Tx and Rx Return Loss Effects in 802.3ap
September 16, 2005
Revised January 11, 2006
Analysis of Current Specification
Xilinx, Inc.

It is shown that the existing return loss specifications for transmitters and receivers can result in excessive attenuation. A channel that satisfies the existing informative Amax requirement, when combined with compliant devices, can produce an overall transfer function that is well below the Amax line.

Notes:

RLC networks are used at the Tx and Rx. Each network is placed between a 50 ohm termination and the device "pins". A given RLC network could represent a package.

The RLC components are chosen to cause a large amount of attenuation. But there is no specific methodology for picking the values or topology. Other RLC circuits might be found that are worse.

There is no attempt to adjust the Tx signal so that it would produce a compliant transmit level into a compliant load.

Procedure:

Convert differential s-parameters to single ended for easier circuit synthesis.

Find RLC circuits that, when combined with a 50 ohm termination, will meet the existing or proposed RL specs.

Build the ADS circuit with the proposed RLC circuits at transmit and receive. Add the S-param block corresponding to the channel. Place a 0.1 ufd AC coupling capacitor at the receiver.

Use ADS to measure the S21 of the full circuit.

Use ADS to verify the S11 of the synthesized Tx and Rx.

First Step: Read in a 4-port S-parameter file, find the mixed-mode S-parameters, and generate 2-port S-parameters (= differential S-parameters).

Reference:C:\units.mcd

Put in MATLAB script to get to current directory:

MATLAB®

CWD = "C:\ieee\rlsynth\"

str2vec(CWD)

Enter the name of the S-parameter file here:

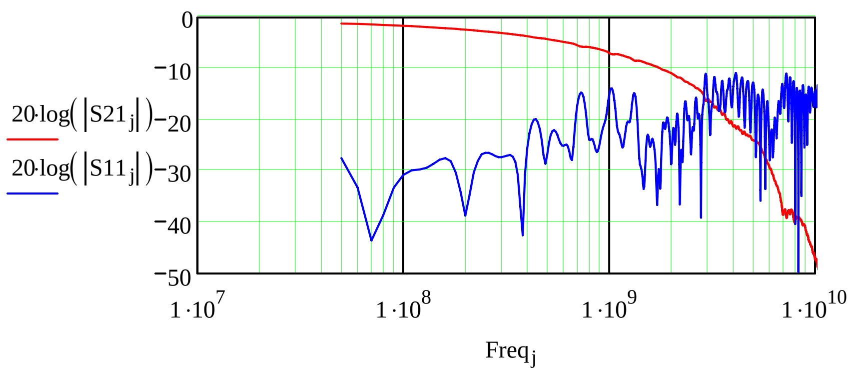
sparam := "Case2FM13SI20TD13L10.s4p"

$$\begin{pmatrix} S21 \\ S11 \\ Freq \end{pmatrix} :=$$

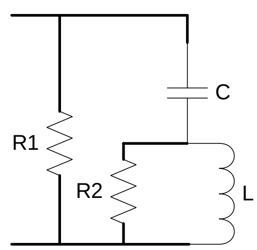
MATLAB®

$j := 0 .. \mathrm{rows}(Freq) - 1$

str2vec(sparam)



Next step: Generate a receiver with RLC network that meets RL spec and has max attenuation. RL spec is limit line shown below.



At Low Freq:

$$\rho rx := 10^{\frac{-10.2}{20}}$$

$$Rinrx := \frac{1 - \rho rx}{1 + \rho rx} \cdot 50 \quad Rinrx = 26.392 \qquad 20 \cdot \log\left(\left|\frac{Rinrx - 50}{Rinrx + 50}\right|\right) = -10.2$$ Verify

$$R1 := \frac{1}{\frac{1}{Rinrx} - \frac{1}{50}} \quad R1 = 55.898$$

Find parallel R needed.

$$\mathrm{Zinrx}(C,L,R2,s) := \frac{1}{\frac{1}{R1}+\frac{1}{50}+\frac{1}{\frac{1}{s\cdot C}+\frac{s\cdot L\cdot R2}{s\cdot L+R2}}}$$

Trial values:

$\mathrm{Cinrx} := 0.85\mathrm{pF}$

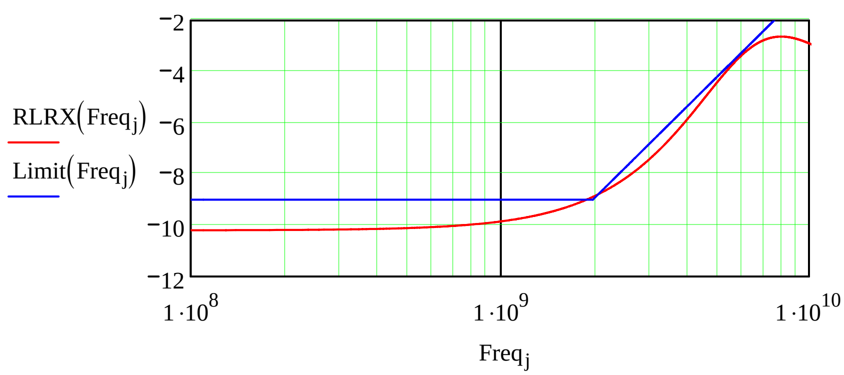
$\mathrm{Linrx} := 0.4\mathrm{nH}$

$\mathrm{Rrx} := 35$

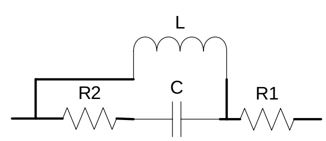
$$\mathrm{RL}(C,L,R2,f) := 20\cdot\log\left(\left|\frac{\mathrm{Zinrx}(C,L,R2,\mathrm{jtwopi}\cdot f)-50}{\mathrm{Zinrx}(C,L,R2,\mathrm{jtwopi}\cdot f)+50}\right|\right)$$

$\mathrm{RL}(\mathrm{Cinrx},\mathrm{Linrx},\mathrm{Rrx},5\mathrm{GHz}) = -4.474$ $\qquad$ $\mathrm{RLRX}(f) := \mathrm{RL}(\mathrm{Cinrx},\mathrm{Linrx},\mathrm{Rrx},f)$

$$\mathrm{Limit}(f) := \mathrm{if}\left(f < 2\mathrm{GHz}, -9, 11.947\cdot\log\left(\frac{f}{2\mathrm{GHz}}\right)-9\right)$$



Next step: Generate a transmitter with series RLC network that meets RL spec and has max attenuation. RL spec is limit line shown below.



At Low Freq:

$$\rho tx := 10^{\frac{-10.2}{20}}$$

$\mathrm{Rintx} := \frac{1+\rho tx}{1-\rho tx}\cdot 50$ $\qquad$ $\mathrm{Rintx} = 94.724$ $\qquad$ $20\cdot\log\left(\left|\frac{\mathrm{Rintx}-50}{\mathrm{Rintx}+50}\right|\right) = -10.2$

$\mathrm{R1tx} := \mathrm{Rintx} - 50$ $\qquad$ $\mathrm{R1tx} = 44.724$

$$\mathrm{Zintx}(C,L,R2,s) := 50 + \mathrm{R1tx} + \frac{1}{\dfrac{1}{s\cdot L} + \dfrac{1}{R2 + \dfrac{1}{s\cdot C}}}$$

Trial values:

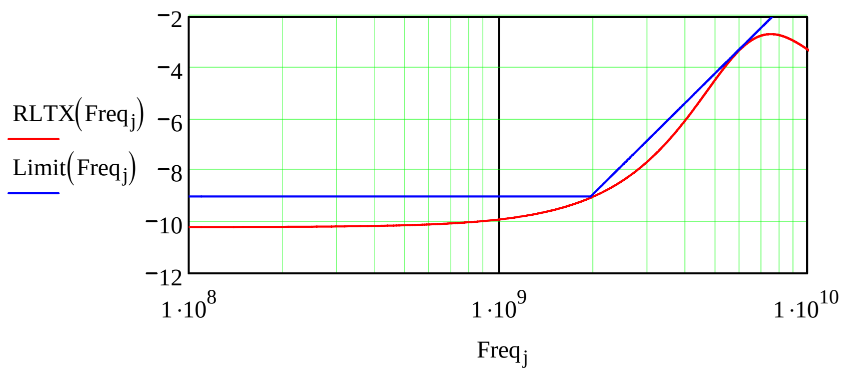
$\mathrm{Ltx} := 1.95\mathrm{nH}$

$\mathrm{Ctx} := 0.2\mathrm{pF}$

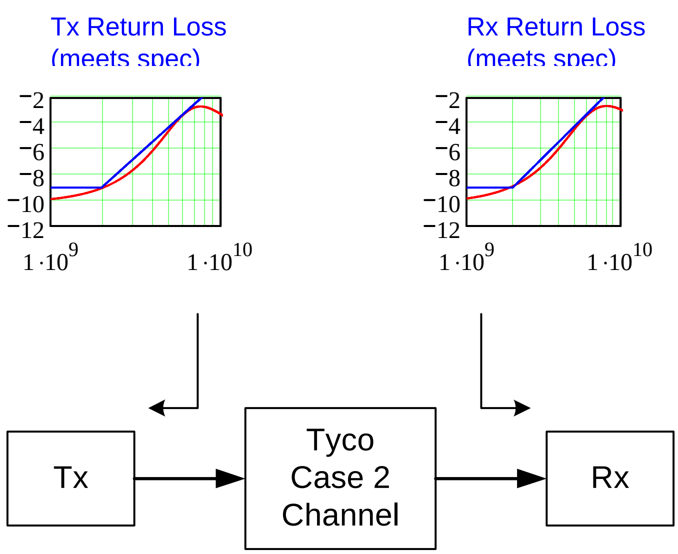
$\mathrm{Rtx} := 50$

$$\mathrm{RLtx}(C,L,R2,f) := 20\log\left(\left|\frac{\mathrm{Zintx}(C,L,R2,\mathrm{jtwopi}\cdot f) - 50}{\mathrm{Zintx}(C,L,R2,\mathrm{jtwopi}\cdot f) + 50}\right|\right)$$

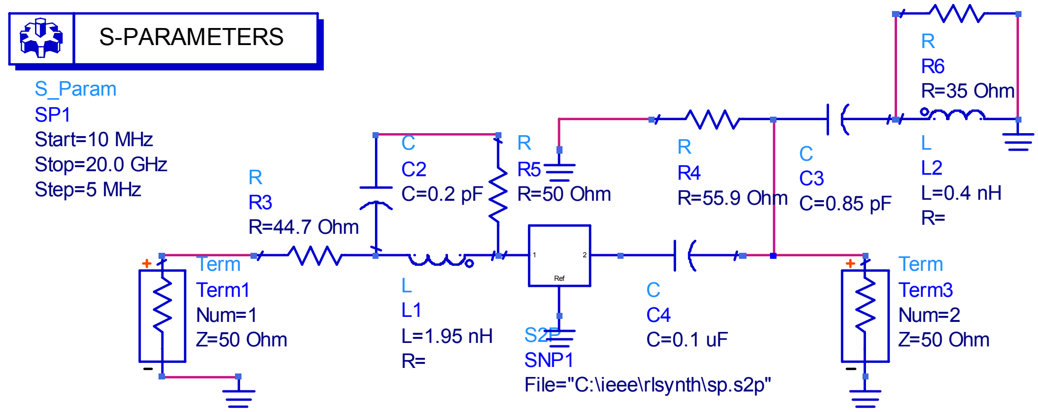
$\mathrm{RLTX}(f) := \mathrm{RLtx}(\mathrm{Ctx},\mathrm{Ltx},\mathrm{Rtx},f)$ $\quad\quad$ $\mathrm{RLTX}(5\mathrm{GHz}) = -4.522$



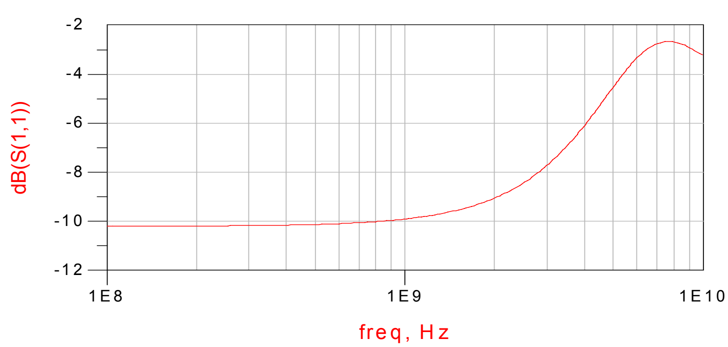
Procedure: Worst Case Tx and Rx Devices were synthesized. These were connected to the Tyco Case 2 channel as shown below. RLC networks are used at both Tx and Rx to create the Return Loss.



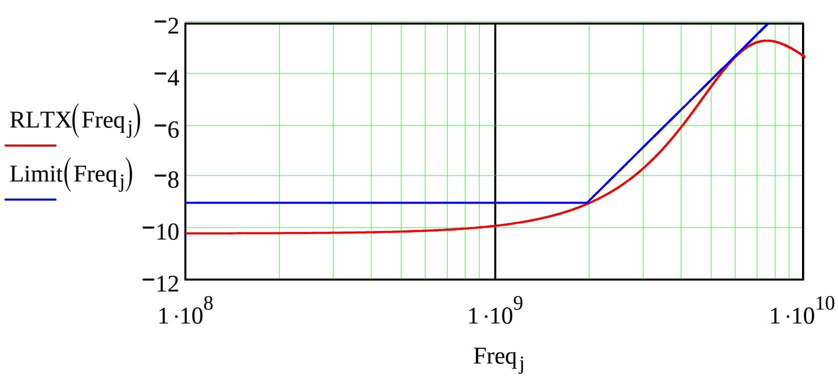
Show the ADS circuit:



Check RL of Tx with ADS:



ADS



Calculated Above

Generate IEEE Attenuation Curve

$b1 := 2.25 \cdot 10^{-5}$ $b2 := 1.2 \cdot 10^{-10}$ $b3 := 3.5 \cdot 10^{-20}$ $b4 := -1.25 \cdot 10^{-30}$

$$\mathrm{Atten}(f) := -20 \cdot \log(\exp(1)) \cdot \left(b1 \cdot \sqrt{f} + b2 \cdot f + b3 \cdot f^{2} + b4 \cdot f^{3}\right)$$

Read in the file of channel-only S21.

S21_noRL := chan_alone.txt

$kk := 0 .. 1999$

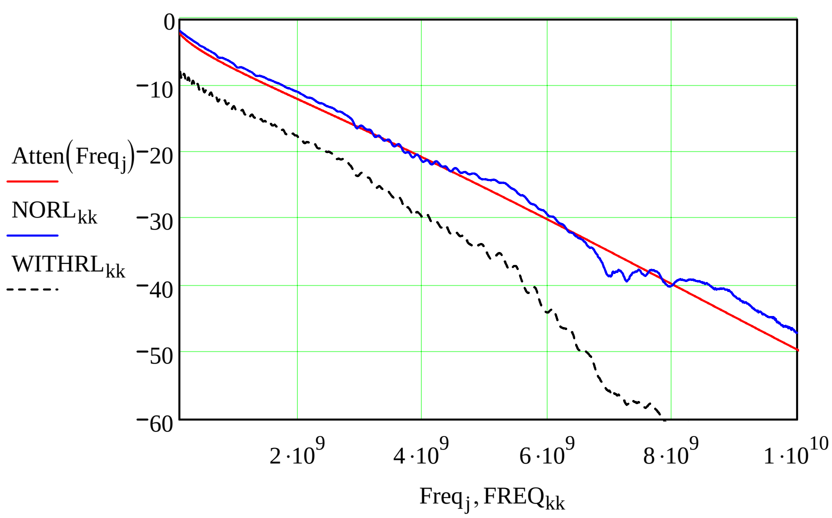
$NORL_{kk} := S21\_noRL_{kk,1}$ $FREQ_{kk} := S21\_noRL_{kk,0}$

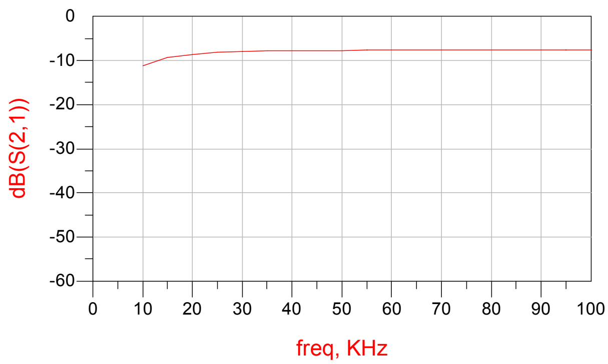
Read in file of S21 with return loss.

S21_withRL := with_rl.txt

$WITHRL_{kk} := S21\_withRL_{kk,1}$

The following graph shows the IEEE Amax line (red); the Tyco Case 2 end-to-end Attenuation with Tx, Rx devices having good Return Loss (blue), and the Tyco Case 2 end-to-end Attenuation with Tx, Rx devices that have poor (but compliant) Return Loss (dotted black). The poor Return Loss causes about an extra 12 dB of attenuation at Nyquist frequency, making it increasingly difficult to transmit across the channel. Analyses were done using ADS.





Low frequency
S21 behavior.
Drops off because
of capacitive
coupling at Rx.