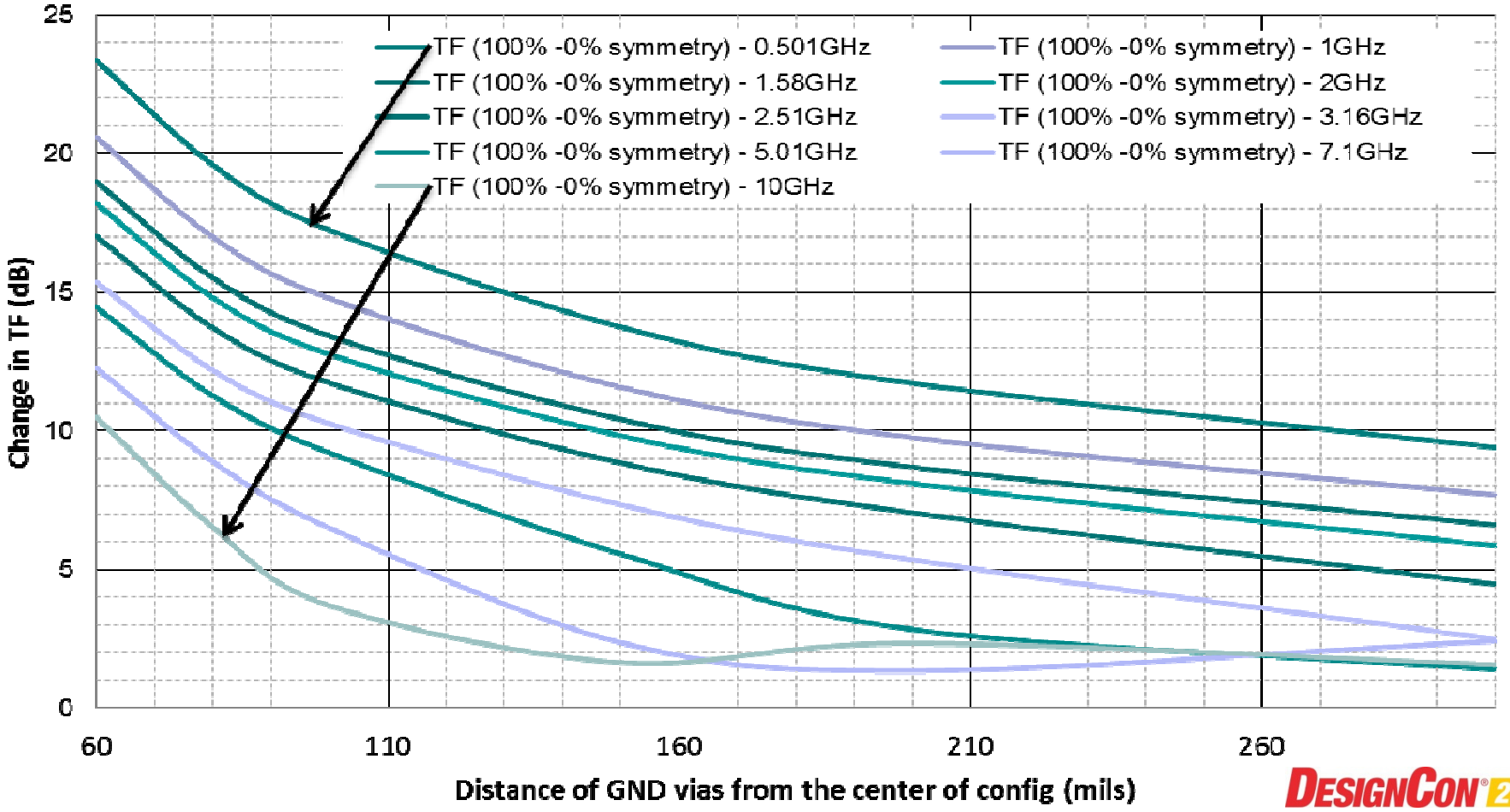


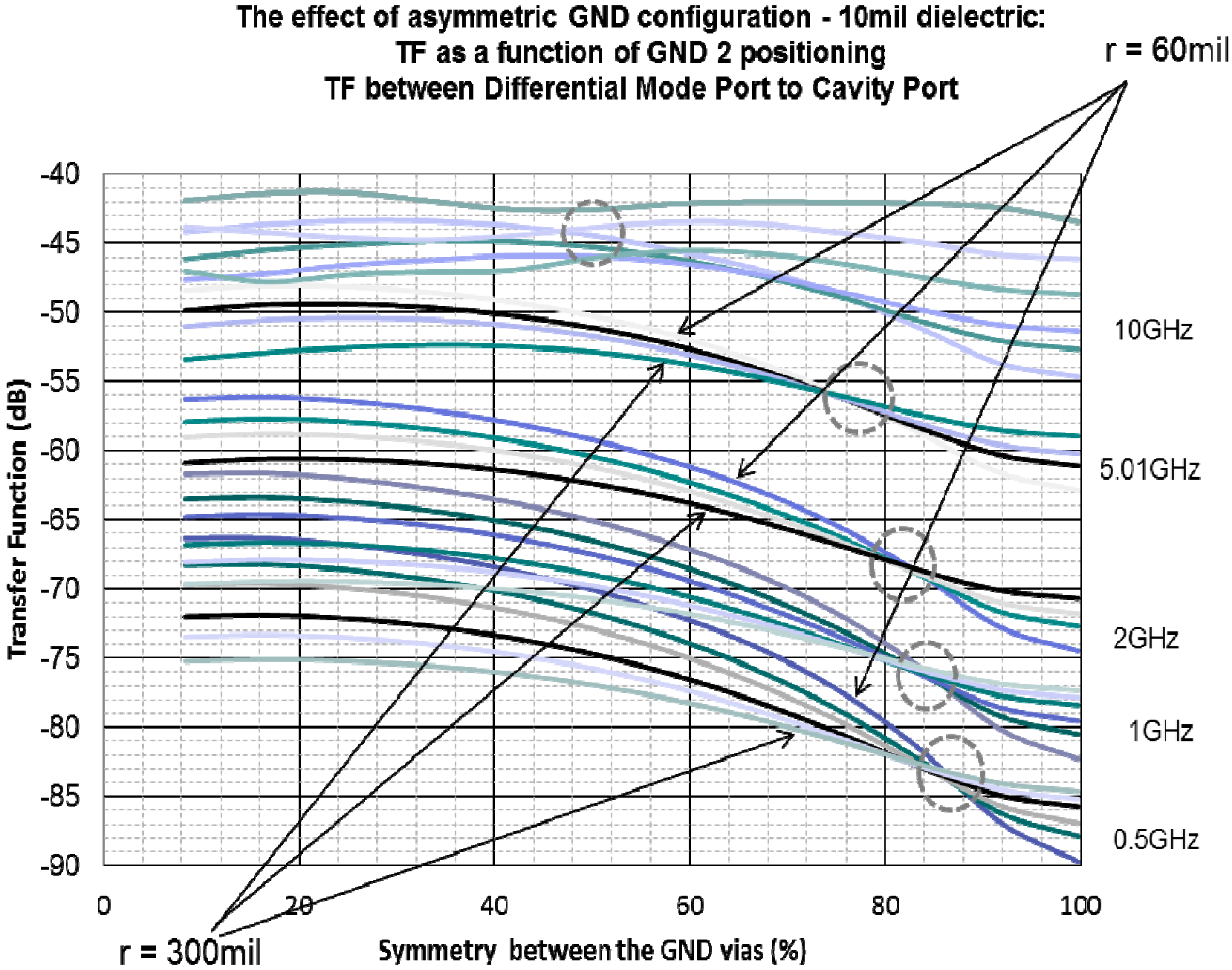
# Maximum Impact of Symmetry for Various Distances



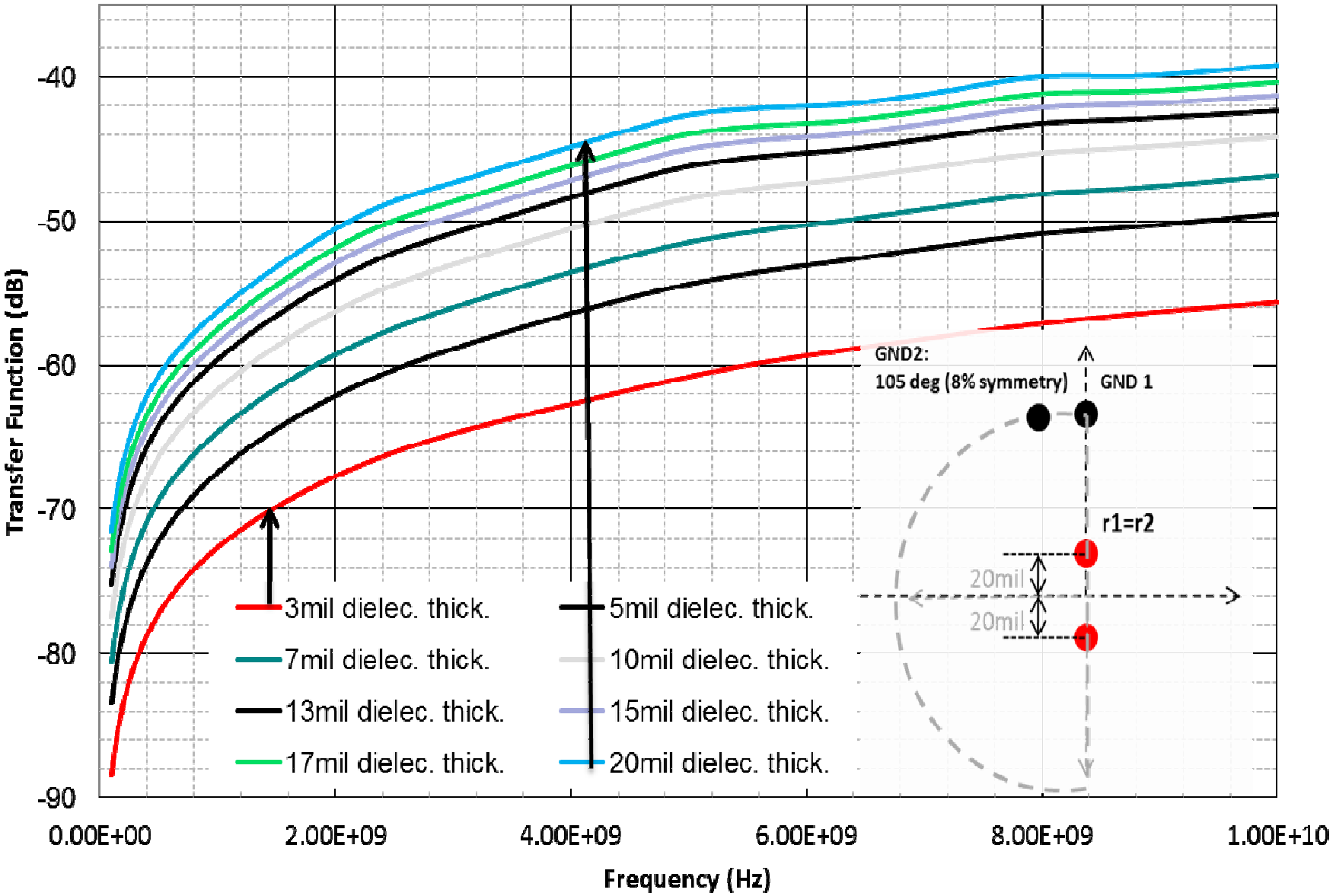
# Maximum Impact of Symmetry vs. Distance for Various Frequencies

**Change in TF while comparing symmetrical and asymmetrical configurations vs. distance of GND vias from the center of config.**

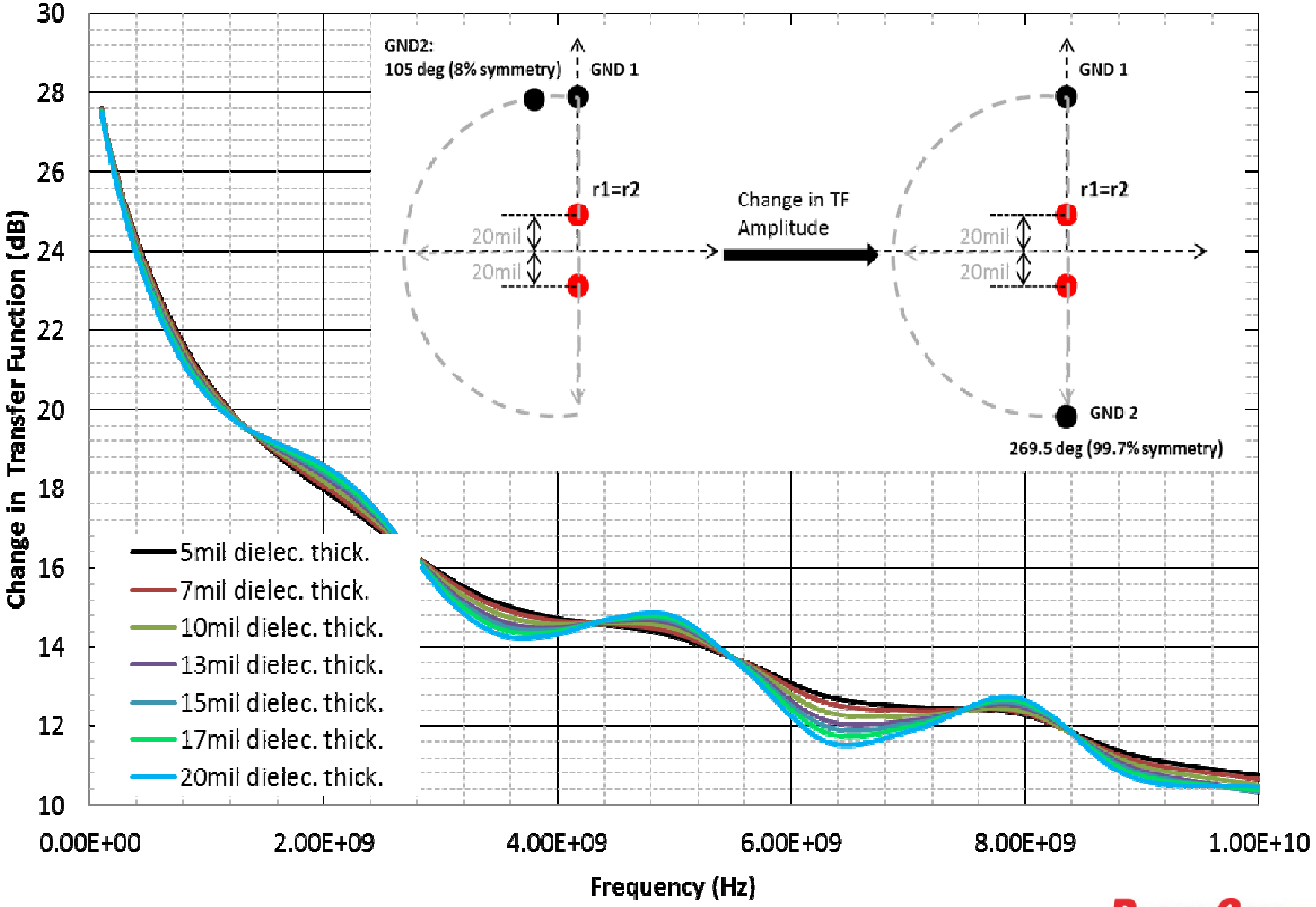



The effect of asymmetric GND configuration - 10mil dielectric:
TF as a function of GND 2 positioning
TF between Differential Mode Port to Cavity Port
r = 60mil
r = 300mil
Transfer Function (dB)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
0
20
40
60
80
100
Symmetry between the GND vias (%)
10GHz
5.01GHz
2GHz
1GHz
0.5GHz

## Dielectric thickness effect on the common mode noise
## GND1 and GND2 are located at r1=r2=60mil - Worst case Symmetry



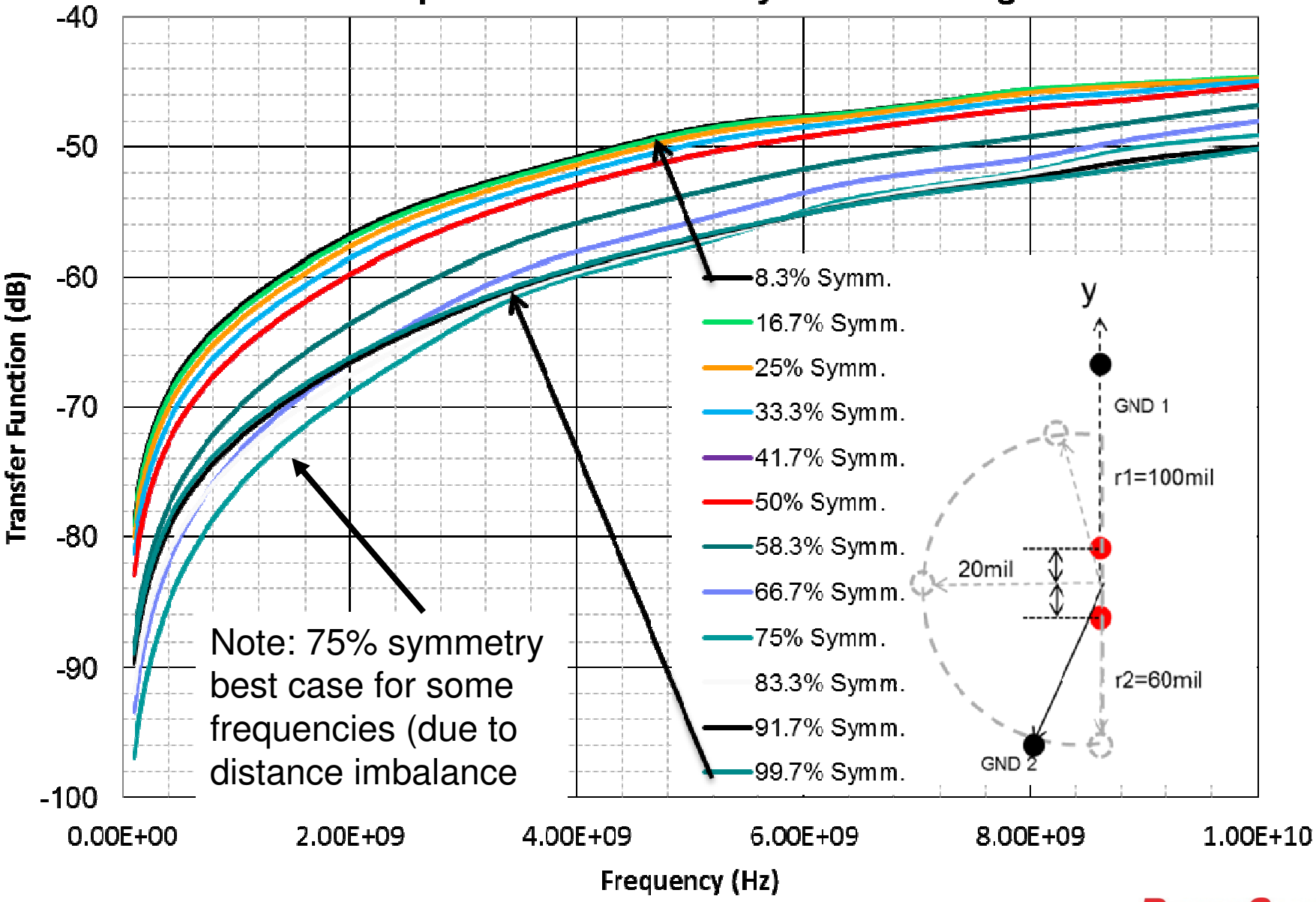
# Total effect of asymmetrical configuration of GND vias on the common mode conversion for a particular dielectric thickness.
## GND1 and GND2 are located at r1=r2=60mil



# Transfer Function: Differential Port to Cavity Port

## GND1 at 90 deg /10mil - GND2 at 60mil /varying symm. config.

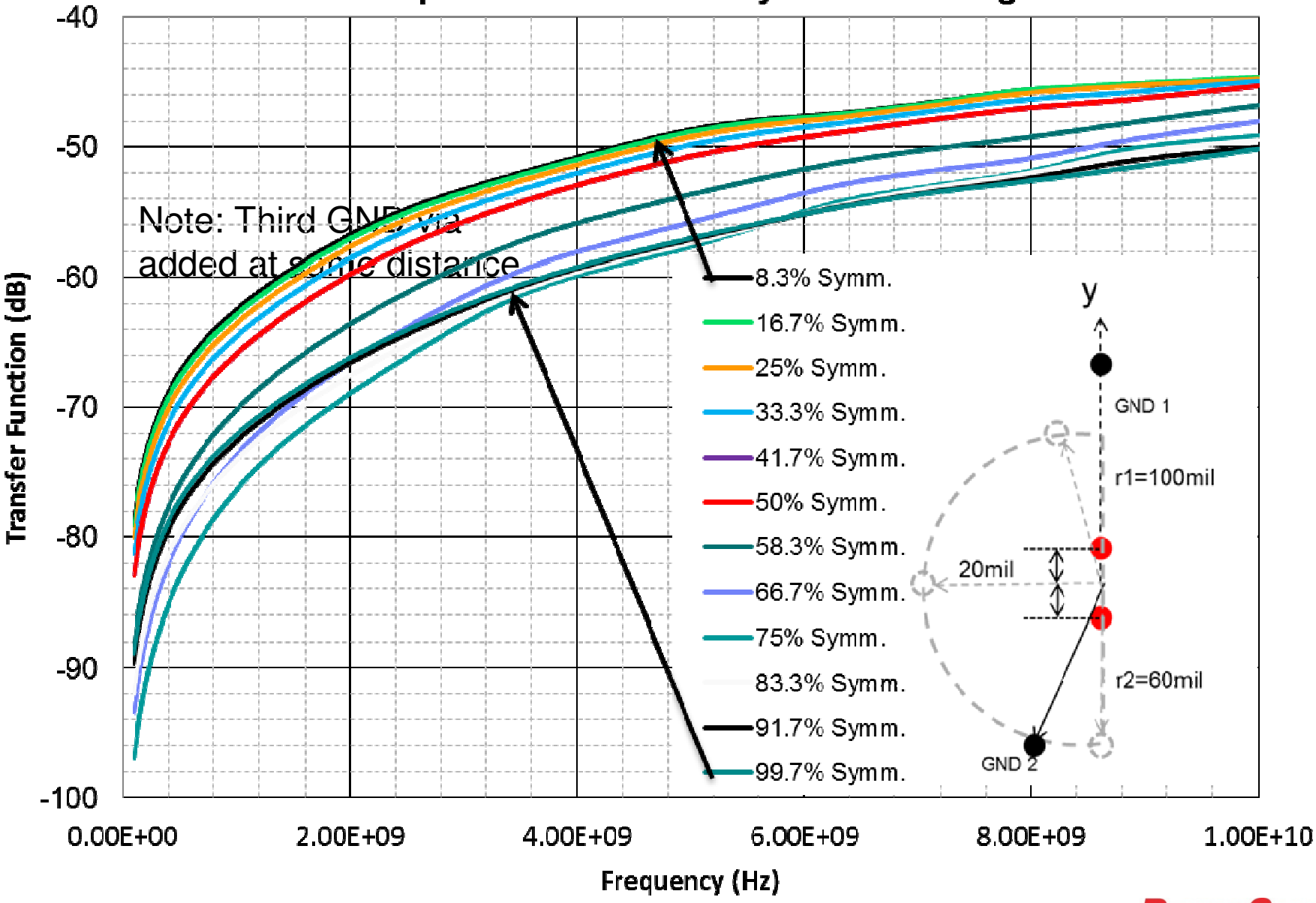
## Comparison of various asymetrical configurations

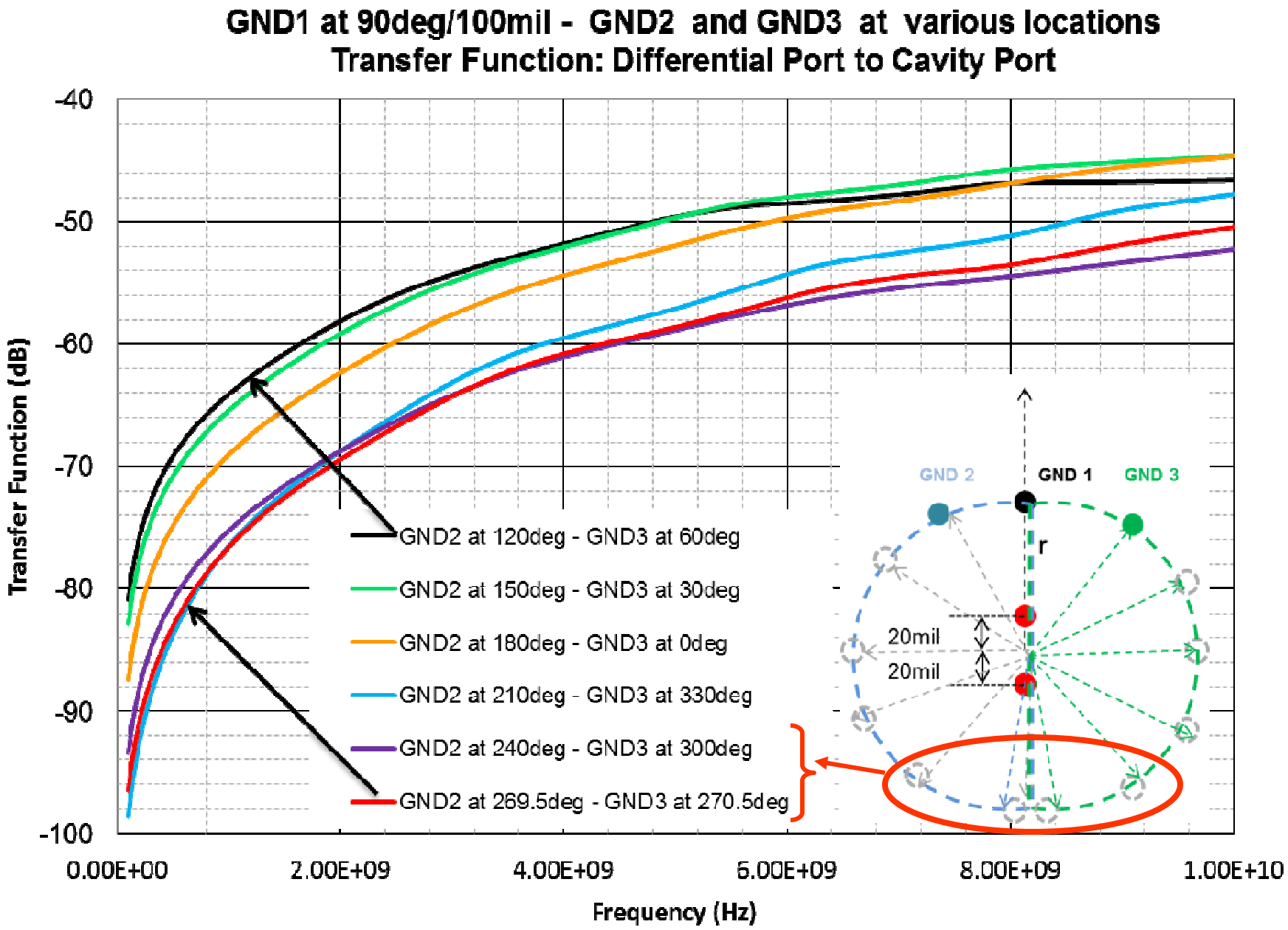


# Transfer Function: Differential Port to Cavity Port

## GND1 at 90 deg /10mil - GND2 at 60mil /varying symm. config.

## Comparison of various asymetrical configurations



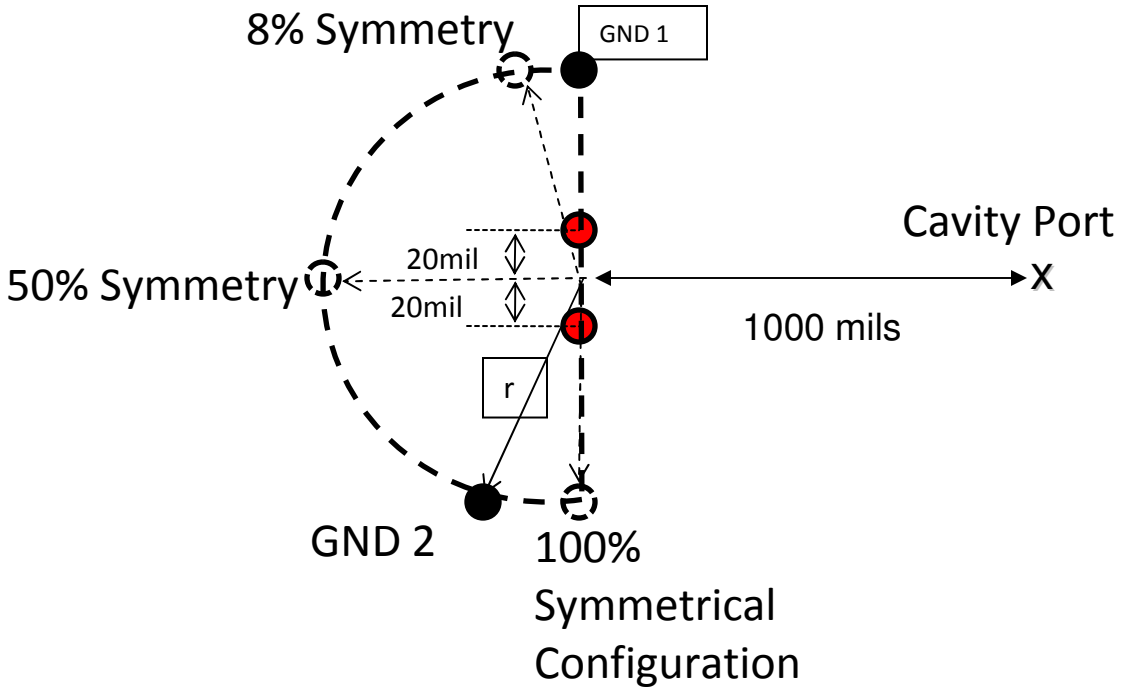

GND1 at 90deg/100mil - GND2 and GND3 at various locations
Transfer Function: Differential Port to Cavity Port
Transfer Function (dB)
-40
-50
-60
-70
-80
-90
-100
0.00E+00
2.00E+09
4.00E+09
6.00E+09
8.00E+09
1.00E+10
Frequency (Hz)
GND2 at 120deg - GND3 at 60deg
GND2 at 150deg - GND3 at 30deg
GND2 at 180deg - GND3 at 0deg
GND2 at 210deg - GND3 at 330deg
GND2 at 240deg - GND3 at 300deg
GND2 at 269.5deg - GND3 at 270.5deg
GND 2
GND 1
GND 3
r
20mil
20mil

# Differential Via Configuration

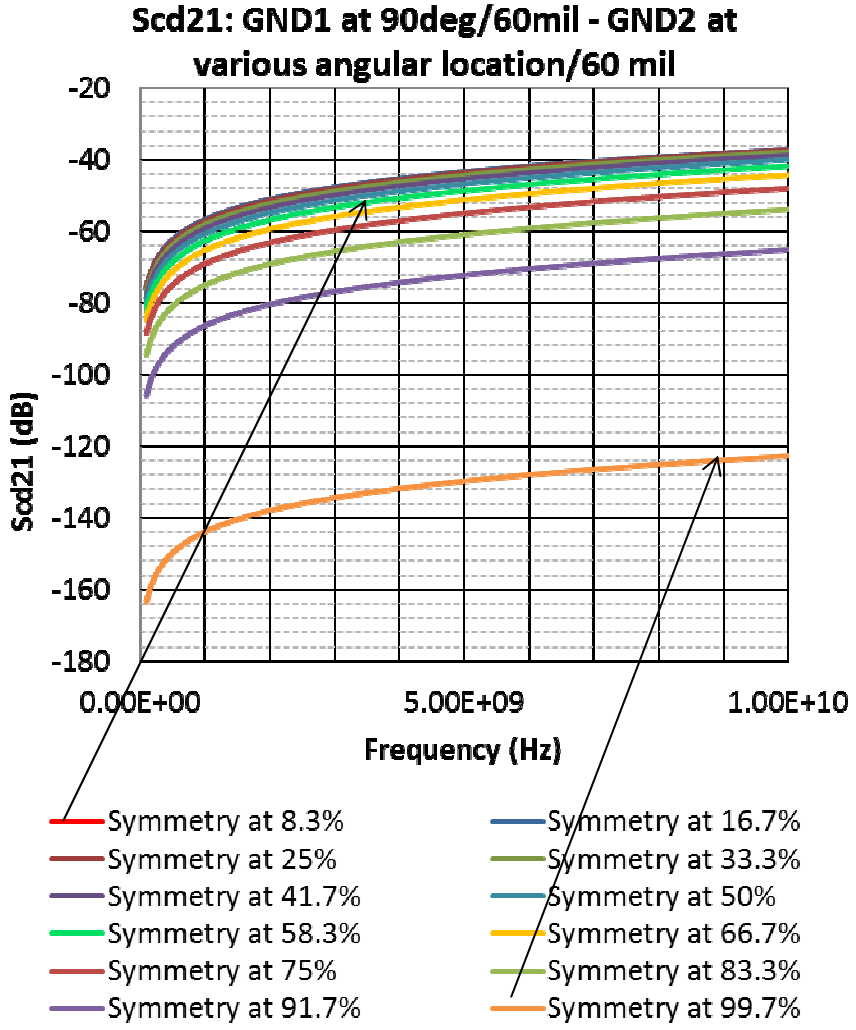
## Two 'Ground' Vias

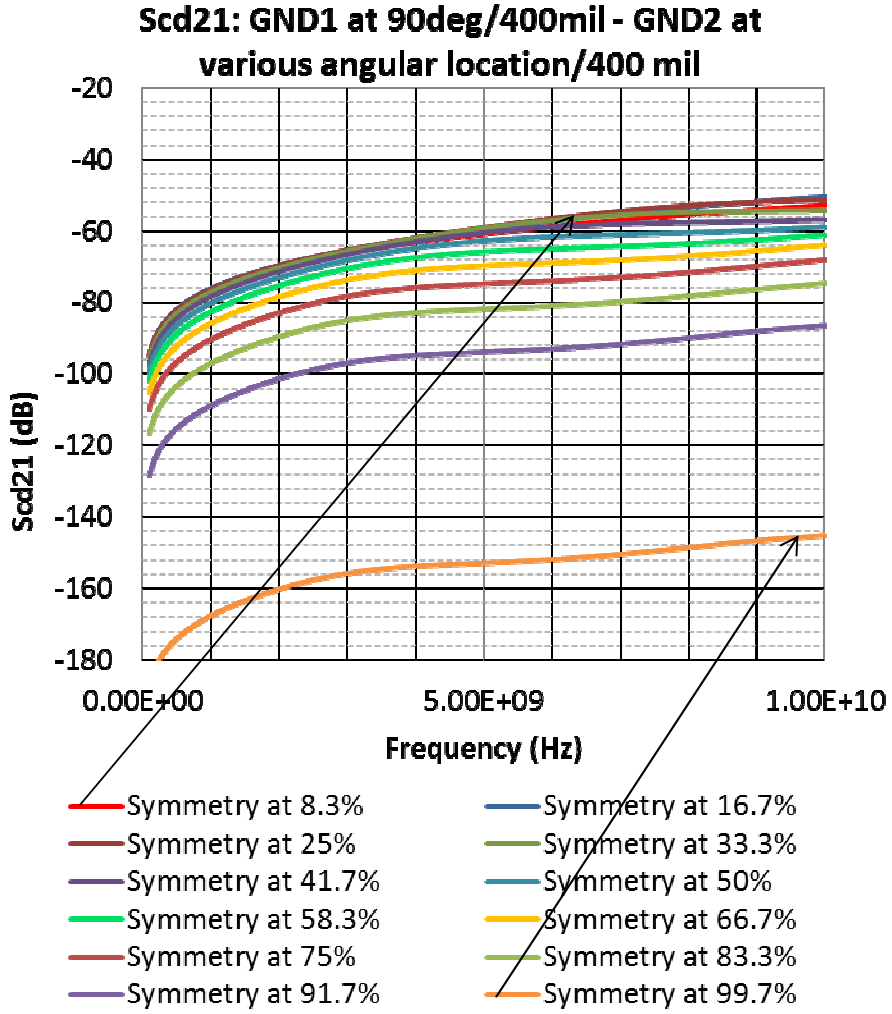
## Differential to Common Mode Conversion $S_{cd21}$

TOP VIEW

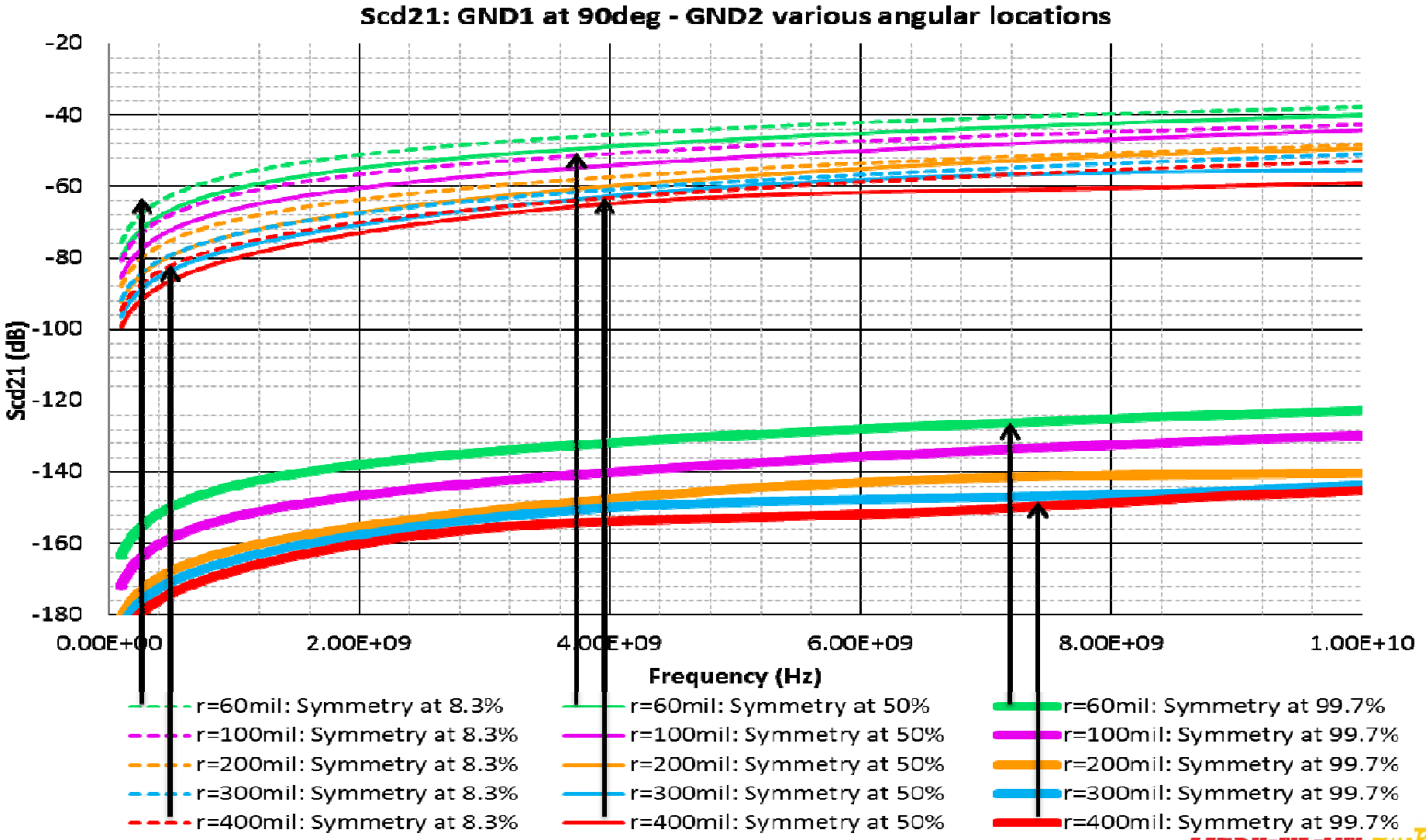


# Effect of Asymmetry on $S_{cd21}$ at 60 mil & 400 mil Distance to GND Vias



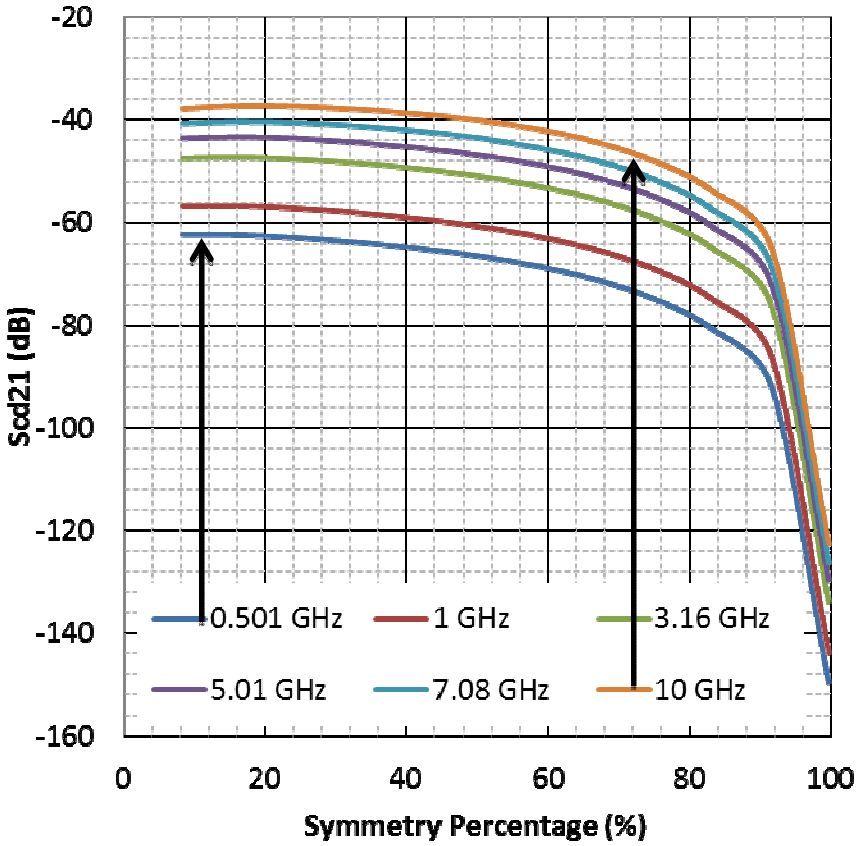



# Effect of Asymmetry on $S_{cd21}$ at Various Distance to GND Vias

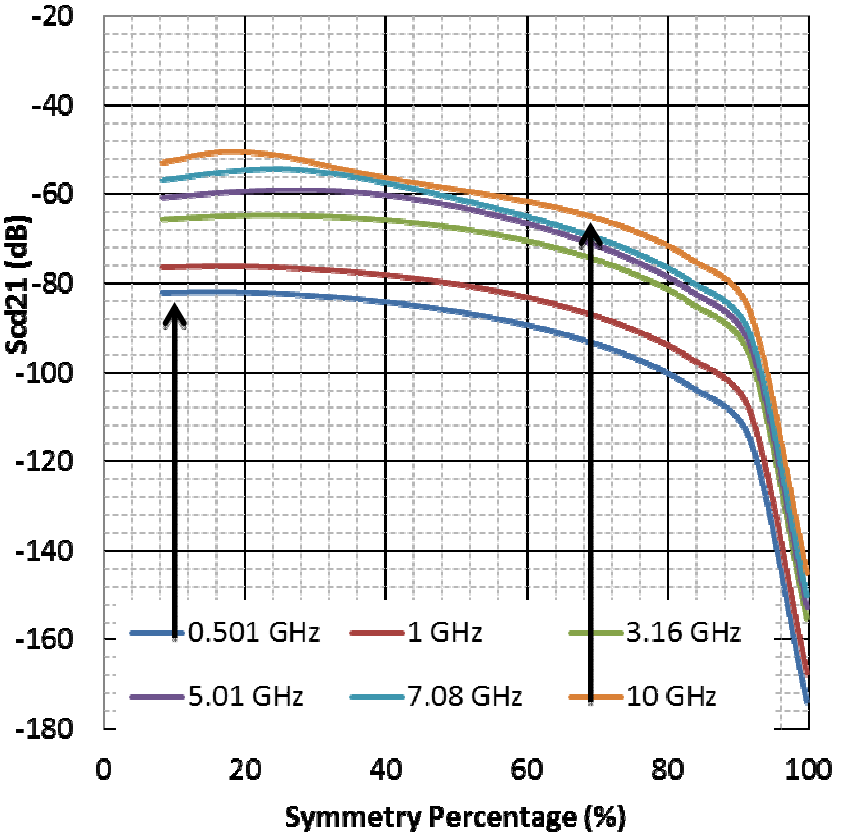


# Effect of Asymmetry on $S_{cd21}$ at Various Frequencies

**Common Mode Conversion: Scd21**
**GND1@90deg/60mil, GND2@60mil**




**Common Mode Conversion: Scd21**
**GND1@90deg/400mil, GND2@400mil**

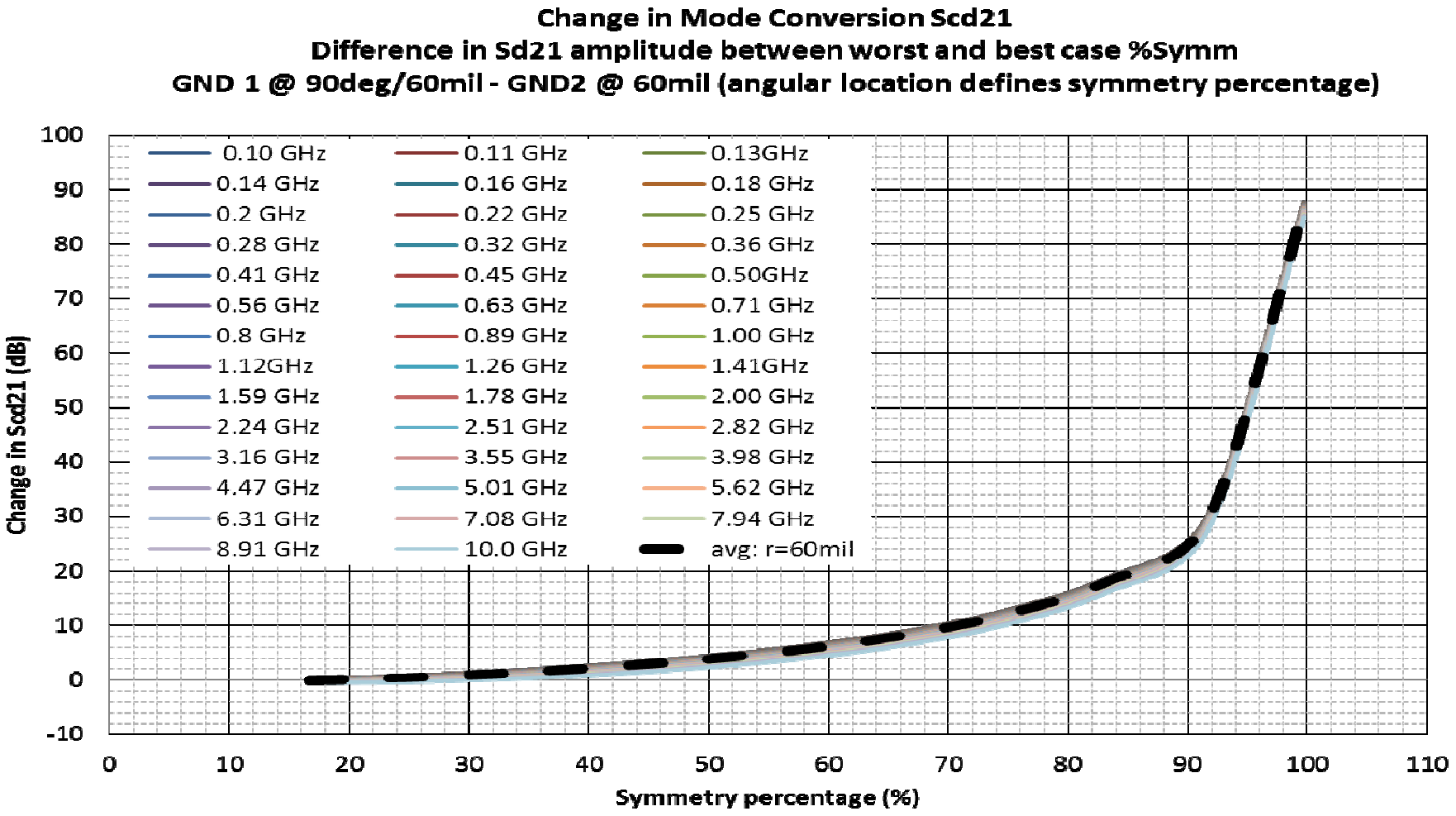


# Maximum Impact of Asymmetry

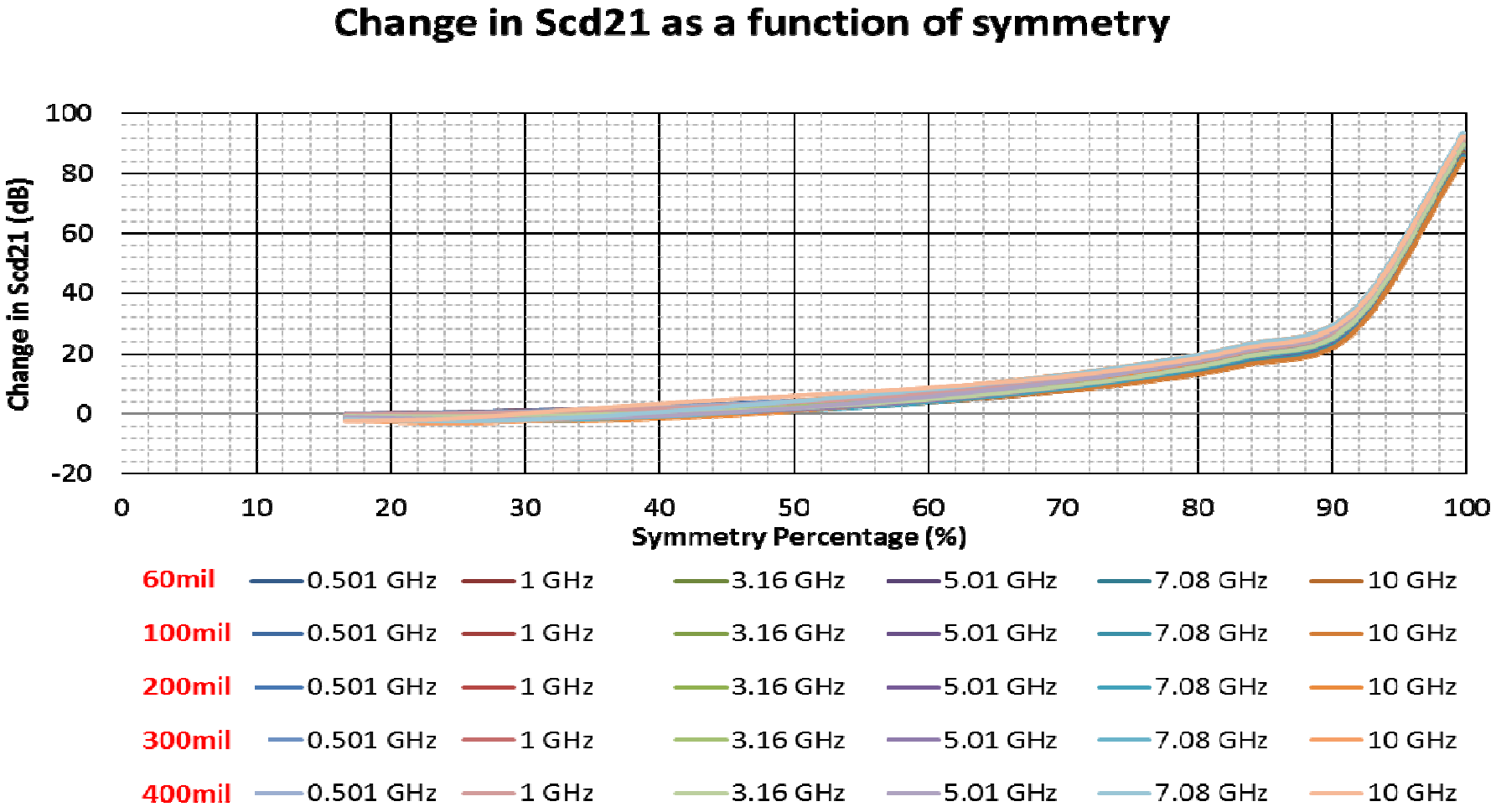
- For a given distance, all frequencies have same impact vs symmetry
  - Biggest maximum impact possible with good symmetry
  - Maximum impact is frequency independent

# Maximum Impact of Asymmetry

## Change in $S_{cd21}$



# Maximum Impact of Symmetry vs Distance to GND vias and Frequency

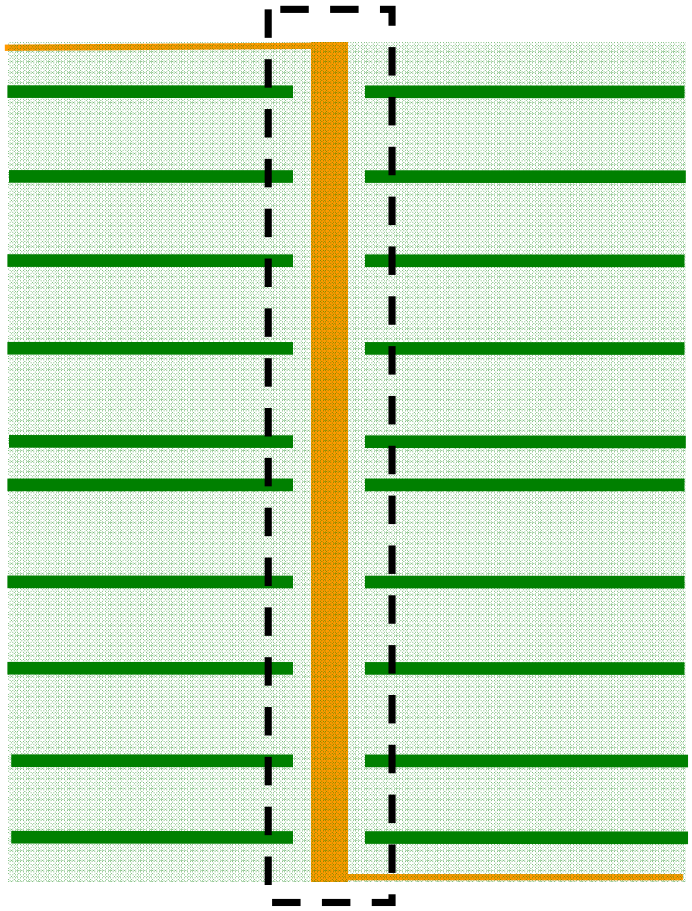


# Differential Via Configuration

## Two 'Ground' Vias

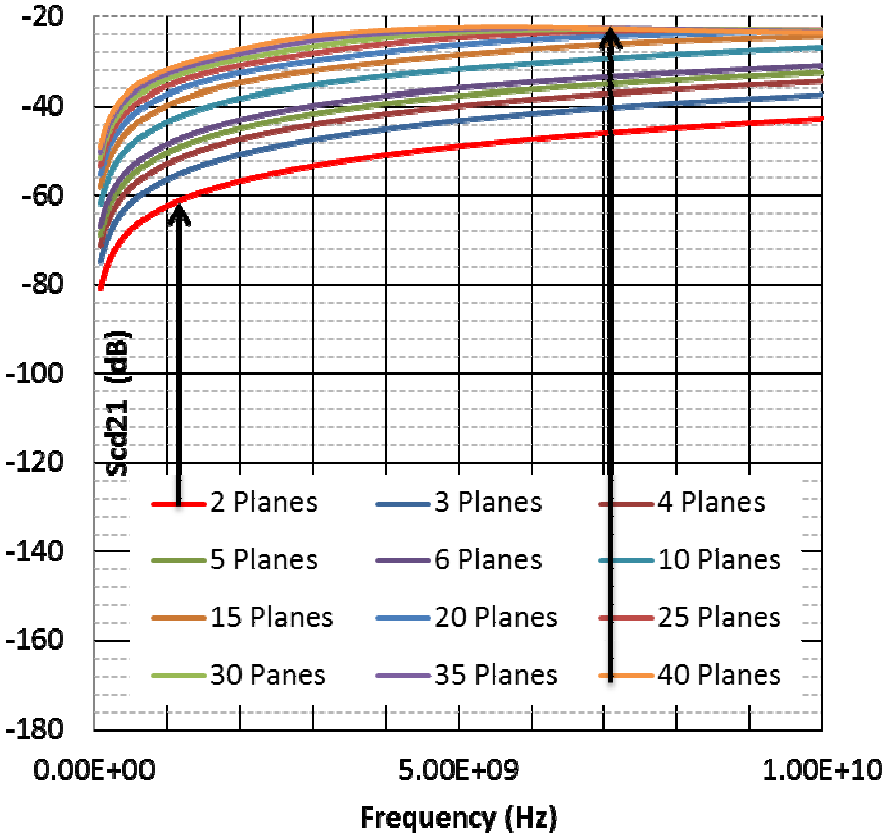
## Differential to Common Mode Conversion Scd21

- Mode conversion is additive for each plane-pair transition

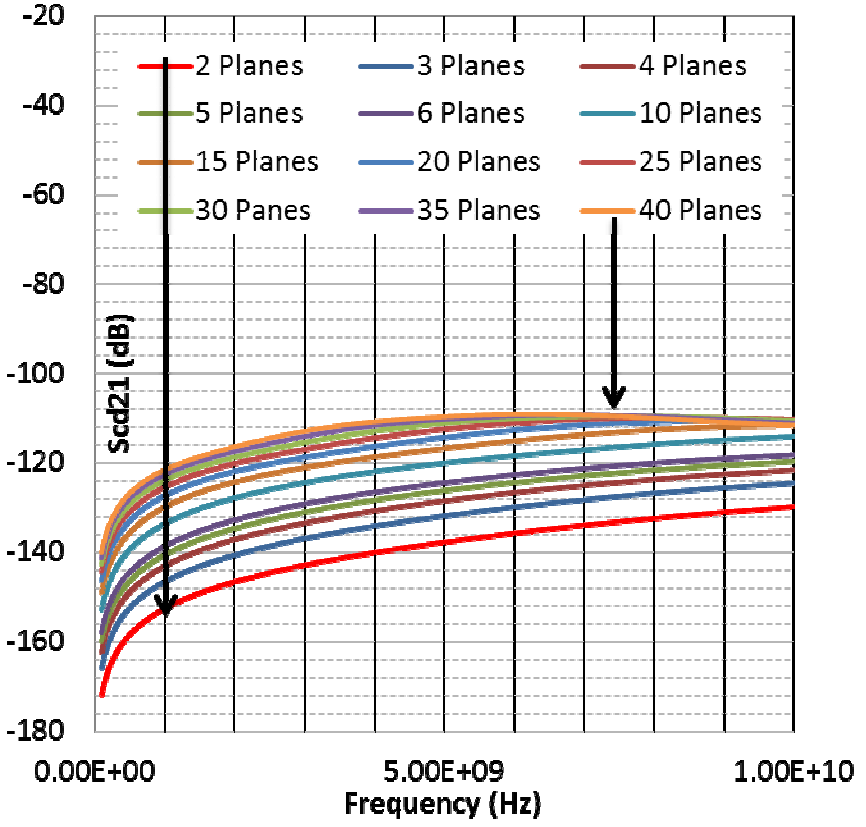


# Mode Conversion for Poor and Good Symmetry for Multiple Plane-Pairs

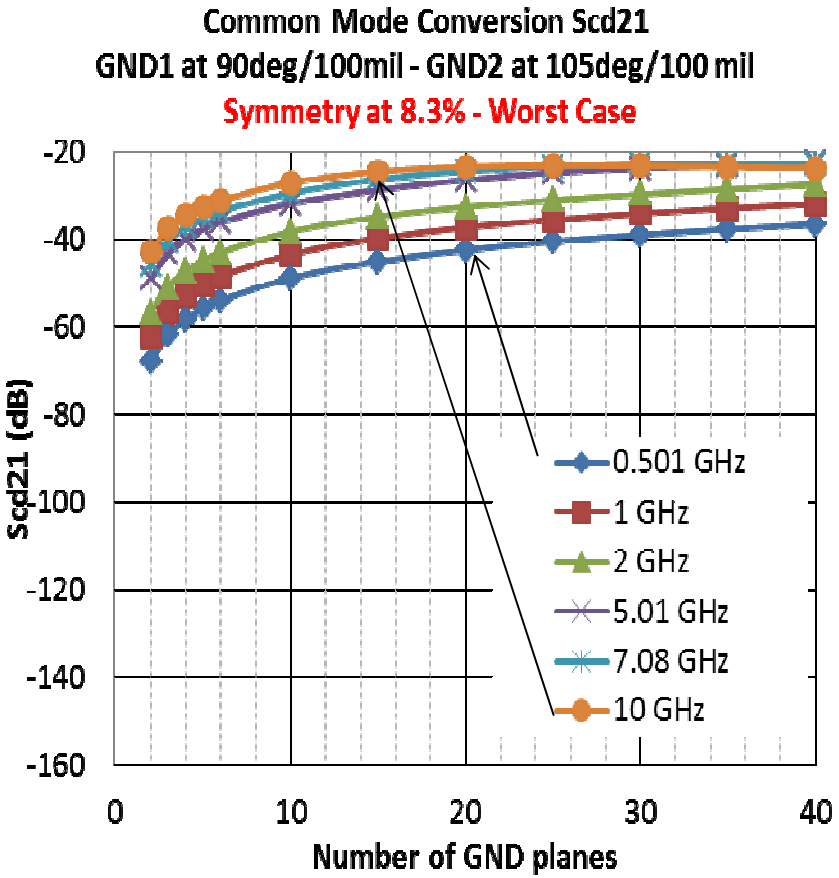
**Scd21: Common Mode Conversion GND1 at 90deg/100mil - GND2 at 105deg/100 mil (8.3%Symmetry)**

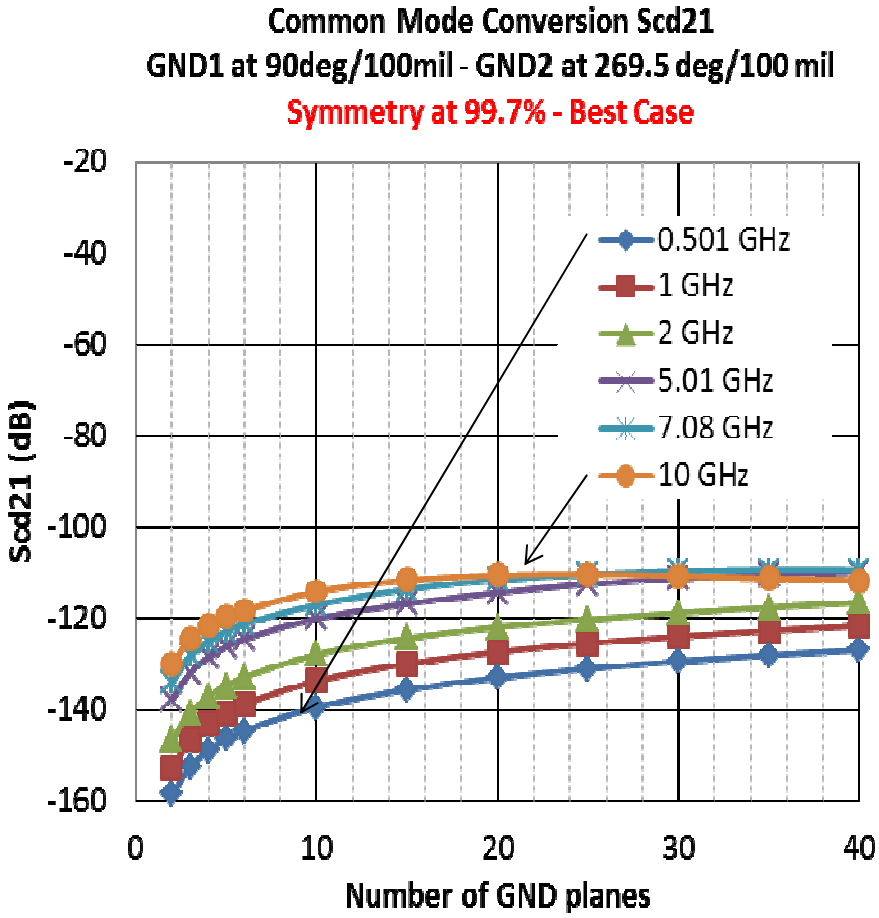



**Scd21: Common Mode Conversion GND1 at 90deg/100mil - GND2 at 269.5deg/100 mil (99.7%Symmetry)**



# Mode Conversion for Poor and Good Symmetry for Multiple Plane-Pairs for Various Frequencies



# Summary

- Single Ended Via
  - Effect of distance to GND via characterized
- Differential Via
  - Effect of symmetry shown to be very important
    - Noise between planes
    - Mode conversion
    - Multiple vias
  - Important for BOTH emissions and Immunity