Broadcast Signal Lab

RFSigns.com

The Role of the Detector

NAB Broadcast Engineering Conference

2008

David Maxson

Overview

- Measuring IBOC Signals
  - Spectrum Occupancy
  - Quality of Service
- Measurement Objectives
  - Accuracy
  - Repeatability

Overview

- Covered in this Presentation
  - Regulation & Standards
    - FCC Rules still in flux
    - NRSC-5-B just adopted
  - Measuring
    - Spectrum Analyzer
    - Application Specific Device
  - Measurement Techniques
    - Signal Acquisition
    - Detection
    - Measurement

Regulation and Standards

Digital Audio Broadcasting Systems and Their Impact on the Terrestrial Radio Broadcast Service,

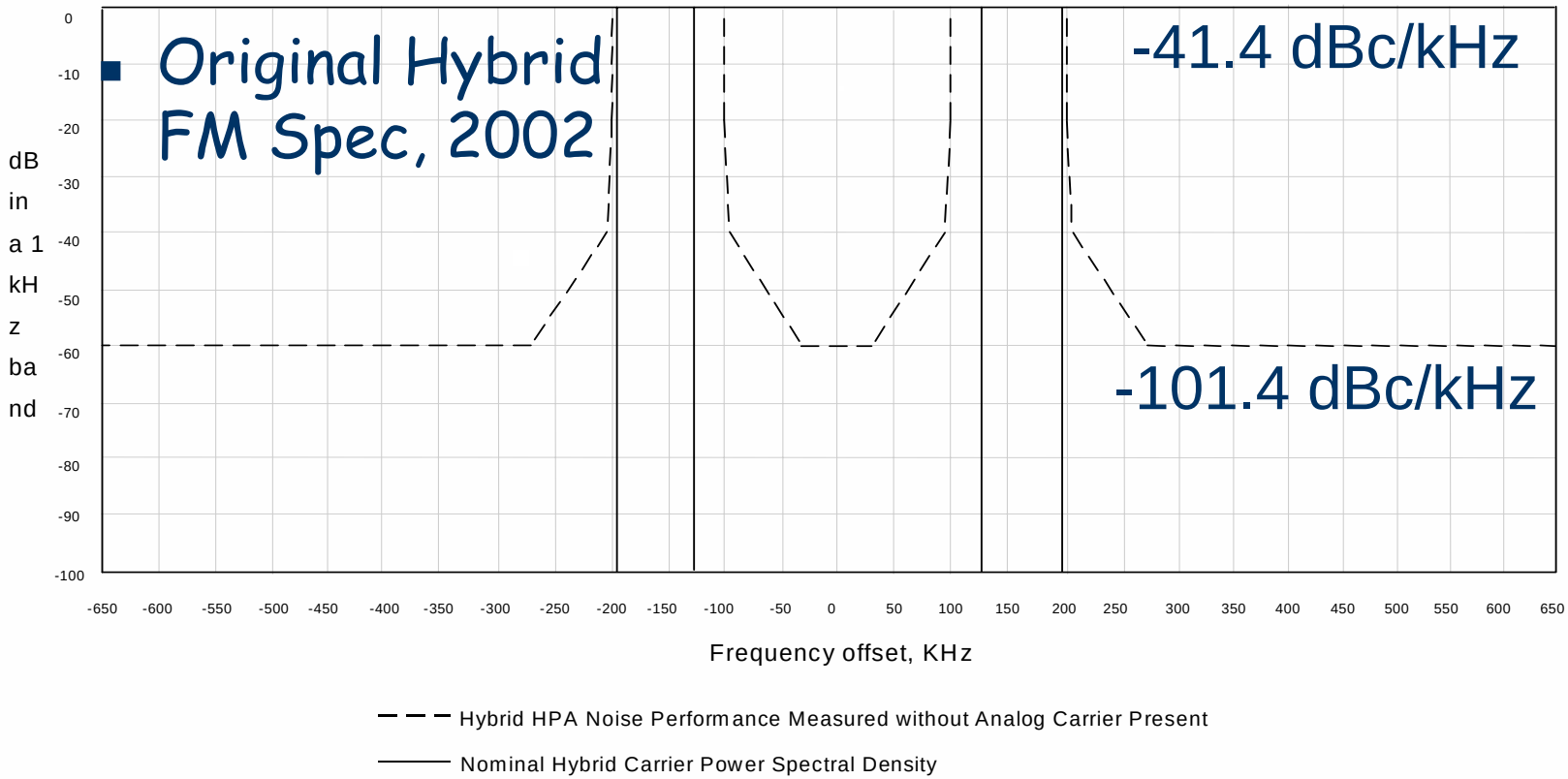
- *First Report and Order*, FCC 02-286, 17 FCC Rcd 19990, released October 11, 2002.

E.41 Interim IBOC Operations

- As of the release of this *Report and Order*, stations may request authority to operate on an interim basis with the hybrid IBOC facilities described in Appendices B and C herein.

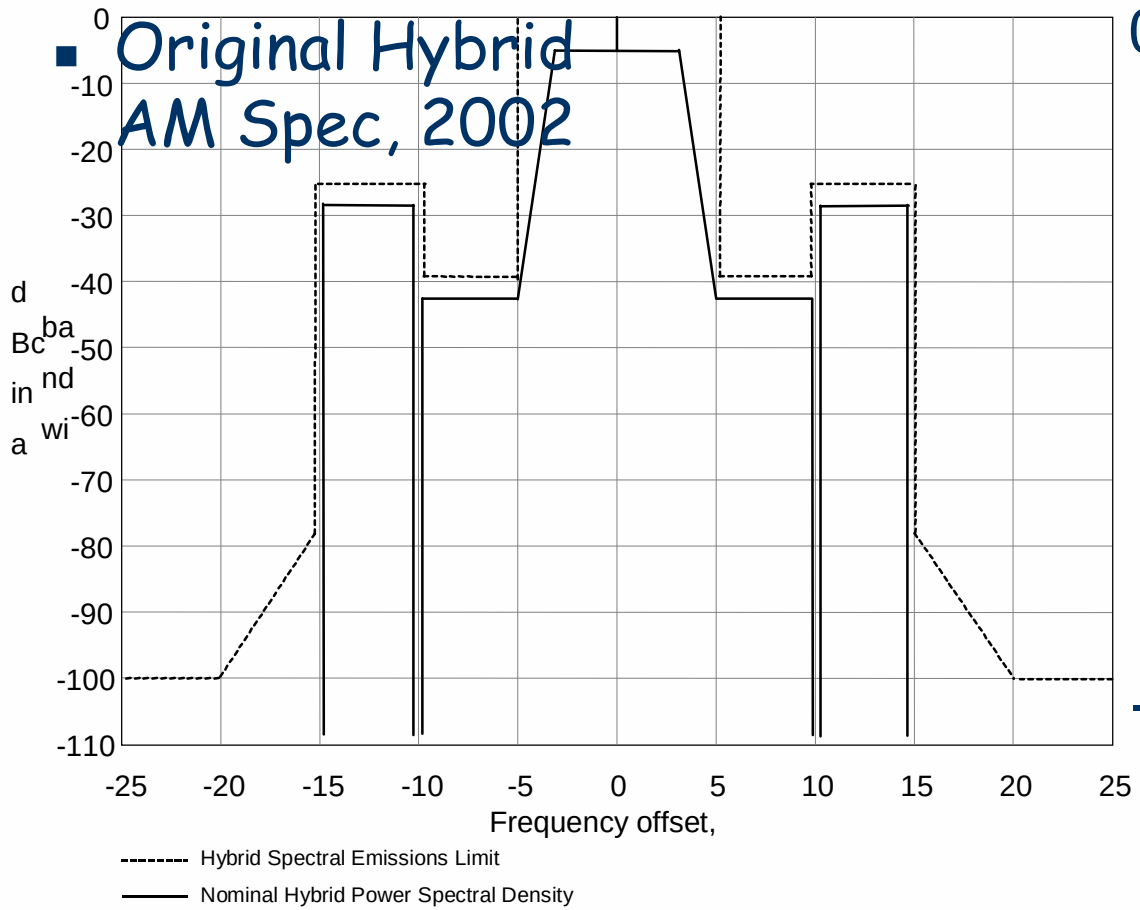
[1] *See* Appendix B, FM IBOC Specification; *see also* Appendix C, AM IBOC Specification.

Regulation and Standards



Regulation and Standards

- Original Hybrid AM Spec, 2002



0 dBc/300 Hz

-100 dBc/300 Hz

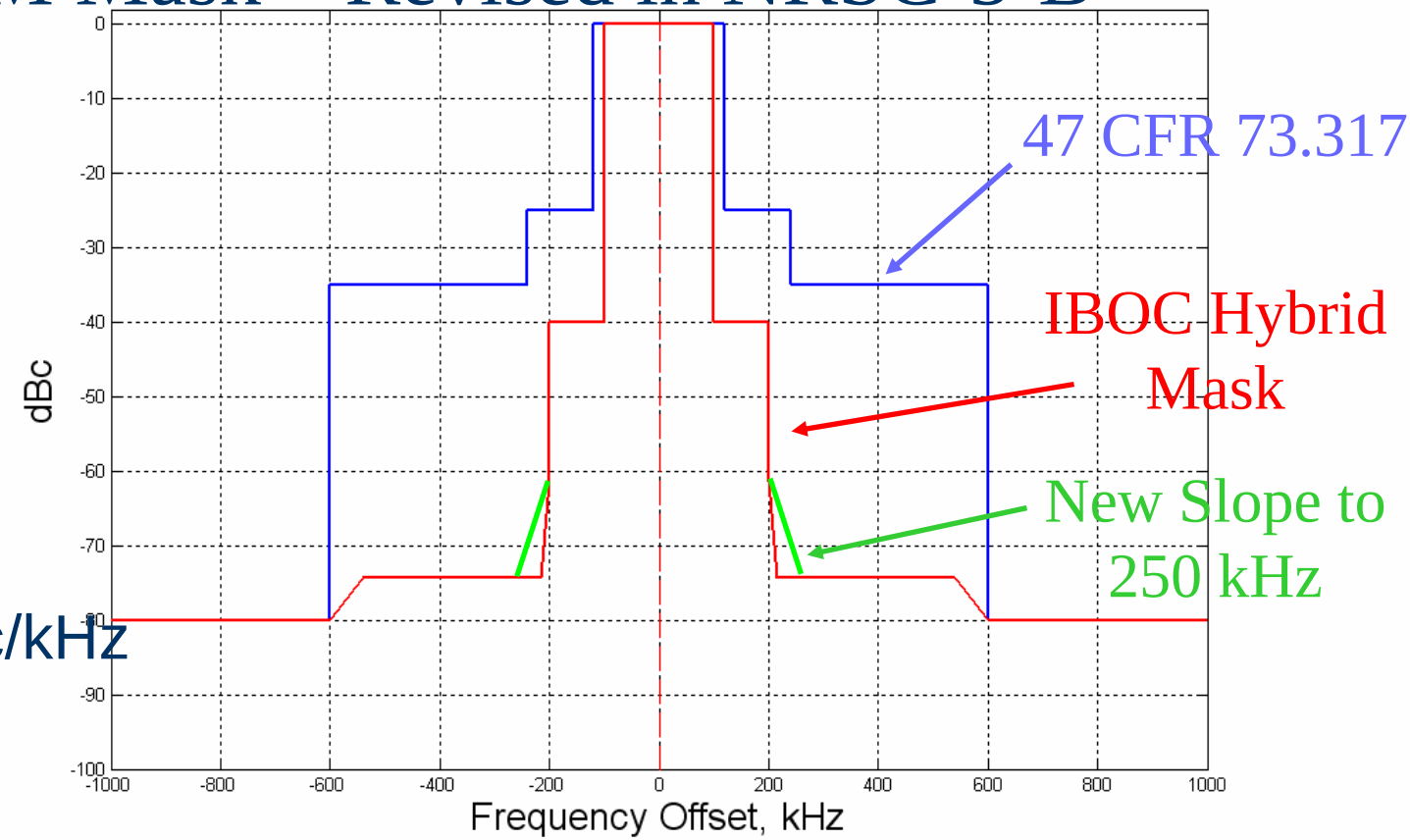
Regulation and Standards

- 2nd Report and Order, May 2007
- **III.9.102 Other Technical Issues**
- In the *DAB FNPRM*, we raised for comment other technical issues relevant to the discussion of DAB operations, including (1) AM and FM definitional issues; (2) interference; (3) AM stereo; (4) operating power; and (5) predicted coverage for digital signals.[1] We find that these issues have been sufficiently addressed in the *DAB R&O* to permit station authorization on an interim basis. Further evaluation of these issues is best undertaken in conjunction with the NRSC-5 standards review.

  [1] *See* 19 FCC Rcd at 7521-26.

Regulation and Standards

- FM Mask – Revised in NRSC-5-B



Regulation and Standards

- FM
  - " For hybrid systems, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 1 kHz bandwidth over a 30-second segment of time."

NRSC-5-A Standard, Reference Document #6, *Doc. No. SY_SSS_1026s rev. D, HD Radio™ FM Transmission System Specifications, iBiquity Digital Corporation, 2/18/05*

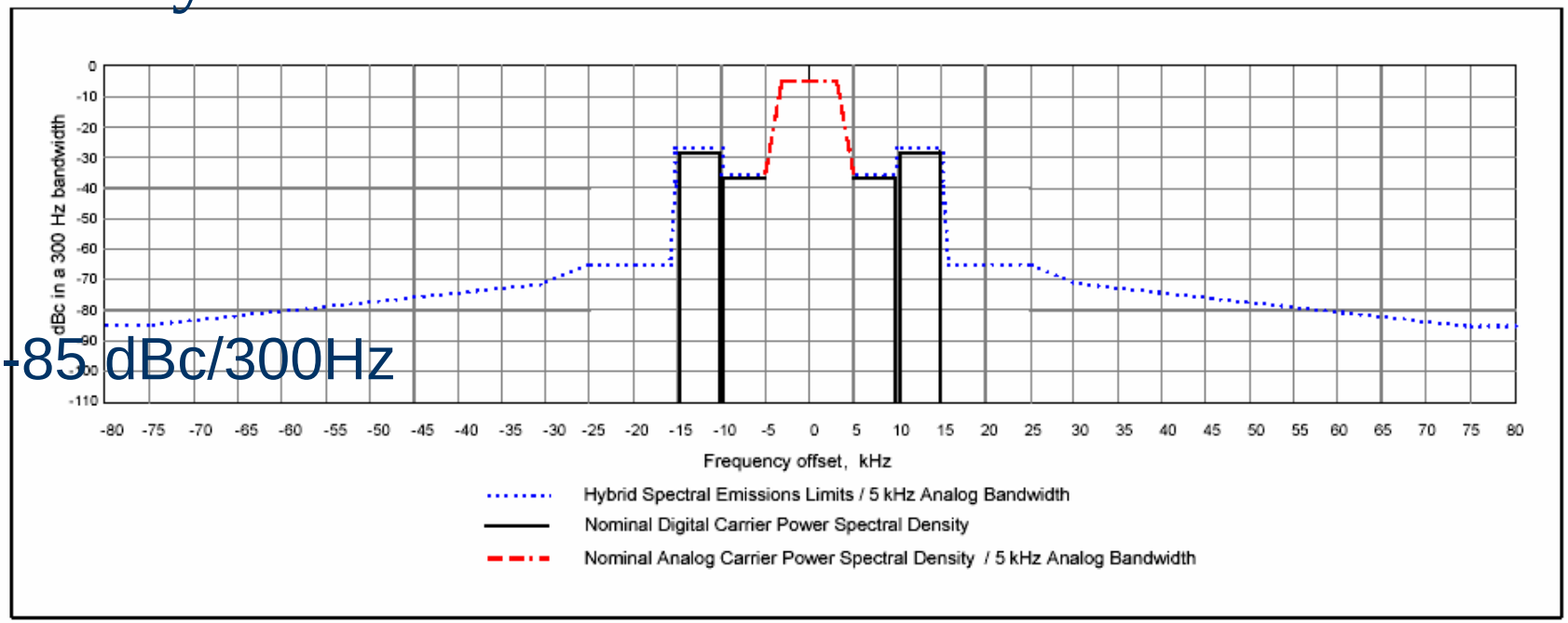
Regulation and Standards

- FM
  - " For hybrid systems, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 1 kHz bandwidth over a 30-second segment of time and a minimum of 100 sweeps."

NRSC-5-B Standard, Reference Document #6, *Doc. No. SY_SSS_1026s rev. E, HD Radio™ FM Transmission System Specifications, iBiquity Digital Corporation, 6/16/06*

Regulation and Standards

- Hybrid AM Mask



-85 dBc/300Hz

Figure 9. NRSC-5 AM hybrid waveform spectral emissions limits for 5 kHz analog bandwith

Regulations and Standards

- AM
  - " For hybrid systems, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 300 Hz bandwidth over a 30-second segment of time."

NRSC-5 Standard, Reference Document #6, *Doc. No. SY_SSS_1026s rev. D, HD Radio™ FM Transmission System Specifications, iBiquity Digital Corporation, 2/18/05*

Regulations and Standards

- AM
  - " For hybrid systems, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 300 Hz bandwidth over a 30-second segment of time and a minimum of 100 sweeps."

NRSC-5-B Standard, Reference Document #6, *Doc. No. SY_SSS_1026s rev. E, HD Radio™ FM Transmission System Specifications, iBiquity Digital Corporation, 6/16/06*

Regulation and Standards

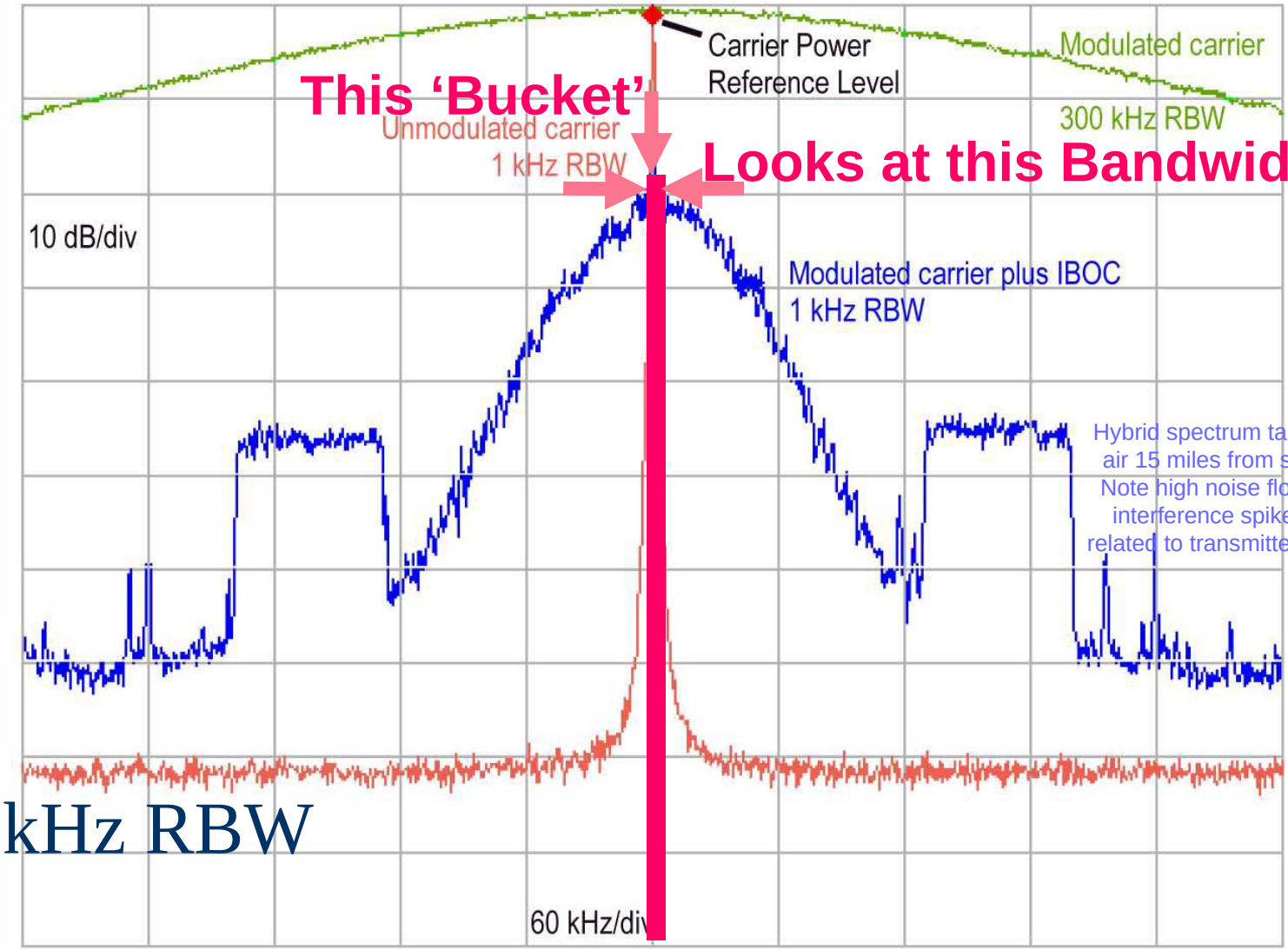
- Current Hybrid Masks
  - Presumed applicable
  - Basic measurement method described
    - Averaging
    - 30 seconds
    - 100 sweeps
    - Specified PSD bandwidths

Regulation and Standards

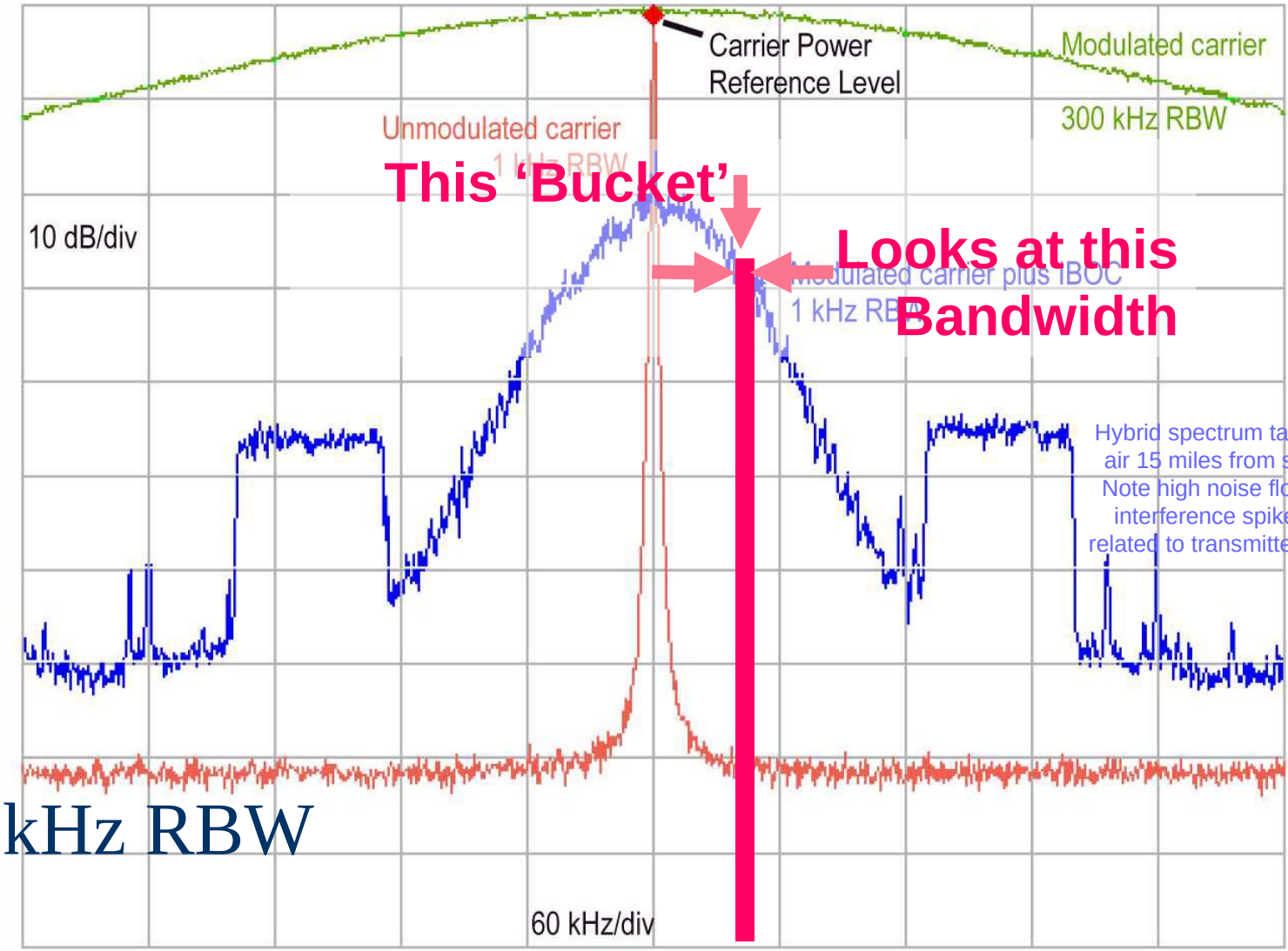
- NRSC Action
  - Accepted iBiquity wording in the NRSC-5-B reference documents
  - Separate guideline document for measurement locations and methods
    - In process
  - Other NRSC Guidelines
- **NRSC-G100**: Bandwidth Options for Analog AM Broadcasters *(September 2007)*
- **NRSC-G200**: Harmonization of RDS and IBOC Program Service Data (PSD) Guideline *(September 2007)*

Swept Analyzer Basics

- Local oscillator and IF filter
  - Sweep across a spectrum
  - Like manually tuning a filter
    - up frequency
    - very quickly
- As it sweeps, data are collected in frequency “buckets”


This 'Bucket'
Looks at this Bandwidth
Carrier Power
Reference Level
Modulated carrier
300 kHz RBW
Unmodulated carrier
1 kHz RBW
10 dB/div
Modulated carrier plus IBOC
1 kHz RBW
Hybrid spectrum taken off-air 15 miles from station. Note high noise floor and interference spikes not related to transmitted signal
60 kHz/div

- 1 kHz RBW


Carrier Power
Reference Level
Modulated carrier
300 kHz RBW
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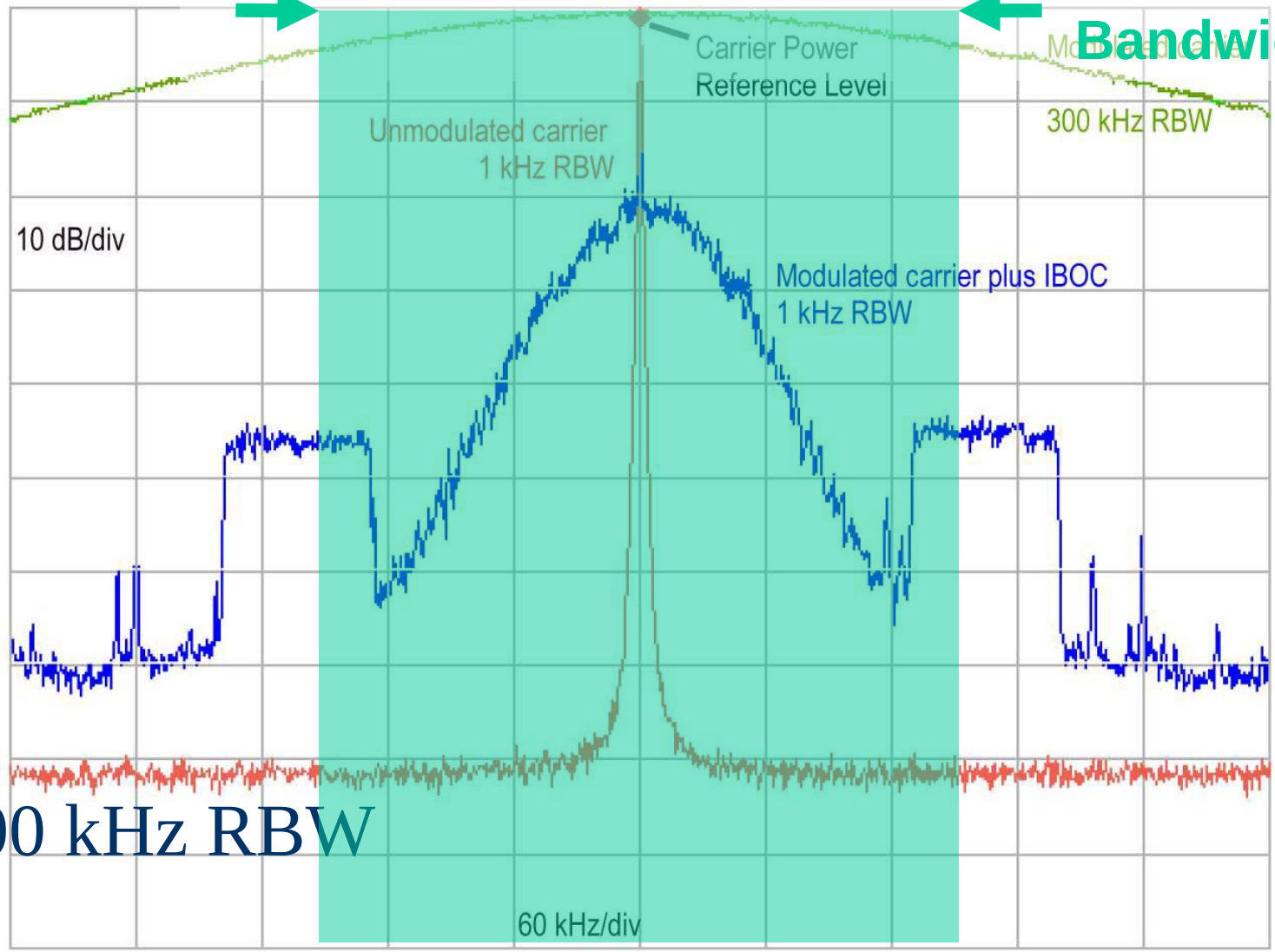
This 'Bucket'
10 dB/div
Looks at this
Bandwidth
1 kHz RBW
Hybrid spectrum taken off-air 15 miles from station. Note high noise floor and interference spikes not related to transmitted signal
60 kHz/div

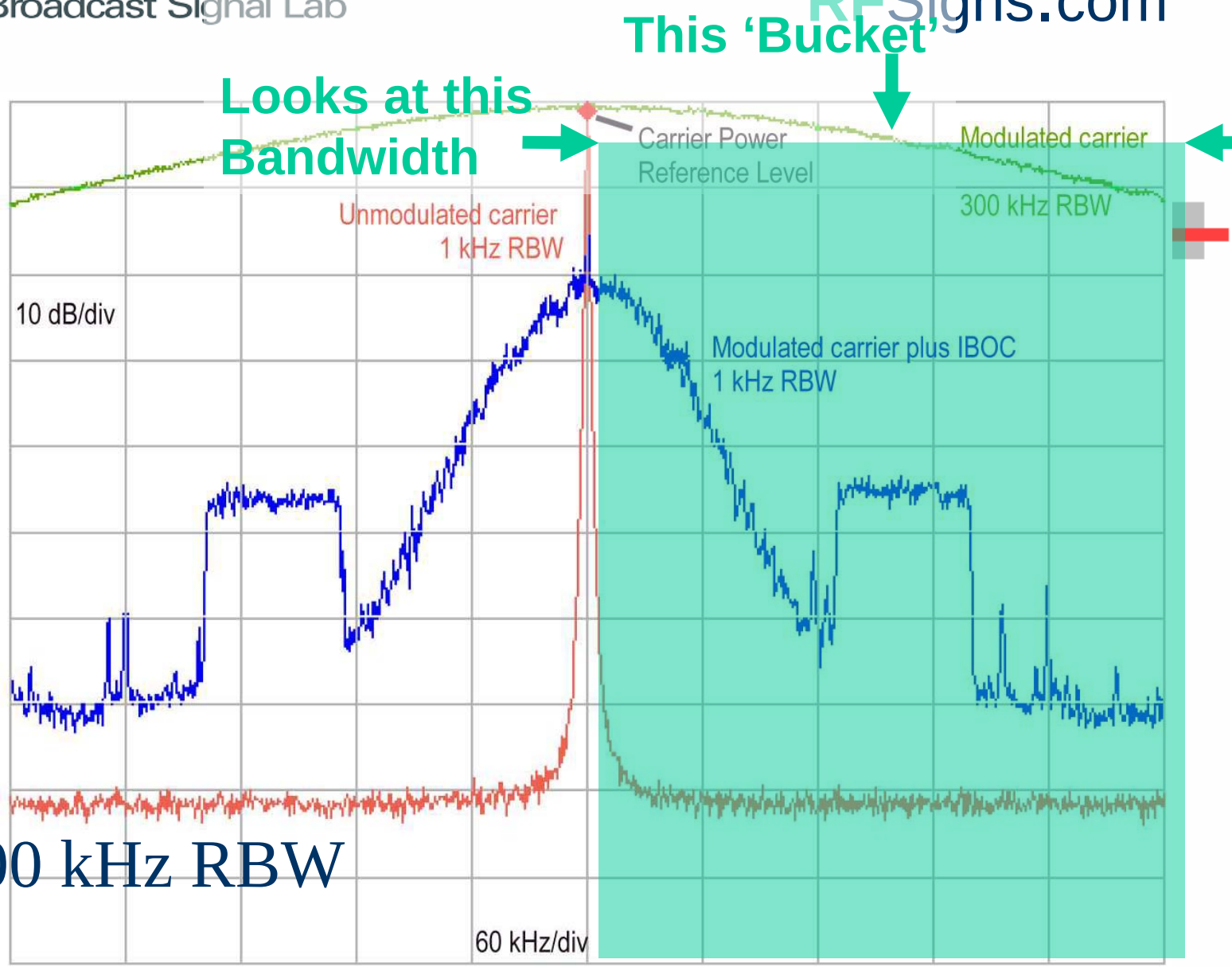
- 1 kHz RBW

This 'Bucket'

Looks at this Bandwidth



- 300 kHz RBW


This 'Bucket'
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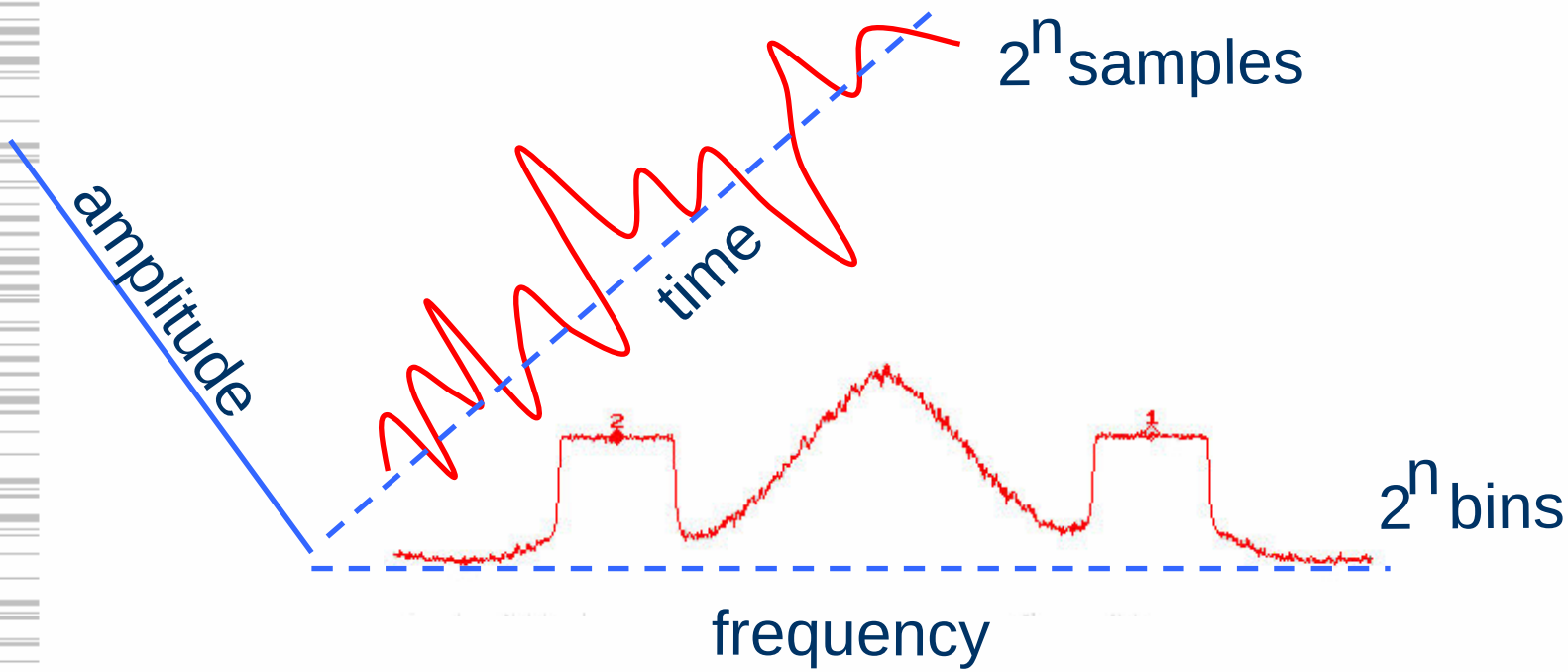
Carrier Power Reference Level
Modulated carrier
300 kHz RBW
Unmodulated carrier
1 kHz RBW
10 dB/div
Modulated carrier plus IBOC
1 kHz RBW
60 kHz/div

- 300 kHz RBW

FFT Analyzer Basics

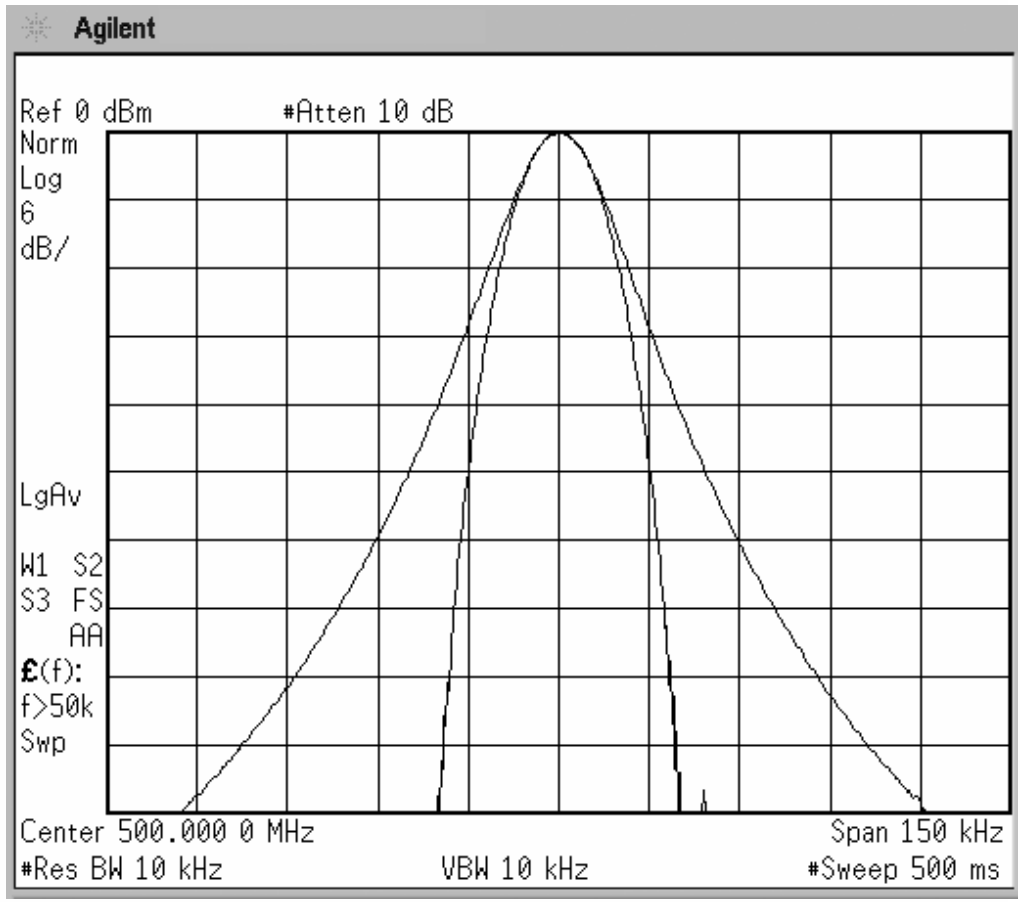
- No swept local oscillator
- Anti-alias filtering
  - Keeps out-of-spectrum energy from digitally folding over to the band of interest
- Number of data points (in time domain) transforms to frequency resolution (in frequency domain)
- After FFT transformation,
  the data points are frequency “bins”
  - FFT *bins* are comparable to swept *buckets*

FFT Analyzer Basics



FFT vs Swept

- FFT uses a *window* instead of *RBW* filter
  - Sharp filtering possible in the digital domain
- Swept analyzer RBW filters have physical properties
  - Wider skirts
- *Shape Factor* and *Noise bandwidth*

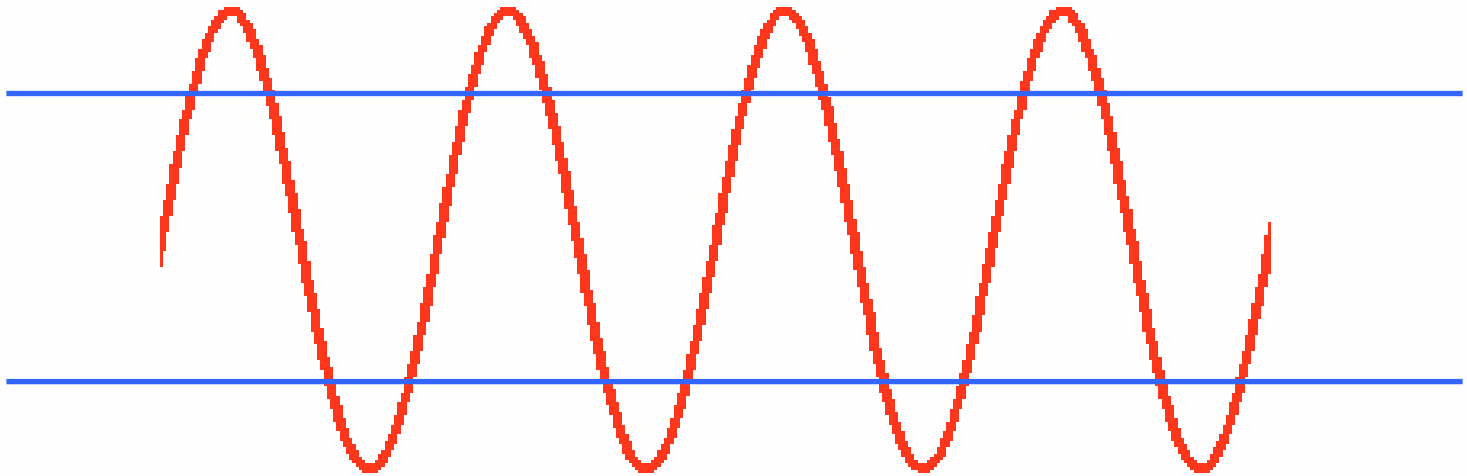


Measuring

- √ Averaging
- 30 seconds ?
- 100 sweeps
- Specified PSD bandwidths ?

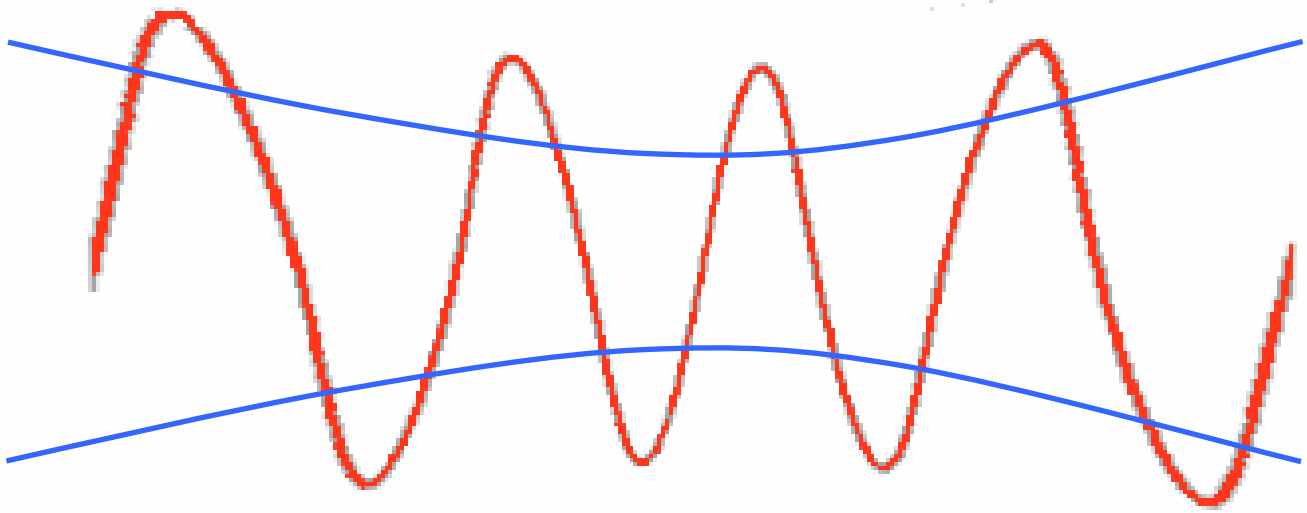
Averaging

- Power within the envelope of the waveform
  - 0.707 times the peak- sinusoidal



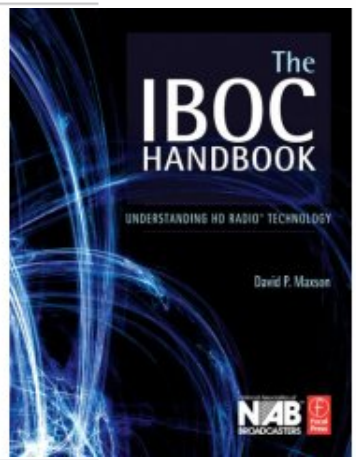
Measuring

- Power within the envelope of the waveform
  - Amplitude modulation changes the peak/average ratio

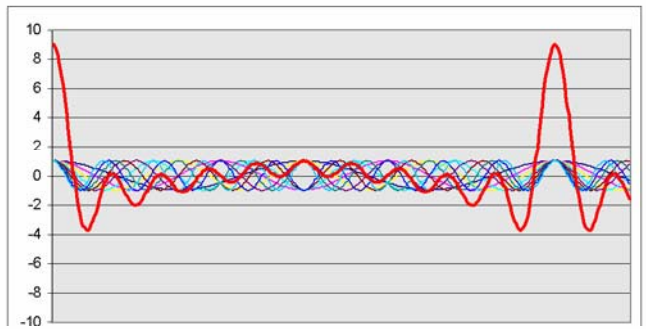


Averaging

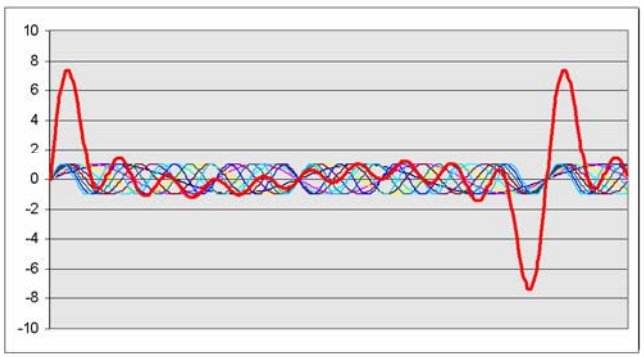
- OFDM is not sinusoidal



Nine Harmonically-Related Sine-Waves
(common peak at start)

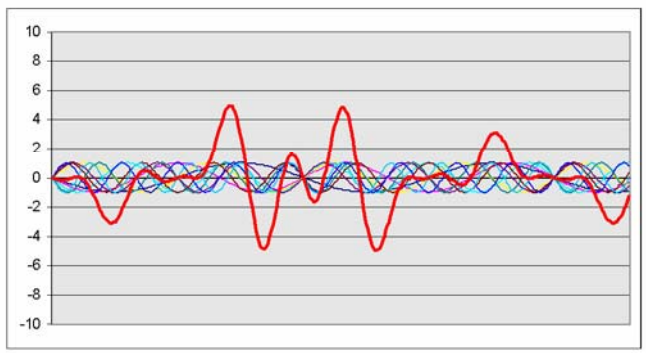


Nine Harmonically-Related Sine-Waves
(common zero-crossing at start)



Bold trace is the sum of nine traces of equal amplitude

Nine Harmonically-Related Sine-Waves
(some randomly shifted 180 degrees)



Bold trace is the sum of nine traces of equal amplitude

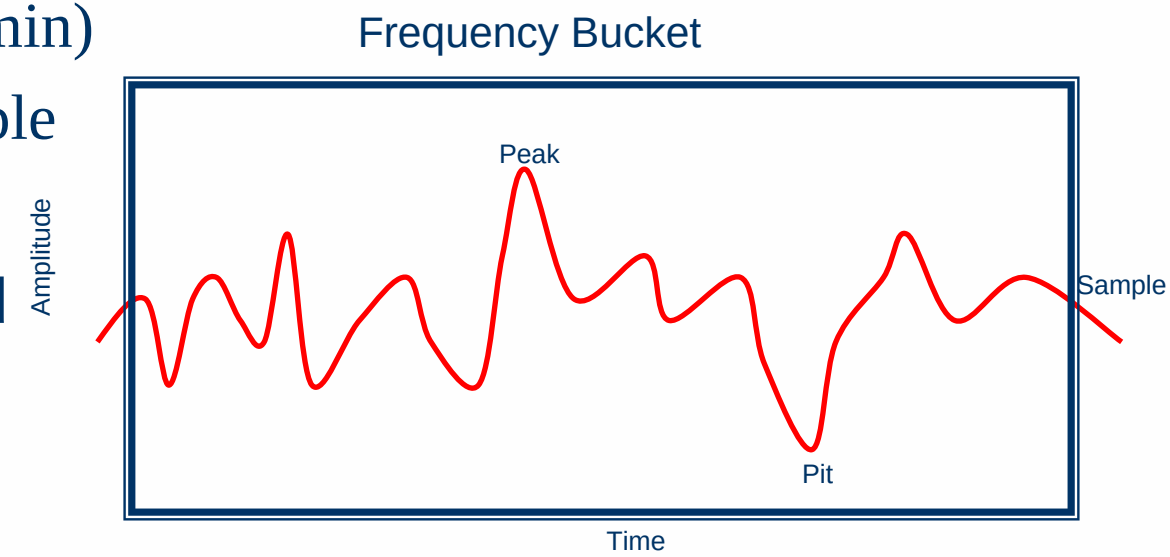
Peak Detection

- Traditional detection modes
  - Peak Detector reports the power level assuming it is seeing a sinusoid
    - = 0.707 x peak voltage
    - Instantaneous measurement
    - Represents the average power of the sinusoid during the bucket time
    - Overstates the average power of a modulated waveform in the bucket time

Peak Detection

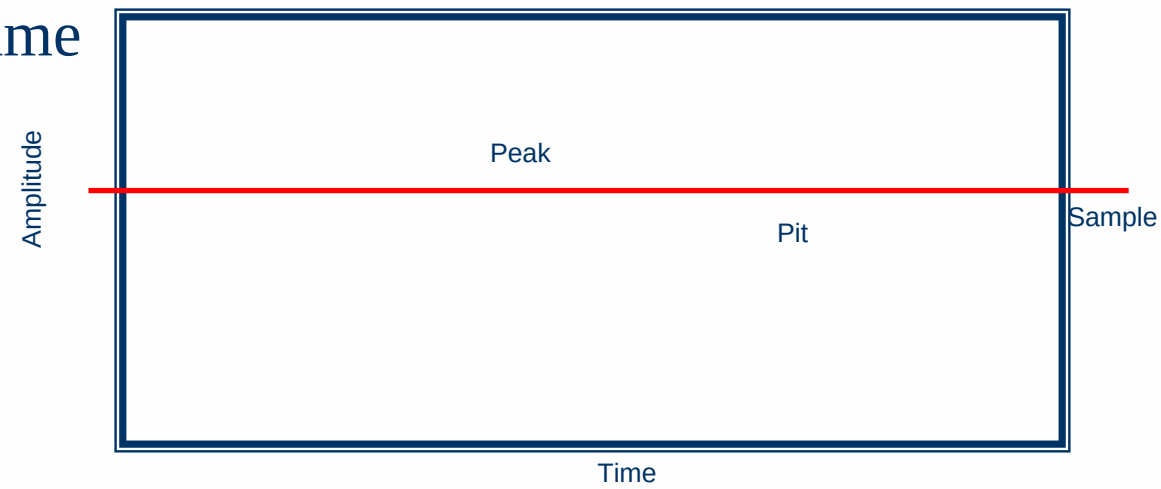
- Traditional detection modes
  - Peak (max)
  - Pit (min)
  - Sample

Modulated Waveform Envelope



Peak Detection

- Traditional detection modes
  - Sinusoid envelope
  - Peak Pit &Sample are same



Peak vs Sample Detection

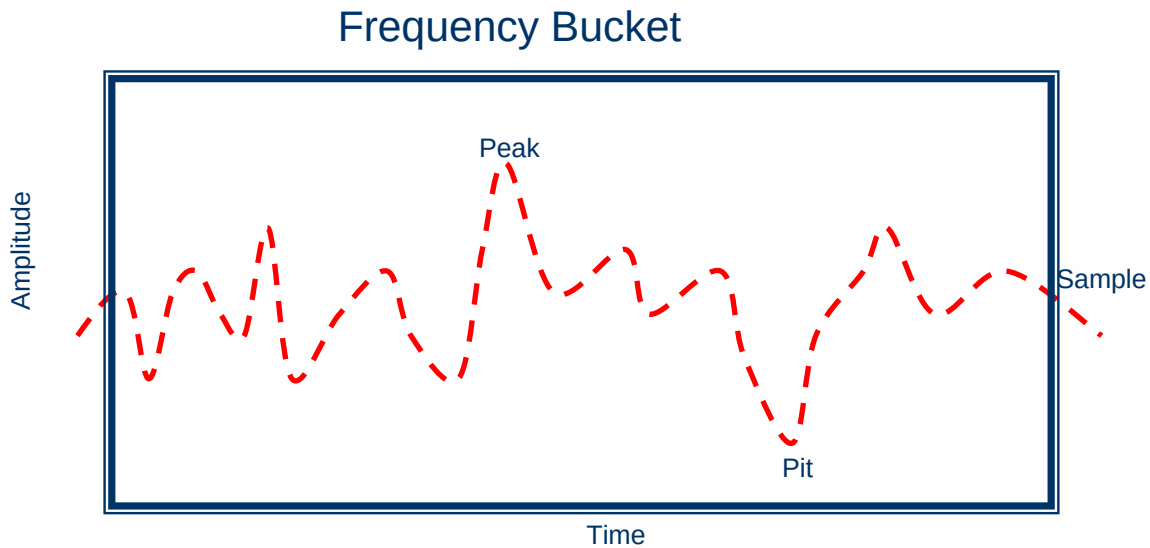
- Traditional detection modes
  - Peak Detector not reliable power indicator for complex waveforms
  - Sample detector OK
    - Have to average numerous traces
    - Provides a series of single random samples to average
    - Trace averaging has implications

Sample Detection

- Sample Detection of a white noise-like waveform
  - Each sample is detected and presented as if it were the sinusoidal power (the 0.707 factor)
  - The noise waveform power is understated by averaging a series of sample-detected traces
    - The average of the logs is not the log of the average
    - 2.51 dB understatement of power
    - Experimentally, IBOC OFDM reads 2.46 dB low with sample detector and log trace averaging
    - Assumes reference level is set without same error (CW-like analog waveform)

State of the Art "Detection"

- Digital analyzers with computed detection
  - RMS, a.k.a Average: Power
  - Average, a.k.a Average: Voltage



  - Multiple samples per bucket

State of the Art "Detection"

- Digital Analyzers have different implementations
  - Some trace averages employ the raw data
    - Accurately report power with no offset
  - Some trace averages store the computed trace data and impose the average-of-the-logs offset.

- Talk to someone who really knows the insides of your analyzer

State of the Art "Detection"

- Some digital analyzers are FFT analyzers with a swept analyzer user interface.
  - Of no consequence to the user
    - Other than providing good power computation capability

Measuring to the Spec

- Averaging
- 30 seconds
- 100 sweeps
- Specified PSD bandwidths

Effect of Filter Bandwidth

- Physical filters
  - Wider shape factor, higher noise BW
    - 4-pole synchronously tuned filters
      - 0.52 dB overstatement of power on noiselike waveform
- Digital filters
  - If ideally shaped Gaussian, only hundredths of a dB overstatement

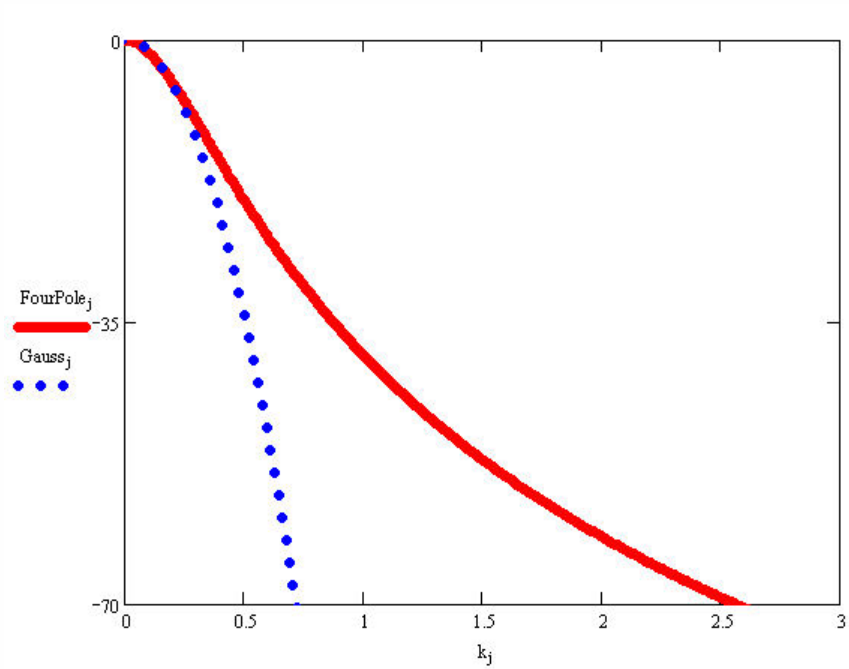
Effect of Filter Bandwidth

- Older spectrum analyzer
  - 4-pole filter
  - Sample detector
  - Trace averaging

- 2.51 – 0.52 = 1.99 dB understatement of power
  - Assumes reference level set without same error

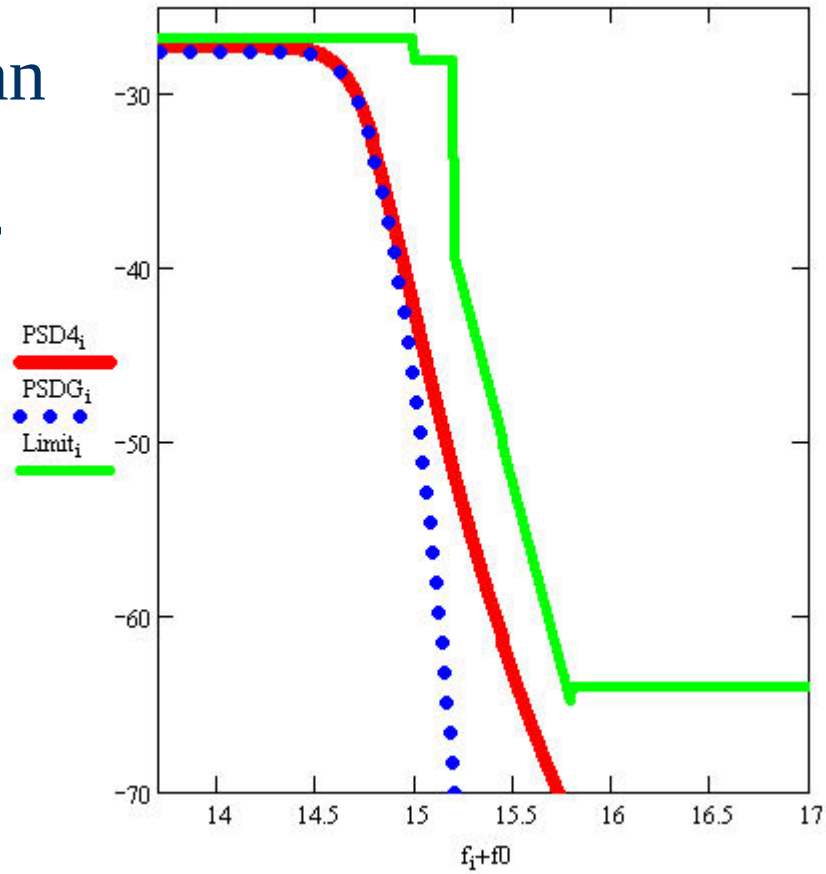
Effect of Filter Bandwidth

- Filter slope is critical in hybrid AM measurements
- 4-pole vs Gaussian filter slopes
- 300 Hz “RBW”



Effect of Filter Bandwidth

- 4-pole and Gaussian filters swept across OFDM cliff
  - Red and Blue
- AM IBOC Mask
  - Green



Measuring to the Spec

- Averaging
- 30 seconds
- 100 sweeps
- Specified PSD bandwidths

Measuring to the Spec

- Maximum sweep rate
  - Typically ½(RBW squared)
  - 1 kHz RBW
    - sweeps ½ MHz per second, max rate
    - About 1.2 seconds to cover a 600 kHz span
  - Only 25 sweeps in 30 seconds!!!
    - 2 minutes for 100 sweeps

Measuring to the Spec

- More detailed interpretation needed
  - Are AM and FM IBOC masks based on 4-pole, sample detected, trace averaged measurements?
    - NRSC Guideline is expected to clarify

Measuring to the Spec

- More detailed interpretation needed
  - What if an equipment manufacturer has an innovative way to assure compliance?
    - Tractable specification might coexist with the operational specification
    - Might be stated in a way that lets instruments evolve without sticking to 4-pole filters, swept analyzer & one specified RBW.

Acknowledgements

- NRSC ISDWG members, plus
- Bert Weiner
- David Gates, Cesium Communications
- Steve Cantrell, Anritsu
- And especially Joe Gorin, Agilent
  - For mathematical support and detector insights

Thank You

Presentation will be available for download
in the digital radio section at:

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