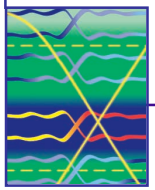
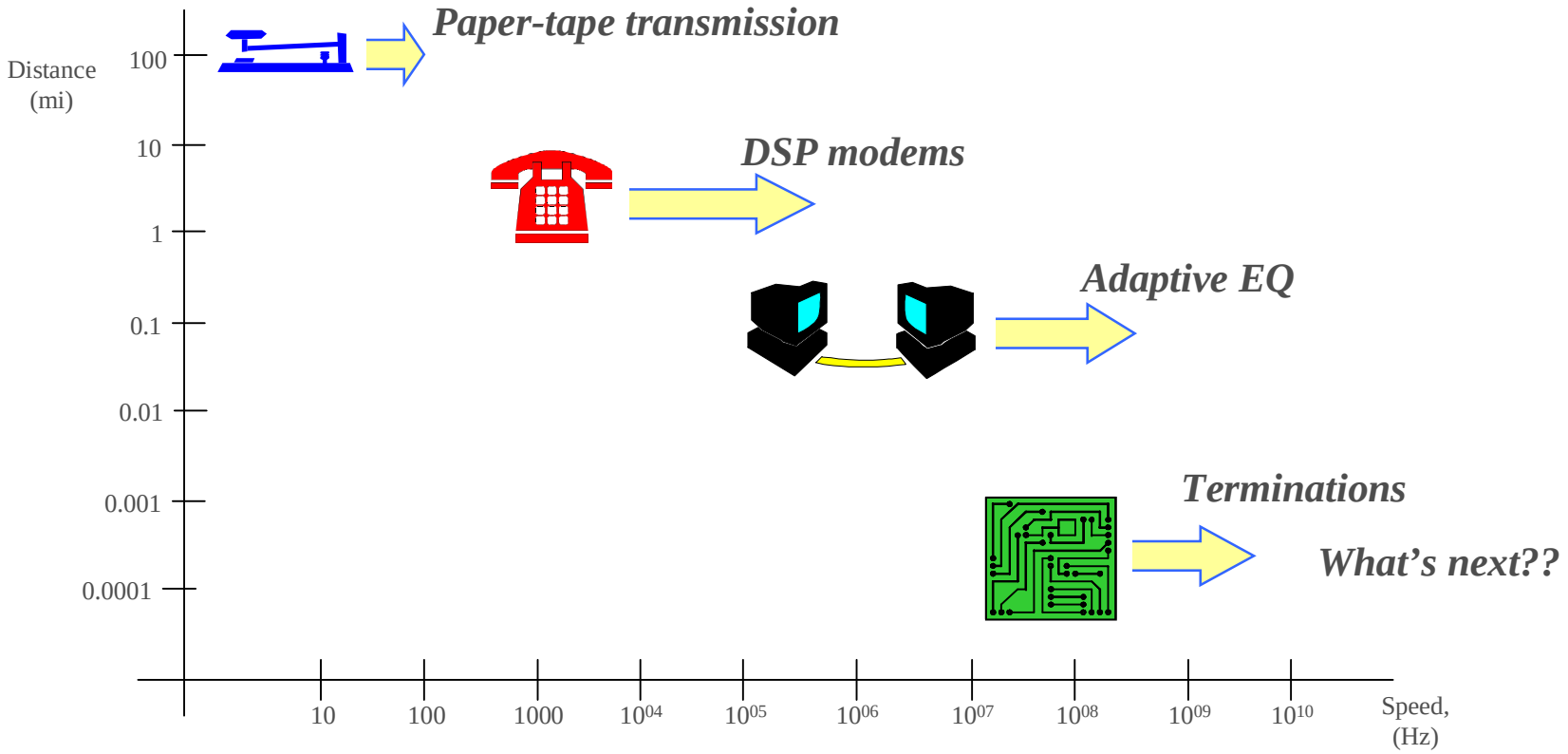
Multi-Level Signaling

High-Performance Backplanes: Where Are They Headed?

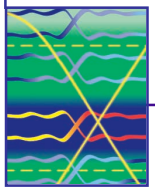
DesignCon 2000
Santa Clara, CA
February 1, 2000



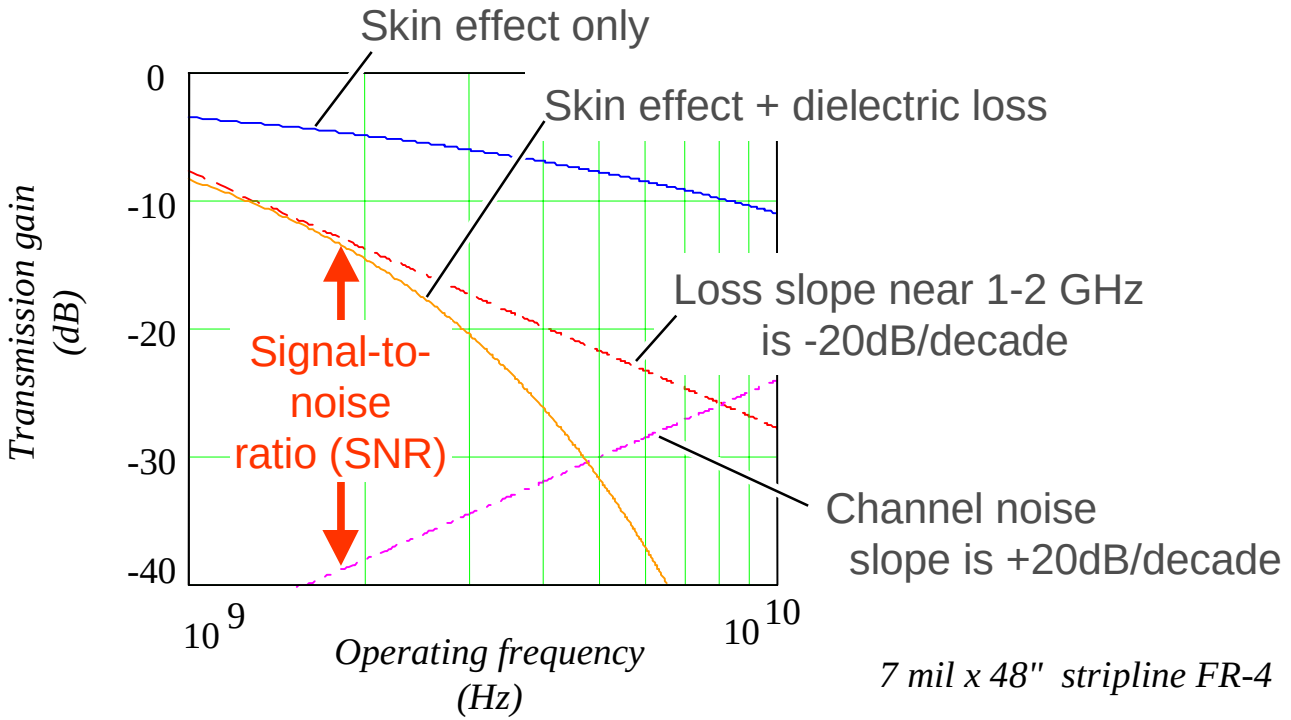
Performance Improves with Time



Simple implementations of each technology initially fall on the basic speed-distance curve. Over time, the development of additional end-unit circuitry always improves performance.



PCB Channel Characteristics (48 in. Trace)

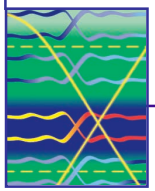


7 mil x 48" stripline FR-4 loss tan=0.02

Channel losses are dominated by skin effect and dielectric loss

Channel noise is dominated by crosstalk in connectors, packages, and PCB

SNR near 1-2 GHz deteriorates at 40 dB/decade



Multi-Amplitude Signaling (MAS) Concept

IF your circuits could go as fast as you wanted, and

IF complexity were free, and

IF your SNR slope is at least -40 dB/decade or worse,

THEN try multi-level signaling

B = number of informational bits carried per baud

f/B = new signaling rate (where f is the old rate)

$N = 2^B$ number of levels

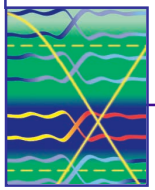
$1/(N\text{-}1) = 1/(2^B\text{-}1)$ = reduction in spacing between levels

simplistic model - things might not be this bad

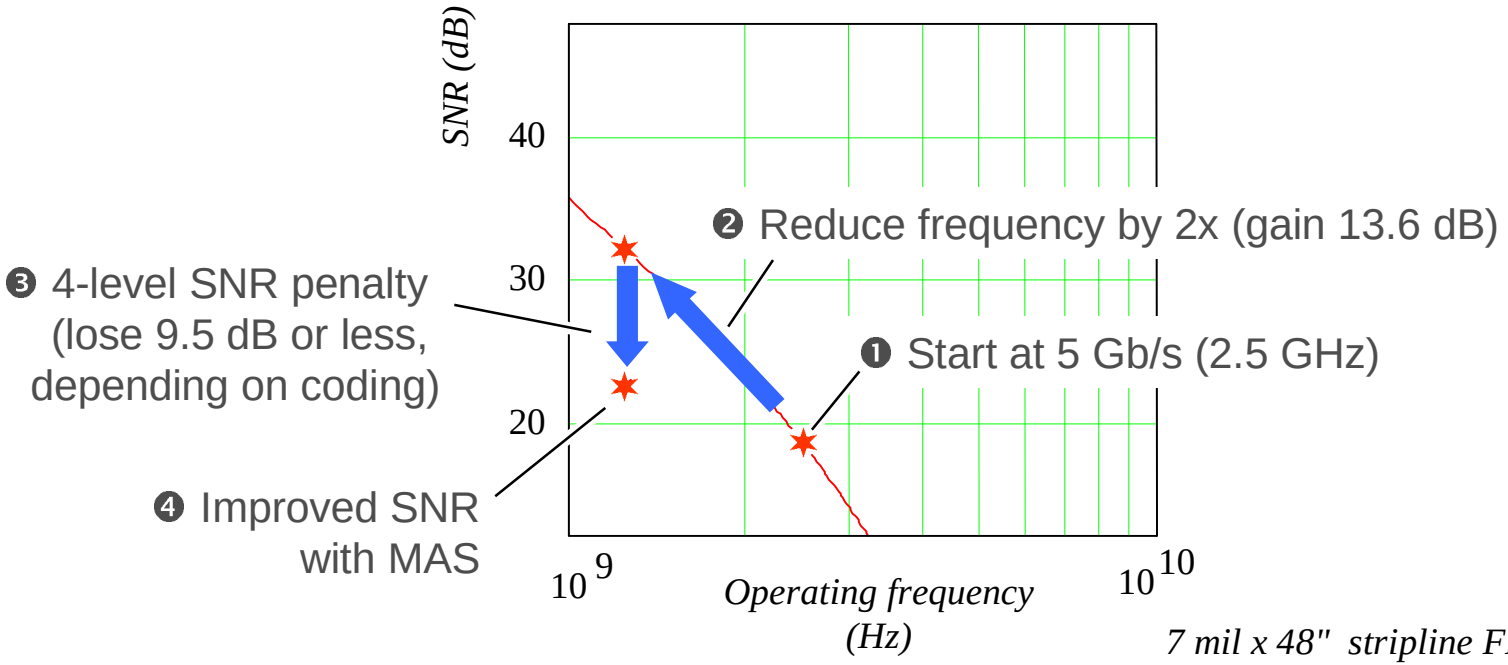
What you GAIN by reduction in baud rate: $\log(B)*(\text{SNR slope})$

Exceeds what you LOSE by reduced level-spacing: $20*\log(2^B\text{-}1)$

With a large enough SNR slope you always GAIN more than you LOSE

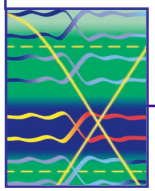


Example at 5 Gb/s



7 mil x 48" stripline FR-4 loss tan=0.02

When the SNR slope exceeds -40 dB/decade at the operating frequency, 4-level signaling is almost always superior.



MAS Architecture

What's required to actually do MAS

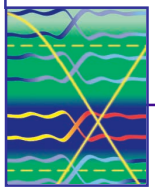
- Multi-level transmitter
- Multiple receiver thresholds

To make it work in the practical world you will also need...

- Adaptive thresholds

While you're doing that, you might as well add...

- Adaptive equalization - to fix problems with channel pulse response
- Scrambled line coding - to fix problems with EMI



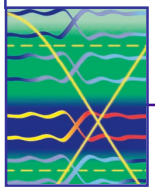
Is It Possible?

MAS is Already in Common Use

- Telephone analog modems - to 56 Kb/s
- Telephone DSL modems - to 1.5 Mb/s
- Gigabit Ethernet - to 1000 Mb/s

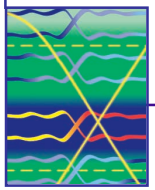
The technology to do high-speed multiple-amplitude signaling exists today

The first PCB applications will be large backplanes with substantial dielectric loss

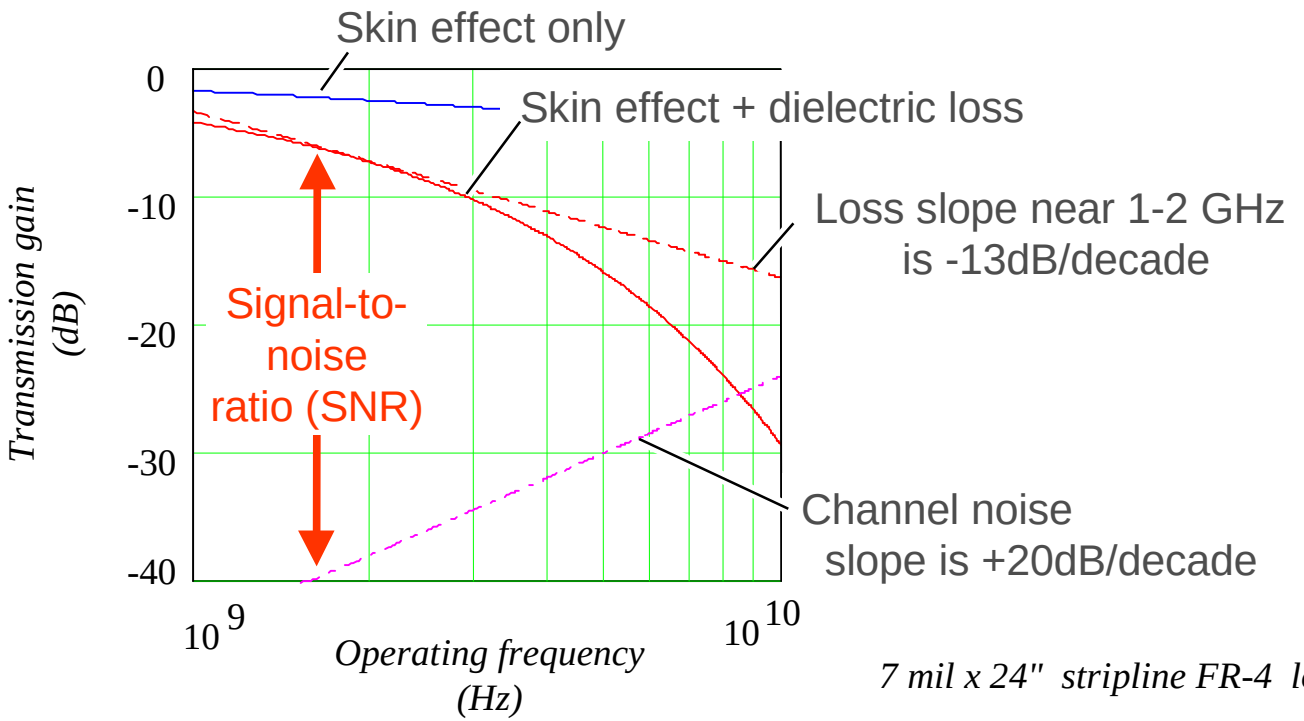


MAS

Coming soon to a backplane near you

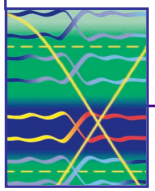


PCB Channel Characteristics (24-in. Trace)

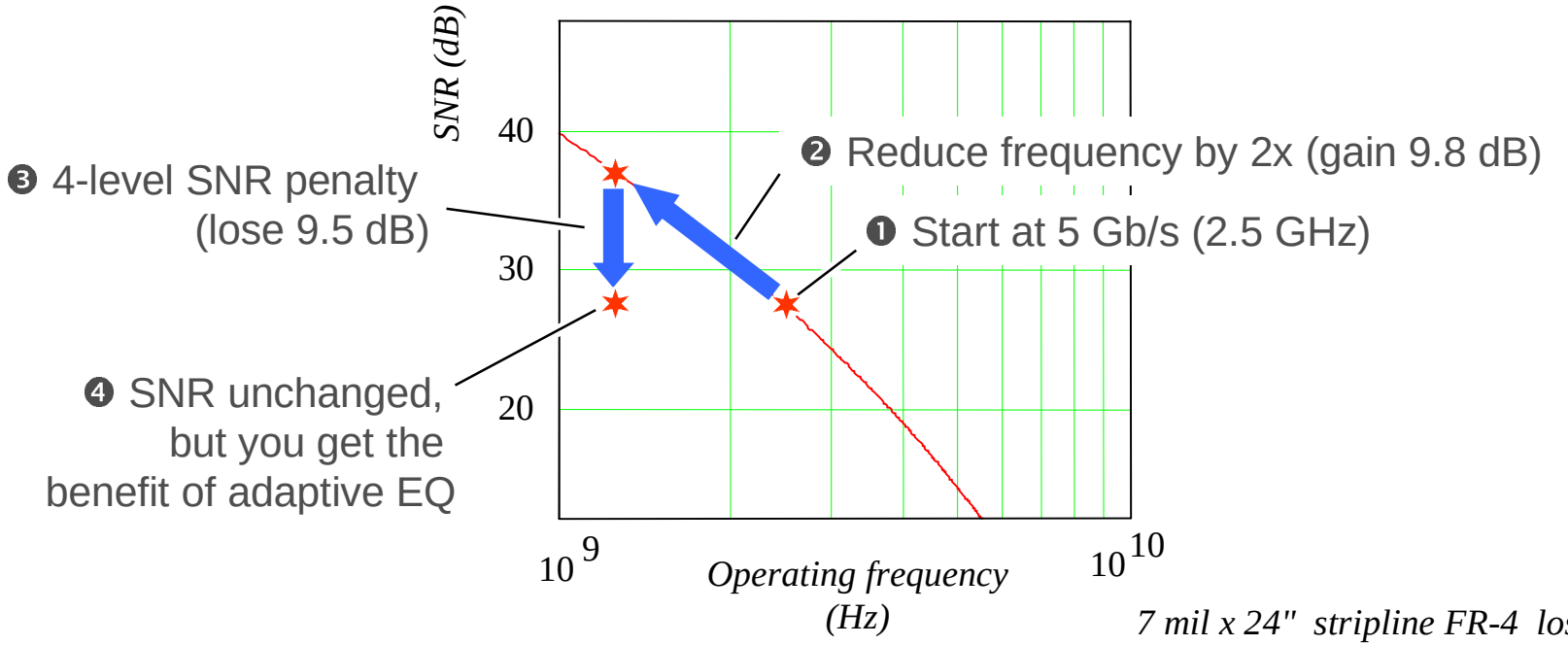


7 mil x 24" stripline FR-4 loss tan=0.02

A 24-in. trace has a loss slope of only -13 dB at 2 GHz.

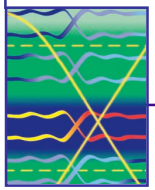


MAS (24-in. Trace)

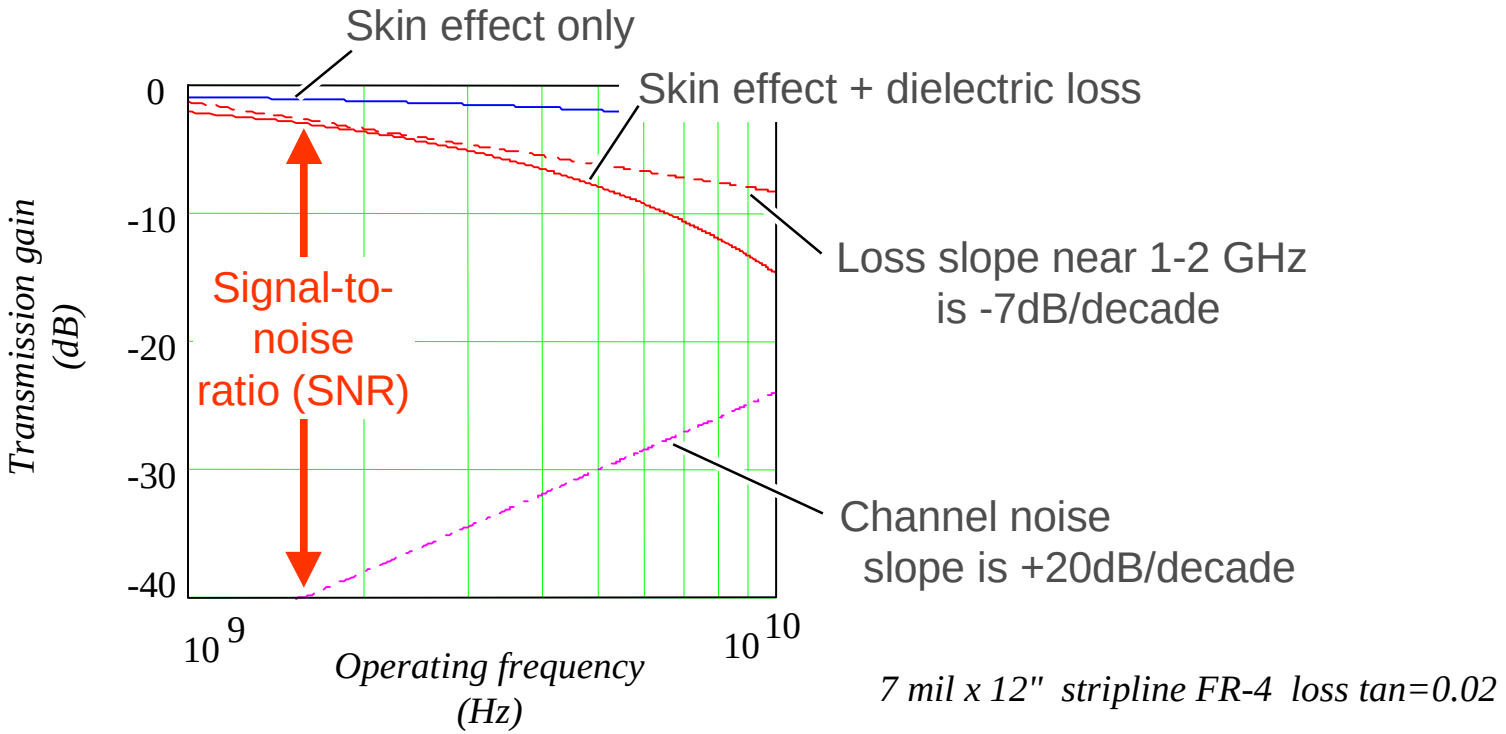


7 mil x 24" stripline FR-4 loss tan=0.02

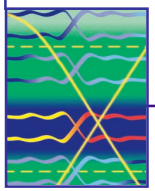
The SNR of this 24-in. trace is unchanged, but the MAS adaptive equalization circuitry will square up the eye opening which helps with clock recovery and immunity to transmission-line imperfections.



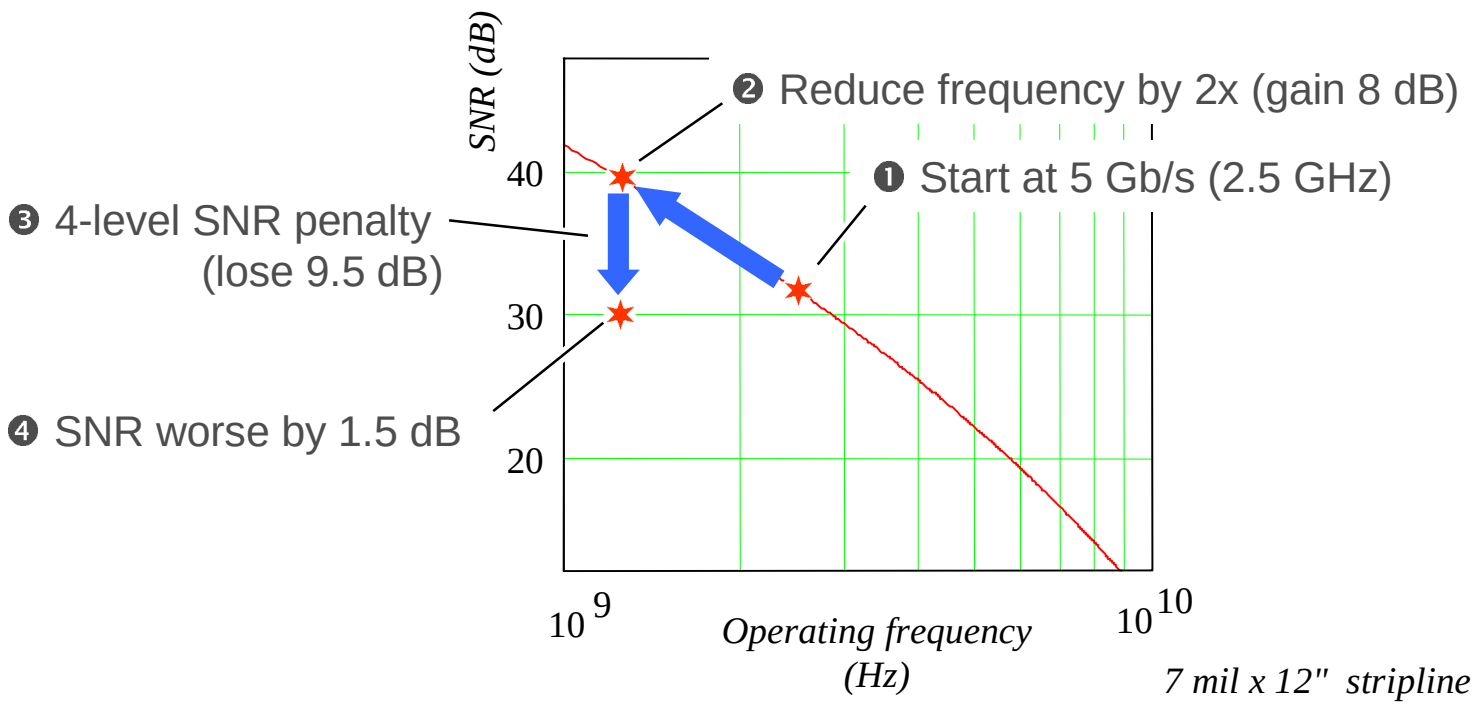
PCB Channel Characteristics (12-in. Trace)



A 12-in. trace has a loss slope of only -7 dB at 2 GHz.



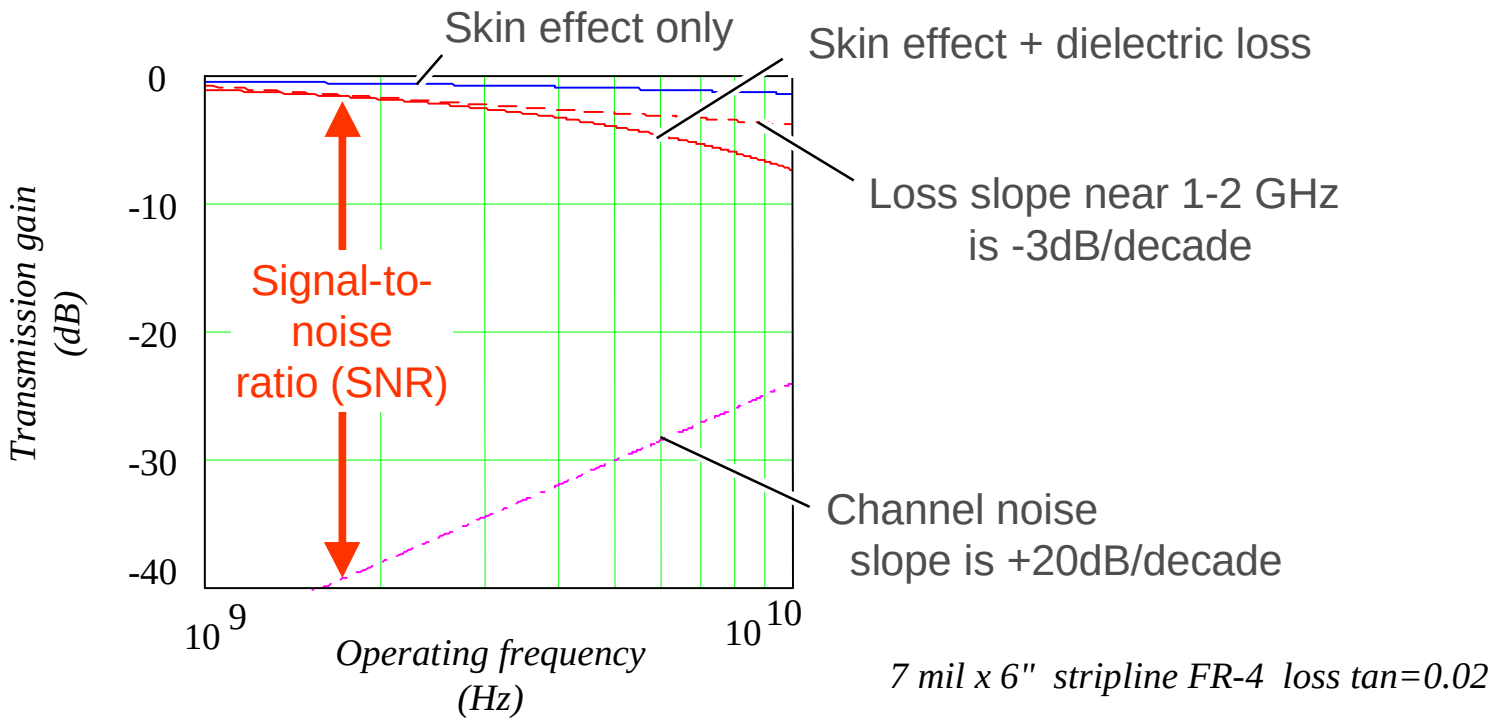
MAS (12-in. Trace)



7 mil x 12" stripline FR-4 loss tan=0.02

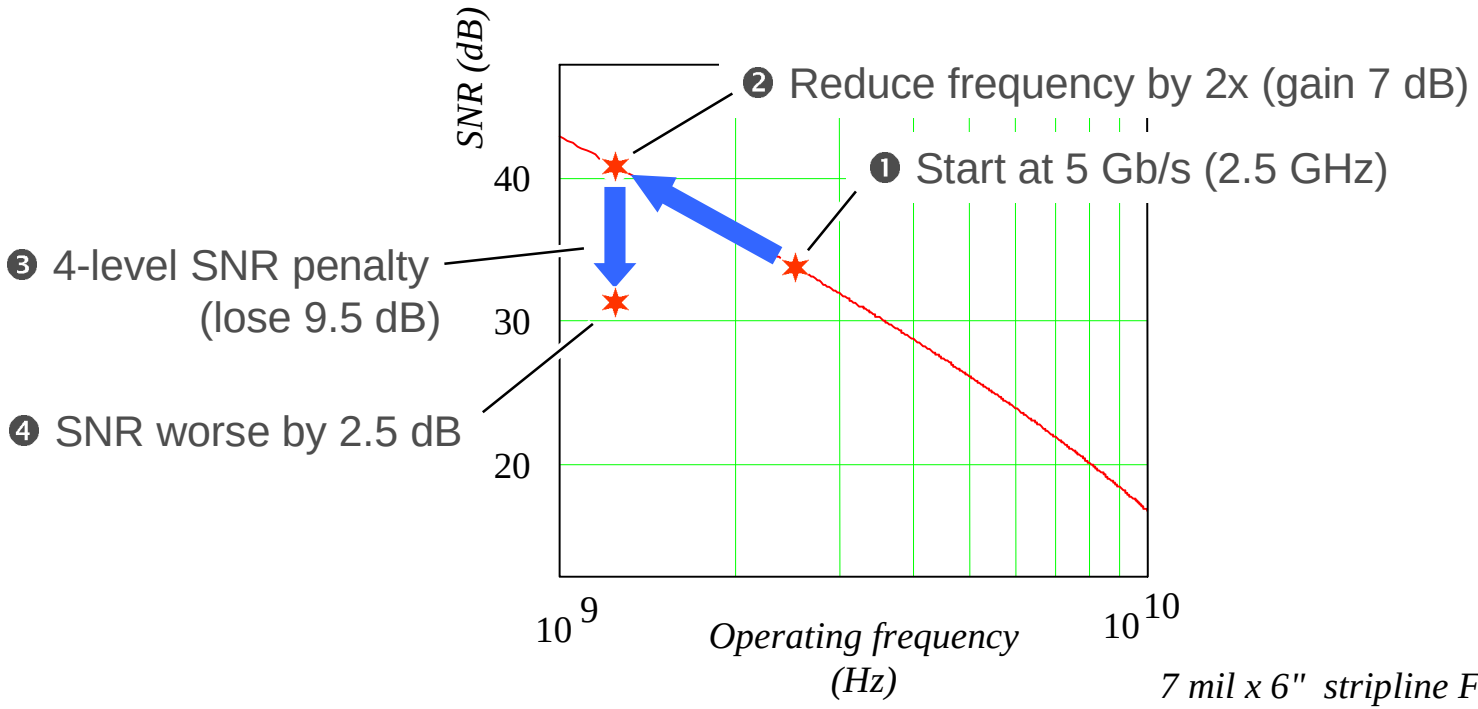
MAS won't help this trace at 5 Gb/s, however, at higher speeds where the loss slope increases MAS again becomes useful.

PCB Channel Characteristics (6-in. Trace)



A 6-in. trace has a loss slope of only -3 dB at 2 GHz.

MAS (6-in. Trace)



7 mil x 6" stripline FR-4 loss tan=0.02

MAS won't help this trace at 5 Gb/s, however, at higher speeds where the loss slope increases MAS again becomes useful.