



Measuring Your IBOC Spectrum

David Maxson

Topics

- ◆ Measuring Power of Digital Waveforms
- ◆ IBOC RF Mask
- ◆ Digital Intermodulation and Interference

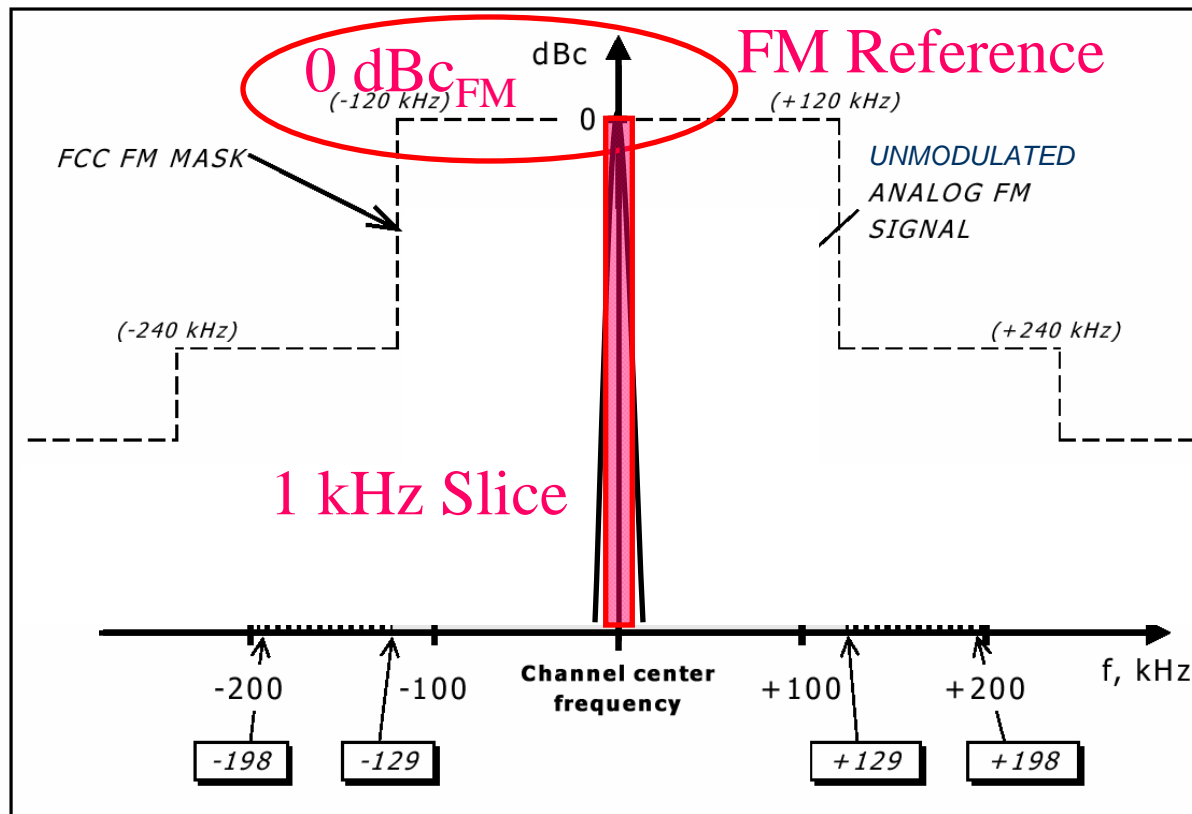
First Thought

- ◆ IBOC is amazing
 - Truly “Hybrid” of analog and digital
- ◆ Measurement issues will be addressed
 - Signals measured differently
 - Signals close in frequency
- ◆ Interference issues are minor
 - No FCC standards yet
 - Working IBOC Mask

Discussing Power

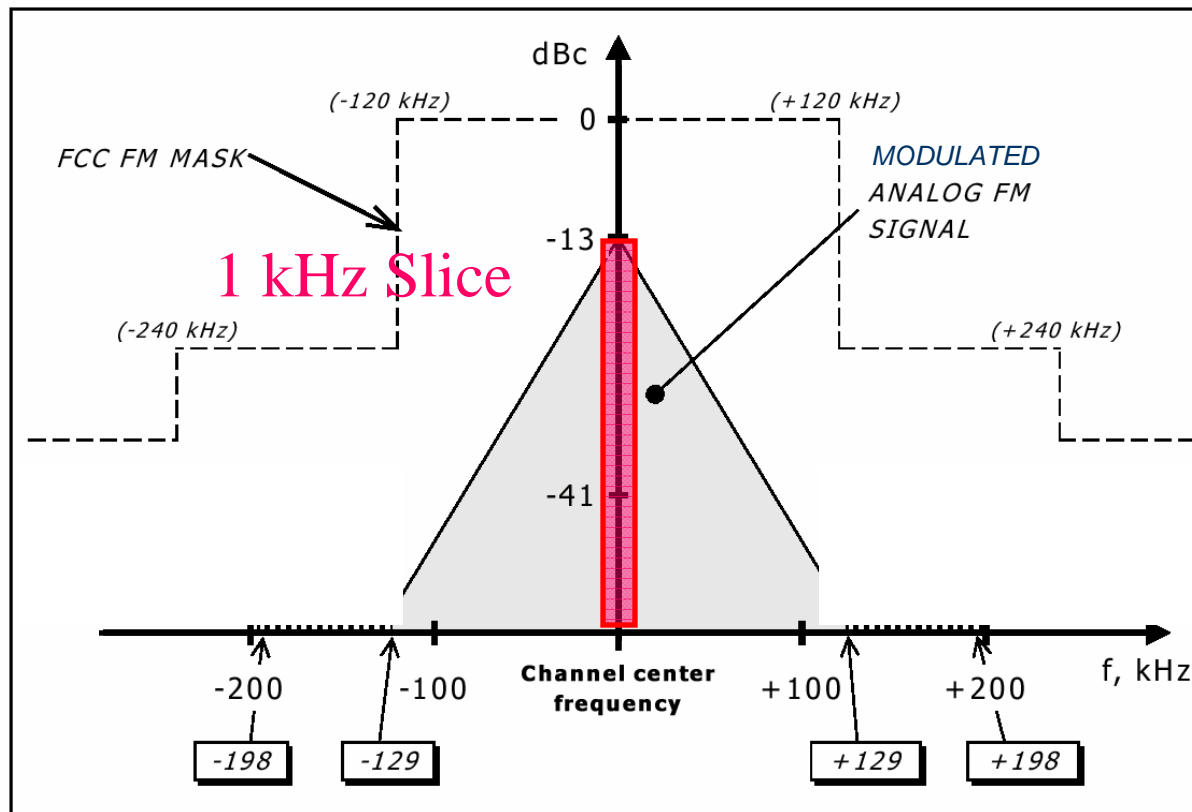
- ◆ FM analog carrier is the reference
 - “dBc” is common term
 - Helpful to differentiate dBc references for FM and for digital
 - Using “ dBc_{FM} ” for analog FM reference
 - Using “ dBc_{PM} ” for IBOC Primary Main OFDM carrier power (stipulate bandwidth!)

Discussing Power

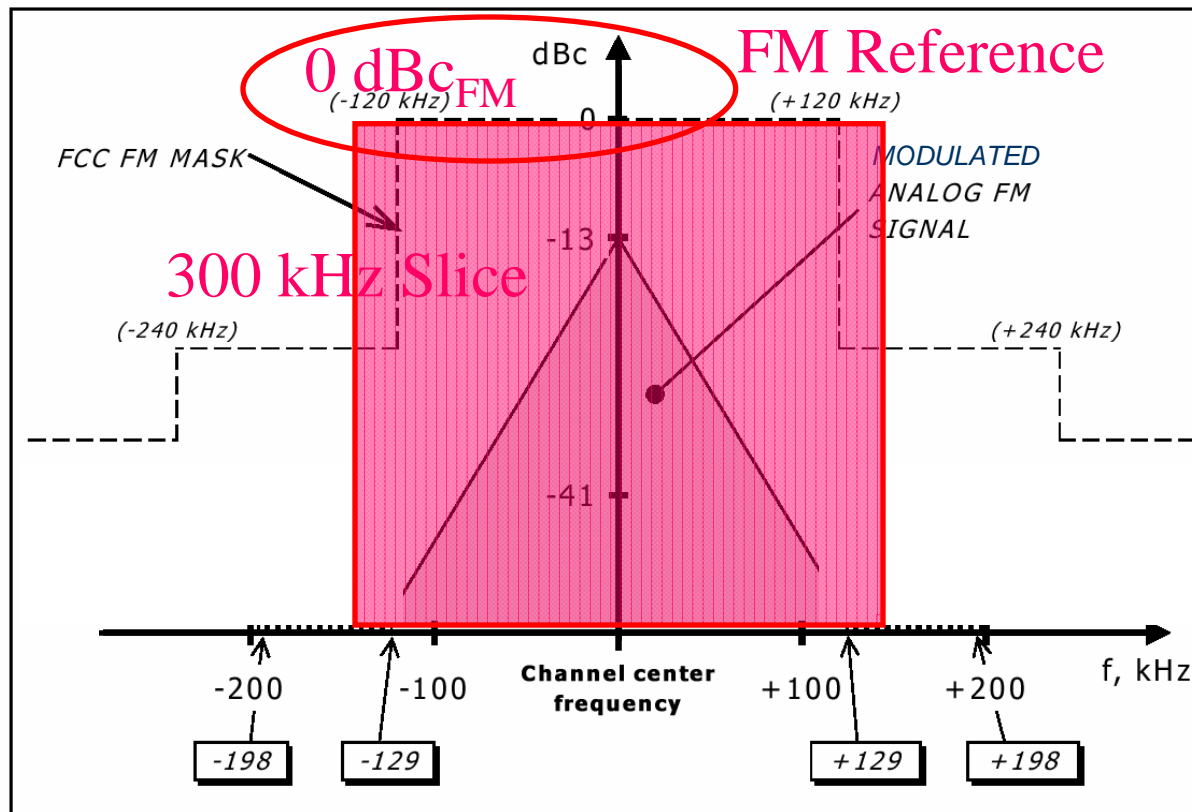


Underlying Graphic From NRSC

Discussing Power



Discussing Power



Discussing Power

- ◆ FM Power Reference Summary
 - Use unmodulated carrier and narrow bandwidth for most certain result
 - Alternatively, measure full bandwidth while modulated
 - Be certain noise not a factor and no foreign energy in bandwidth of analyzer
 - Watch your levels

Discussing Power

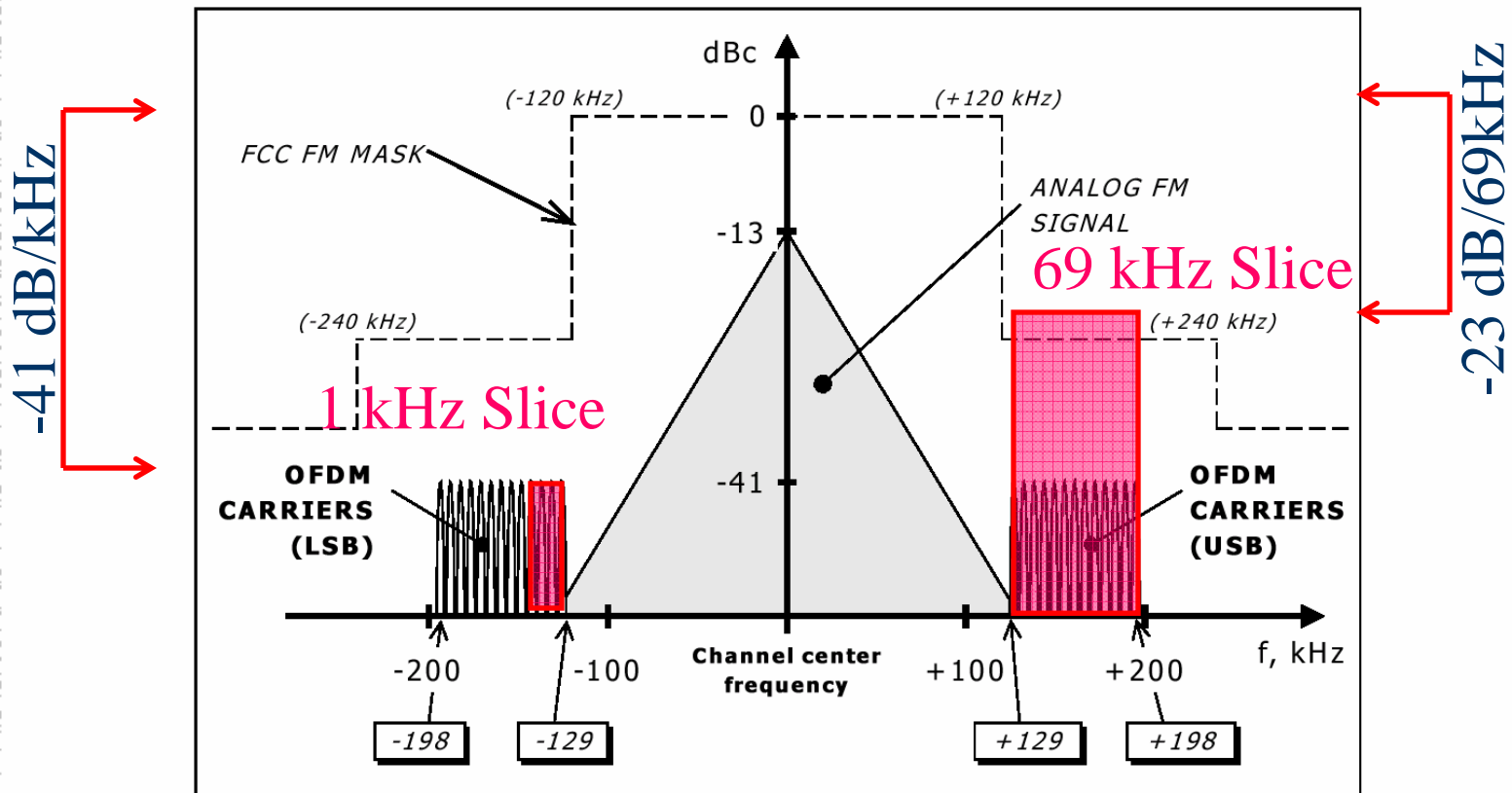


Figure 1. iBiquity FM IBOC system signal spectral power density

Discussing Power

- ◆ IBOC Primary Main “subcarriers”
 - Total digital power 20 dB down
 - (from FM analog)
 - One side 23 dB down
 - Power in 1 kHz bandwidth 41 dB down
 - System design specification
 - Balances analog compatibility with digital performance

Discussing Power

- ◆ IBOC Primary Main “subcarriers”
 - Linear amplification
 - Push transmitter into compression
 - For more efficiency
 - Reduces hardware cost per watt
 - With compression comes intermodulation
 - “Spectral regrowth”

Precorrection

- ◆ What's the Opposite of "Compond"?
 - Compress-Expand = Compond
 - Expand-Compress = Express????
- ◆ Precorrection is Expansion
 - Anticipates the compression of the Power Amp

Precorrection

- ◆ Compression Example:
 - A digital exciter without precorrection, measured 6-7 dB peak to average power ratio
 - After going through the PA, peak to average 4-5 dB

Discussing Power

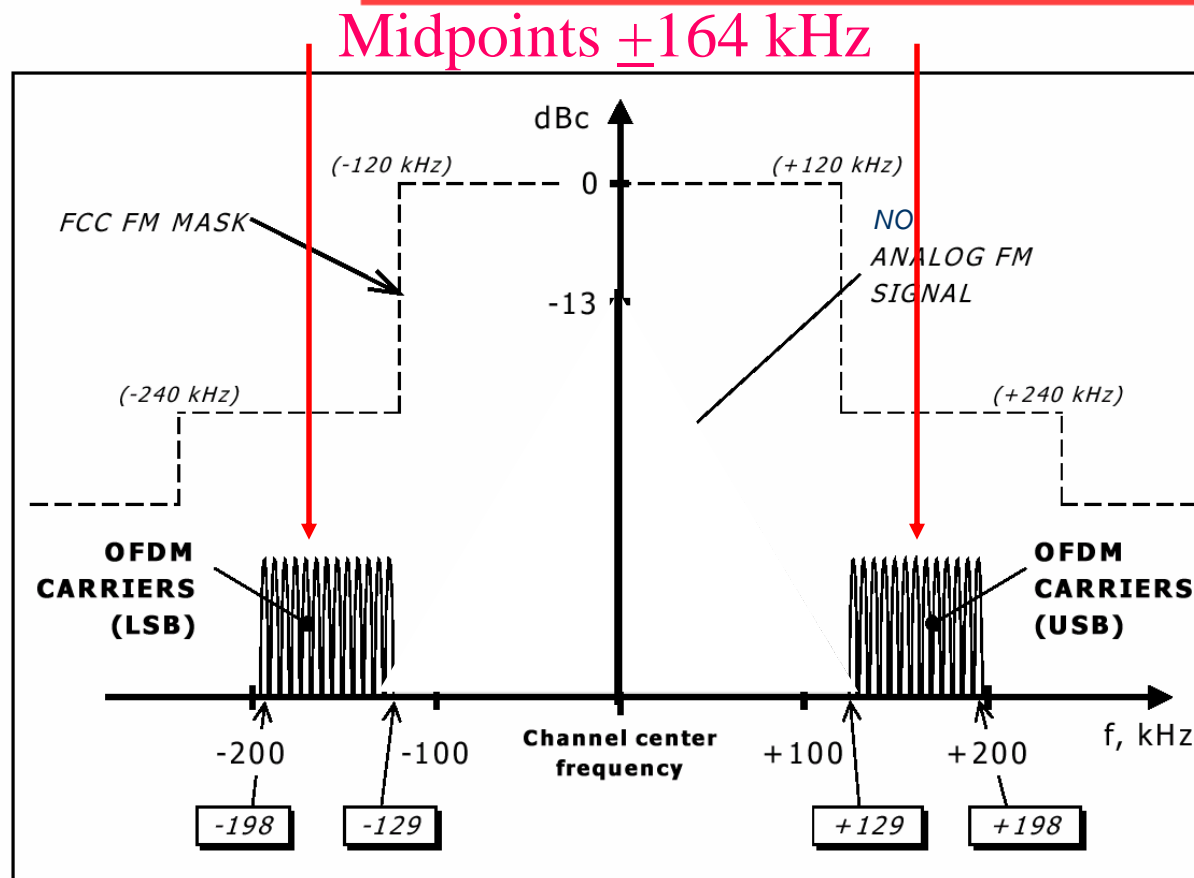


Figure 1. iBiquity FM IBOC system signal spectral power density

Discussing Power

Upper and Lower PM Intermodulation at
 ± 328 kHz Intervals



-492
(2A - B)

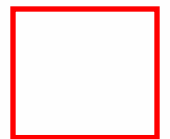


-164
(A)

Center



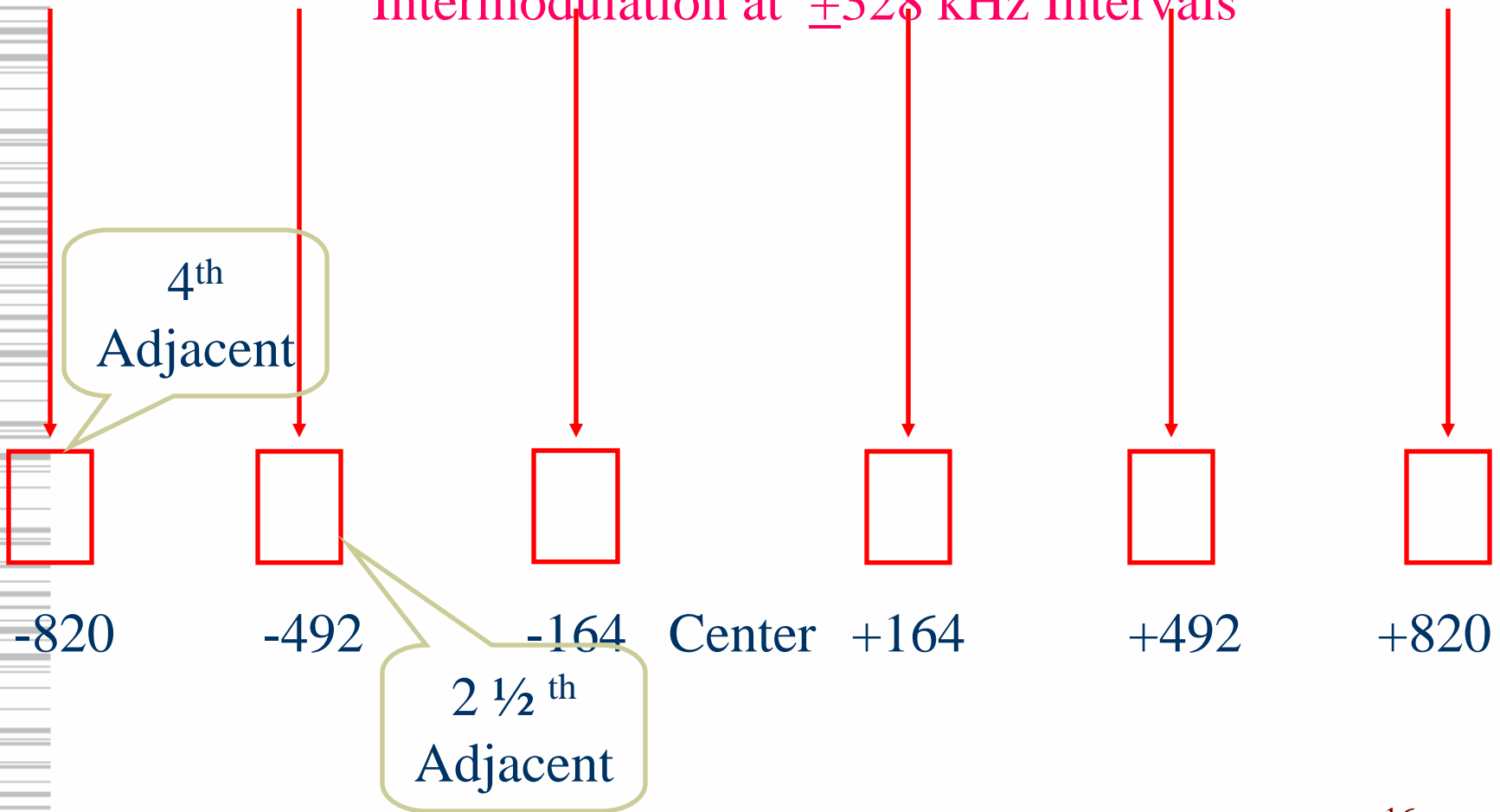
+164
(B)



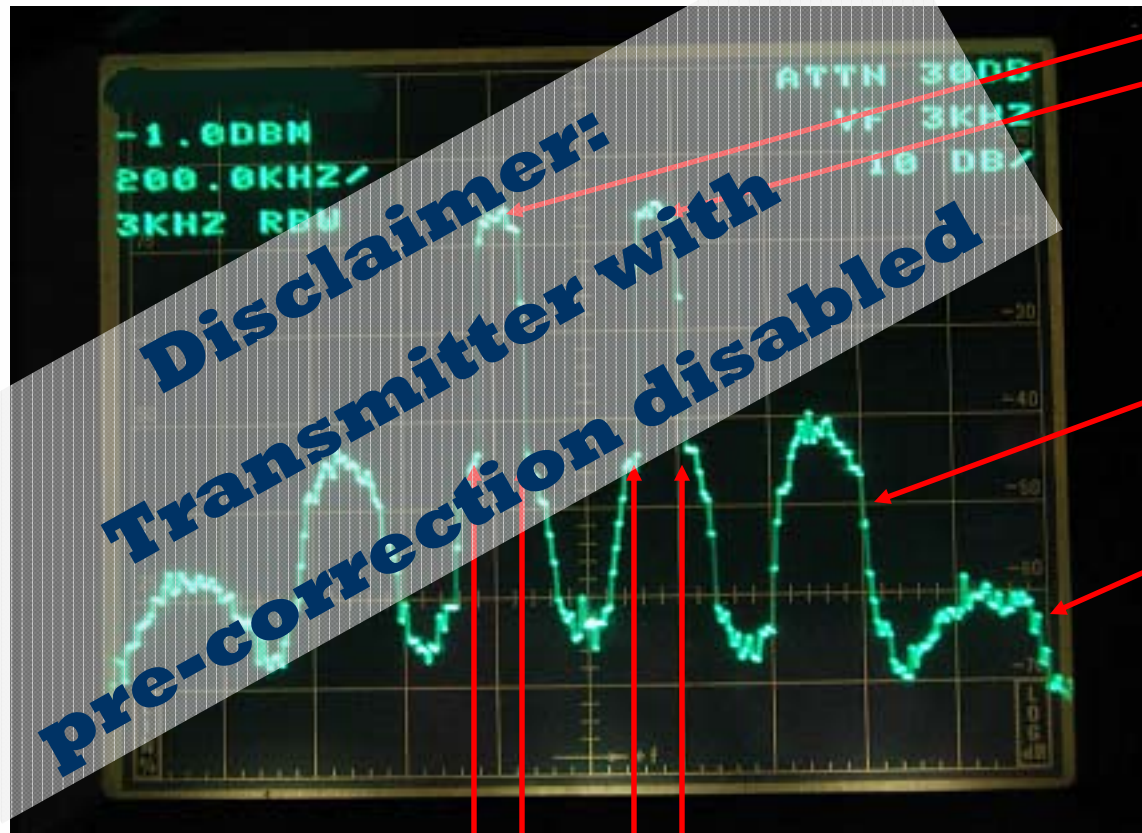
+492
(2B - A)

Discussing Power

Intermodulation at ± 328 kHz Intervals



Discussing Power



Primary Main IBOC at \pm 164 kHz

Regrowth at +492 kHz;

At +820 kHz

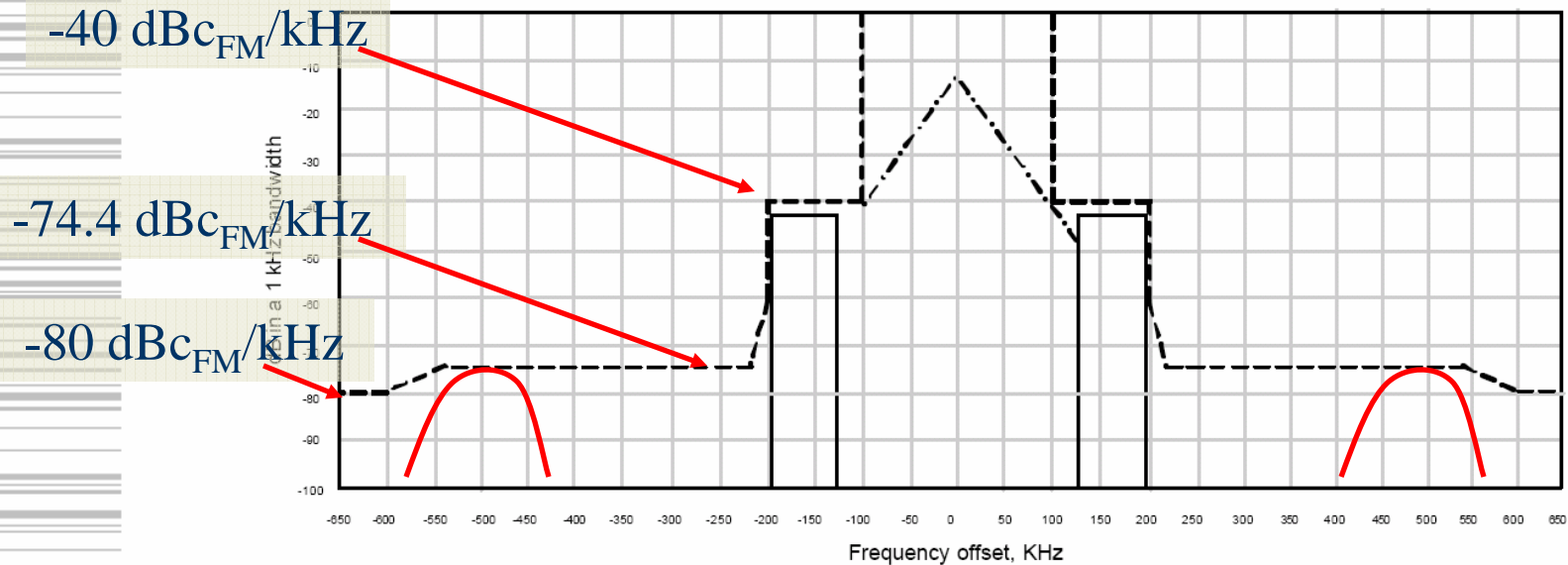
OFDM Carriers in same group interact with each other

Discussing Power



What
Should
this Ratio
Be?

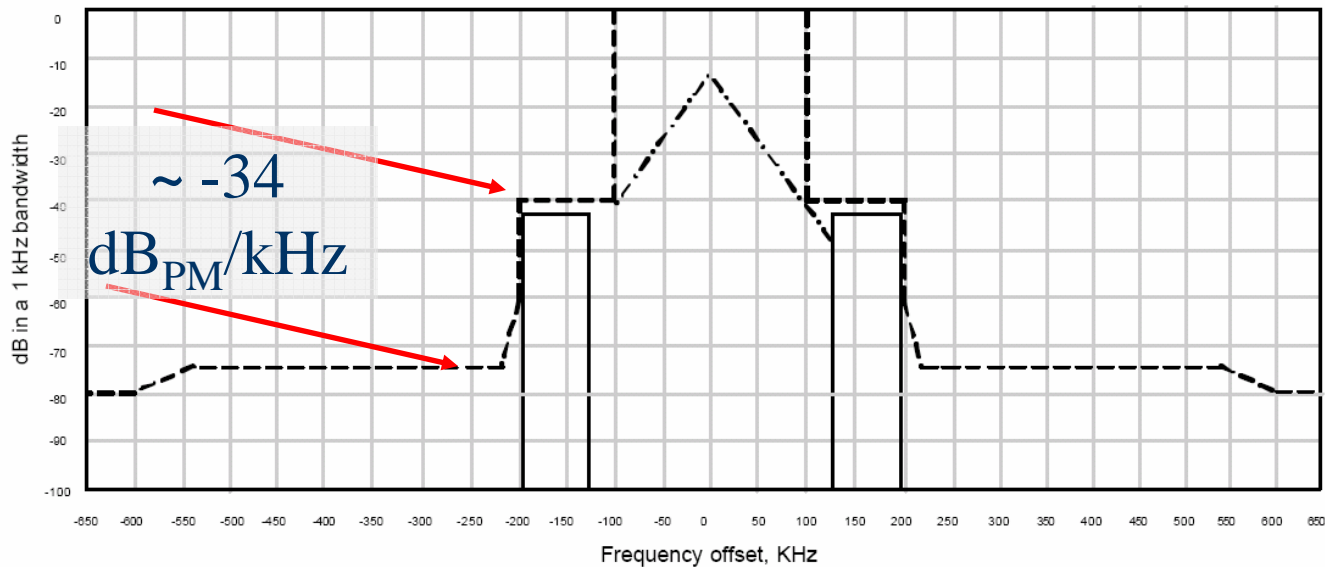
iBiquity RF Mask



Frequency, F, Offset Relative to Carrier	Level, dB/kHz
200-215 kHz offset	$[-61.4 - (\text{frequency in kHz} - 200 \text{ kHz}) \cdot 0.867] \text{ dB}$
215-540 kHz offset	-74.4 dB
540-600 kHz offset	$[-74.4 - (\text{frequency in kHz} - 540 \text{ kHz}) \cdot 0.093] \text{ dB}$
>600 kHz offset	-80 dB

Table 3: iBiquity FM Hybrid Mode Noise and Spurious Emission Limits

iBiquity RF Mask



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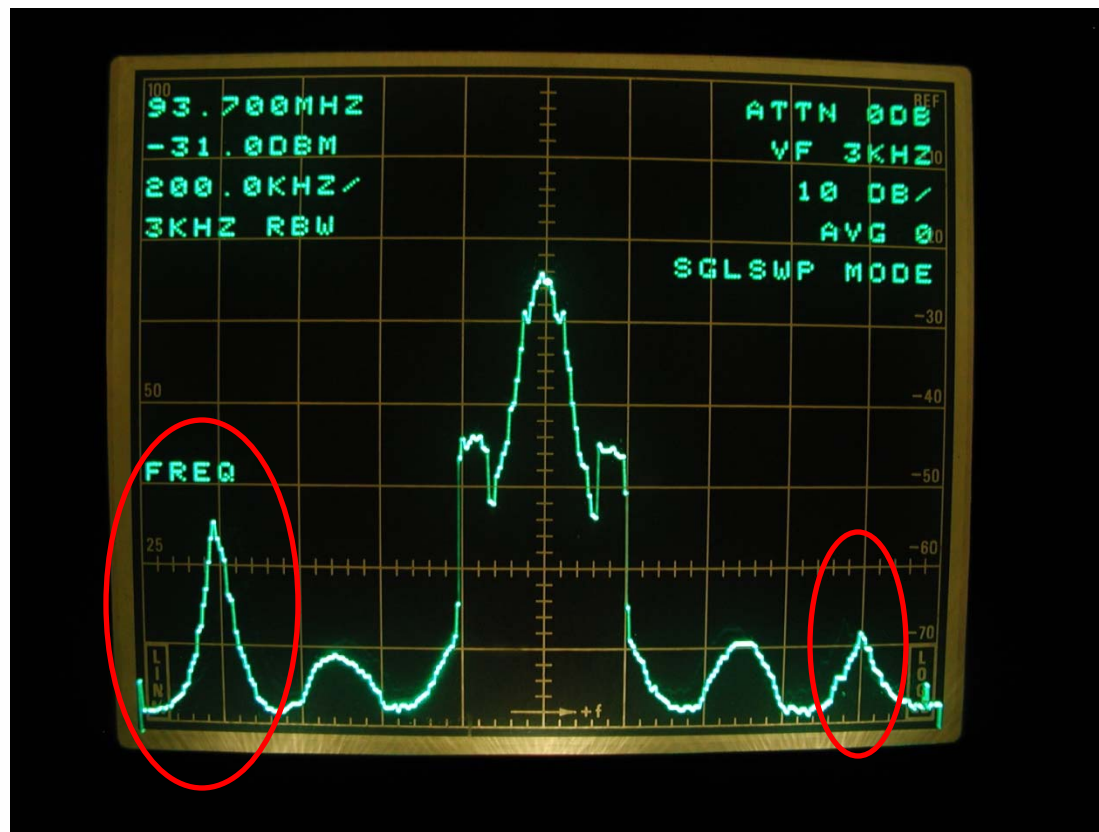
iBiquity RF Mask



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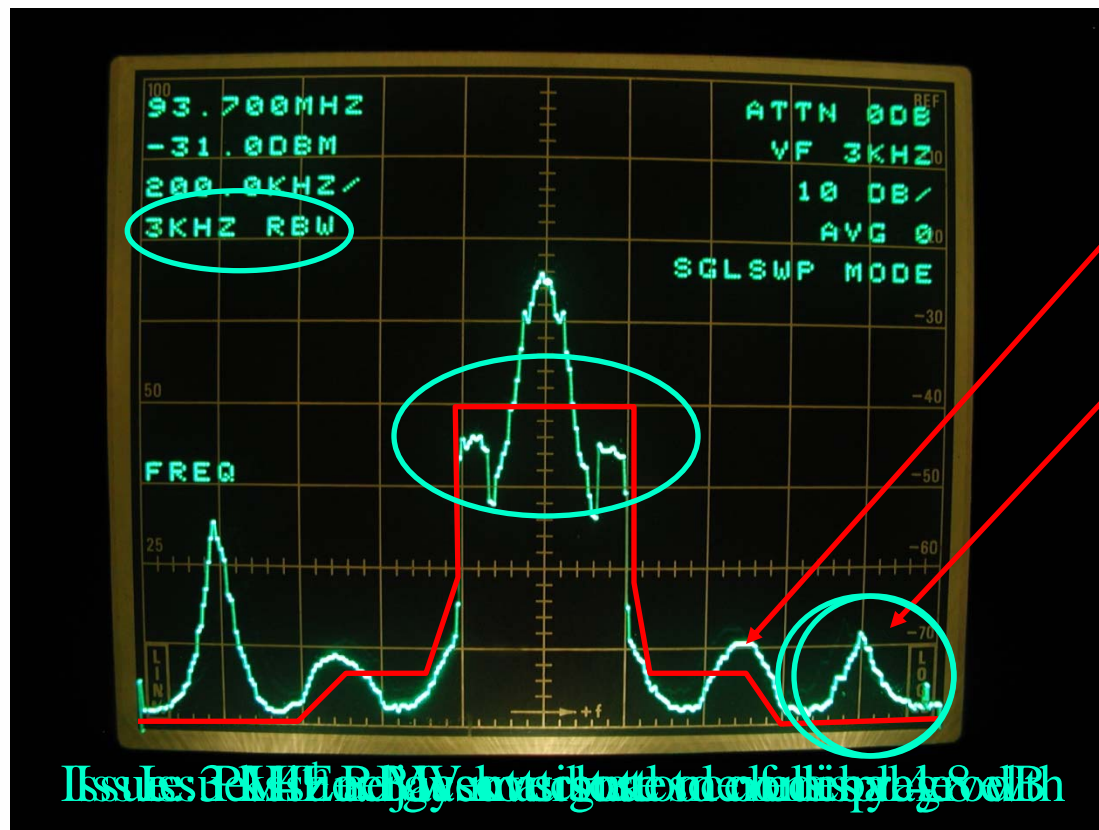
Table 3: iBiquity FM Hybrid Mode Noise and Spurious Emission Limits

Why Regrowth Matters



Field Measurement with 4th Adjacent Signals

What's Wrong with this Picture?



Should Be
< -74.4 dB_c_{FM}
in 1kHz

Should Be
< -80dB_c_{FM}
in 1kHz

Measurements

- ◆ Vector Signal Analyzer
 - Theoretically ideal
 - Complex
 - Cost-prohibitive

Measurements

- ◆ Spectrum analyzer
 - Isolates spectra
 - Sampling issues
 - Dynamic range issues

Measurements

- ◆ Power Meter
 - Precise
 - Doesn't differentiate signal components

Measurements

- ◆ Spectrum Analyzer
 - Variations among detectors
 - The noise-like waveform problem
 - Level understated by $\sim 2\text{dB}$

Measurements

◆ Spectrum Analyzer

■ Variations among detection modes

- “Sample”

- ◆ Random sample in each “bin”

- ◆ Average of series of random samples
(by averaging n sweeps)

- “Max-Min”

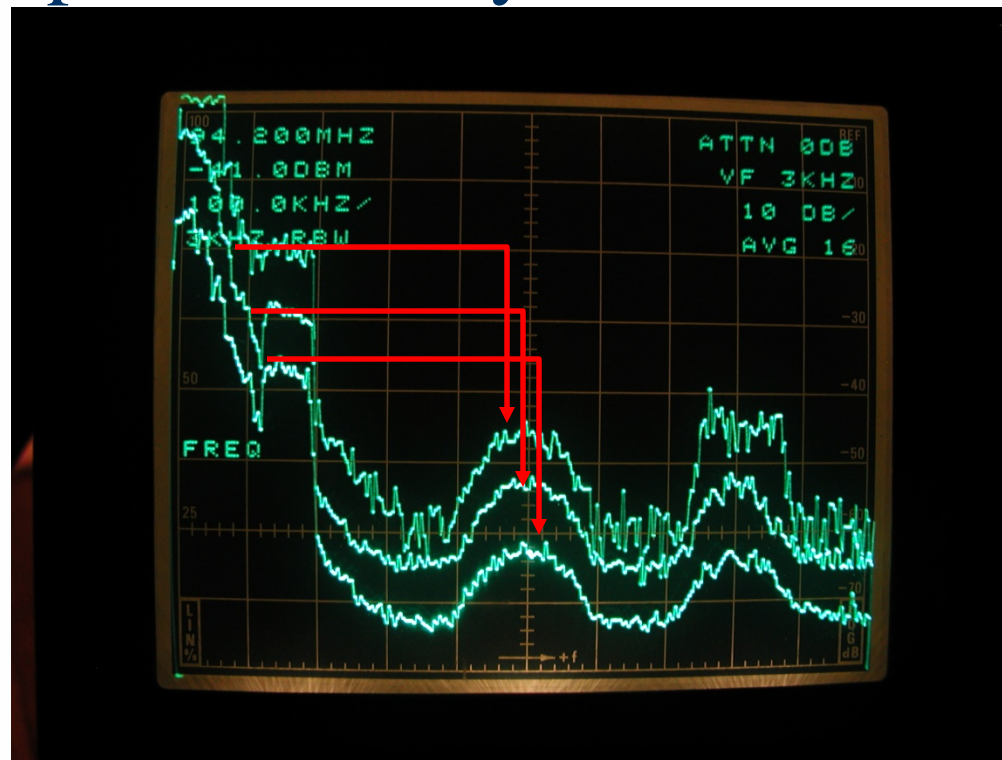
- ◆ Average Max and Min values in successive sweeps

- Video filtering

- Peak

Measurements

◆ Spectrum analyzers



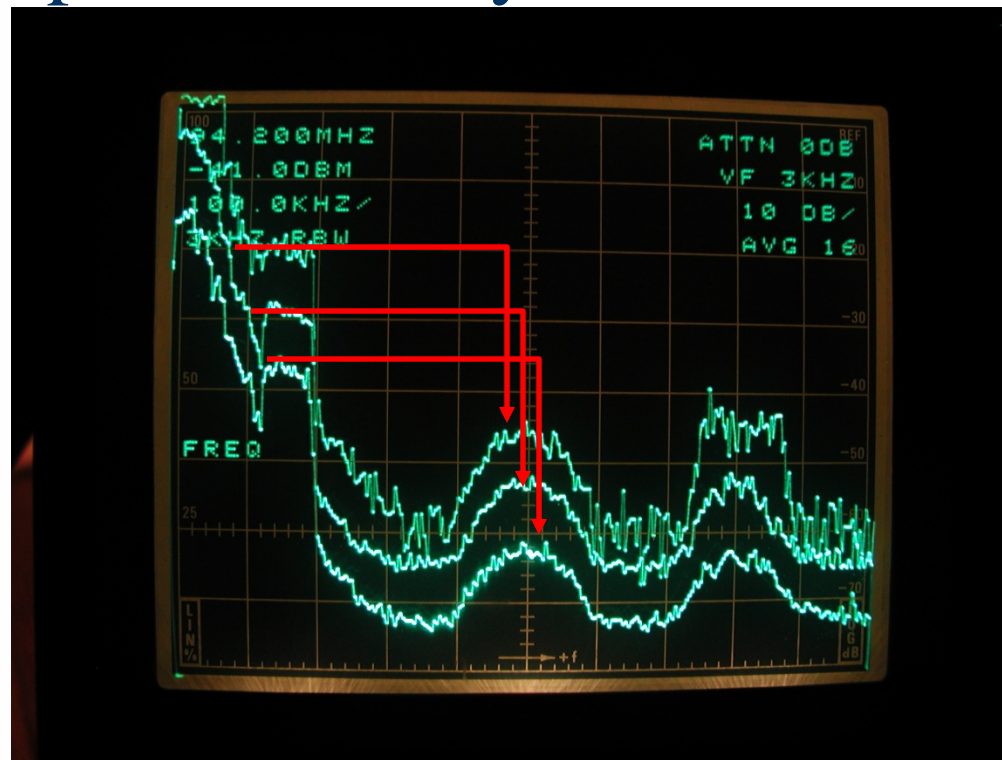
Peak Hold

Peak Average

Max-Min Average

Measurements

◆ Spectrum analyzers



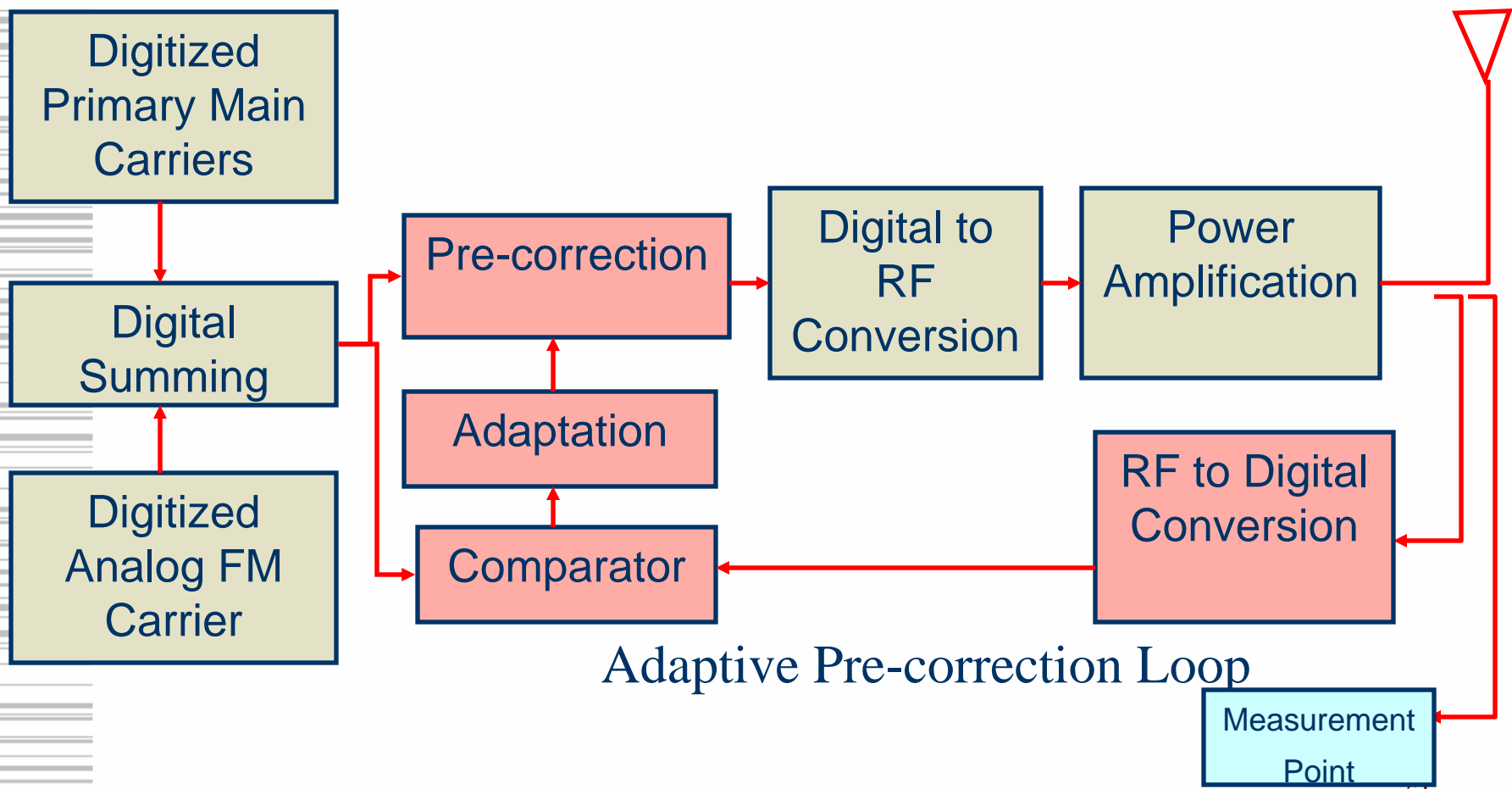
Any sampling mode shows relation between PM and regrowth

Measurements

- ◆ Case Study
 - KUVO, Denver
 - Nautel V-10 Transmitter
 - Adaptive Precorrection

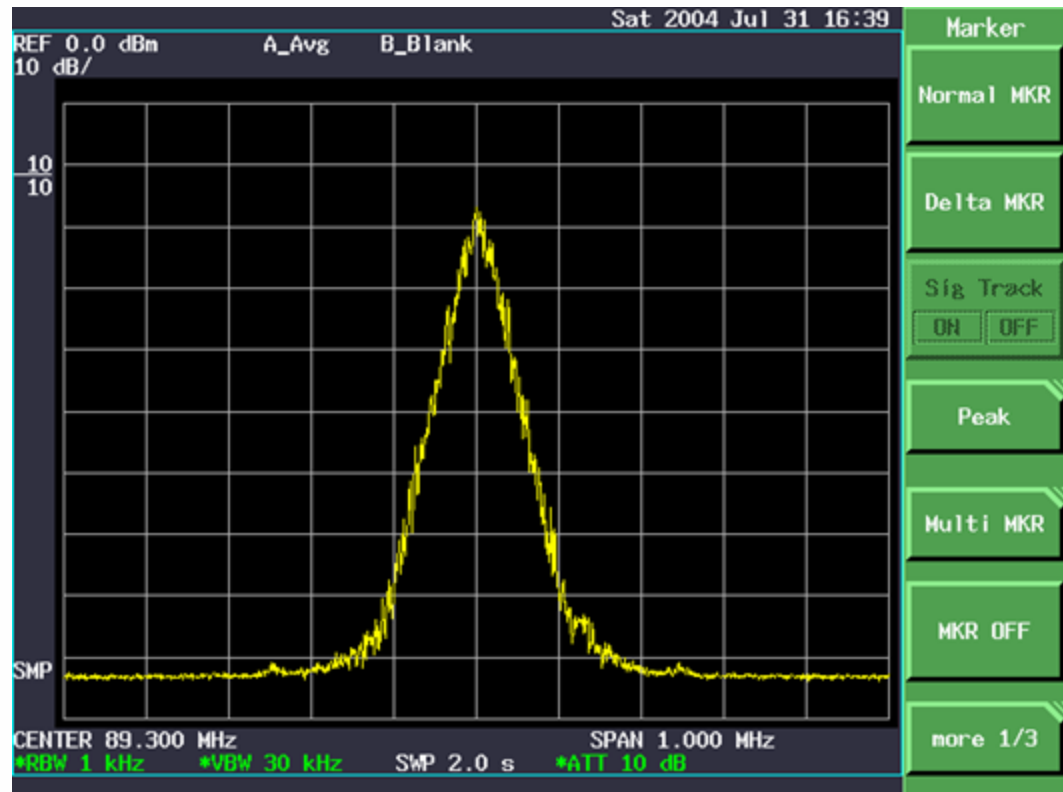


KUVO Nautel Flow



Measurements

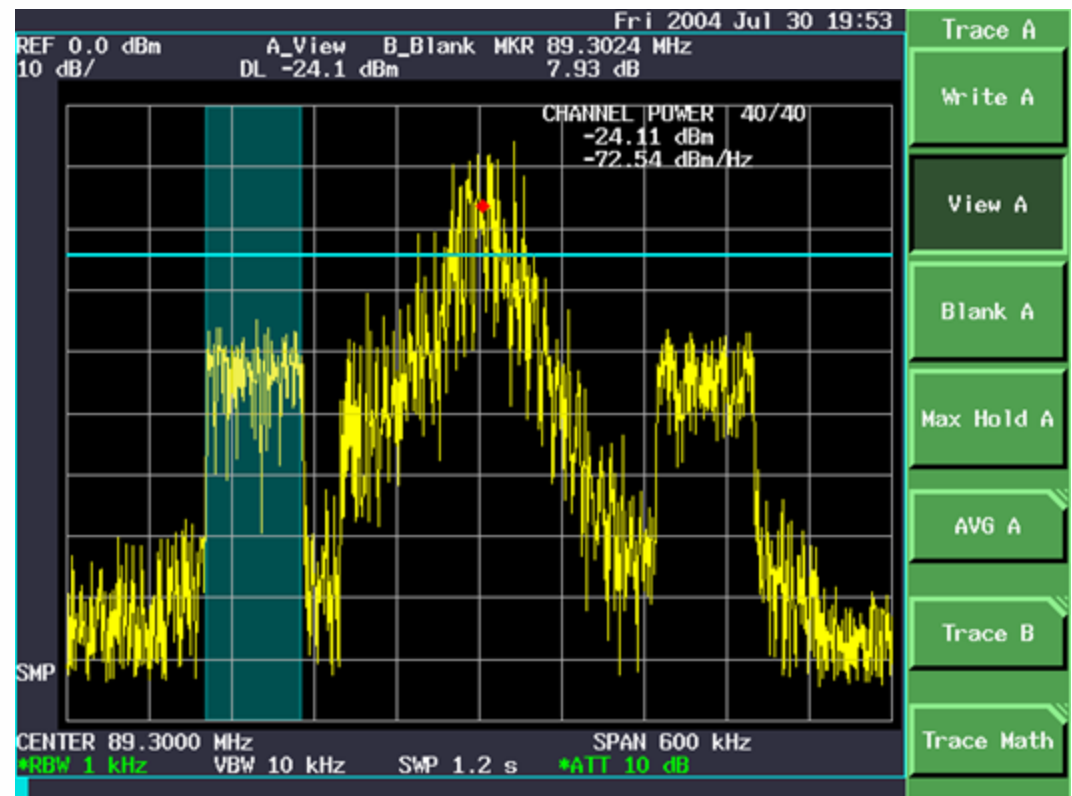
- ◆ KUVO
FM only



Measurements

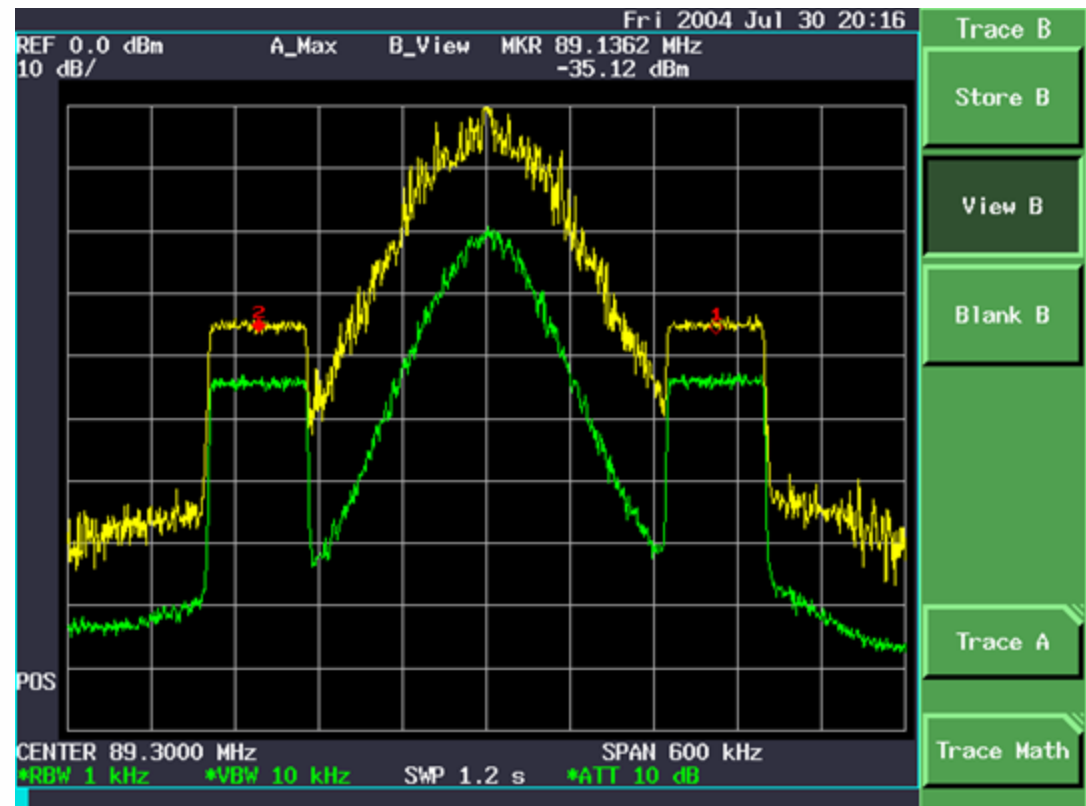
◆ Channel Power

- Analyzer utility
- Computes power in a bandwidth



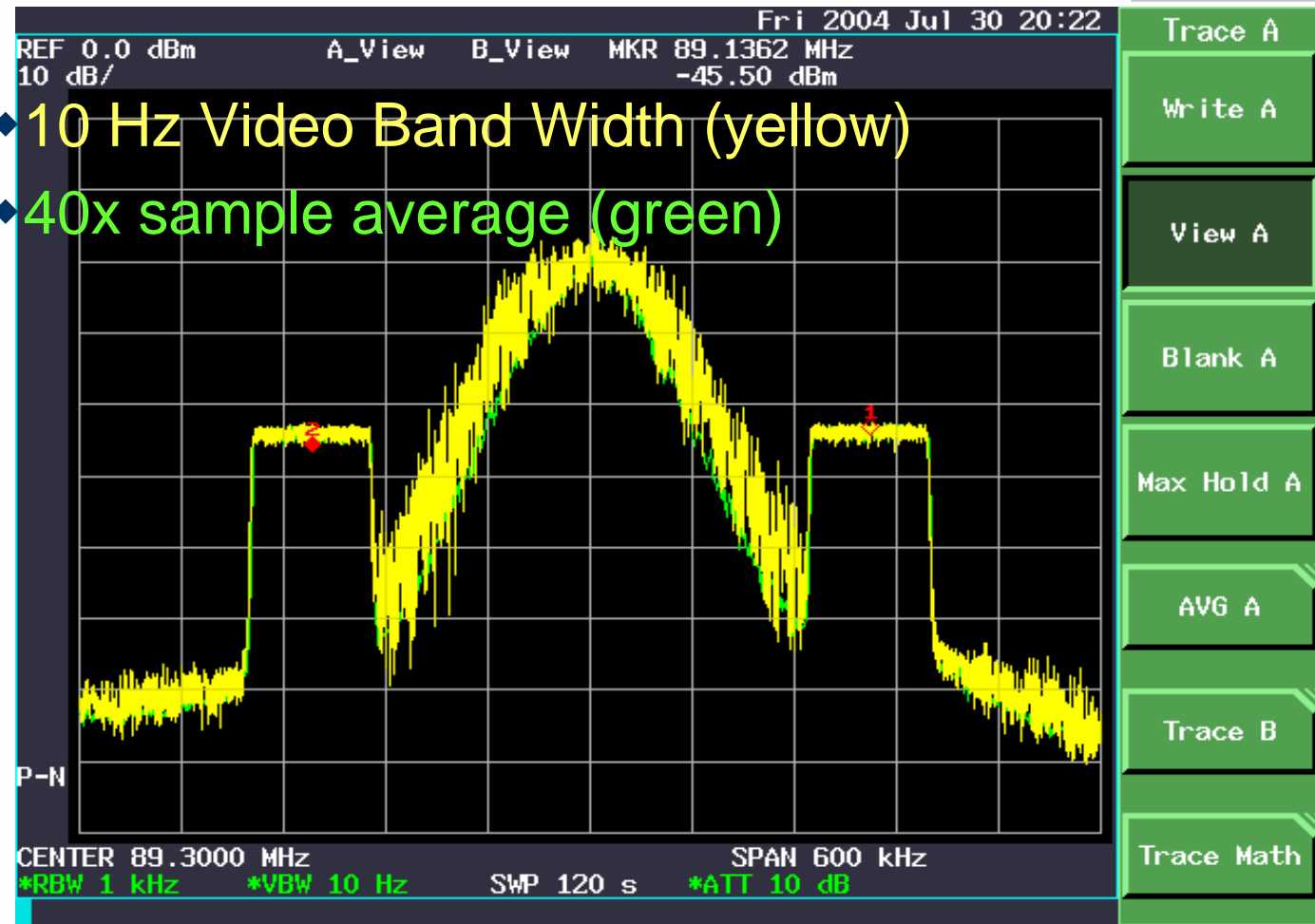
Measurements

- ◆ Positive Peaks
 - Averaged
- ◆ Sample
 - Averaged



Measurements

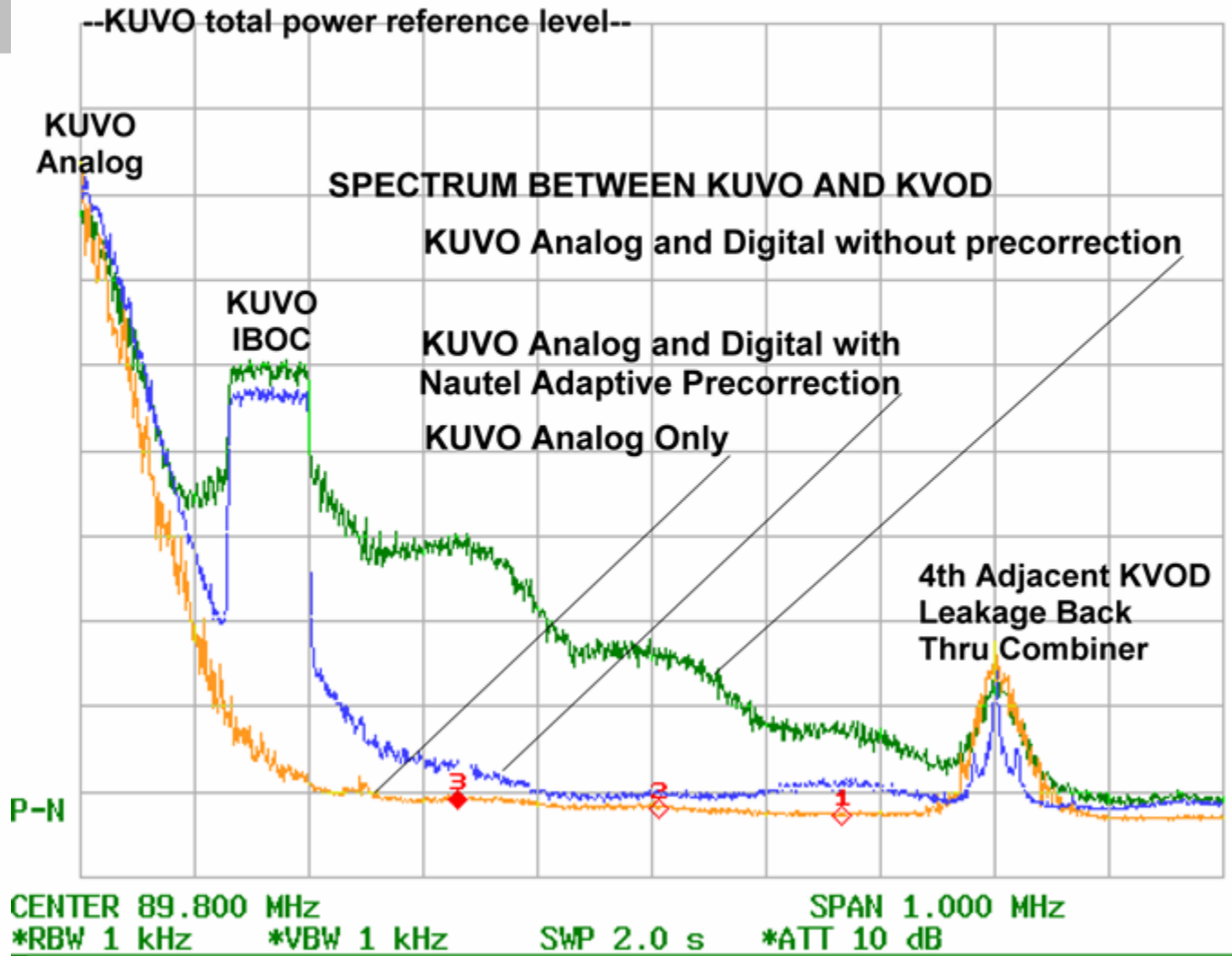
- ◆ 10 Hz Video Band Width (yellow)
- ◆ 40x sample average (green)



Fri 2004 Jul 30 21:56

REF 0.0 dBm
10 dB/

A_View B_View MKR 89.630 MHz
-90.97 dBm

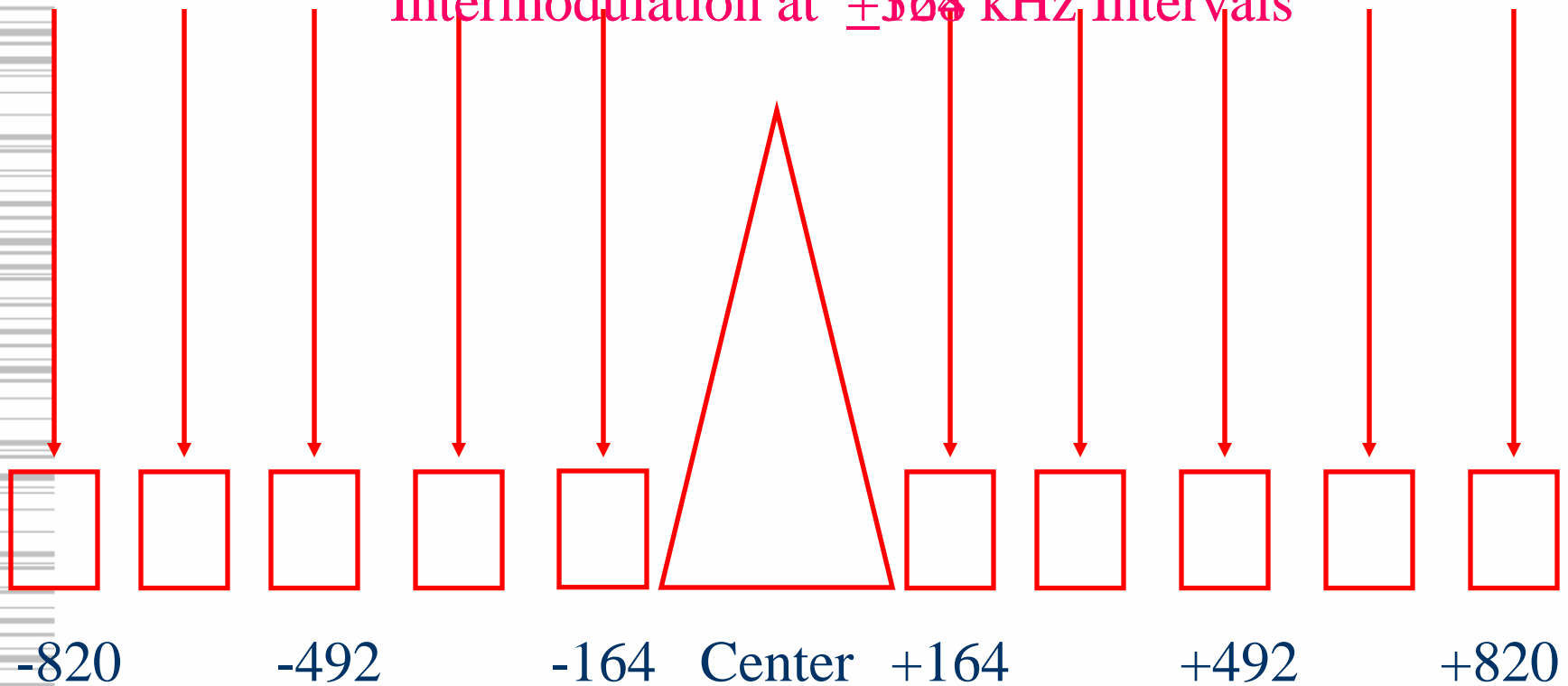


Common Amplification

- ◆ Common Amplification
 - Analog Signal Amplified with Digital
 - More Points of Regrowth

Common Amplification

Intermodulation at ± 308 kHz Intervals



How to Do It

- ◆ Where to sample?
 - If digital-only is accessible, check it out
 - Helps verify analyzer settings before dealing with extra analog power
 - May be only way with separate antennas

How to Do It

- ◆ Where to sample?
 - If signals are combined before antenna, sample there
 - Watch out for other signal ingress
 - Combiner systems, local signals
 - Could overload analyzer

How to Do It

- ◆ Where to sample?
 - Off-air sampling is most challenging
 - May be only way to see full hybrid signal

How to Do It

- ◆ Analyzer setting
 - Must have good intermodulation specs
 - 100-dB on-screen range helpful
 - Read The Manual!
 - Total power into analyzer must be safely below analyzer compression
 - Minimum measured signal must be above instrument noise floor

How to Do It

- ◆ Analyzer setting
 - Channel Power computation feature
 - Most desirable
 - Sample detection mode and multi-sweep averaging
 - Good (15 sweeps OK, 50 pretty)
 - Max-Min (a.k.a. Pos-Neg) trace averaging
 - Less precise
 - Very narrow Video Bandwidth
 - In the ballpark, but slow and less precise.

Acknowledgements

Mike Pappas and
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jazz 89
kuvo.org

Colorado's FIRST FM radio station
to broadcast digital HD Radio!



Mike Woods,
Chris Mahaney



Thank You

www.broadcastsignallab.com