# C2C Channel Equalization

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**IEEE 802.3ck Taskforce Meeting**

**Geneva**

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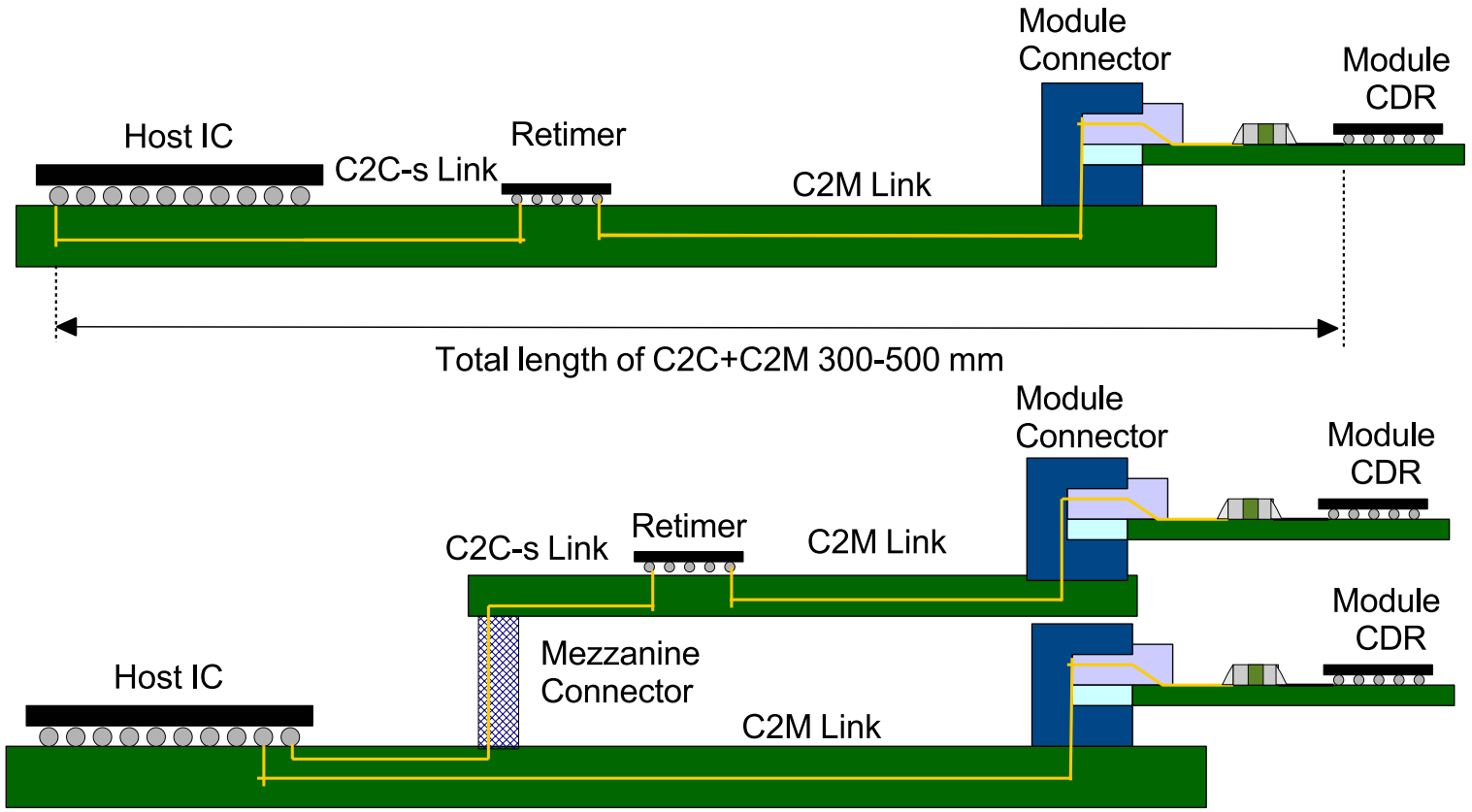
# Overview

- **C2C COM analysis**
  - 4 Lim channels between 16.5 to 17.5 dB loss
  - 1 Gore PCB channel with 20 dB loss
  - 1 Gore cabled channel with 20 dB loss
- **Equalizer considered**
  - 5 tap DFE, 12 tap DFE, and 3 tap FFE + 2T floating DFE with 12 UI span
- **Key consideration for C2C link are:**
  - Operation with end-end FEC where link must operate with acceptable burst error rate
  - Given that key application of C2C links are retimers/inverse-gearbox
  - Low power is a key consideration
- **Addressing comment 178.**

# Two Common C2C-S Applications

- **These two common C2C applications can satisfied with ~300 mm trace and by repurposing 16 dB C2M budget**
  - Connecting to far-side of the ASIC IO may require retimer
  - Modules mounted on mezzanine card.



# COM 2.7.6 Table for C2C

| Table 93A-1 parameters | | | |
|---|---|---|---|
| **Parameter** | **Setting** | **Units** | **Information** |
| f_b | 53.125 | GBd | |
| f_min | 0.05 | GHz | |
| Delta_f | 0.01 | GHz | |
| C_d | [1.2e-4 1.2e-4] | nF | [TX RX] |
| L_s | [0.12, 0.12] | nH | [TX RX] |
| C_b | [0.3e-4 0.3e-4] | nF | [TX RX] |
| z_p select | [ 1 2 3 4 5 ] | | [test cases to run] |
| z_p (TX) | [13 13 13 31 31; 1.8 1.8 1.8 1.8 1.8] | mm | [test cases] |
| z_p (NEXT) | [13 13 13 31 31; 1.8 1.8 1.8 1.8 1.8] | mm | [test cases] |
| z_p (FEXT) | [13 13 13 31 31; 1.8 1.8 1.8 1.8 1.8] | mm | [test cases] |
| z_p (RX) | [7 11 13 13 29; 1.8 1.8 1.8 1.8 1.8] | mm | [test cases] |
| C_p | [0.87e-4 0.87e-4] | nF | [TX RX] |
| R_0 | 50 | Ohm | |
| R_d | [ 45 50] | Ohm | [TX RX] |
| A_v | 0.413 | V | |
| A_fe | 0.413 | V | |
| A_ne | 0.608 | V | |
| L | 4 | | |
| M | 32 | | |
| **filter and Eq** | | | |
| f_r | 0.75 | *fb | |
| c(0) | 0.54 | | min |
| c(-1) | [-0.34:0.02:0] | | [min:step:max] |
| c(-2) | [0:0.02:0.12] | | [min:step:max] |
| c(-3) | [-0.06:0.02: 0] | | [min:step:max] |
| c(1) | [-0.2:0.05:0] | | [min:step:max] |
| N_b | 5 | UI | |
| b_max(1) | 0.75 | | |
| b_max(2..N_b) | 0.1 | | |
| g_DC | [-16:1:0] | dB | [min:step:max] |
| f_z | 21.25 | GHz | |
| f_p1 | 21.25 | GHz | |
| f_p2 | 53.125 | GHz | |
| g_DC_HP | [-4:1:0] | | [min:step:max] |
| f_HP_PZ | 0.6640625 | GHz | |

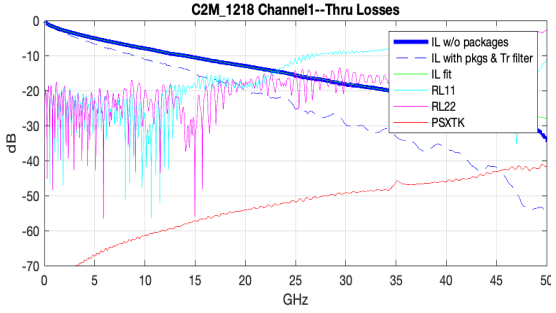
| I/O control | | |
|---|---|---|
| DIAGNOSTICS | 1 | logical |
| DISPLAY_WINDOW | 1 | logical |
| CSV_REPORT | 1 | logical |
| RESULT_DIR | .\results\100GEL_KR_{date}\ | |
| SAVE_FIGURES | 0 | logical |
| Port Order | [1 3 2 4] | |
| RUNTAG | KR_eval_ | |
| COM_CONTRIBUTION | 0 | logical |
| **Operational** | | |
| COM Pass threshold | 3 | dB |
| ERL Pass threshold | 10.5 | dB |
| DER_0 | 1.00E-05 | |
| T_r | 6.16E-03 | ns |
| FORCE_TR | 1 | logical |
| | | |
| **TDR and ERL options** | | |
| TDR | 1 | logical |
| ERL | 1 | logical |
| ERL_ONLY | 0 | logical |
| TR_TDR | 0.01 | ns |
| N | 300 | |
| beta_x | 2.3407E+09 | |
| rho_x | 0.19 | |
| fixture delay time | [ 0 0 ] | [ port1 port2 ] |
| TDR_W_TXPKG | 0 | |
| N_bx | 5 | UI |
| **Receiver testing** | | |
| RX_CALIBRATION | 0 | logical |
| Sigma BBN step | 5.00E-03 | V |
| **Noise, jitter** | | |
| sigma_RJ | 0.01 | UI |
| A_DD | 0.02 | UI |
| eta_0 | 8.2E-09 | V^2/GHz |
| SNR_TX | 33 | dB |
| R_LM | 0.95 | |

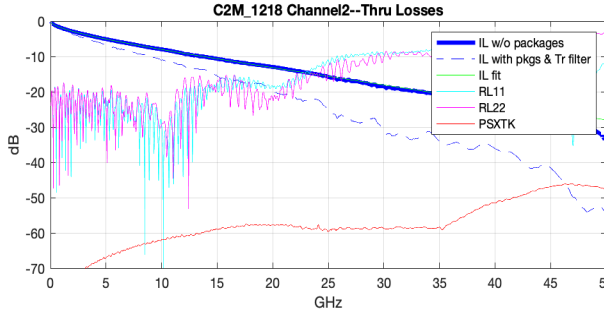
| Table 93A–3 parameters | | |
|---|---|---|
| **Parameter** | **Setting** | **Units** |
| package_tl_gamma0_a1_a2 | [0 0.0009909 0.0002772] | |
| package_tl_tau | 6.141E-03 | ns/mm |
| package_Z_c | [87.5 87.5 ; 92.5 92.5 ] | Ohm |
| benartsi_3ck_01_0119 & mellitz_3ck_01_0119 | | |
| **Table 92–12 parameters** | | |
| **Parameter** | **Setting** | |
| *board_tl_gamma0_a1_a2* | *[0 3.8206e-04 9.5909e-05]* | |
| *board_tl_tau* | *5.790E-03* | ns/mm |
| *board_Z_c* | 100 | Ohm |
| *z_bp (TX)* | *110.3* | mm |
| *z_bp (NEXT)* | *110.3* | mm |
| *z_bp (FEXT)* | *110.3* | mm |
| *z_bp (RX)* | *110.3* | mm |
| *C_0* | [0.29e-4] | nF |
| *C_1* | [0.19e-4] | nF |
| **Include PCB** | **0** | **logical** |
| **Floating Tap Control** | | |
| N_bg | 0 | 0 1 2 or 3 groups |
| N_bf | 2 | taps per group |
| N_f | 12 | UI span for floating taps |
| bmaxg | 0.1 | max DFE value for floating taps |
| **B_float_RSS_MAX** | **0.03** | rss tail tap limit |
| **N_tail_start** | **25** | (UI) start of tail taps limit |
| **ICN parameters** | | |
| f_v | 0.723 | *Fb |
| f_f | 0.723 | *Fb |
| f_n | 0.723 | *Fb |
| f_2 | 39.844 | GHz |
| A_ft | 0.600 | V |
| **A_nt** | **0.600** | V |
| heck_3ck_03b_0319 | **Adopted Mar 2019** | **kasapi_3ck_02_1119** |
| **walker_3ck_01d_0719** | **Adopted July 2019** | **Adopted Nov 2019** |
| **result of R_d=50** | | under consideration |
| **benartsi_3ck_01a_0719** | **no used for KR** | |
| **mellitz_3ck_03_0919** | | |

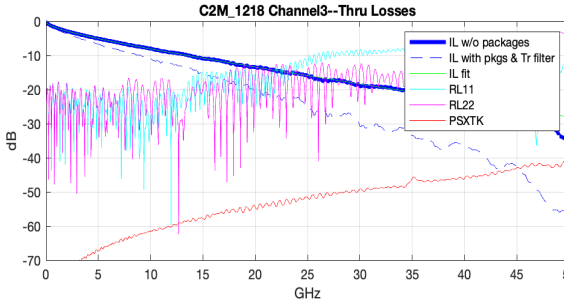
# Lim C2C Channels

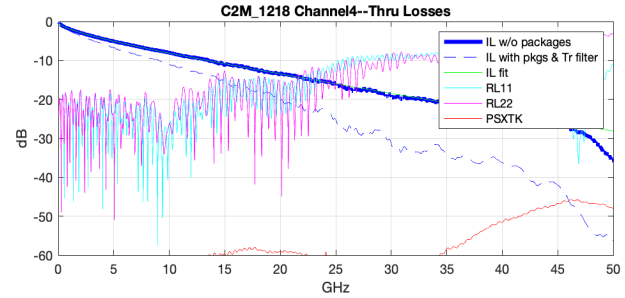
- **Total of 4 channels were built with optimized host ASIC, retimer & mezzanine connector footprint (shallow via breakout). Both shallow and long via are considered at connector and retimer footprint.**
  - Channel 1: ASIC BGA footprint (mid via – L17) TX + host trace 7” + Mezzanine footprint & connector (shallow via breakout) + daughtercard trace 4” + Retimer footprint (shallow via) ; including 2 FEXT & 2 NEXT
  - Channel 2: ASIC BGA footprint (mid via – L17) TX + host trace 7” + Mezzanine footprint & connector (shallow via breakout) + daughtercard trace 4” + Retimer footprint (long via); including 2 FEXT & 2 NEXT
  - Channel 3: ASIC BGA footprint (mid via – L17) TX + host trace 7” + Mezzanine footprint & connector (long via breakout) + daughtercard trace 4” + Retimer footprint (shallow via) ; including 2 FEXT & 2 NEXT
  - Channel 4: ASIC BGA footprint (mid via – L17) TX + host trace 7” + Mezzanine footprint & connector (long via breakout) + daughtercard trace 4” + Retimer footprint (long via) ; including 2 FEXT & 2 NEXT
  - http://www.ieee802.org/3/ck/public/tools/c2c/lim_3ck_05_0719_c2c.zip.

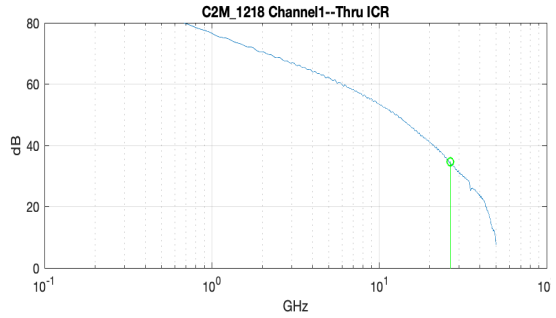
# Lim C2C Channels

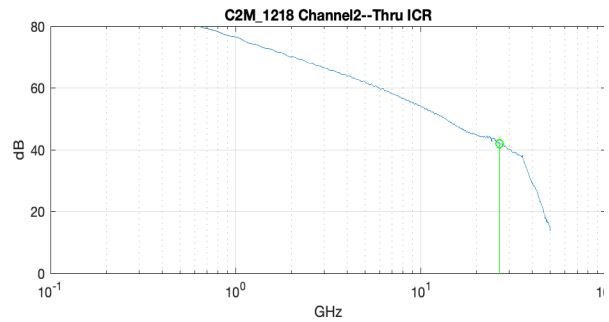


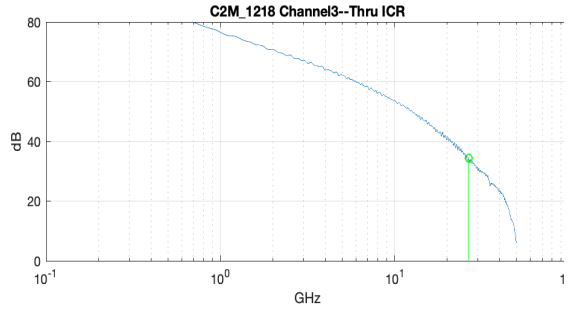



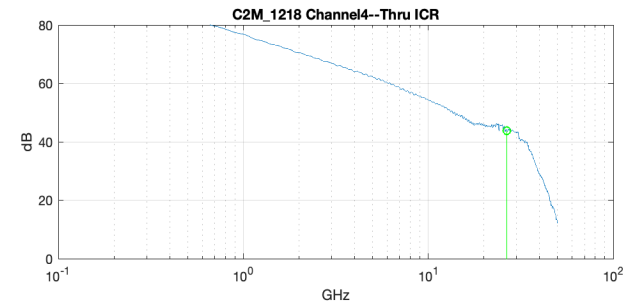



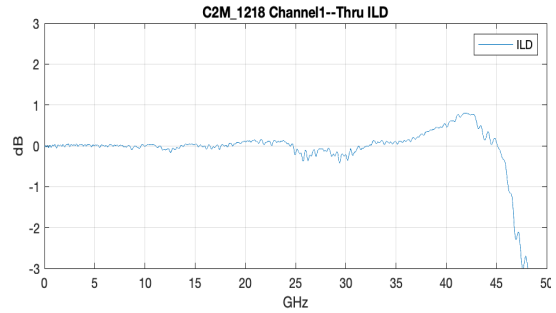



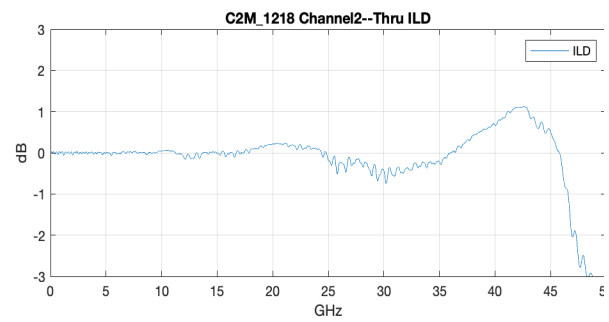



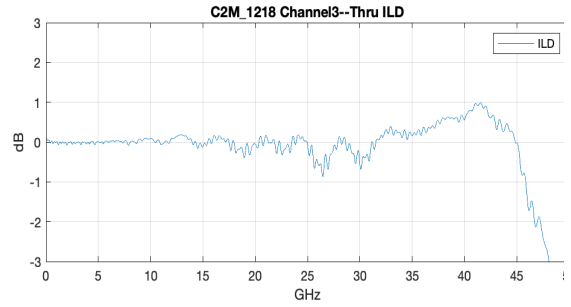



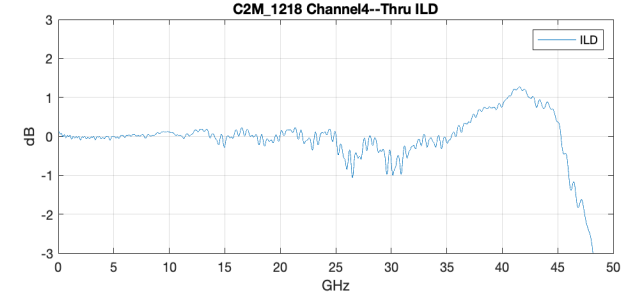



# COM Summary Lim C2C Channel 1

| Lim C2C Channel 1 | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 16.6 | 24.7 | 18.4/17.4 | 0.06 | 1.87 | 3.9 | 3.5 |
| Package [13,11] mm | 5T | 16.6 | 24.0 | 18.4/17.4 | 0.06 | 1.87 | 4.9 | 4.4 |
| Package [13,13] mm | 5T | 16.6 | 25.4 | 18.4/17.4 | 0.06 | 1.87 | 2.3 | 1.9 |
| Package [13,29] mm | 5T | 16.6 | 26.7 | 18.4/17.4 | 0.06 | 1.87 | 3.8 | 3.7 |
| Package [31,29] mm | 5T | 16.6 | 27.9 | 18.4/17.4 | 0.06 | 1.87 | 5.2 | 5.0 |
| Package [13,7] mm | 12T | 16.6 | 24.7 | 18.4/17.4 | 0.06 | 1.87 | 6.4 | 6.4 |
| Package [13,11] mm | 12T | 16.6 | 24.0 | 18.4/17.4 | 0.06 | 1.87 | 6.5 | 6.3 |
| Package [13,13] mm | 12T | 16.6 | 25.4 | 18.4/17.4 | 0.06 | 1.87 | 6.2 | 6.1 |
| Package [13,29] mm | 12T | 16.6 | 26.7 | 18.4/17.4 | 0.06 | 1.87 | 5.9 | 5.7 |
| Package [31,29] mm | 12T | 16.6 | 27.9 | 18.4/17.4 | 0.06 | 1.87 | 5.6 | 5.4 |
| Package [13,7] mm | 3T+2T Float 12 UI | 16.6 | 24.7 | 18.4/17.4 | 0.06 | 1.87 | 4.1 | 3.7 |
| Package [13,11] mm | 3T+2T Float 12 UI | 16.6 | 24.0 | 18.4/17.4 | 0.06 | 1.87 | 5.6 | 5.4 |
| Package [13,13] mm | 3T+2T Float 12 UI | 16.6 | 25.4 | 18.4/17.4 | 0.06 | 1.87 | 4.1 | 4.0 |
| Package [13,29] mm | 3T+2T Float 12 UI | 16.6 | 26.7 | 18.4/17.4 | 0.06 | 1.87 | 4.6 | 4.5 |
| Package [31,29] mm | 3T+2T Float 12 UI | 16.6 | 27.9 | 18.4/17.4 | 0.06 | 1.87 | 5.2 | 5.0 |

# COM Summary Lim C2C Channel 2

| Lim C2C Channel 1 | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 16.9 | 26.5 | 18.4/16.2 | 0.095 | 1.34 | 3.9 | 3.3 |
| Package [13,11] mm | 5T | 16.9 | 25.1 | 18.4/16.2 | 0.095 | 1.34 | 5.6 | 5.1 |
| Package [13,13] mm | 5T | 16.9 | 27.1 | 18.4/16.2 | 0.095 | 1.34 | 2.2 | 1.8 |
| Package [13,29] mm | 5T | 16.9 | 28.4 | 18.4/16.2 | 0.095 | 1.34 | 3.5 | 3.4 |
| Package [31,29] mm | 5T | 16.9 | 29.4 | 18.4/16.2 | 0.095 | 1.34 | 5.4 | 5.2 |
| Package [13,7] mm | 12T | 16.9 | 26.5 | 18.4/16.2 | 0.095 | 1.34 | 6.8 | 6.4 |
| Package [13,11] mm | 12T | 16.9 | 25.1 | 18.4/16.2 | 0.095 | 1.34 | 6.8 | 6.9 |
| Package [13,13] mm | 12T | 16.9 | 27.1 | 18.4/16.2 | 0.095 | 1.34 | 6.5 | 6.3 |
| Package [13,29] mm | 12T | 16.9 | 28.4 | 18.4/16.2 | 0.095 | 1.34 | 6.1 | 5.9 |
| Package [31,29] mm | 12T | 16.9 | 29.4 | 18.4/16.2 | 0.095 | 1.34 | 5.8 | 5.6 |
| Package [13,7] mm | 3T+2T Float 12 UI | 16.9 | 26.5 | 18.4/16.2 | 0.095 | 1.34 | 3.9 | 3.6 |
| Package [13,11] mm | 3T+2T Float 12 UI | 16.9 | 25.1 | 18.4/16.2 | 0.095 | 1.34 | 5.8 | 5.7 |
| Package [13,13] mm | 3T+2T Float 12 UI | 16.9 | 27.1 | 18.4/16.2 | 0.095 | 1.34 | 4.1 | 4.0 |
| Package [13,29] mm | 3T+2T Float 12 UI | 16.9 | 28.4 | 18.4/16.2 | 0.095 | 1.34 | 4.6 | 4.5 |
| Package [31,29] mm | 3T+2T Float 12 UI | 16.9 | 29.4 | 18.4/16.2 | 0.095 | 1.34 | 5.3 | 5.3 |

# COM Summary Lim C2C Channel 3

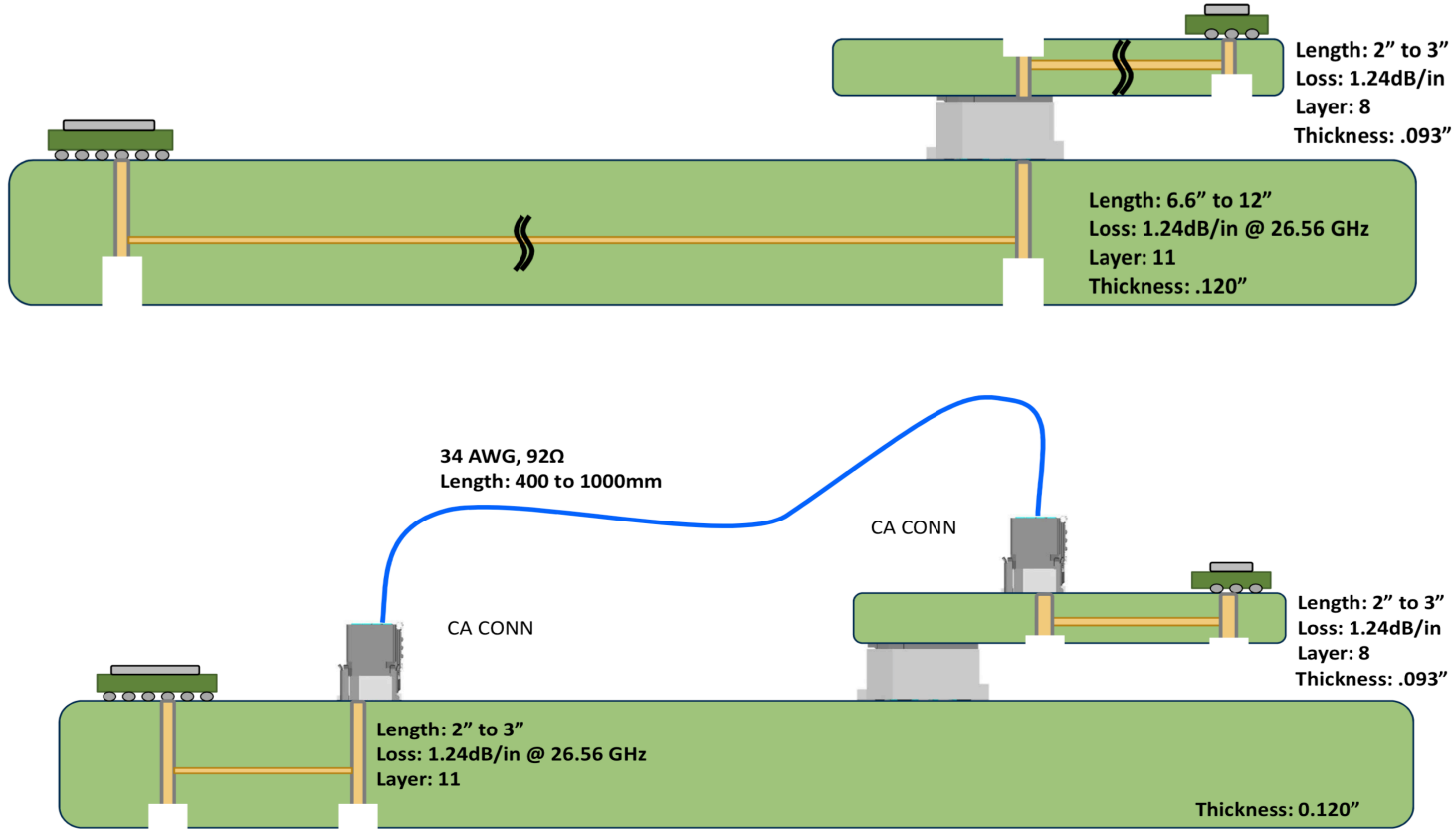
| Lim C2C Channel 1 | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 16.7 | 25.9 | 17.3/15.4 | 0.108 | 1.81 | 3.6 | 3.3 |
| Package [13,11] mm | 5T | 16.6 | 25.3 | 17.3/15.4 | 0.108 | 1.87 | 4.2 | 5.3 |
| Package [13,13] mm | 5T | 16.6 | 26.6 | 17.3/15.4 | 0.108 | 1.87 | 2.3 | 2.0 |
| Package [13,29] mm | 5T | 16.6 | 27.7 | 17.3/15.4 | 0.108 | 1.87 | 3.4 | 4.1 |
| Package [31,29] mm | 5T | 16.6 | 29.0 | 17.3/15.4 | 0.108 | 1.87 | 4.7 | 4.5 |
| Package [13,7] mm | 12T | 16.6 | 24.7 | 17.3/15.4 | 0.108 | 1.87 | 5.7 | 5.6 |
| Package [13,11] mm | 12T | 16.6 | 24.0 | 17.3/15.4 | 0.108 | 1.87 | 5.5 | 5.4 |
| Package [13,13] mm | 12T | 16.6 | 25.4 | 17.3/15.4 | 0.108 | 1.87 | 5.5 | 5.4 |
| Package [13,29] mm | 12T | 16.6 | 26.7 | 17.3/15.4 | 0.108 | 1.87 | 5.1 | 5.0 |
| Package [31,29] mm | 12T | 16.6 | 27.9 | 17.3/15.4 | 0.108 | 1.87 | 5.0 | 4.8 |
| Package [13,7] mm | 3T+2T Float 12 UI | 16.6 | 24.7 | 17.3/15.4 | 0.108 | 1.87 | 3.7 | 3.3 |
| Package [13,11] mm | 3T+2T Float 12 UI | 16.6 | 24.0 | 17.3/15.4 | 0.108 | 1.87 | 4.6 | 4.5 |
| Package [13,13] mm | 3T+2T Float 12 UI | 16.6 | 25.4 | 17.3/15.4 | 0.108 | 1.87 | 3.9 | 2.6 |
| Package [13,29] mm | 3T+2T Float 12 UI | 16.6 | 26.7 | 17.3/15.4 | 0.108 | 1.87 | 4.9 | 4.0 |
| Package [31,29] mm | 3T+2T Float 12 UI | 16.6 | 27.9 | 17.3/15.4 | 0.108 | 1.87 | 4.7 | 4.5 |

# COM Summary Lim C2C Channel 4

| Lim C2C Channel 1 | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 17.8 | 28.2 | 17.1/14.4 | 0.125 | 1.18 | 3.8 | 3.3 |
| Package [13,11] mm | 5T | 17.8 | 26.6 | 17.1/14.4 | 0.125 | 1.18 | 5.0 | 4.6 |
| Package [13,13] mm | 5T | 17.8 | 28.8 | 17.1/14.4 | 0.125 | 1.18 | 2.3 | 1.9 |
| Package [13,29] mm | 5T | 17.8 | 30.0 | 17.1/14.4 | 0.125 | 1.18 | 3.4 | 3.3 |
| Package [31,29] mm | 5T | 17.8 | 30.9 | 17.1/14.4 | 0.125 | 1.18 | 4.9 | 4.7 |
| Package [13,7] mm | 12T | 17.8 | 28.2 | 17.1/14.4 | 0.125 | 1.18 | 6.1 | 6.0 |
| Package [13,11] mm | 12T | 17.8 | 26.6 | 17.1/14.4 | 0.125 | 1.18 | 6.0 | 5.9 |
| Package [13,13] mm | 12T | 17.8 | 28.8 | 17.1/14.4 | 0.125 | 1.18 | 5.8 | 5.7 |
| Package [13,29] mm | 12T | 17.8 | 30.0 | 17.1/14.4 | 0.125 | 1.18 | 5.3 | 5.2 |
| Package [31,29] mm | 12T | 17.8 | 30.9 | 17.1/14.4 | 0.125 | 1.18 | 5.1 | 4.9 |
| Package [13,7] mm | 3T+2T Float 12 UI | 17.8 | 28.2 | 17.1/14.4 | 0.125 | 1.18 | 3.9 | 3.4 |
| Package [13,11] mm | 3T+2T Float 12 UI | 17.8 | 26.6 | 17.1/14.4 | 0.125 | 1.18 | 5.1 | 4.9 |
| Package [13,13] mm | 3T+2T Float 12 UI | 17.8 | 28.8 | 17.1/14.4 | 0.125 | 1.18 | 3.8 | 3.7 |
| Package [13,29] mm | 3T+2T Float 12 UI | 17.8 | 30.0 | 17.1/14.4 | 0.125 | 1.18 | 4.0 | 3.9 |
| Package [31,29] mm | 3T+2T Float 12 UI | 17.8 | 30.9 | 17.1/14.4 | 0.125 | 1.18 | 4.9 | 4.7 |

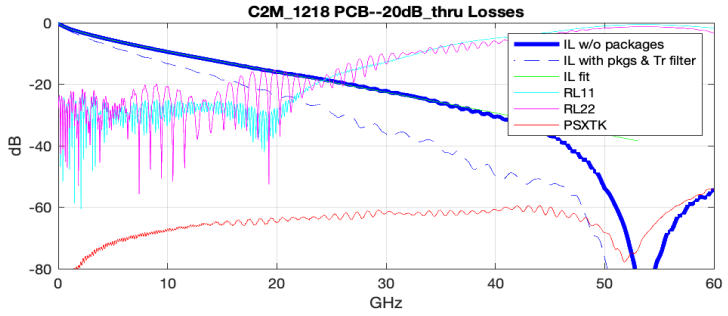
# Gore C2C Channels

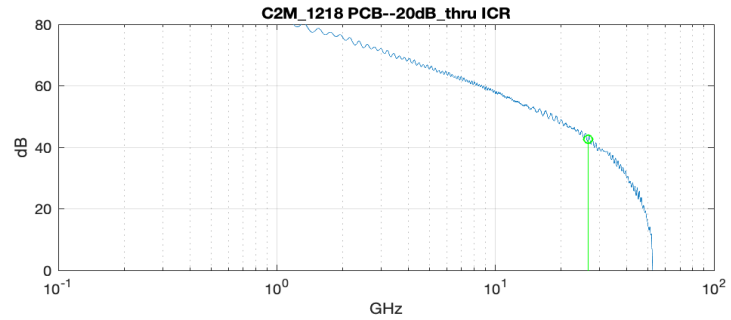
- **Construction of C2C channels based on PCB and cable construction provided by Brandon Gore**
  - http://www.ieee802.org/3/ck/public/19_05/gore_3ck_01a_0519.pdf

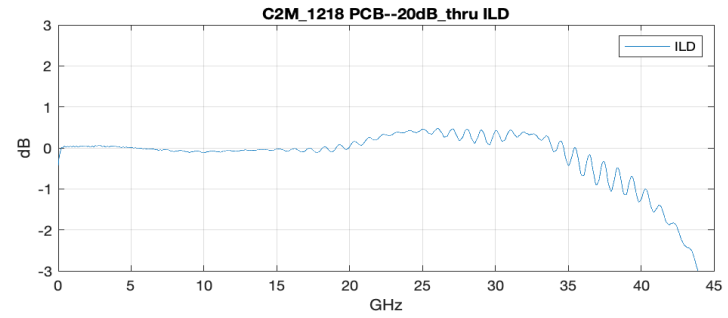


# Gore C2C 20 dB Channels

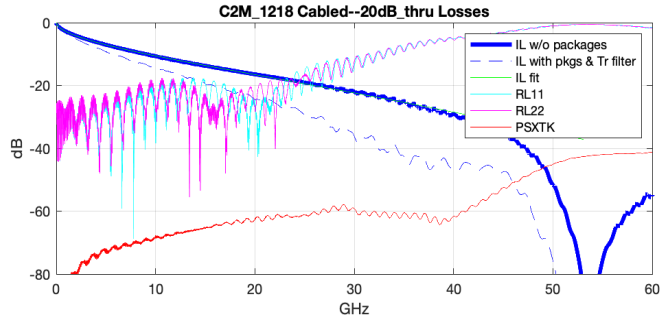
## PCB Channel

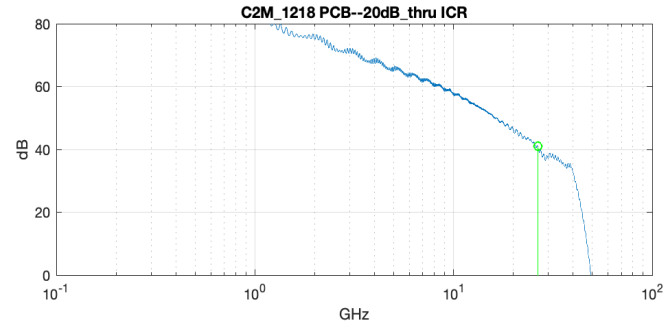


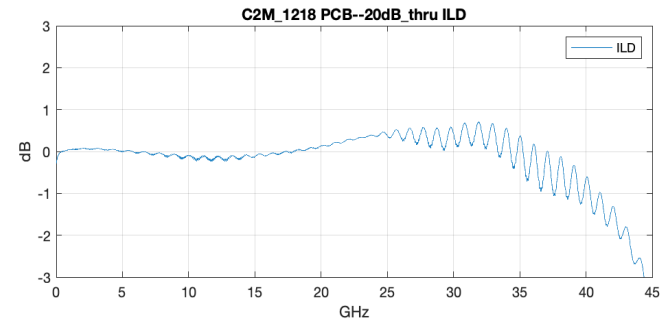




## Cabled Channel



# COM Summary Gore C2C Channels

| 20 dB PCB Channel | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 20.1 | 28.6 | 22.8/15.8 | 0.118 | 0.61 | 4.2 | 3.7 |
| Package [13,11] mm | 5T | 20.1 | 27.5 | 22.8/15.8 | 0.118 | 0.61 | 5.5 | 5.3 |
| Package [13,13] mm | 5T | 20.1 | 29.1 | 22.8/15.8 | 0.118 | 0.61 | 3.6 | 3.2 |
| Package [13,29] mm | 5T | 20.1 | 30.5 | 22.8/15.8 | 0.118 | 0.61 | 4.4 | 4.3 |
| Package [31,29] mm | 5T | 20.1 | 31.7 | 22.8/15.8 | 0.118 | 0.61 | 5.4 | 5.2 |

| 20 dB Cabled Channel | DFE Type | Fitted IL at 26.55 GHz (dB) | Total IL w PKG at 26.55 GHz (dB) | ERL (dB) | FOM ILD | ICN (mV) | COM RD=45 Ω | COM RD=50 Ω |
|---|---|---|---|---|---|---|---|---|
| Package [13,7] mm | 5T | 20.2 | 28.6 | 22.8/15.8 | 0.118 | 0.69 | 4.0 | 3.6 |
| Package [13,11] mm | 5T | 20.2 | 27.7 | 22.8/15.8 | 0.118 | 0.69 | 5.4 | 5.0 |
| Package [13,13] mm | 5T | 20.2 | 29.1 | 22.8/15.8 | 0.118 | 0.69 | 3.0 | 2.7 |
| Package [13,29] mm | 5T | 20.2 | 30.4 | 22.8/15.8 | 0.118 | 0.69 | 4.0 | 3.9 |
| Package [31,29] mm | 5T | 20.2 | 31.7 | 22.8/15.8 | 0.118 | 0.69 | 5.0 | 4.8 |

# Options for C2C Reference Receiver

- **CTLE(14 dB HF, 4 dB LF) + 5T DFE**
  - Sufficient for 20 dB channels but can't support two pathological worst case [13,13] mm packages
  - DFE B1(max) ≤ 0.75, B[2-5] ≤ 0.1
  - Offers lowest power solution and most package combination will meet 3 dB
- **CTLE(14 dB HF, 4 dB LF) + 12T DFE**
  - Can support 20 dB including pathological [13,13] mm packages combinations
  - DFE B1(max) ≤ 0.5, B[2-12] ≤ 0.1
  - 12T DFE power will result in significant added power and overkill for the channel
- **CTLE(14 dB HF, 4 dB LF) + 3T DFE+2T floating DFE with 12 U span**
  - Can support 20 dB including pathological [13,13] mm packages combinations
  - DFE B1(max) ≤ 0.5, B[2-5] ≤ 0.1
  - Will have lower power than 12T DFE and will cancel pathological reflection from [13,13] mm package combination.