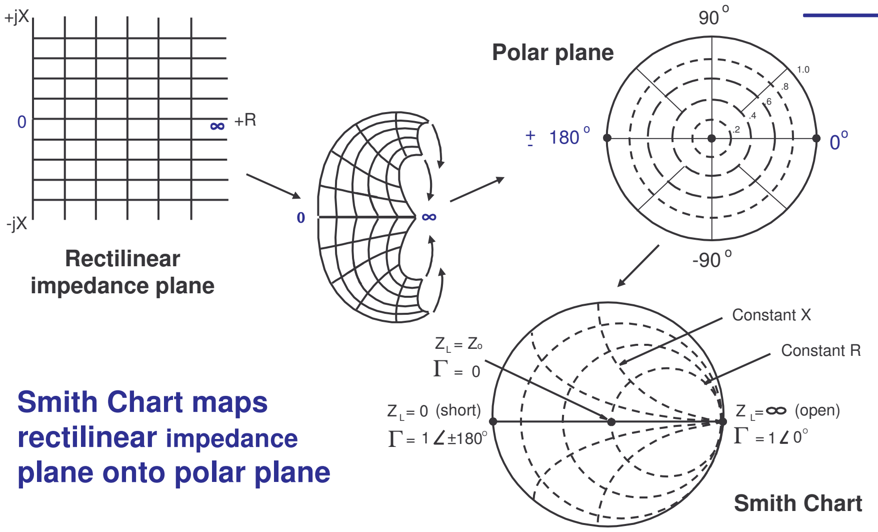
Smith Chart

Smith Chart Review



Smith Chart maps rectilinear impedance plane onto polar plane

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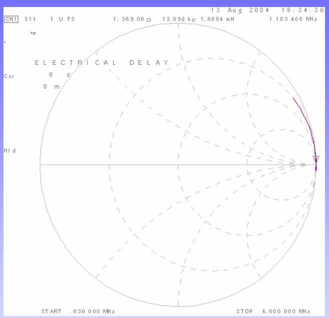
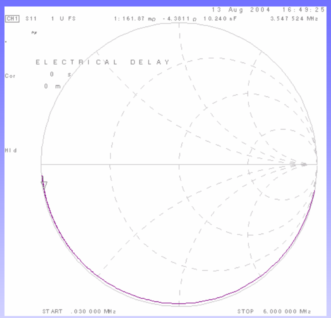
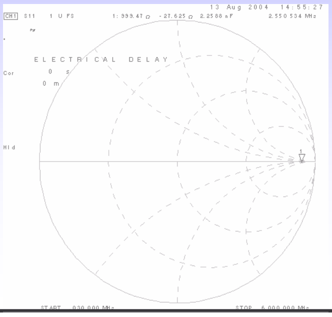
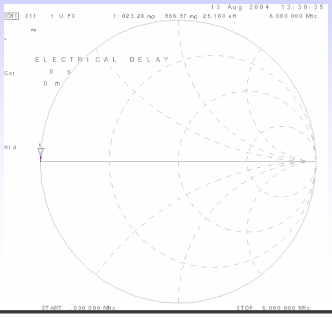
Circuits components

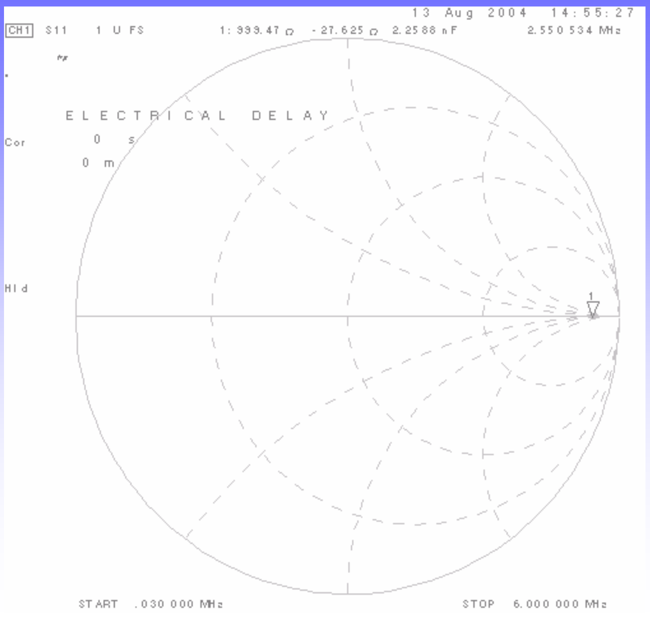








Smith Chart main points



From S parameters to impedance

IF BW and averaging

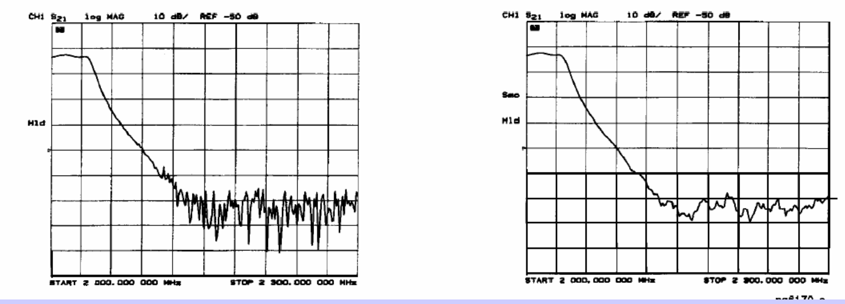
Heterodyne detection scheme

IF BW reduction

Averaging

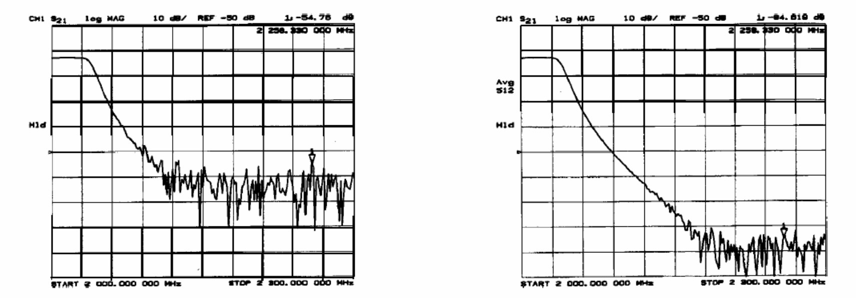
Dynamic Range (definition)

Smoothing trace



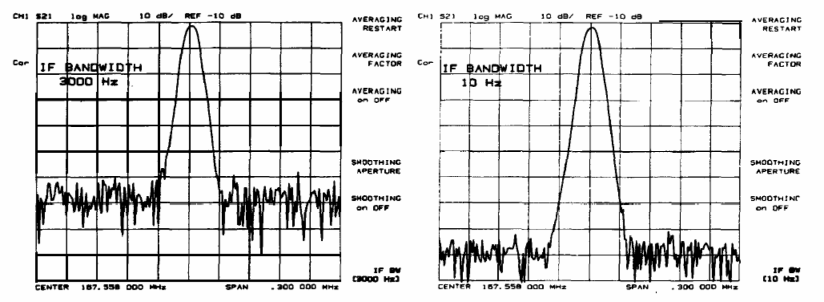
Smoothing (similar to video filtering) averages the formatted active channel data over a portion of the displayed trace. Smoothing computes each displayed data point based on one sweep only, using a moving average of several adjacent data points for the current sweep. The smoothing aperture is a percent of the swept stimulus span, up to a maximum of 20%.
Rather than lowering the noise floor, smoothing finds the mid-value of the data. Use it to reduce relatively small peak-to-peak noise values on broadband measured data. Use a sufficiently high number of display points to avoid misleading results. Do not use smoothing for measurements of high resonance devices or other devices with wide trace variations, as it will introduce errors into the measurement.

Averaging trace



Averaging computes each data point based on an exponential average of consecutive sweeps weighted by a user-specified averaging factor. Each new sweep is averaged into the trace until the total number of sweeps is equal to the averaging factor, for a fully averaged trace. Each point on the trace is the vector sum of the current trace data and the data from the previous sweep. A high averaging factor gives the best signal-to-noise ratio, but slows the trace update time. Doubling the averaging factor reduces the noise by 3 dB.

IF BW reduction

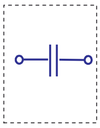


IF bandwidth reduction lowers the noise floor by digitally reducing the receiver input bandwidth. It works in all ratio and non-ratio modes. It has an advantage over averaging as it reliably filters out unwanted responses such as spurs, odd harmonics, higher frequency spectral noise, and line-related noise. Sweep-to-sweep averaging, however, is better at filtering out very low frequency noise. A tenfold reduction in IF bandwidth lowers the measurement noise floor by about 10 dB. Bandwidths less than 300 Hz provide better harmonic rejection than higher bandwidths.

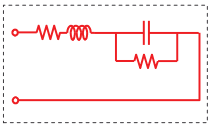
Impedance Measurements

Which Value Do We Measure?

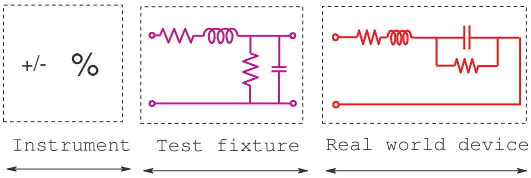
- TRUE



- EFFECTIVE

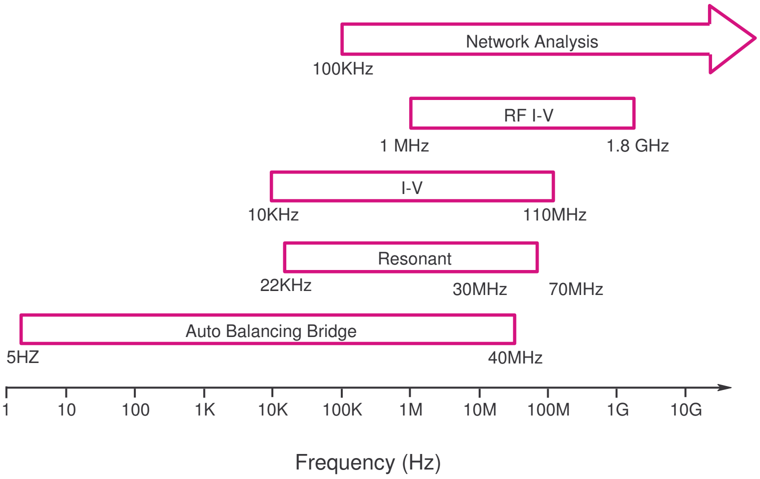


- INDICATED



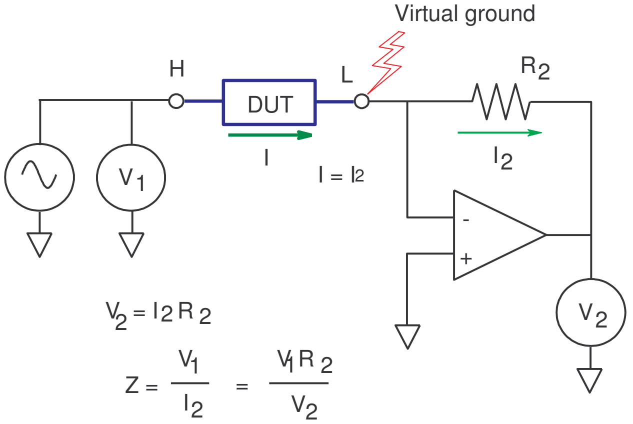
H

Frequency vs. Measurement Techniques



H

Auto Balancing Bridge
Theory of Operation



$V_2 = I_2 R_2$

$$Z = \frac{V_1}{I_2} = \frac{V_1 R_2}{V_2}$$

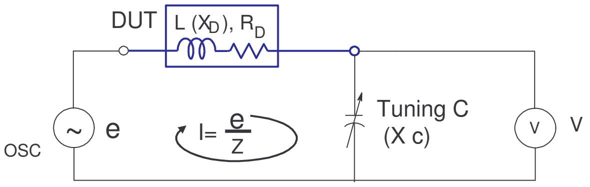
Auto Balancing Bridge

Advantages and Disadvantages

- Most accurate, basic accuracy 0.05%
- Widest measurement range
- C,L,D,Q,R,X,G,B,Z,Y,O,...
- Widest range of electrical test conditions
- Simple-to-use
- Low frequency, f < 40MHz

Resonance (Q - Meter) Technique
Theory of Operation

- Tune C so the circuit resonates
- At resonance $X_D = -X_C$, only R_D remains



$$X_C = \frac{V}{I} = \frac{R_D V}{e} \quad \text{(at resonance)}$$

$$Q = \frac{|X_D|}{R_D} = \frac{|X_C|}{R_D} = \frac{|V|}{e}$$

Resonant Method
Advantages and Disadvantages

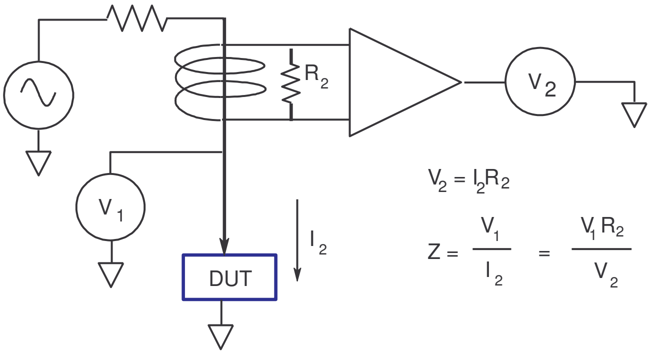
Very good for high Q - low D measurements

Requires reference coil for capacitors

Limited L,C values accuracy

Vector		Scalar
75kHz - 30MHz	■	22kHz - 70MHz
automatic and fast	■	manual and slow
easy to use	■	requires experienced user
limited compensation	■	No compensation

I - V Probe Technique
Theory of Operation



$$V_2 = I_2R_2$$

$$Z = \frac{V_1}{I_2} = \frac{V_1R_2}{V_2}$$

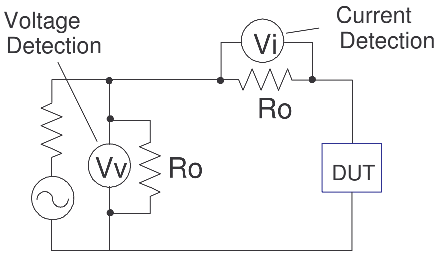
I-V (Probe)

Advantages and Disadvantages

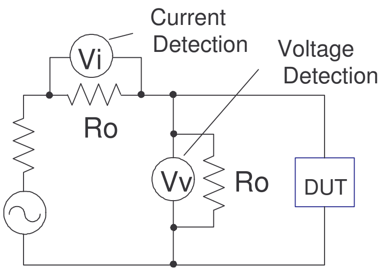
- Medium frequency, 10kHz < f < 110MHz
- Moderate accuracy and measurement range
- Grounded and in-circuit measurements
- Simple-to-use

RF I-V
Theory of Operation

High Impedance Test Head



Low Impedance Test Head

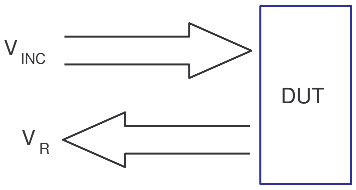


RF I-V

Advantages and Disadvantages

- High frequency, 1MHz < f < 1.8GHz
- Most accurate method at > 100 MHz
- Grounded device measurement

Network Analysis (Reflection) Technique
Theory of Operation



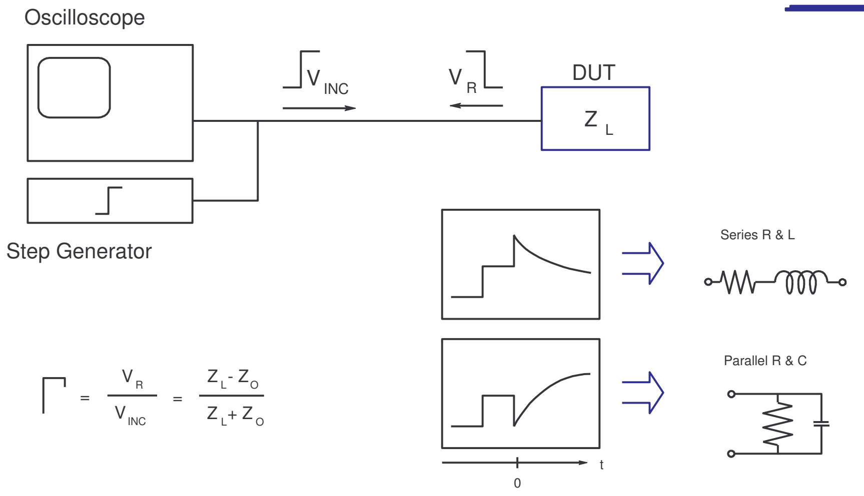
$$\Gamma = \frac{V_R}{V_{INC}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

Network Analysis

Advantages and Disadvantages

- High frequency
  - Suitable, f > 100 kHz
  - Best, f > 1.8 GHz
- Moderate accuracy
- Limited impedance measurement range
  (DUT should be around 50 ohms)

TDR
Theory of Operation



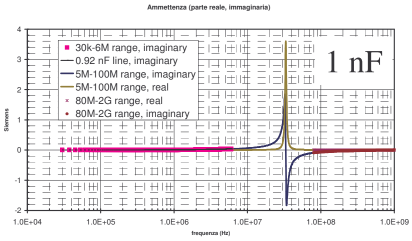
$$\Gamma = \frac{V_R}{V_{INC}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

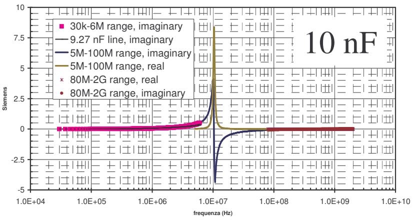
TDNA (TDR)

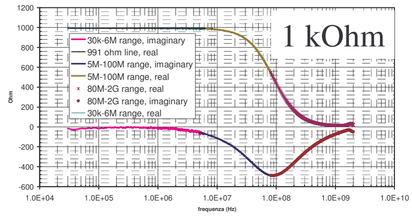
Advantages and Disadvantages

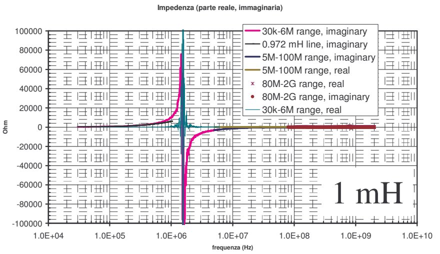
- Reflection and transmission measurements
- Single and multiple discontinuities or impedance mismatches ("Inside" look at devices)
- DUT impedance should be around 50 ohms
- Not accurate for m Ω or M Ω DUTs or with multiple reflections
- Good for test fixture design, transmission lines, high frequency evaluations

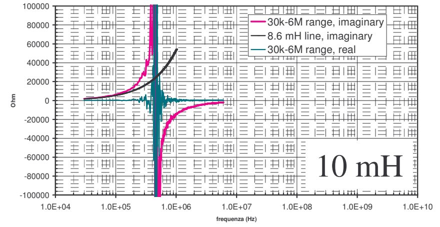
Measurement examples

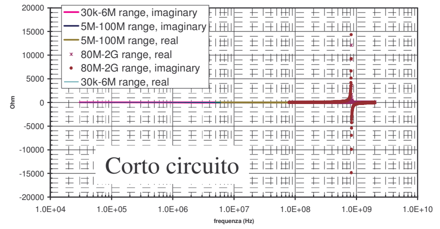


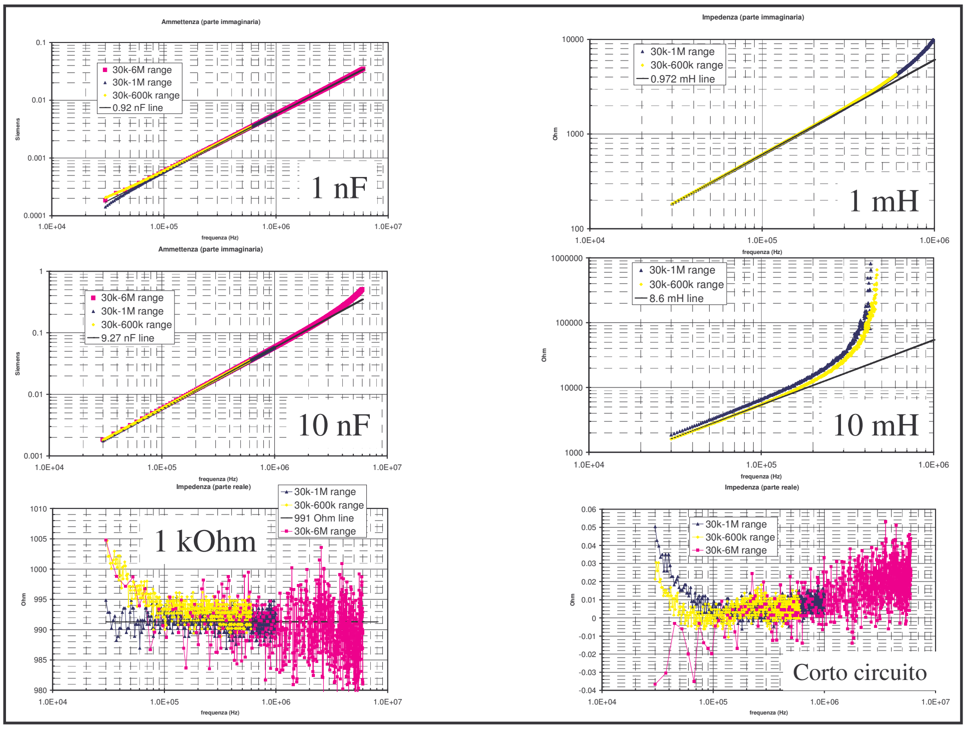






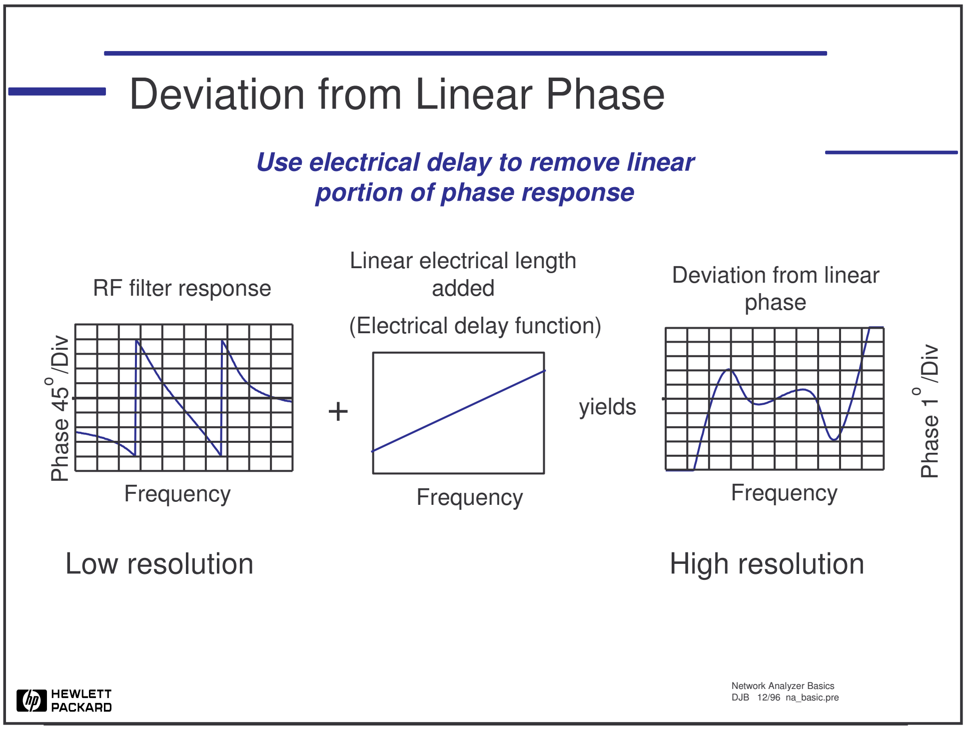






RF Device Characterization

Group delay



Deviation from Linear Phase

Use electrical delay to remove linear portion of phase response

RF filter response

Phase 45° /Div

Frequency

+

Linear electrical length added

(Electrical delay function)

Frequency

yields

Deviation from linear phase

Phase 1° /Div

Frequency

Low resolution

High resolution

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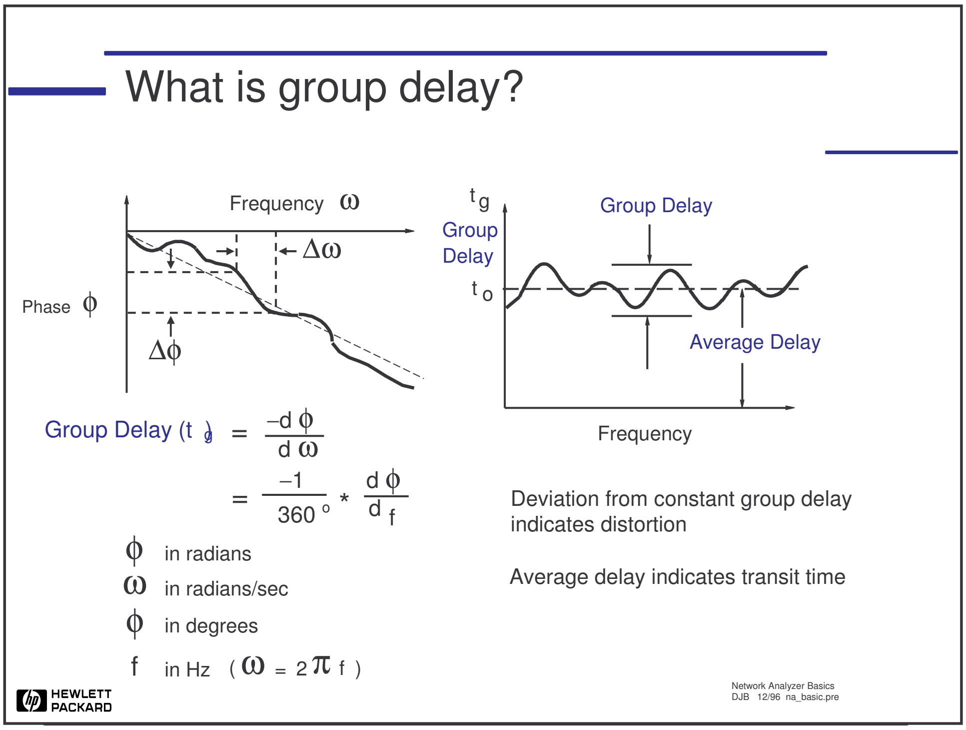


What is group delay?

$$\text{Group Delay } (t_g) = \frac{-d\,\phi}{d\,\omega} = \frac{-1}{360^{\circ}} * \frac{d\,\phi}{d\,f}$$

ϕ in radians

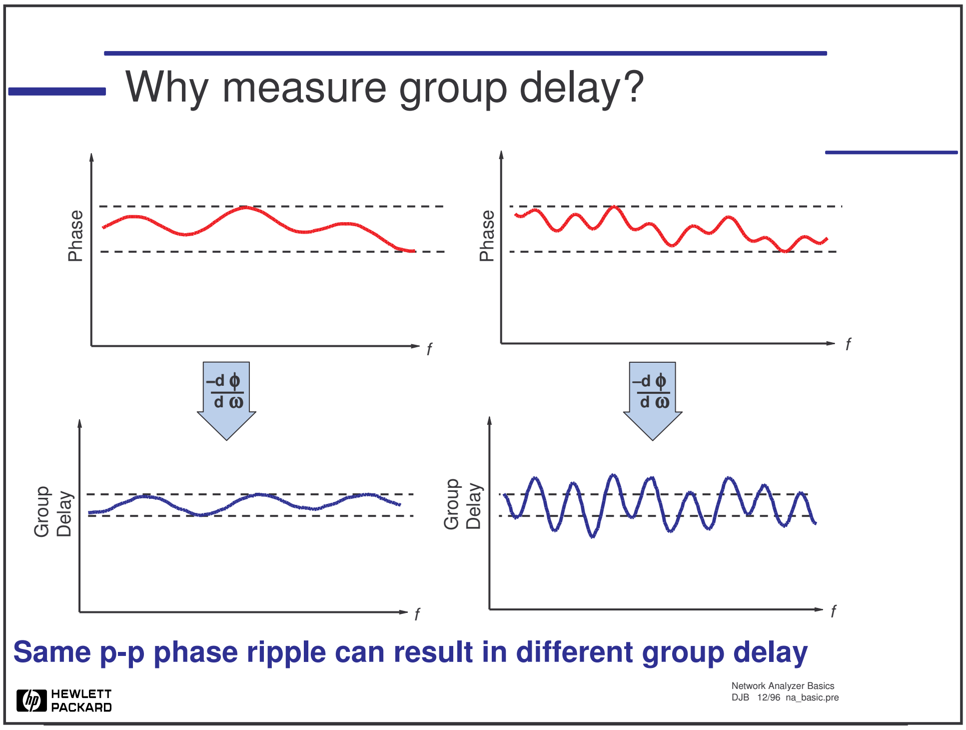
ω in radians/sec

ϕ in degrees

f in Hz ($\omega = 2\pi f$)

Deviation from constant group delay indicates distortion

Average delay indicates transit time



Why measure group delay?

Same p-p phase ripple can result in different group delay