XAUI
Compliance Channel

Phase Response Specification

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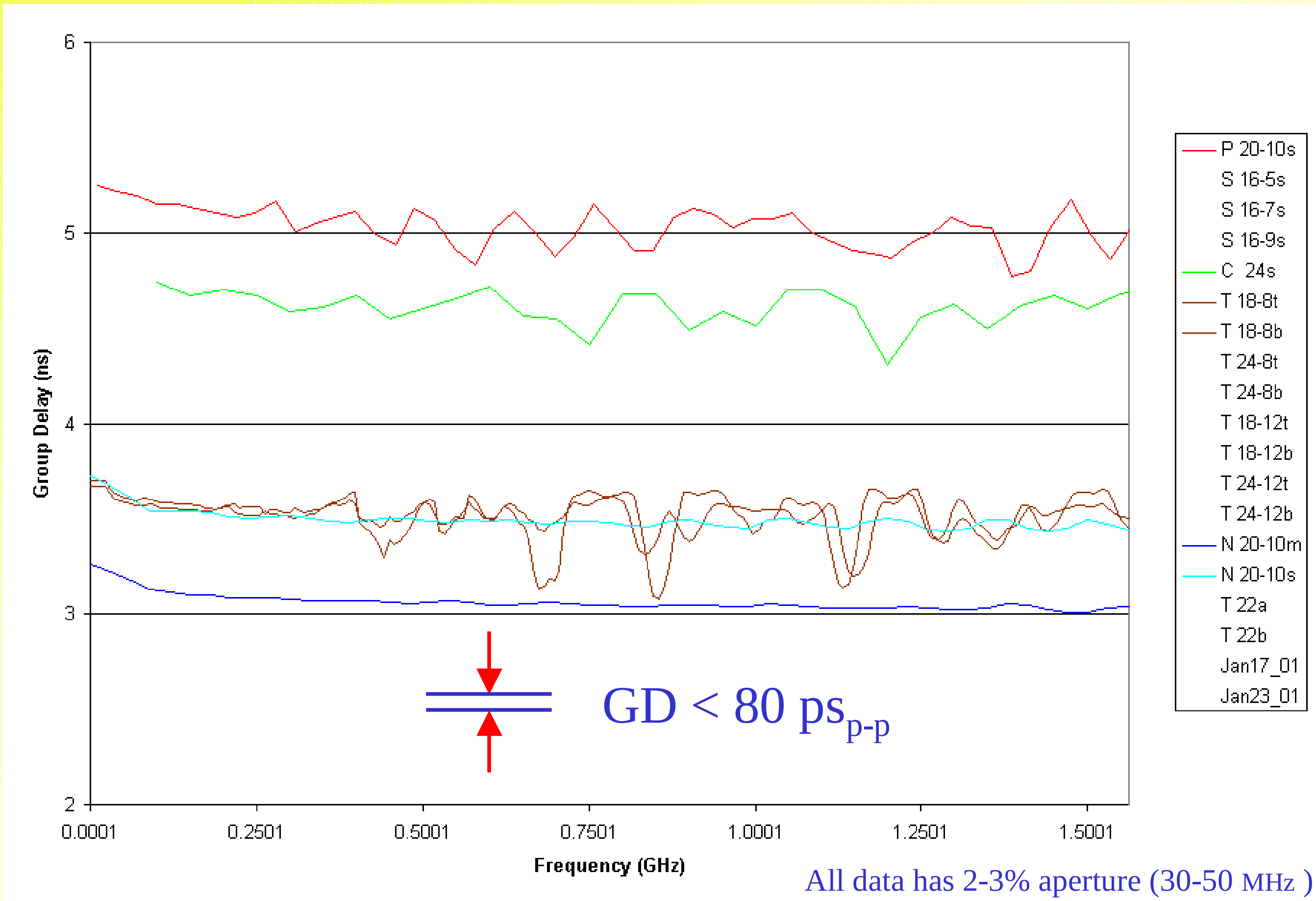
The Problem with Group Delay

The GD requirement is not met by any measured channel



Data contributed by Cisco, Intel, PMC, National and Tyco

The Real Problem with Group Delay

Linear phase $v(t) = A \sin(\omega [t - T_d])$

$\phi_{lin} = \omega T_d$

Non-linear phase $v(t) = A \sin(\omega [t - t_d(\omega)])$

$\phi = \omega t_d(\omega)$

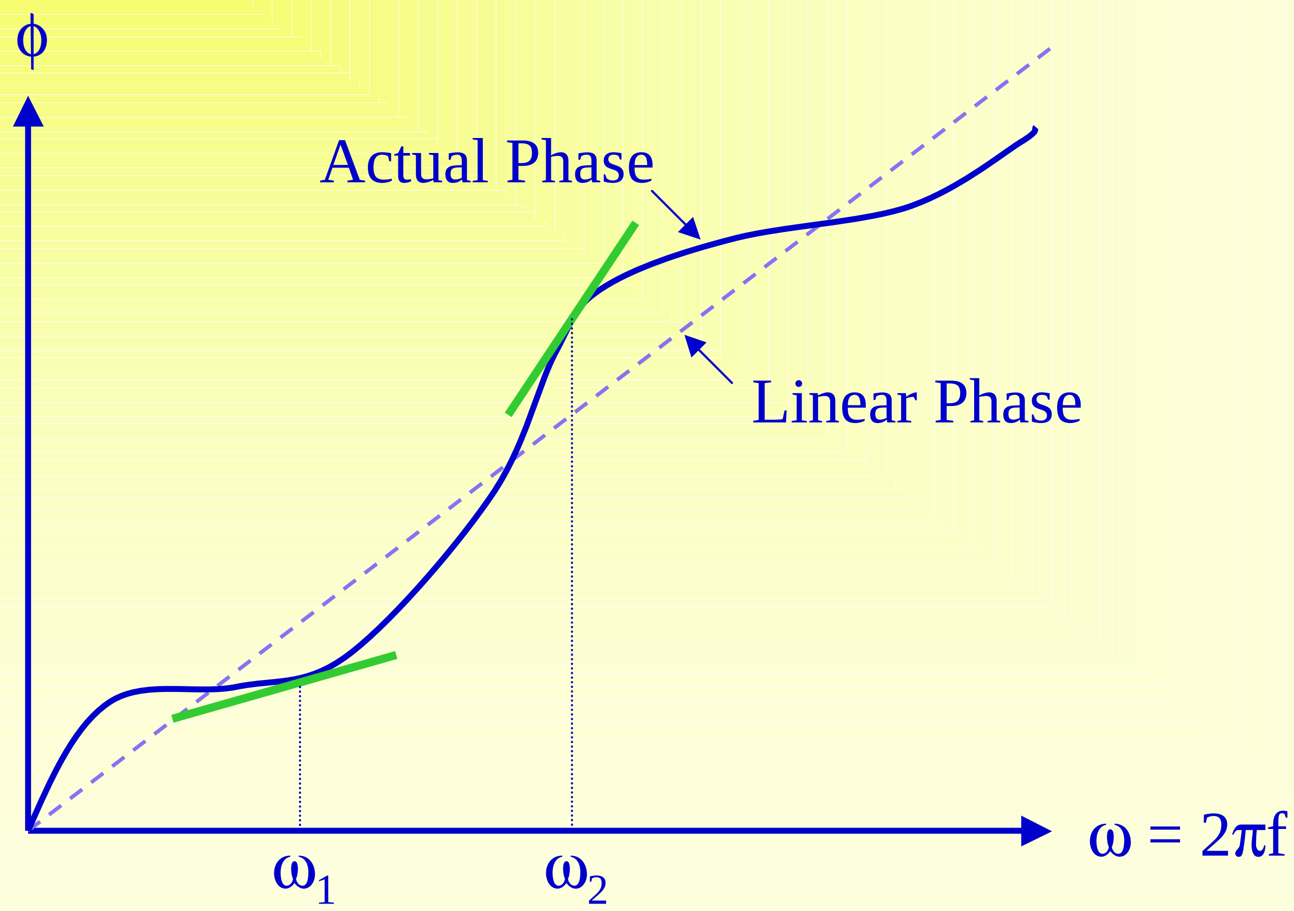
GD $= - d\phi/d\omega$

$= - t_d(\omega) [dt_d/d\omega]_\omega$

- GD is a derivative, and is inherently "spiky".
- GD does not relate directly to jitter.
- GD is not as useful for baseband as for RF specifications.
- We should not have used GD < 80 ps (0.25 UI) for phase specification

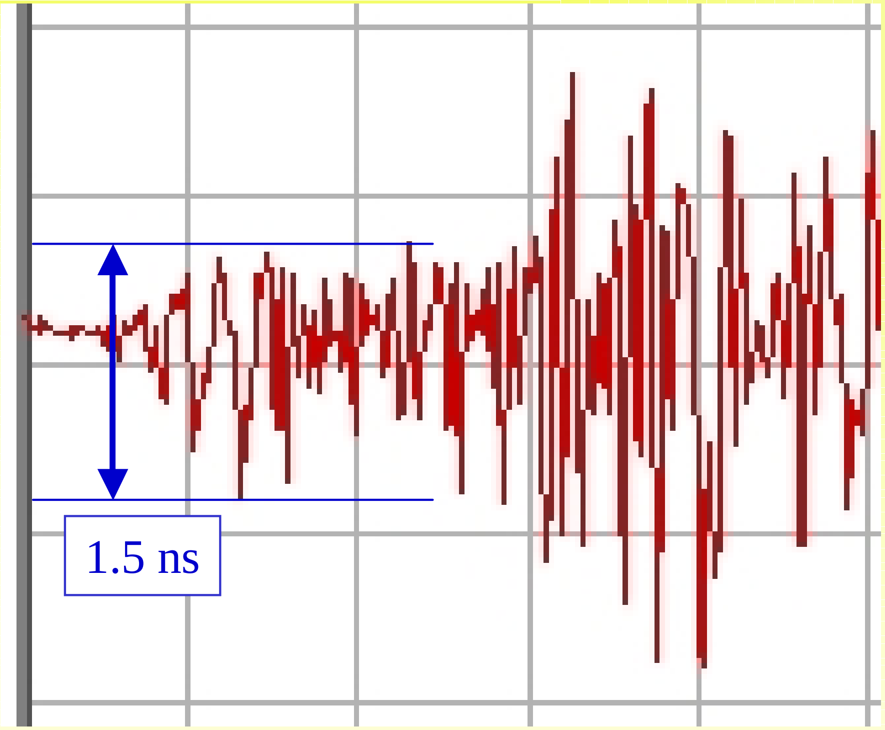
Group Delay

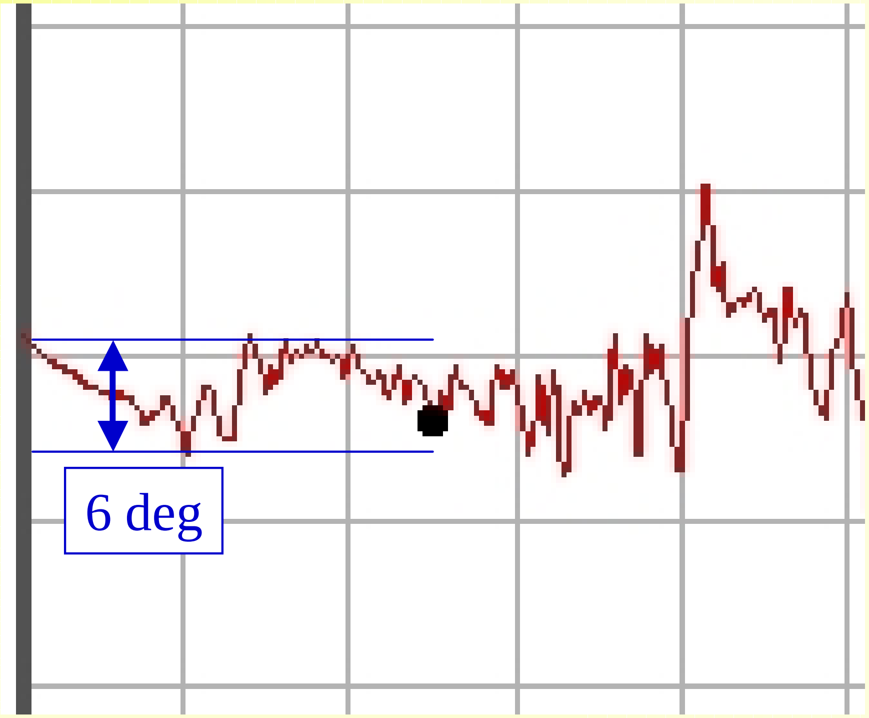
$d\phi / d\omega$ is the slope of the tangent to the phase response.



Data: Group Delay vs. Flat Phase

Measured data suggests that flat phase is smoother.
Is it a more appropriate parameter for specification?





Measured data contributed by TI

Two-tone DJ

We need something related to jitter.

Non-linear phase: $\phi(\omega) = \omega\, t_d(\omega)$

Solve for delay: $t_d(\omega) = \phi(\omega)/\omega$

A difference in arrival time causes DJ.

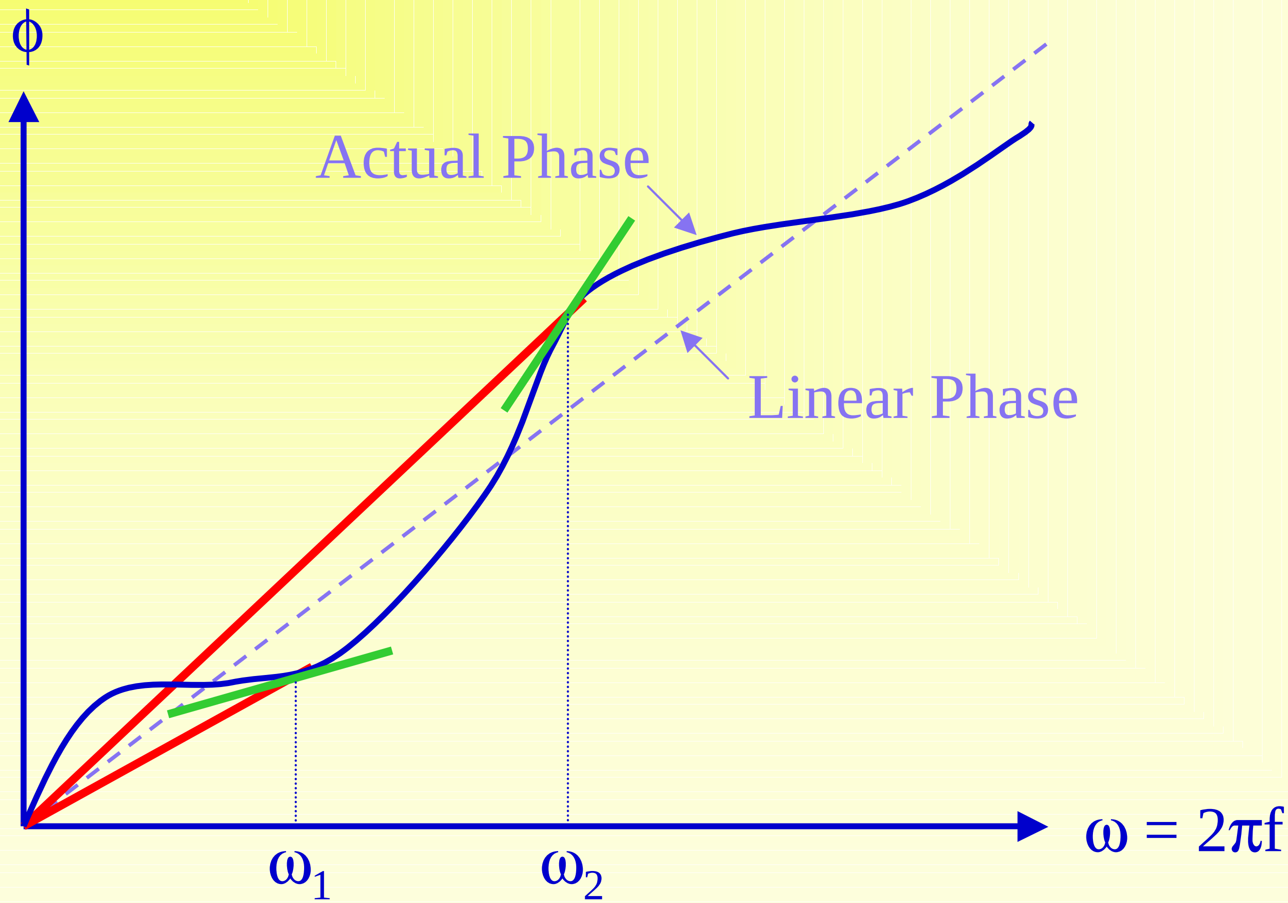
Define "two-tone DJ": $J = t_d(\omega_2) - t_d(\omega_1)$

$$= \phi_2/\omega_2 - \phi_1/\omega_1$$

Two-Tone DJ vs. Group Delay

$GD_2 – GD_1 = d\phi /d\omega|_2 - d\phi /d\omega|_1$ is the difference in green slopes.

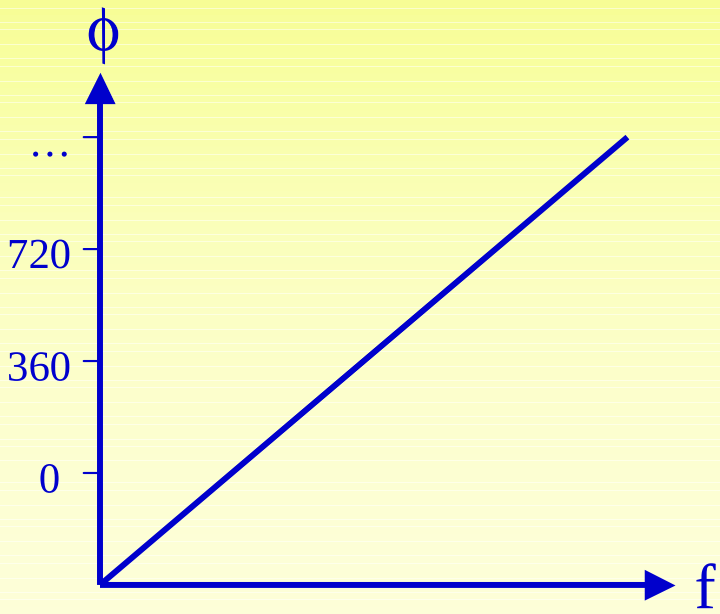
$J = \phi_2/\omega_2 – \phi_1/\omega_1$ is the difference in <u>red</u> slopes.



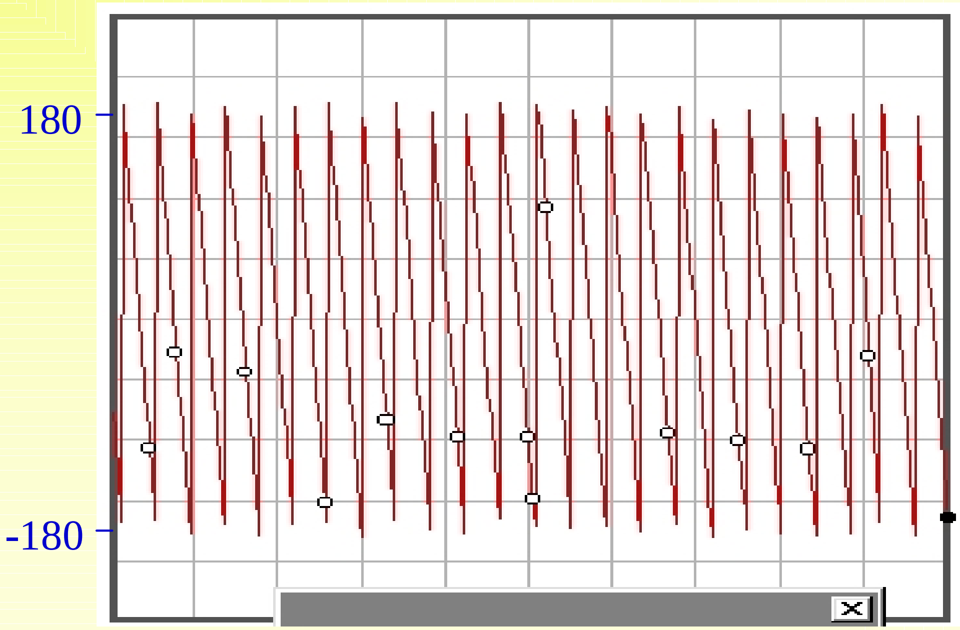
Wrapped Phase

We're interested in the arrival time, $t_d(\omega) = \phi/\omega$, but phase gets wrapped around 360 degrees on network analyzers. This requires post-processing.

Physical Reality



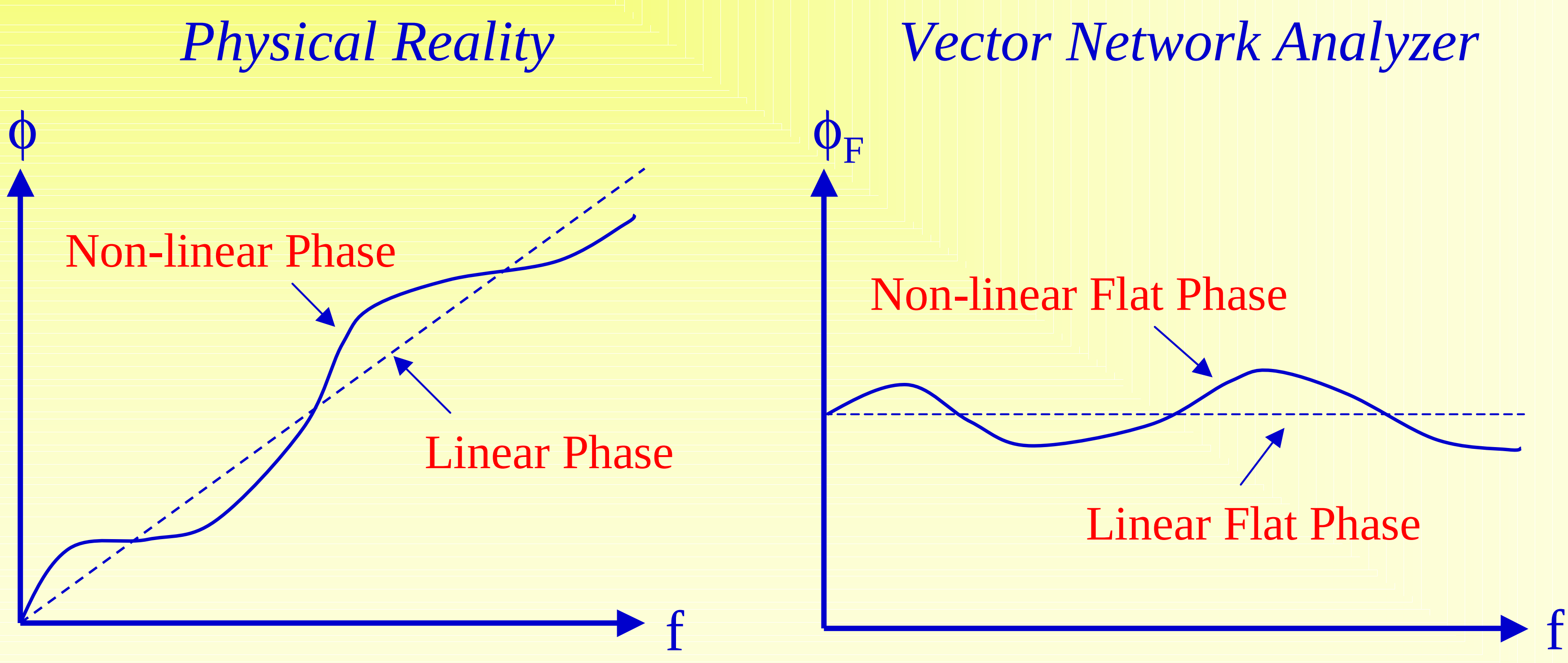
Vector Network Analyzer



Flat Phase

True phase is wrapped and requires post-processing.

But flat phase is directly available: $\phi_F = \phi - \phi_{lin}$



Two-Tone DJ from Flat Phase

J can be expressed in terms of flat phase.

Flat phase $\phi_F(\omega) = \phi(\omega) - \phi_{lin}(\omega)$

$$= \omega\,[t_d\,(\omega) - T_d]$$

We want J $= t_d(\omega_2) - t_d(\omega_1)$

$$= \phi_{F_2}/\omega_2 - \phi_{F_1}/\omega_1$$

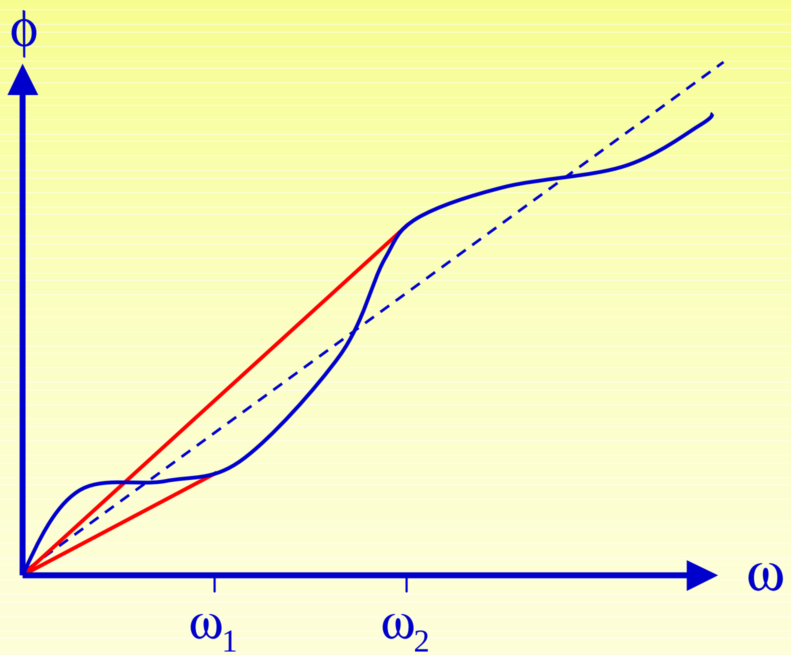
- The linear phase components cancel, giving the same form as for true phase.

Two-Tone DJ from flat phase

J is still the difference in slopes.

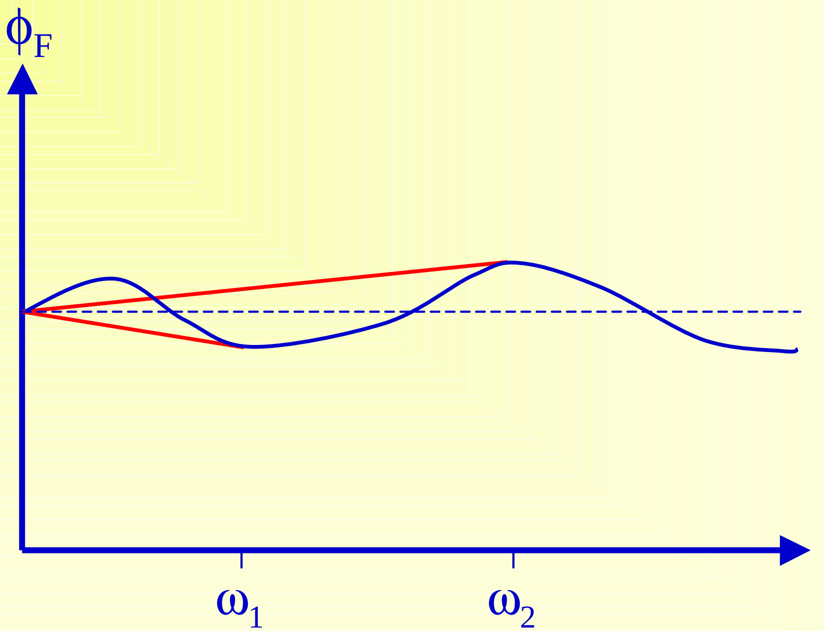
Phase

$$J = \phi_2/\omega_2 - \phi_1/\omega_1$$



Flat phase

$$J = \phi_{F_2}/\omega_2 - \phi_{F_1}/\omega_1$$



Two-tone DJ specification

We have $J = t_d(\omega_2) - t_d(\omega_1)$

$= \phi_{F_2}/\omega_2 - \phi_{F_1}/\omega_1$

Solving for ϕ_{F_2}

$$\phi_{F_2} = [\phi_{F_1} + \omega_1 J]\ \omega_2/\omega_1$$

- This is the flat phase corresponding to peak two-tone DJ.

Two-tone DJ specification

If we require $|J| > J_o$

Then we get $\phi_{F_2} > [\phi_{F_1} + \omega_1 J_o]\, \omega_2/\omega_1$

for $J > J_o$

$\phi_{F_2} < [\phi_{F_1} - \omega_1 J_o]\, \omega_2/\omega_1$

for $J < -J_o$

- This is the flat phase required to exceed a minimum amount of peak two-tone DJ, J_o.

Multi-tone DJ

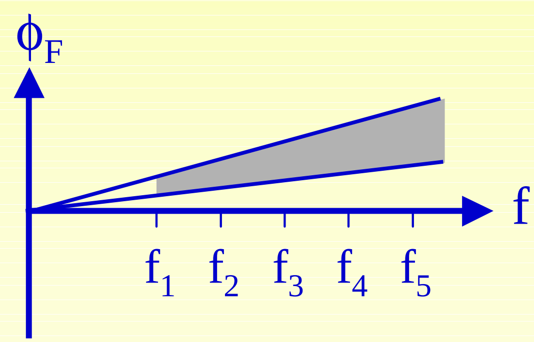
Fix ω_1 and generalize ω_2 to $\omega_n = n\,\omega_1$

If we choose: $J_o = 0.15$ UI / 2 = 24 ps

$f_1 = 312.5$ MHz

Then ϕ_{F_n} $> [\phi_{F_{312.5MHz}} + 0.047]\, n$

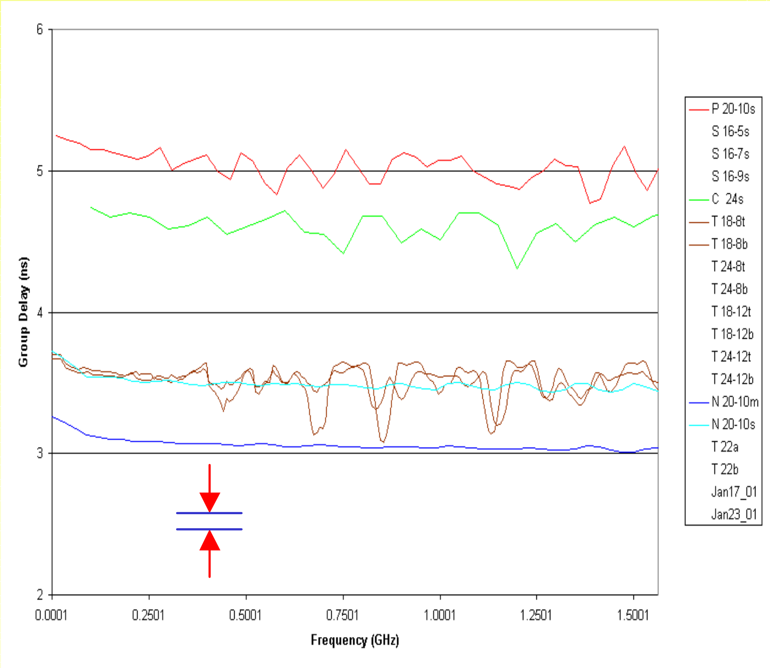
$< [\phi_{F_{312.5MHz}} - 0.047]\, n$



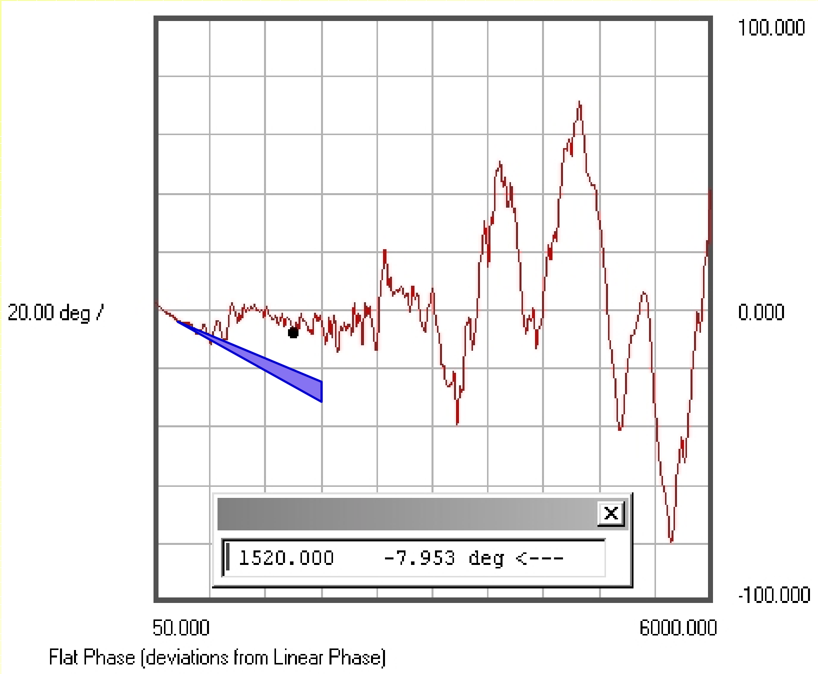
In general, some phase points must lie outside this area to get the minimum required DJ.

Next Steps

- Check the theory
- Check against measured data
- Make recommendation in next ballot cycle



Group Delay



Flat Phase