Bandwidth

and Bandwidth Measurement

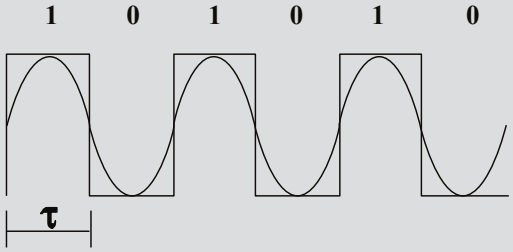
Communications Signal Processing Group

Prof. Dr.-Eng. habil. Steffen Lochmann

Hochschule Wismar, University of Technology, Business and Design

Bitrate = Bandwidth ?

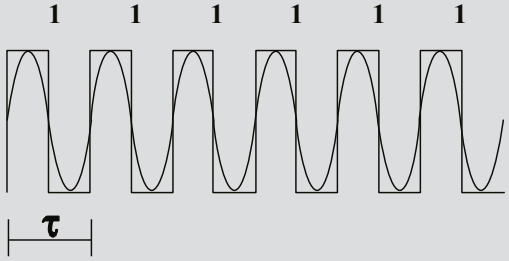
NRZ:



$$B = \frac{1}{2\tau}$$

$$2B = BR$$

RZ:



$$B = \frac{1}{\tau}$$

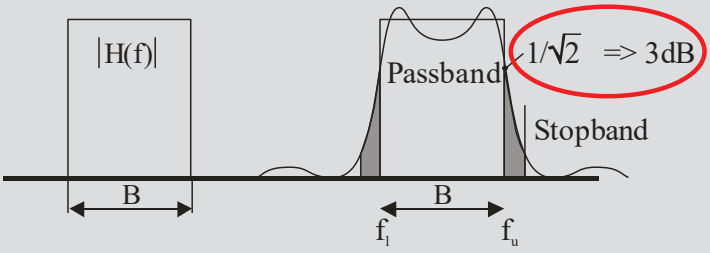
$$B = BR$$

Gaussian Impuls:

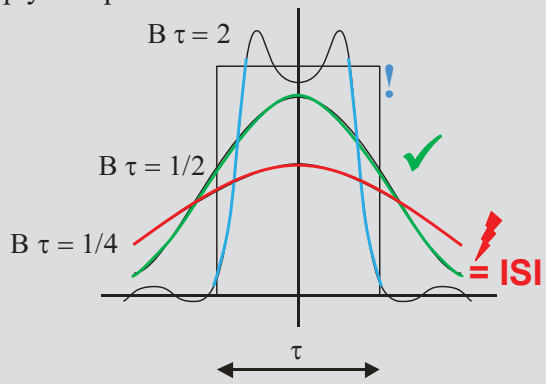
$$B = \frac{0.2}{\tau_\sigma}$$

Bandwidth ?

- ideal and real filters:

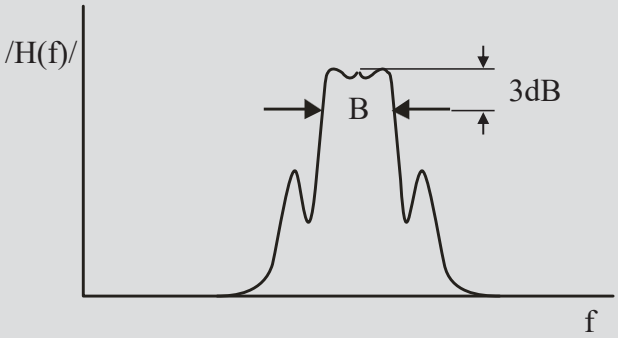


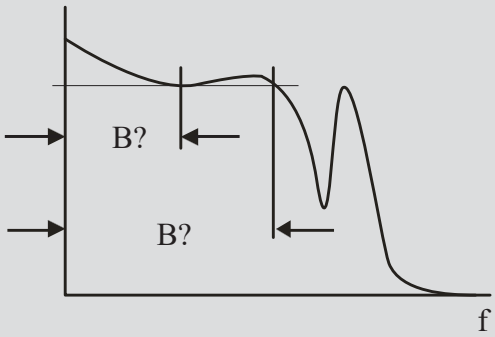
- apply rect pulse to ideal LPF:



Prof. S. Lochmann Bandwidth

Bandwidth ?

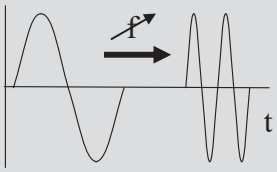




Principles of Bandwidth Measurement

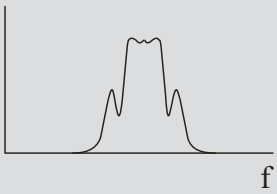
A) Measurement with Spectrum Analyzer

Signal Source
= Wobbel-Generator



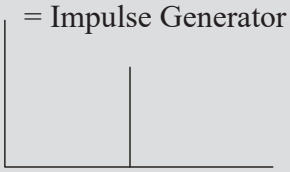
DUT attenuates or amplifies frequencies

Spectum of DUT

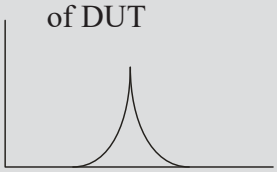


B) Measurement of Impulse Response

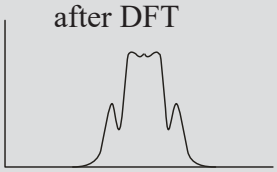
Signal Source
= Impulse Generator



Impulse response of DUT

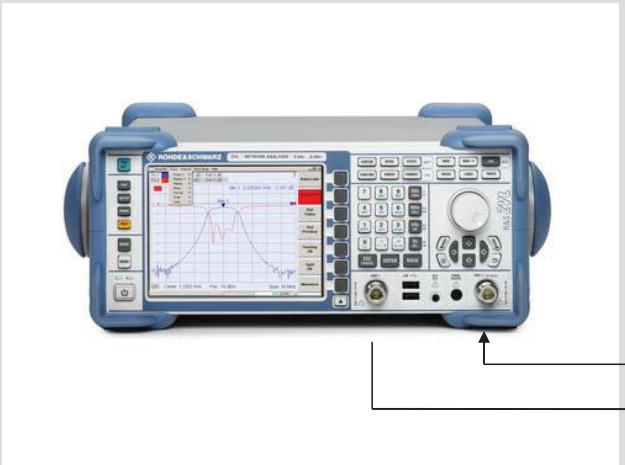


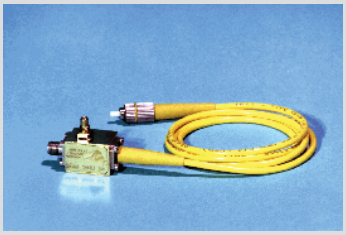
Spectrum after DFT



Prof. S. Lochmann Bandwidth
Communications Signal Processing GROUP

Spectrum Analyzer

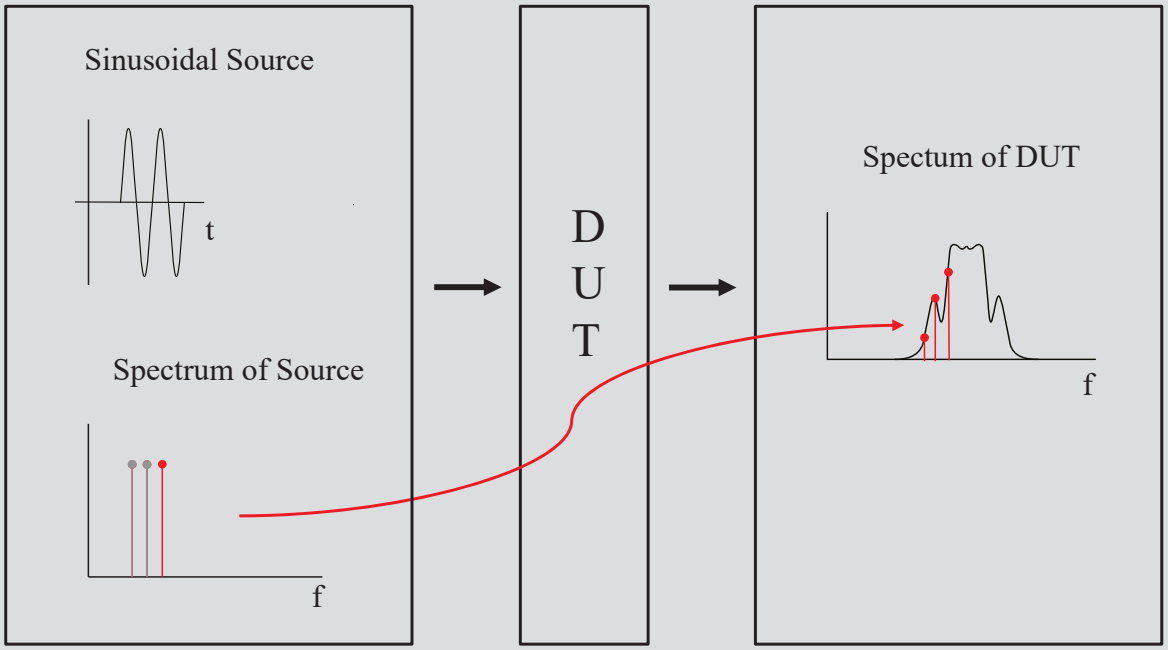




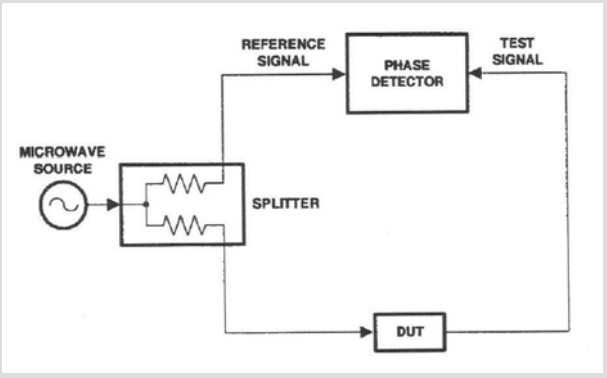
Spectrum Analyzer or
Vector Netwerk Analyzer

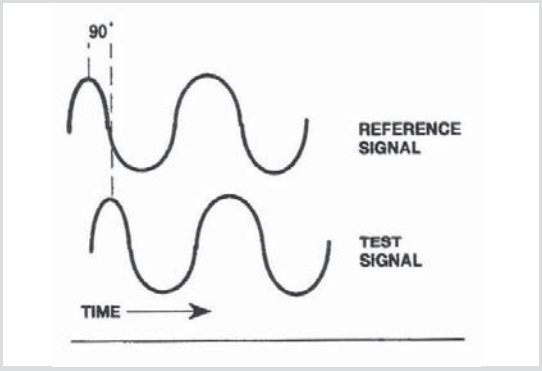
DUT

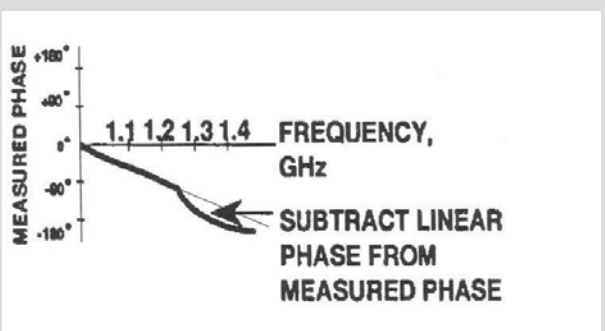
Spectrum Analyzer

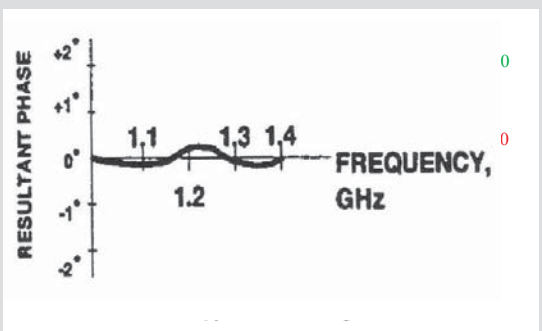


(Vector) Network Analyzer



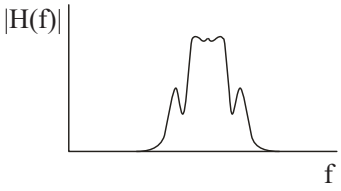




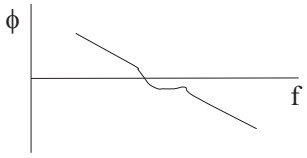


(Vector) Network Analyzer

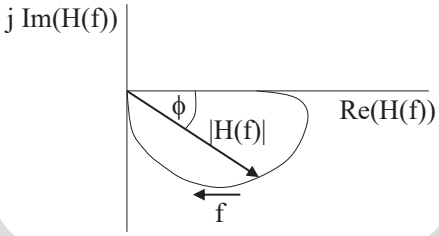
Magnitude



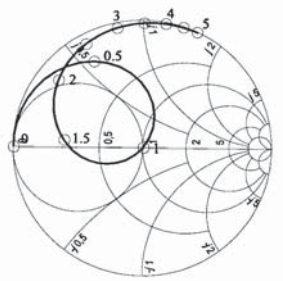
Phase



Frequency Response Locus

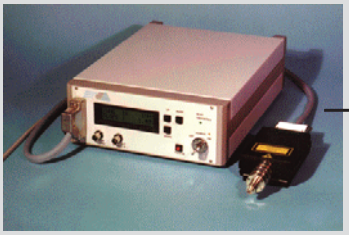


Smith Chart

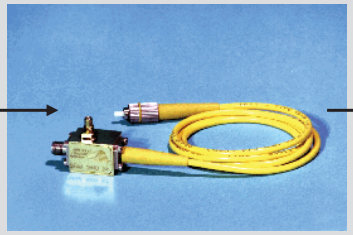


Measurement of Impulse Response

Impulse Generator

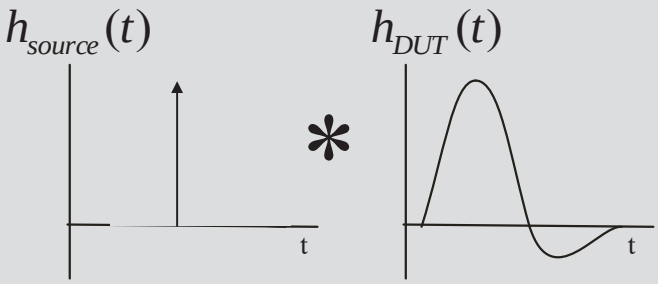


DUT



Oscilloscope

Measurement of Impulse Response



$$h_{meas}(t) = \delta(t) * h_{DUT}(t)$$

$$\downarrow FFT$$

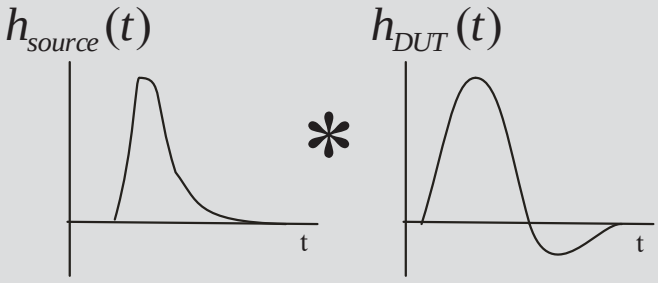
$$H_{meas}(f) = 1 \bullet H_{DUT}(f)$$

$$H_{DUT}(f) = H_{meas}(f)$$

$$H_{DUT}(f)[dB] = 20\log(H_{meas}(f))$$

Prof. S. Lochmann Bandwidth

Measurement of Impulse Response



$$h_{meas}(t) = h_{source}(t) * h_{DUT}(t)$$

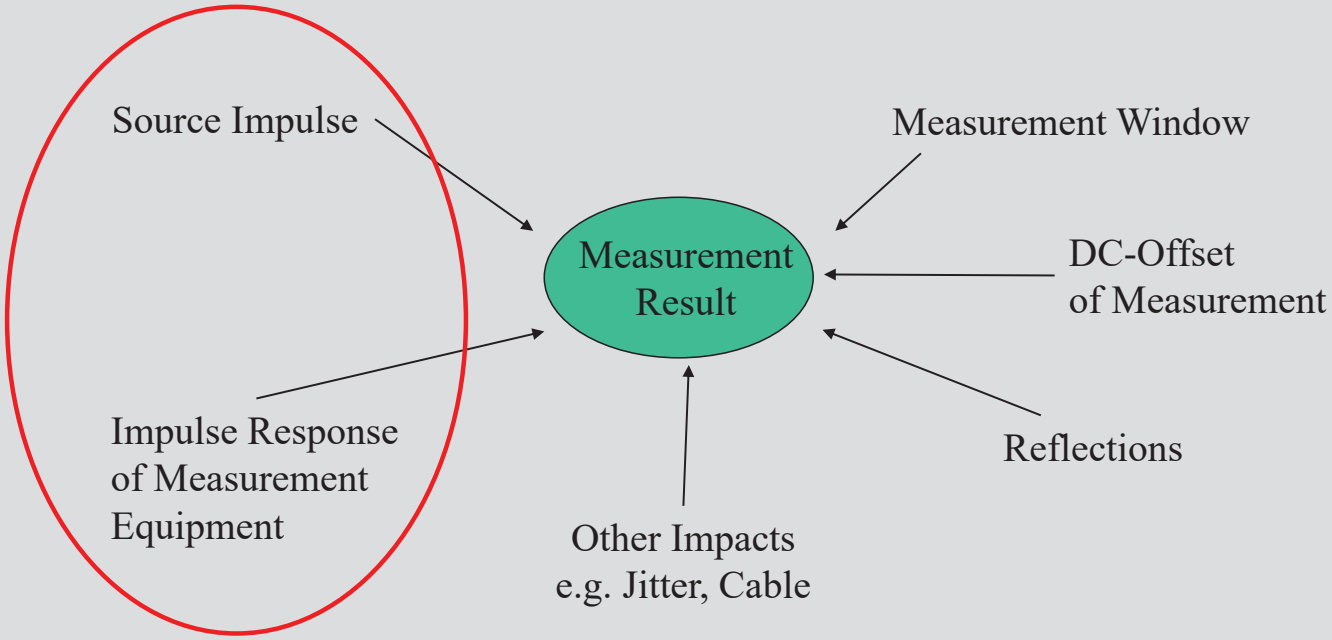
$$\downarrow FFT$$

$$H_{meas}(f) = H_{source}(f) \bullet H_{DUT}(f)$$

$$H_{DUT}(f) = H_{meas}(f) / H_{source}(f)$$

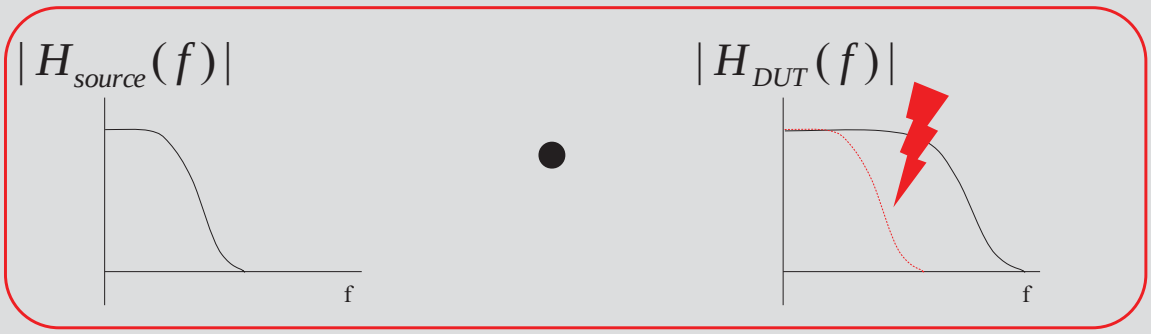
$$H_{DUT}(f)[dB] = 20\log(H_{meas}(f)) - 20\log(H_{source}(f))$$

Impacts on Measurement

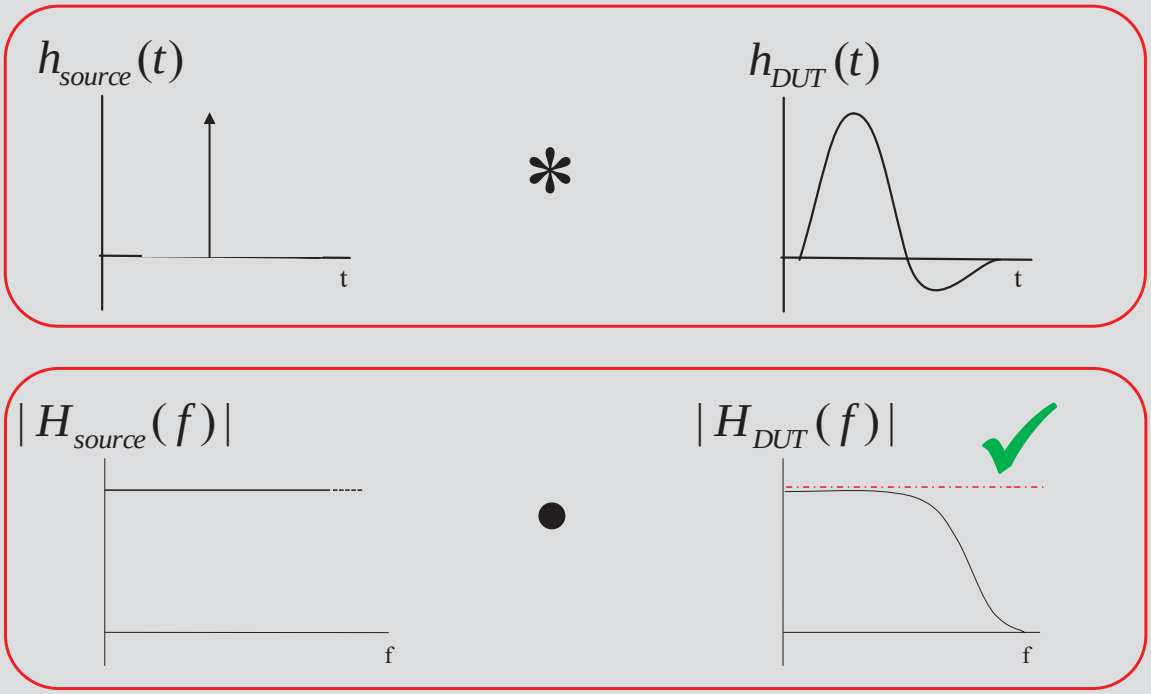


Prof. S. Lochmann Bandwidth
Communications Signal Processing GROUP

Impacts on Measurement

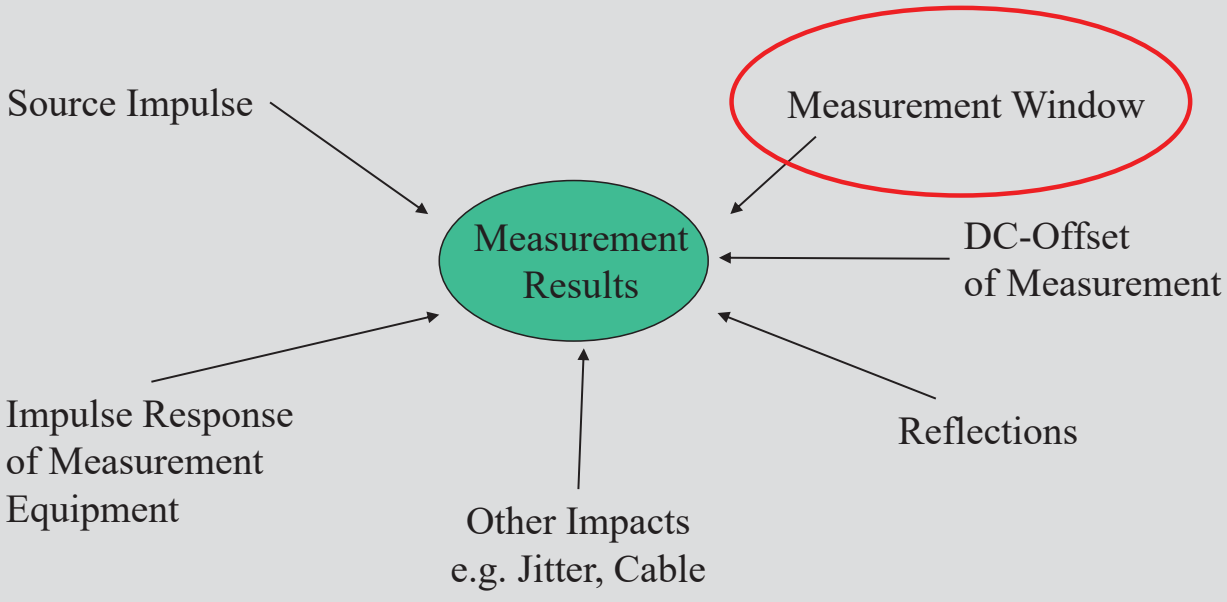


Impacts on Measurement

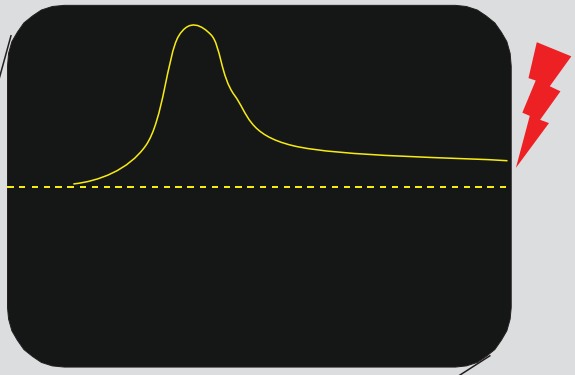


Prof. S. Lochmann Bandwidth

Impacts on Measurement



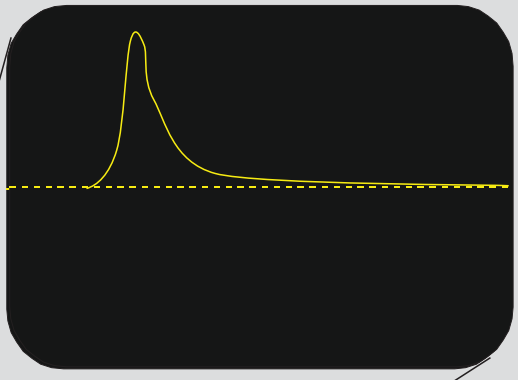
Impacts on Measurement



→ missing late events (low frequencies) !

Prof. S. Lochmann Bandwidth

Impacts on Measurement

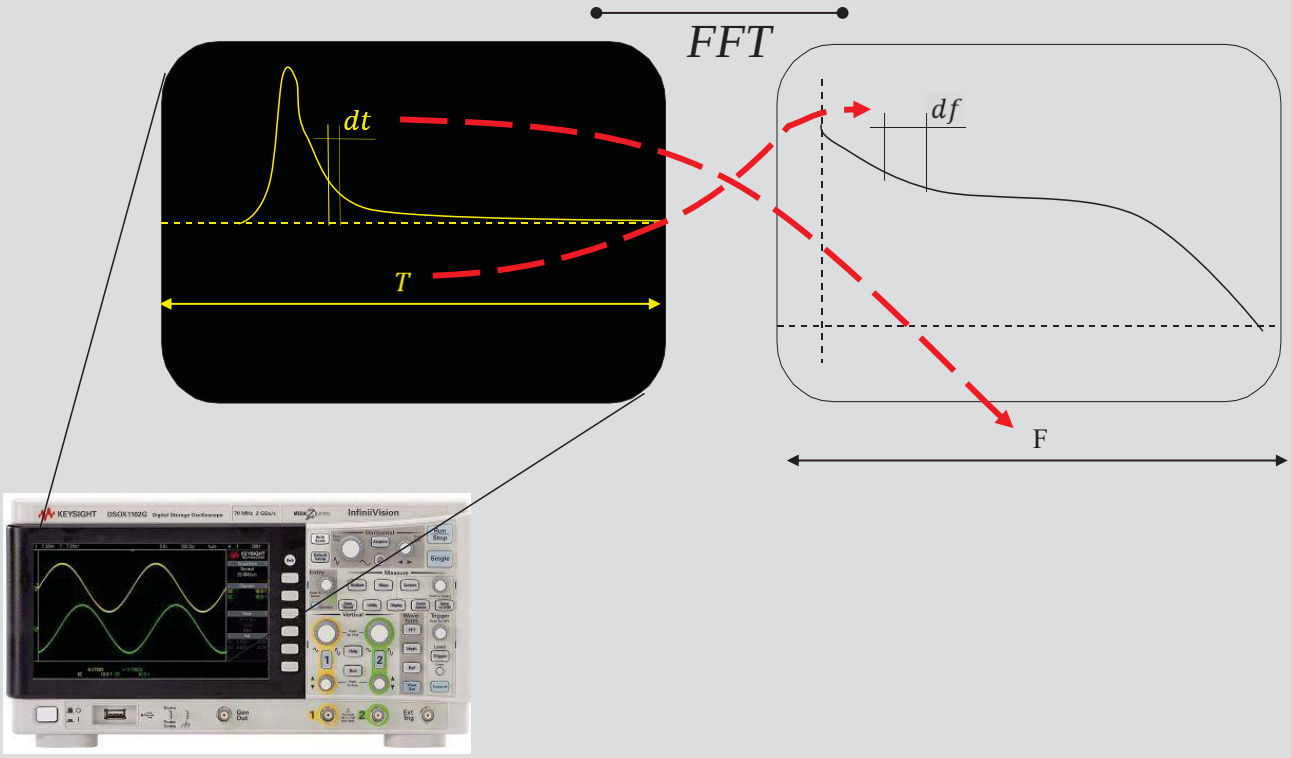


✓

→ better using lower resolution,

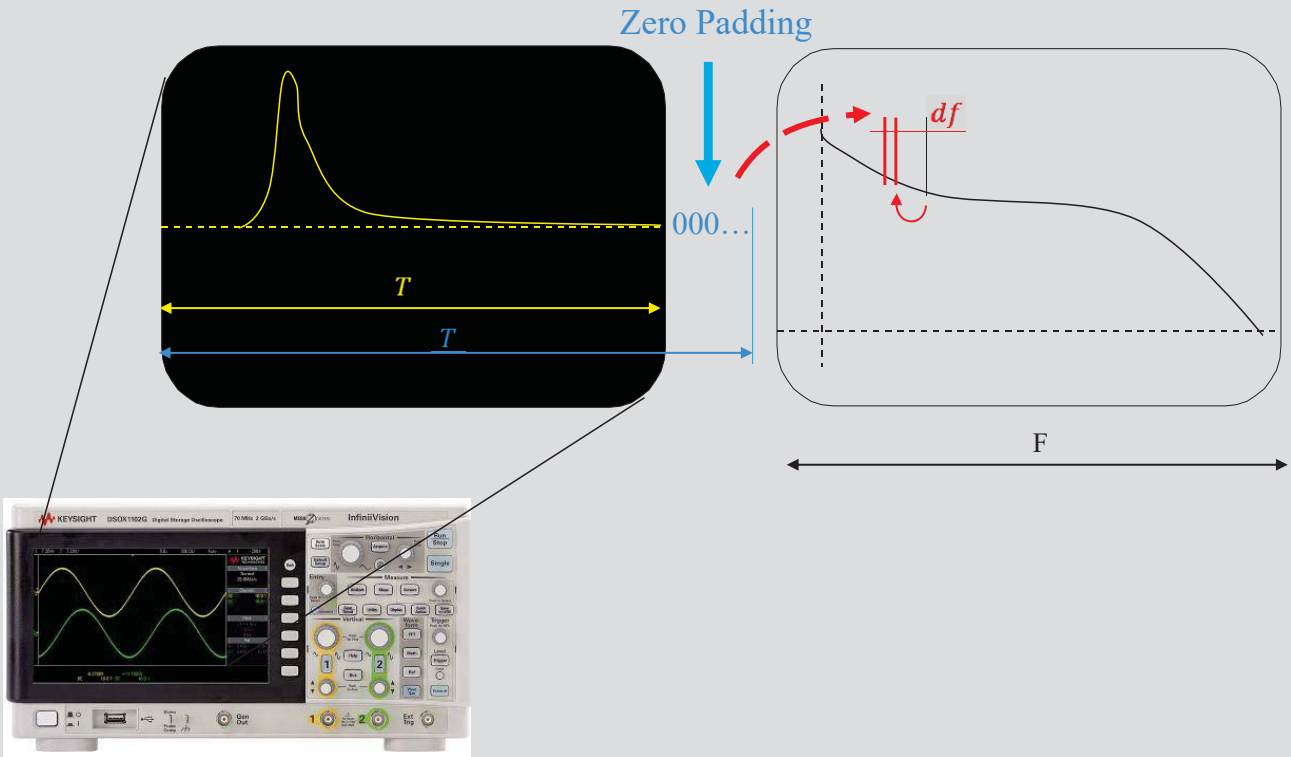
but how low?

Impacts on Measurement

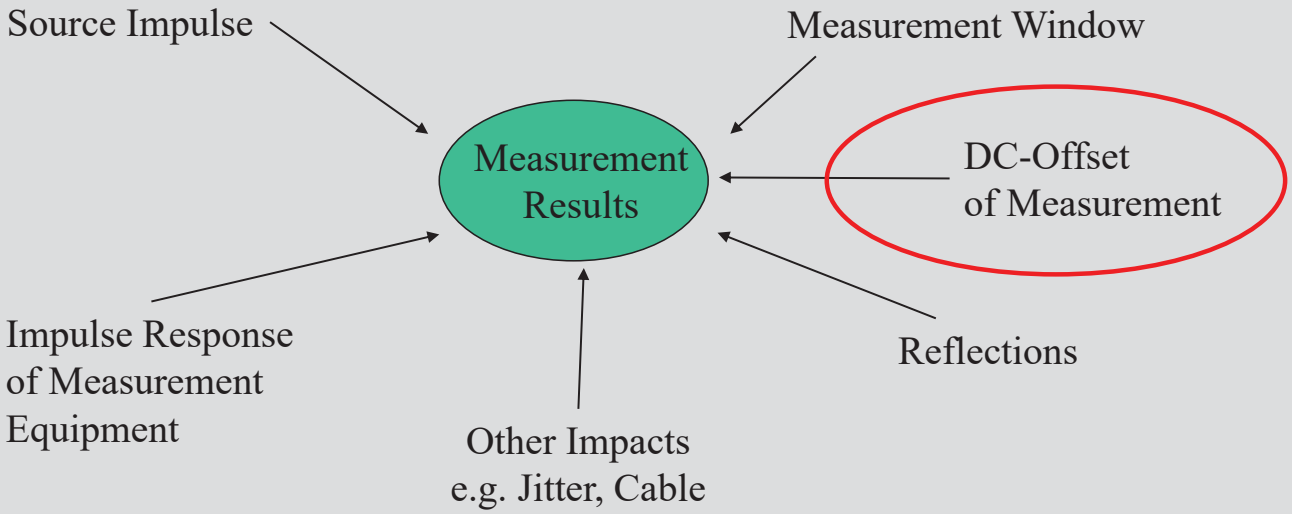


Prof. S. Lochmann Bandwidth

Impacts on Measurement

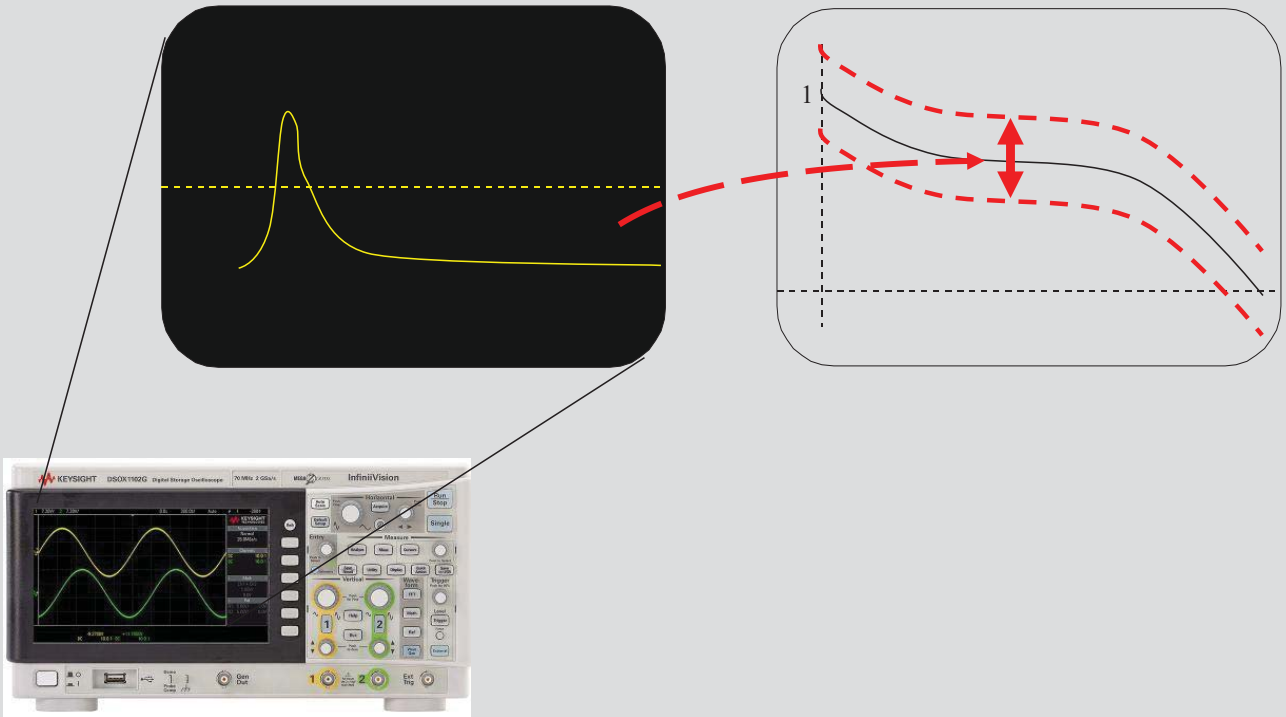


Impacts on Measurement

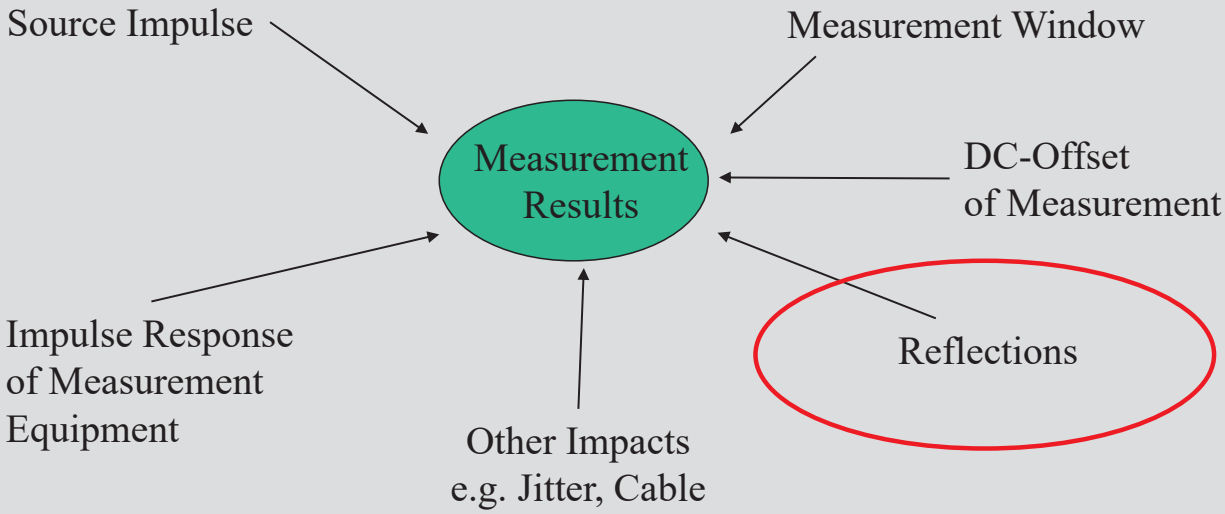


Prof. S. Lochmann Bandwidth

Impacts on Measurement



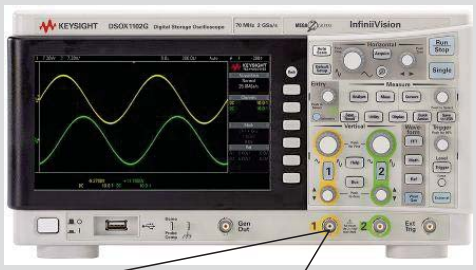
Impacts on Measurement

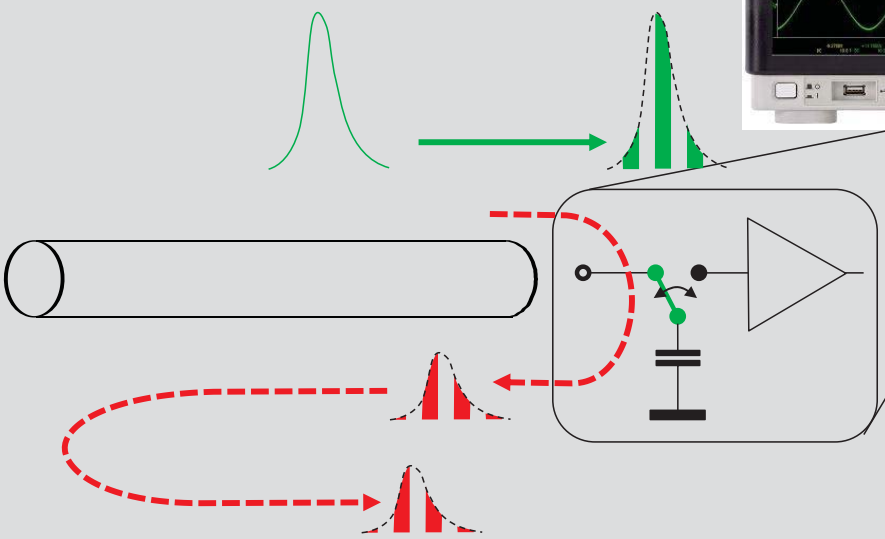


Prof. S. Lochmann Bandwidth

Impacts on Measurement

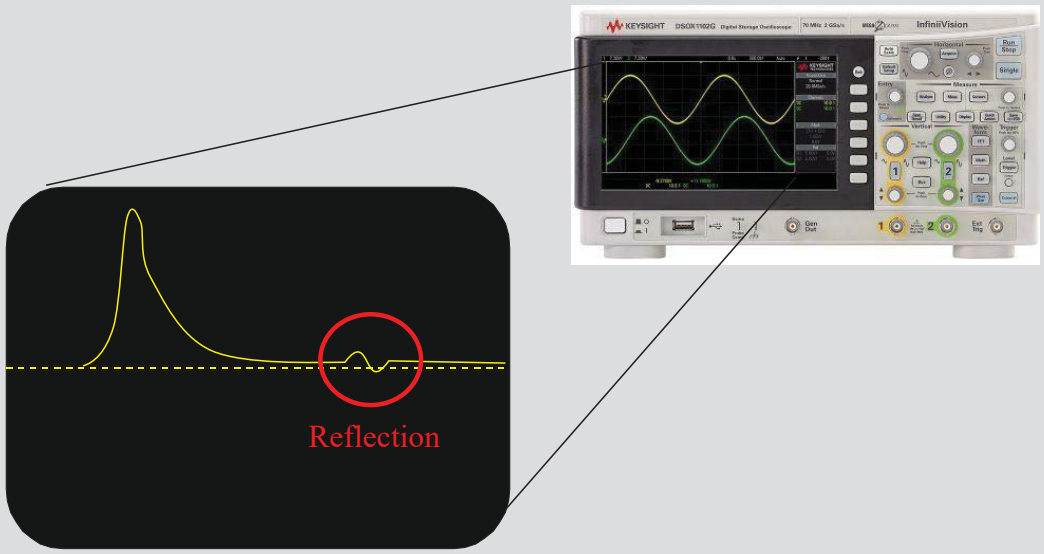
mismatching input impedance:





causing late events – low frequency impacts

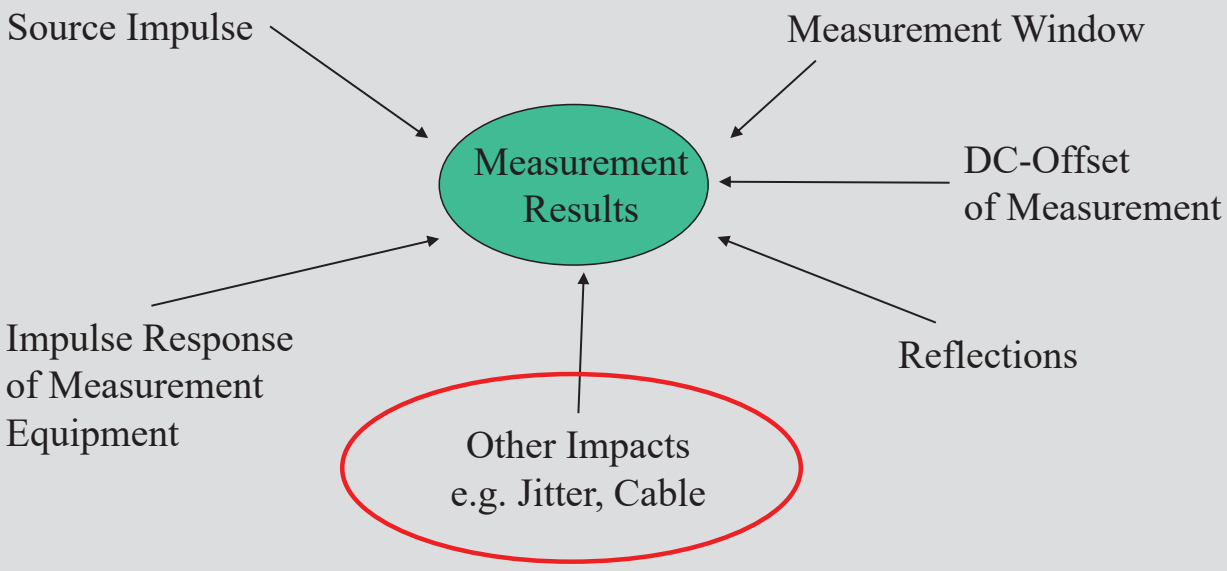
Impacts on Measurement



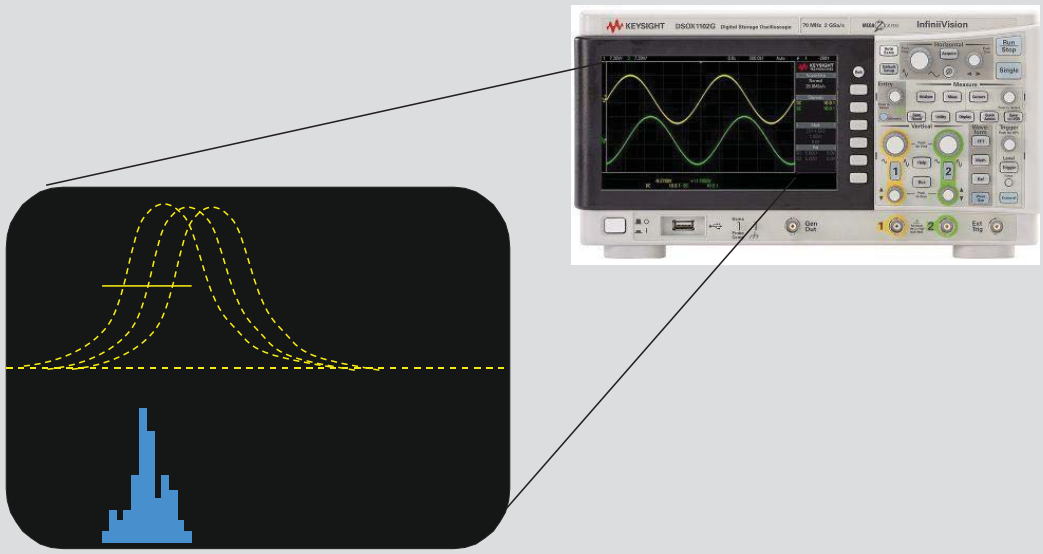
→ causing late events – low frequency impacts

Prof. S. Lochmann Bandwidth

Impacts on Measurement



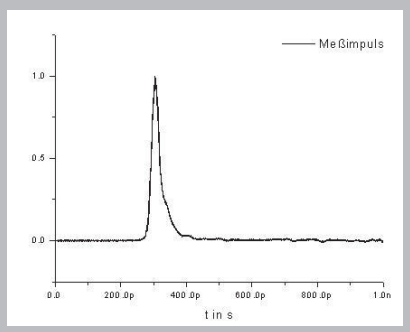
Impacts on Measurement

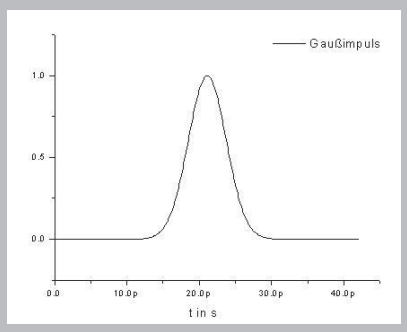


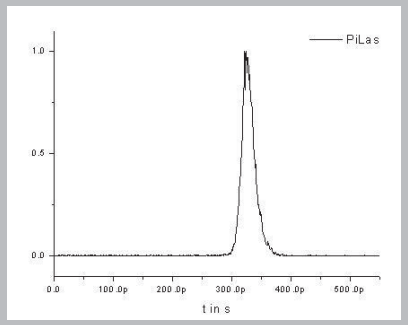
jitter histogram

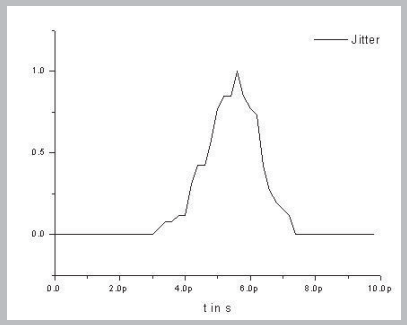
Prof. S. Lochmann Bandwidth

Measurement of Impulse Response

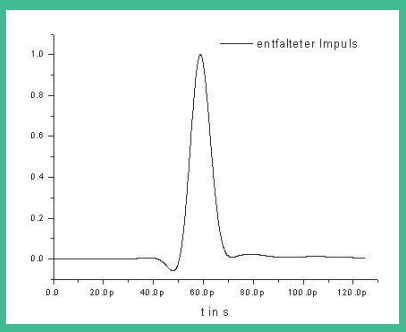


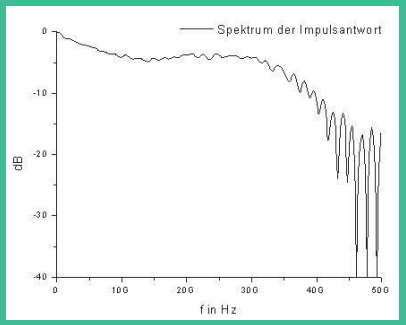






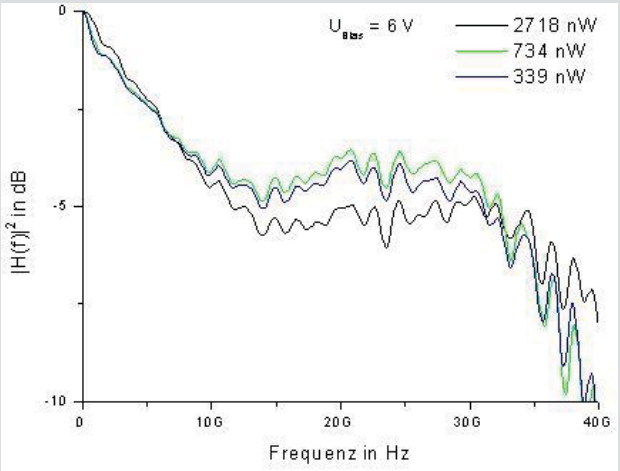
Input data



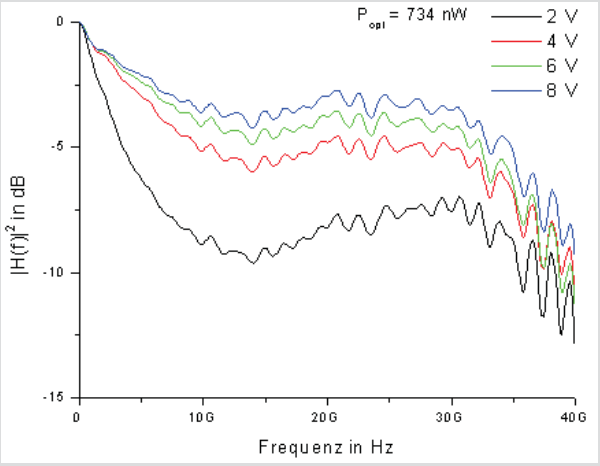


Output data

MSM-PD Bandwidth



Bandwidth depending of optical power



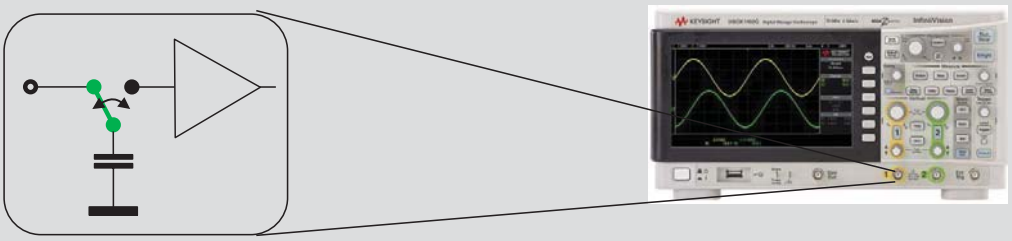
Bandwidth depending of bias voltage

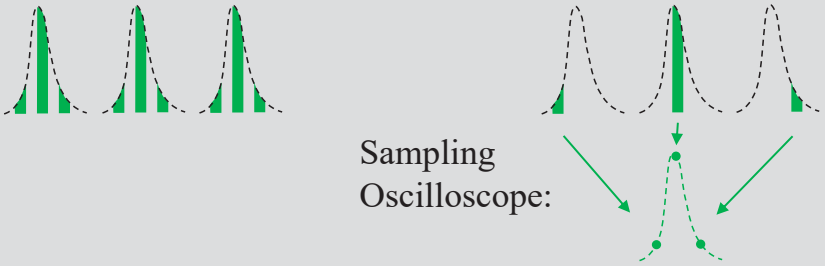
Real Time Oscilloscope and

Sampling Oscilloscope

Prof. Dr.-Eng. habil. Steffen Lochmann

Real Time and Sampling Oscilloscopes





Real Time Oscilloscope:

Sampling Oscilloscope:

- Suited for single signal recovery
- Internal triggering possible
- Usually lower bandwidth than sampling oscilloscopes
- Less suited for eye diagrams/error measurements

- Needs signal repetition
- Needs trigger
- Very high bandwidths possible
- Higher SNR
- Particularely suited for eye diagrams/error measurements