EE 240C
Analog-Digital Interface Integrated Circuits

Digital Filter Production Testing

Production Testing

It's obvious that decimation filters obscure many details of modulator analog performance

- Most of the shaped quantization noise is filtered away
- Was the modulator fabricated correctly? Are there defects in a given chip?
- We need production test modes …

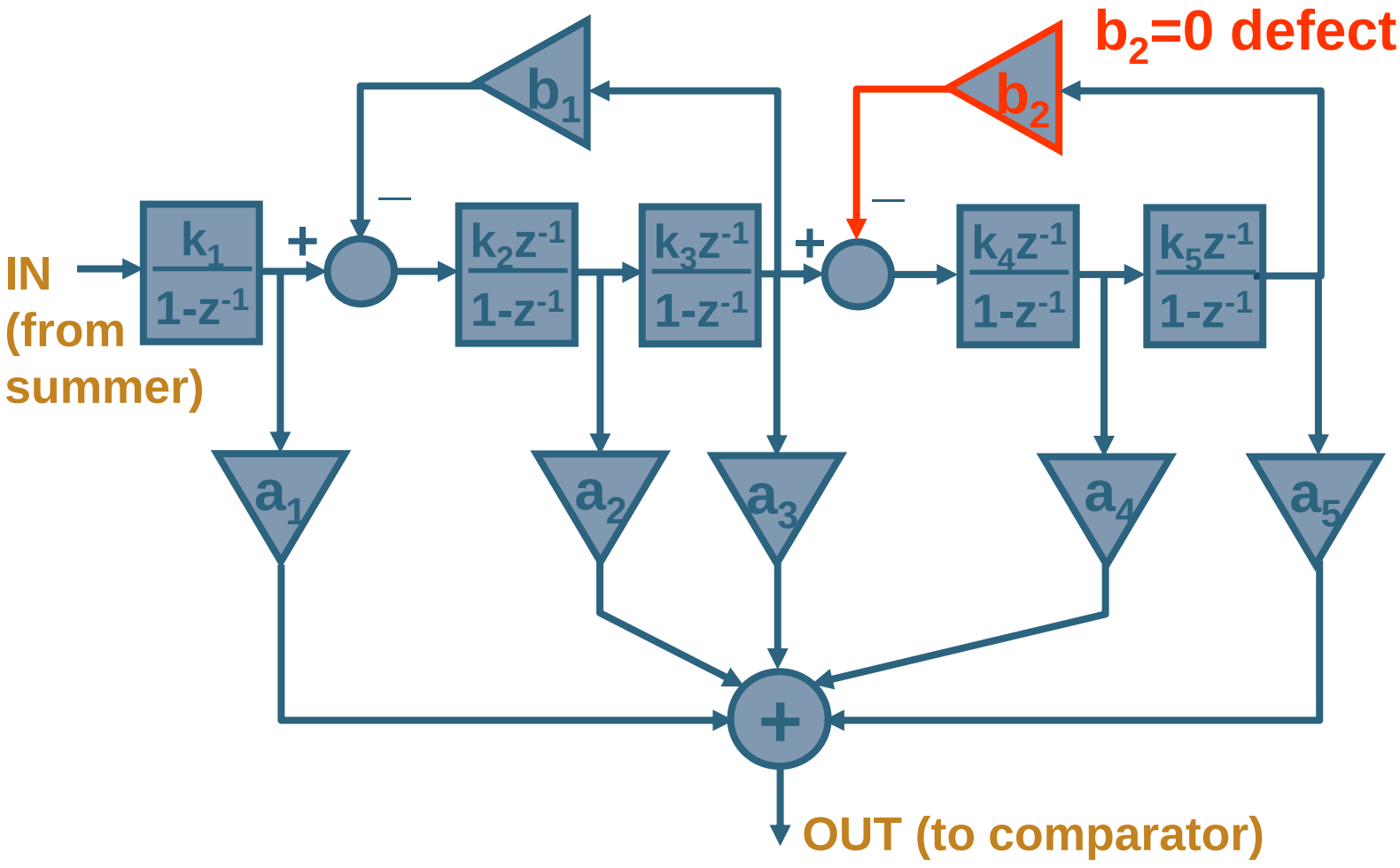
Test Modes

- ΣΔ ADC designs must provide at least the following test modes:
  - Output unfiltered 1-bit modulator output samples
  - Insert test vectors at the decimation filter input
- Any mixed-signal IC which includes an ADC must provide for observability of unprocessed ADC output samples
- Let's see how our decimation filter obscures a typical modulator manufacturing defect …

Test Modes

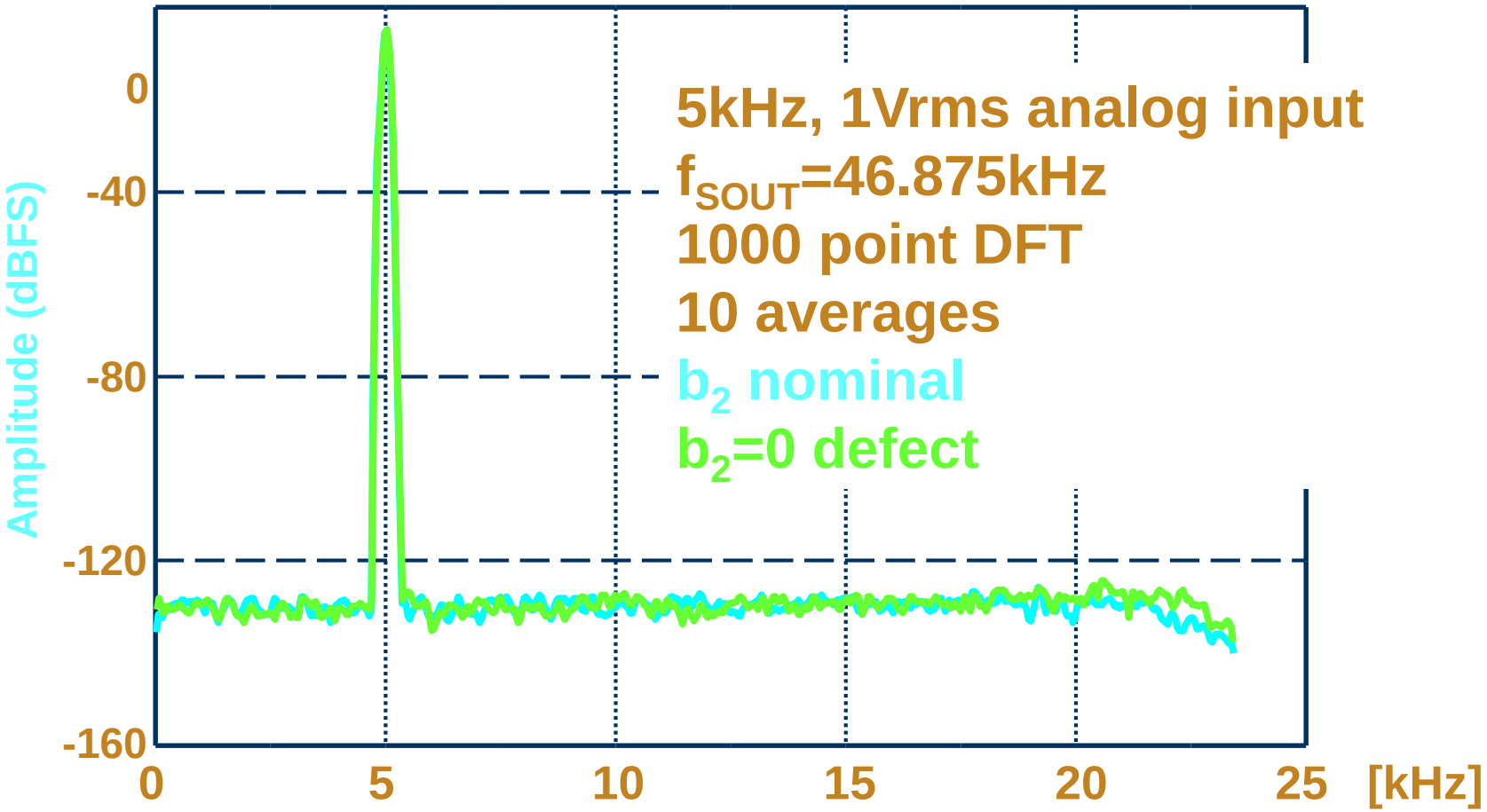
- Suppose the modulator is built with an open fault in a metal trace which connects up the switched capacitor implementing the b_2 capacitor
  - b_2 sets one of the quantization noise zeroes
  - If the b_2 capacitor is missing, b_2=0
  - In the real world, this defect might occur in 1–10ppm of production units
- The next two slides highlight the loop filter defect, and show decimated DFTs with and without the defect

Loop Filter Defect



[Eric Swanson]

ΣΔ ADC Output DFT



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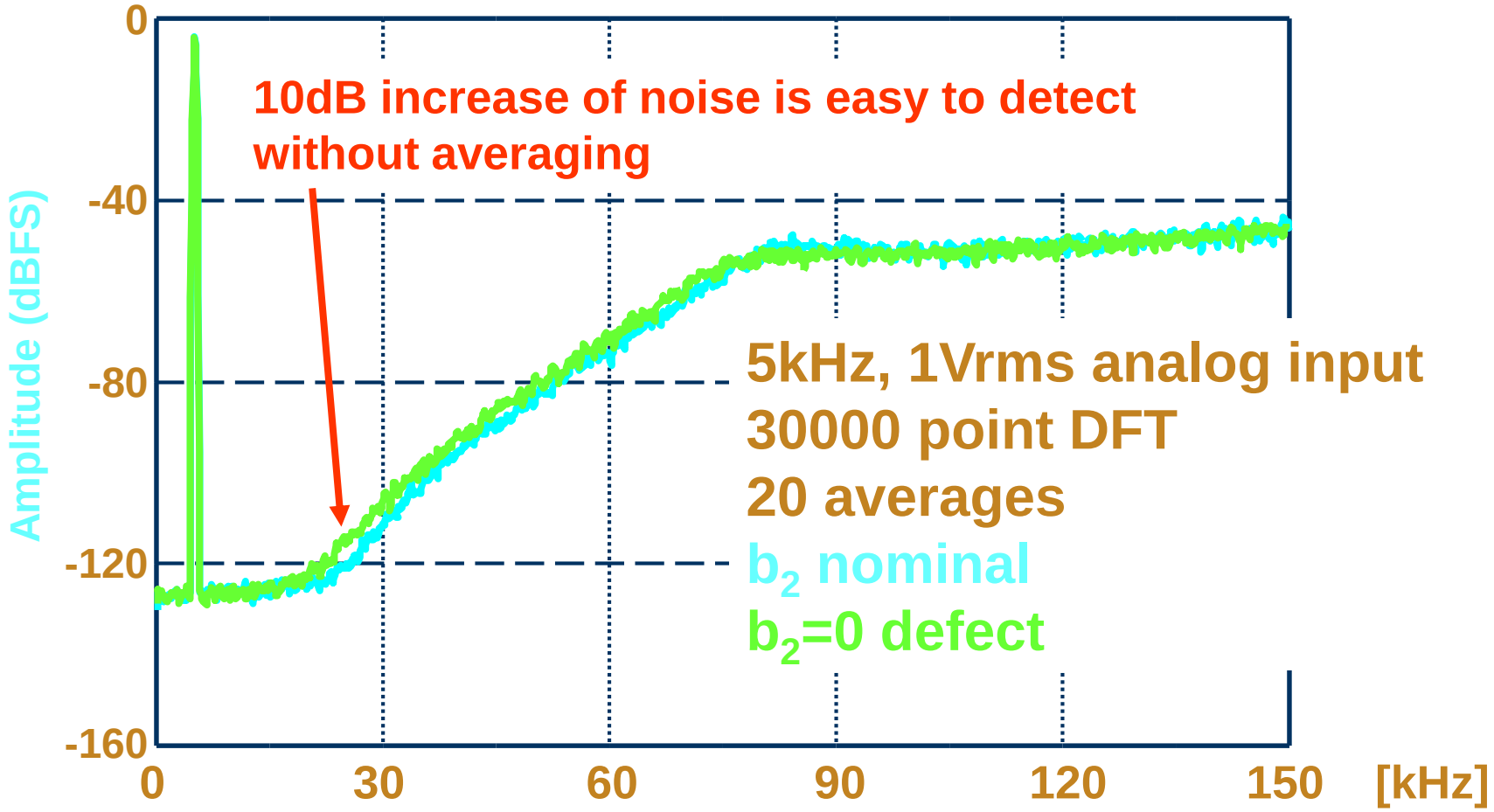
Test Modes

- The small increase in noise above 20kHz would probably be missed in production test
  - Dynamic range is specified to include only noise from 0–20kHz
- Should we ship the defective unit?
  - Absolutely not
  - The metal pattern associated with the defect is unknown, and it may lead to a catastrophic failure later (reliability problem)
- Let's see if a 1-bit test mode can detect the fault …

ΣΔ ADC 1-bit Test Mode



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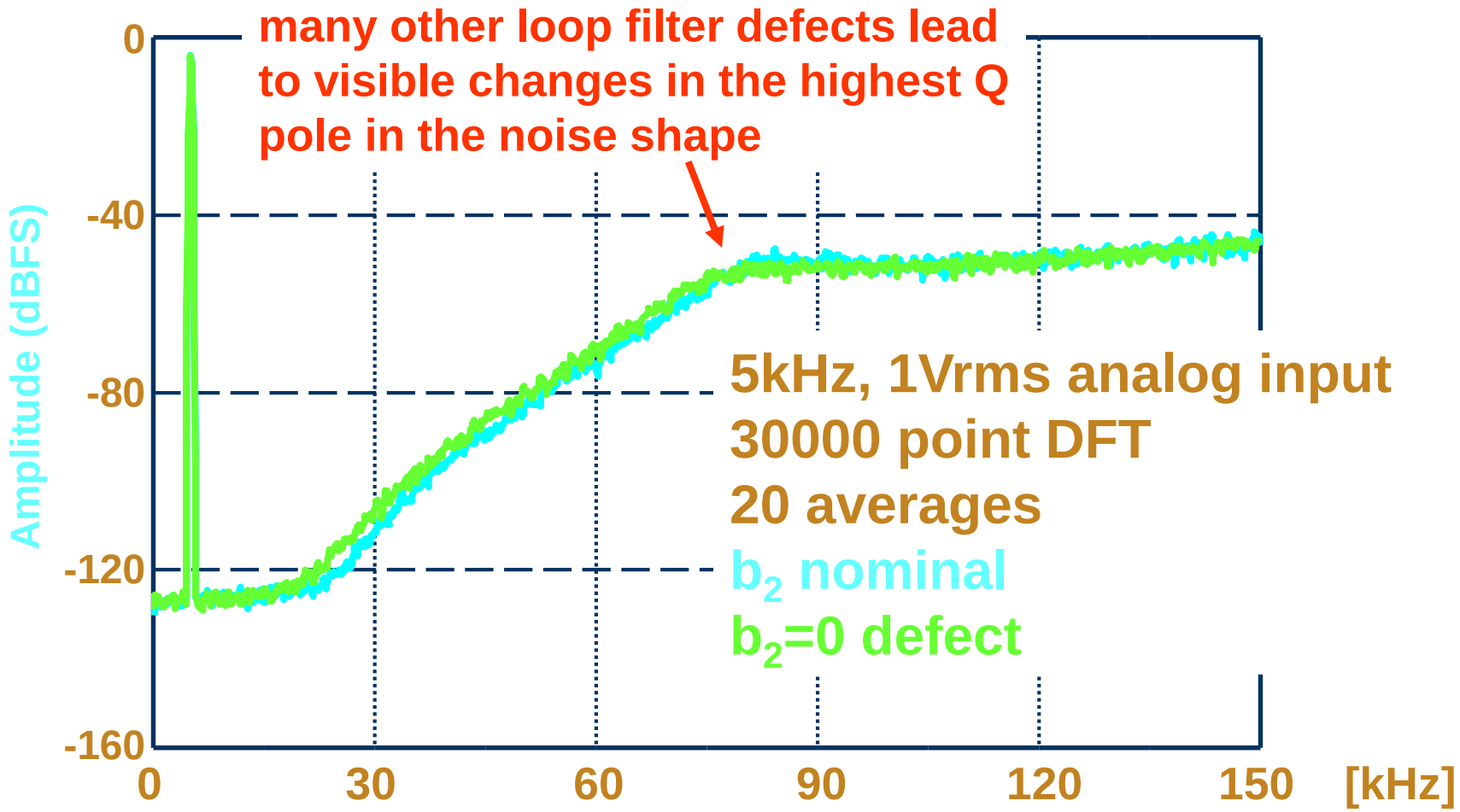
ΣΔ ADC 1-bit Test Mode



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Test Modes

- Models can analyze whether or not a specific defect is observable with a given test mode
  - Many defect-observability analyses are required to improve quality levels from ~100ppm defective to <10ppm defective
- These models improve over the production life of a chip and from generation-to-generation
  - If big customers detect a quality defect, they demand corrective action to improve tests so that units with the same defect won't be shipped again
  - Without 1-bit test modes, you're sunk!

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Multi-tone Tests

Multitone Tests

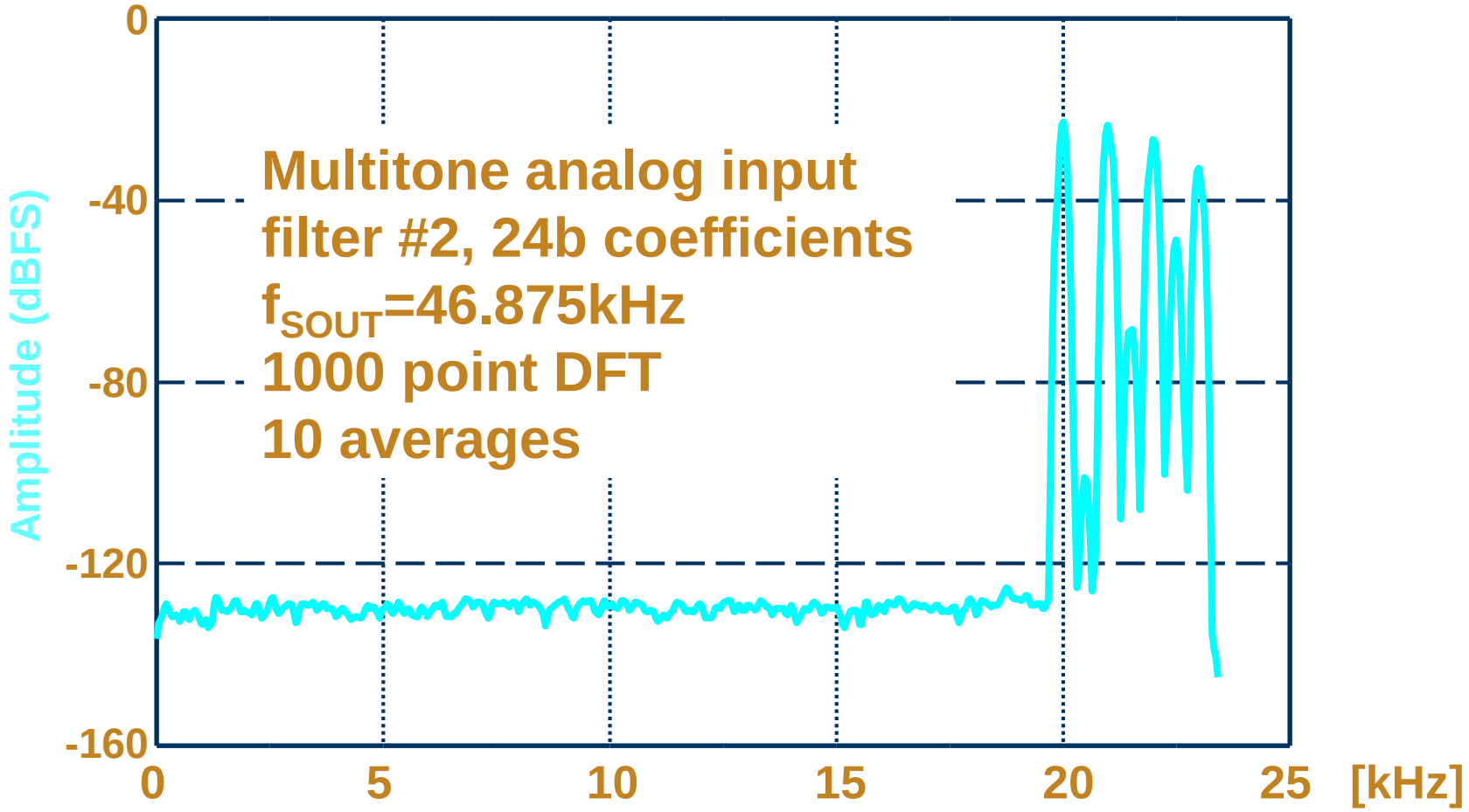
- As long as we're on the subject of testing, let's examine a fast, effective method to look at the frequency response of a filter or ADC
  - This method is used extensively in production tests of both analog filters and ADCs
  - It is not a substitute for classic, fault coverage testing of digital filters

Multitone Tests

- IC testers can synthesize and add sinewaves at many different frequencies in the digital domain
  - The digital sum is sent to a test system DAC which generates the analog input for a device under test
  - Frequency response at many different input frequencies can be determined with one test

- Let's see how our ΣΔ ADC responds to an input which is a sum of 20, 21, 22, 23, 24.375, 25.375, 26.375, and 27.375kHz sinewaves

ΣΔ ADC Multitone DFT



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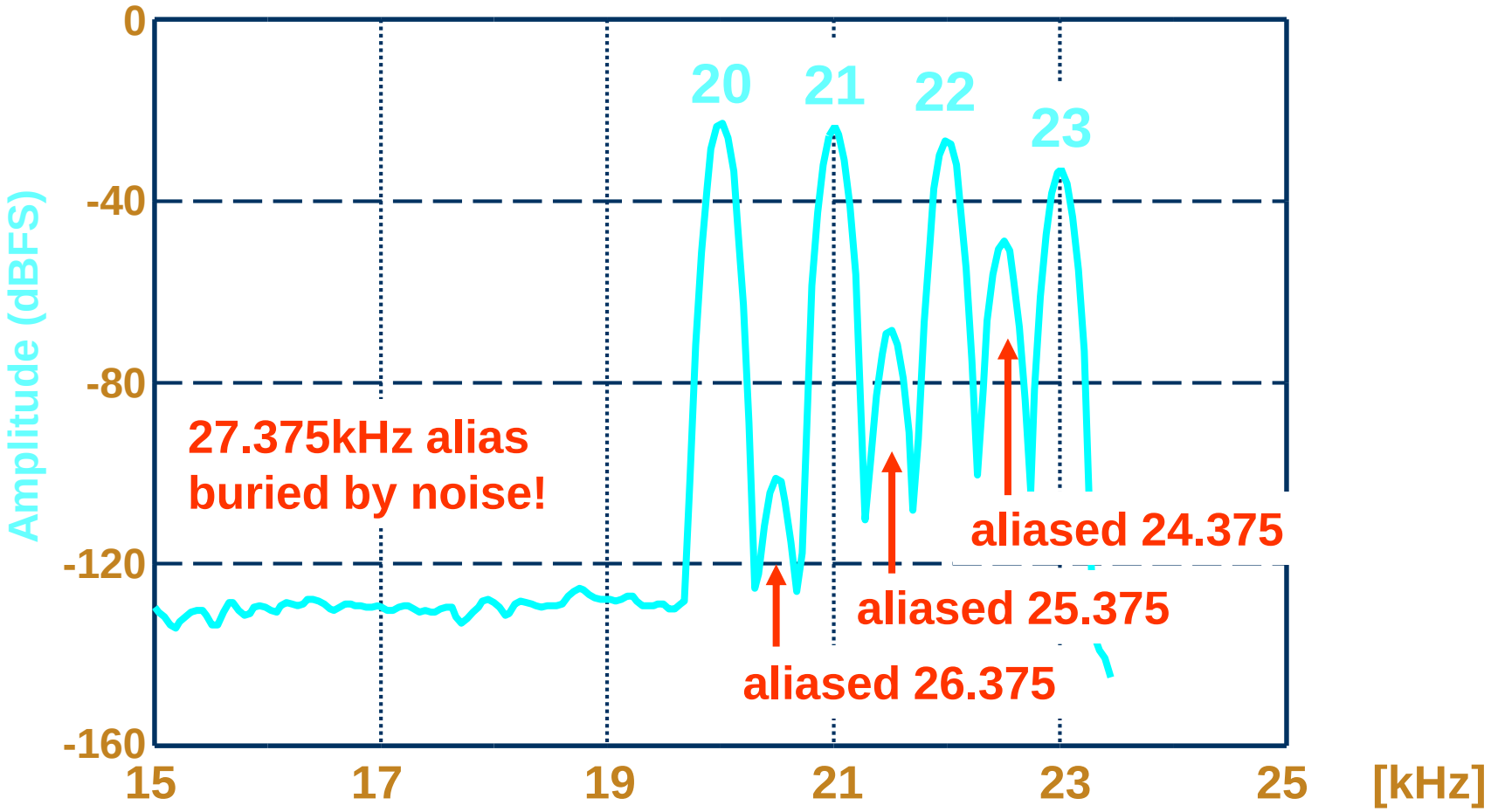
ΣΔ ADC Multitone DFT



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Multitone Tests

- Note how elegantly the multitone output amplitudes trace the transition band of the decimation filter

- Total observation time must be long enough to resolve each of the individual frequencies
  - Hz/bin is the reciprocal of the total observation time
  - ~1000 ADC output samples in this example