Broadcast Signal Lab

Measuring Your IBOC Spectrum

David Maxson

Topics

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

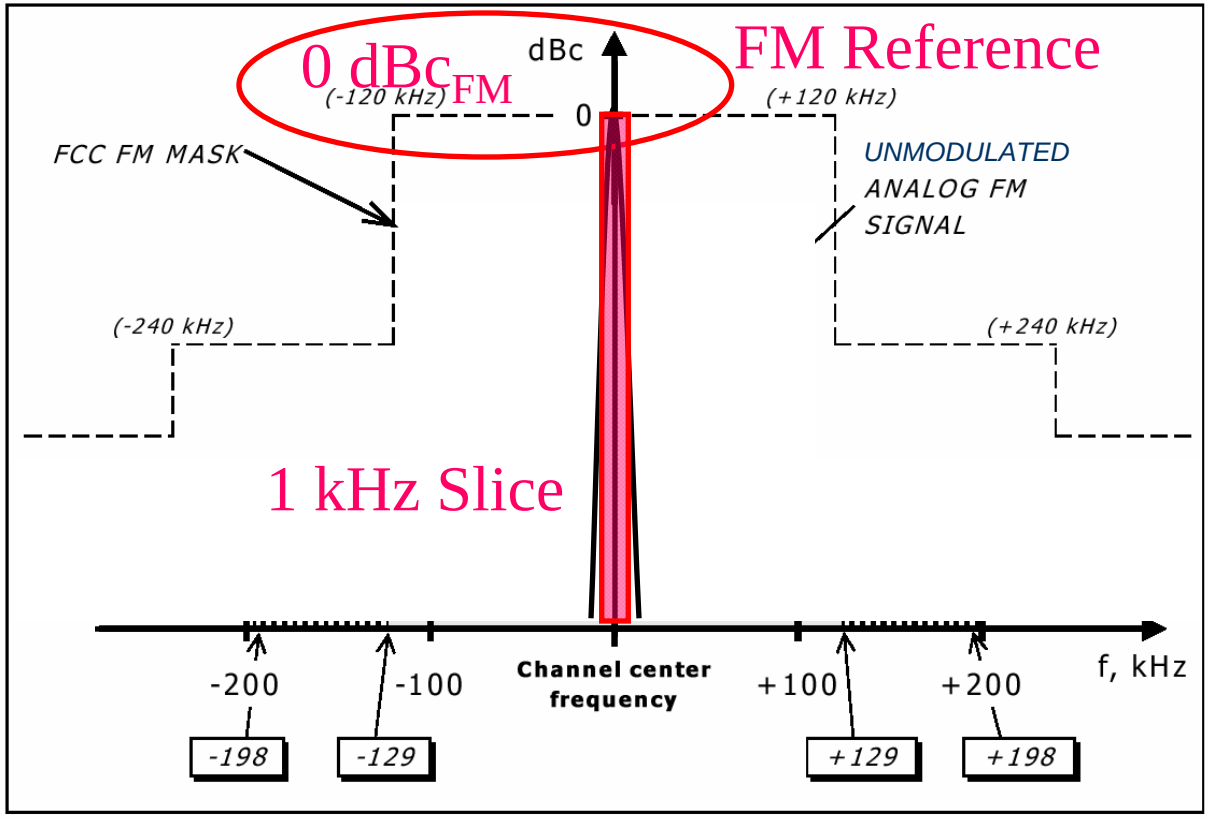
First Thought

- 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

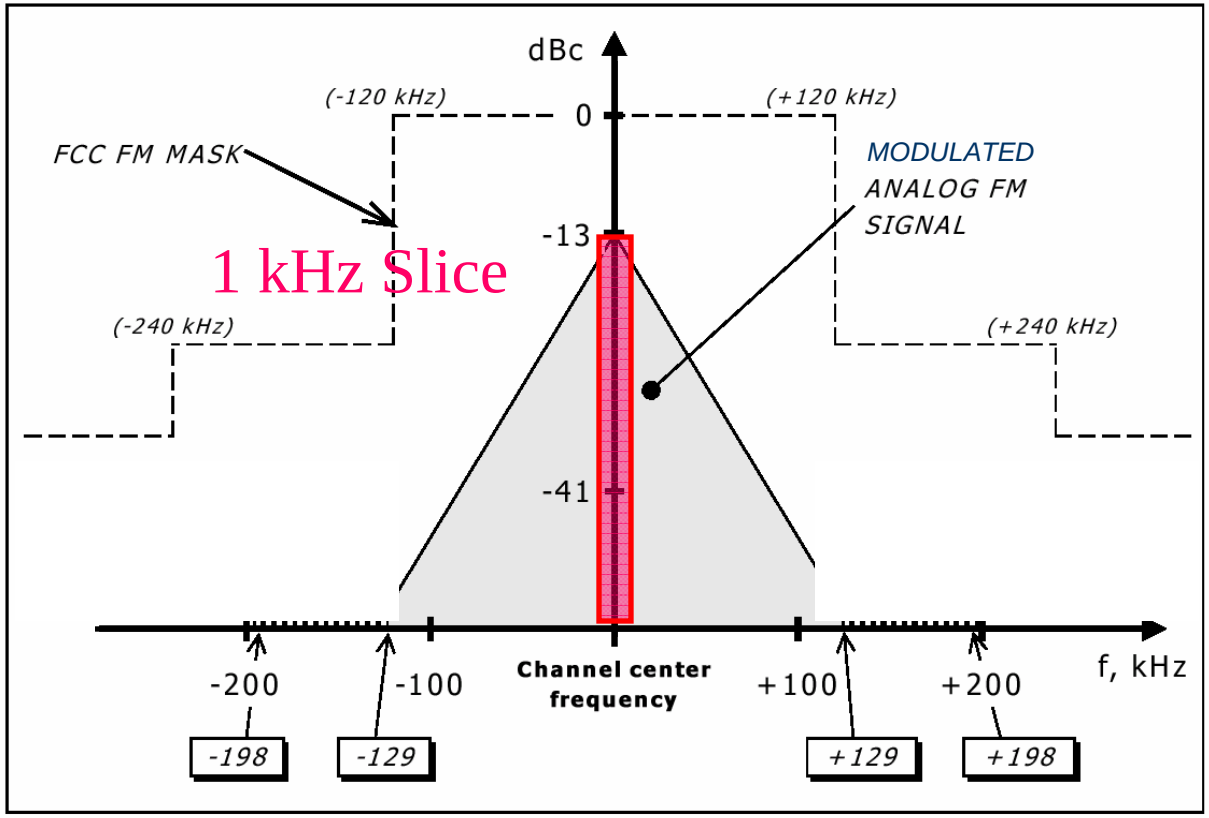
- FM analog carrier is the reference
  - "dBc" is common term
  - Helpful to differentiate dBc references for FM and for digital
    - Using "dBc_{FM}" for analog FM reference
    - Using "dBc_{PM}" for IBOC Primary Main OFDM carrier power (stipulate bandwidth!)

Discussing Power

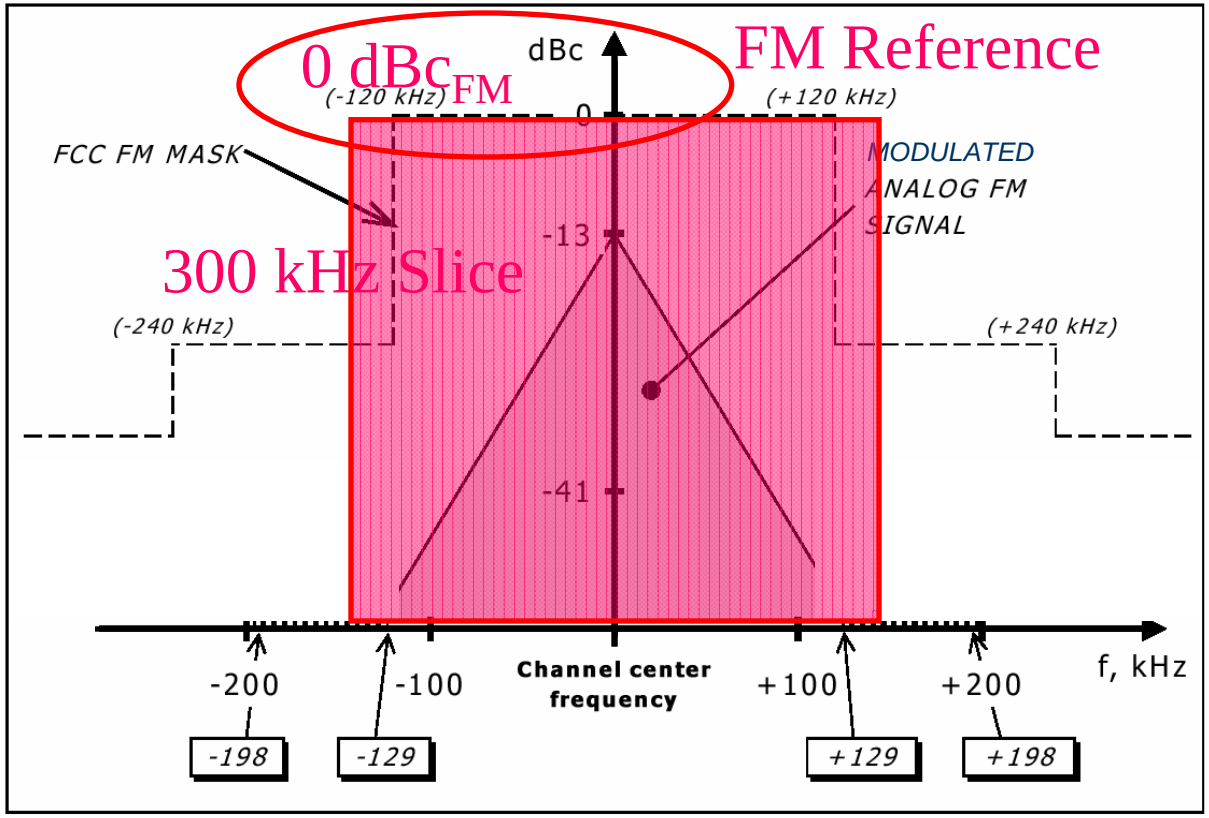


Underlying Graphic From NRSC

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

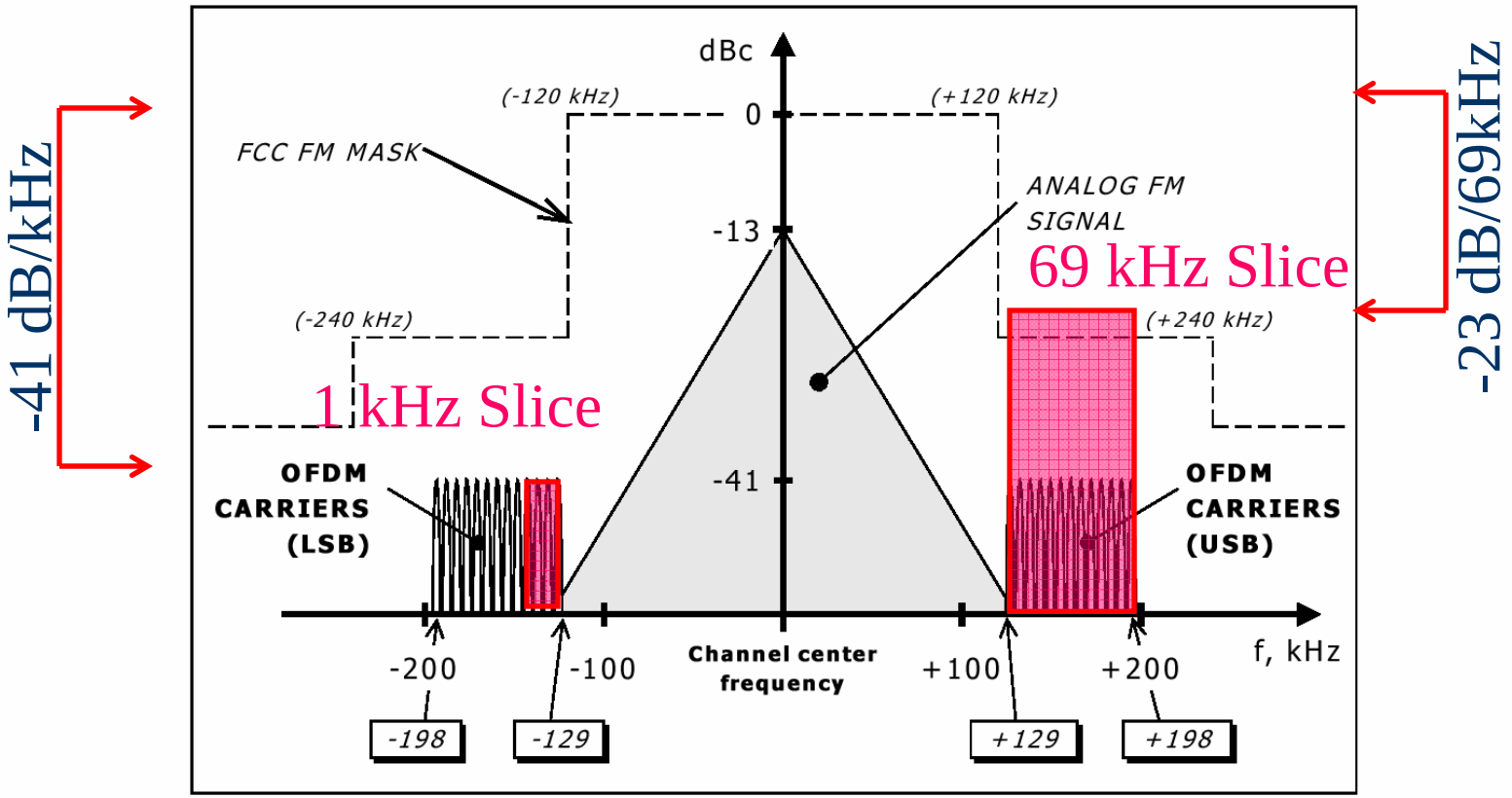


Figure 1. iBiquity FM IBOC system signal spectral power density

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 "Compand"?
  - Compress-Expand = Compand
  - 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

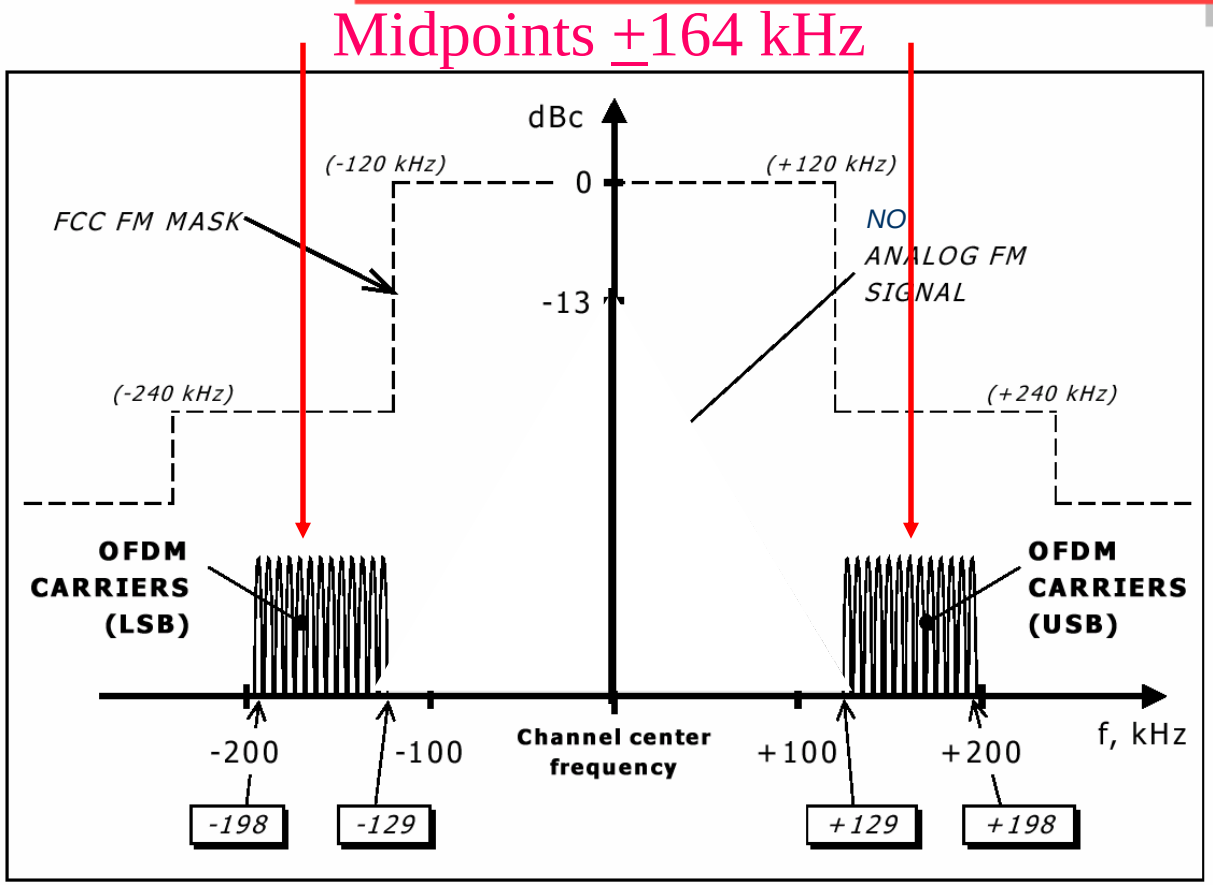
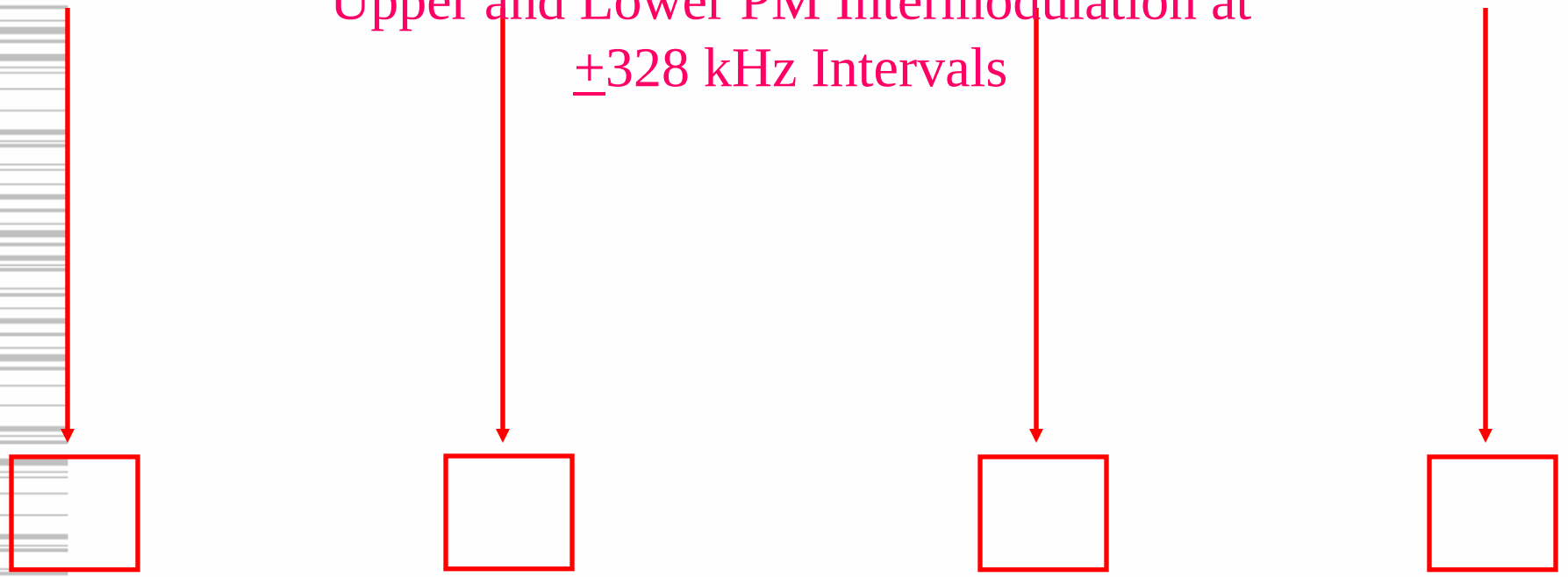


Figure 1. iBiquity FM IBOC system signal spectral power density

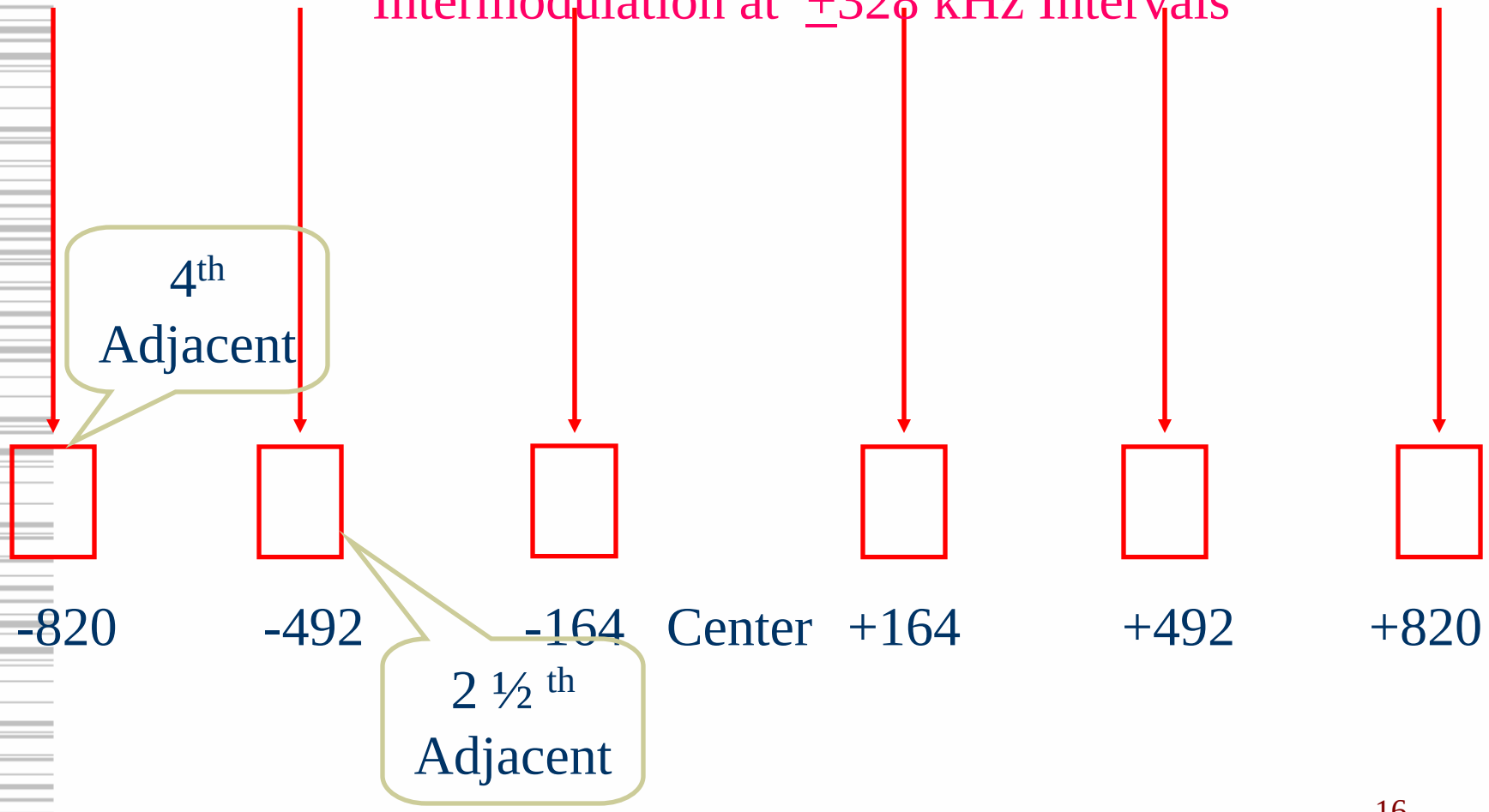
Discussing Power

Upper and Lower PM Intermodulation at ±328 kHz Intervals

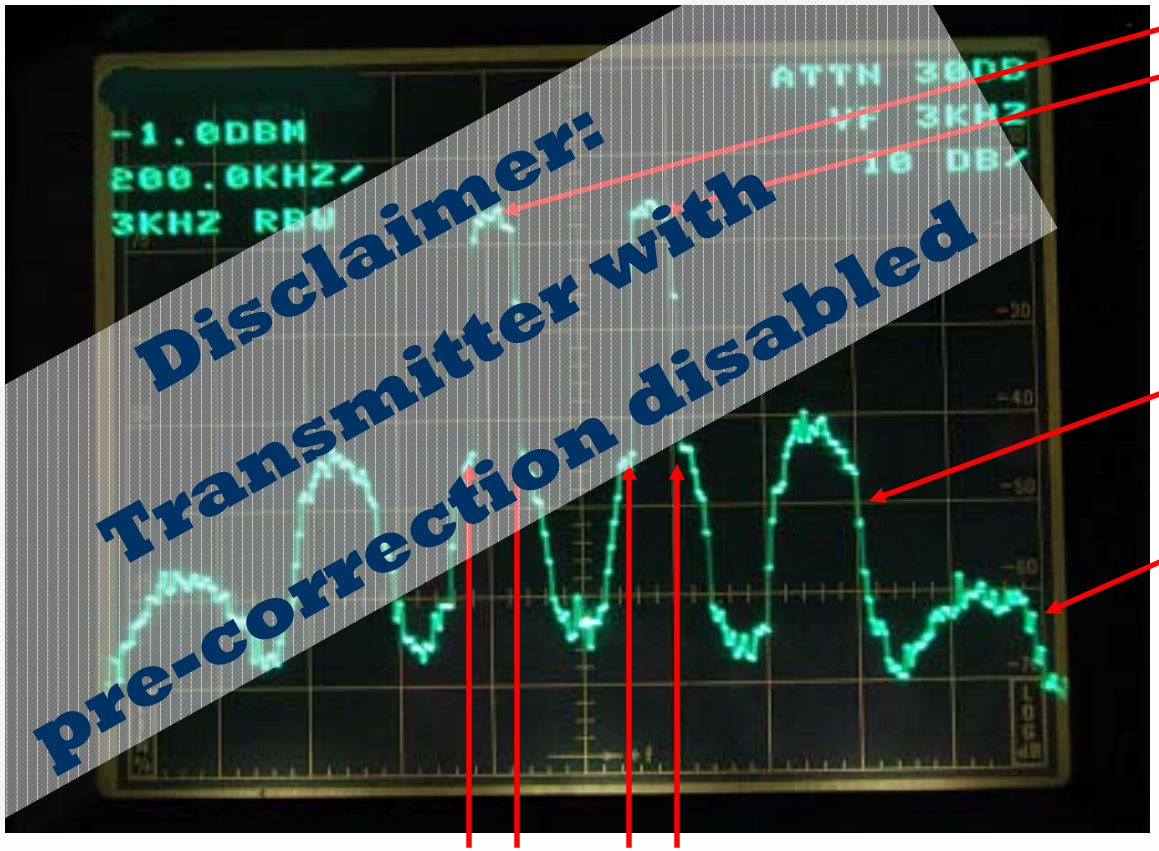


Discussing Power

Intermodulation at ±328 kHz Intervals



Discussing Power



Primary Main IBOC at ± 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?

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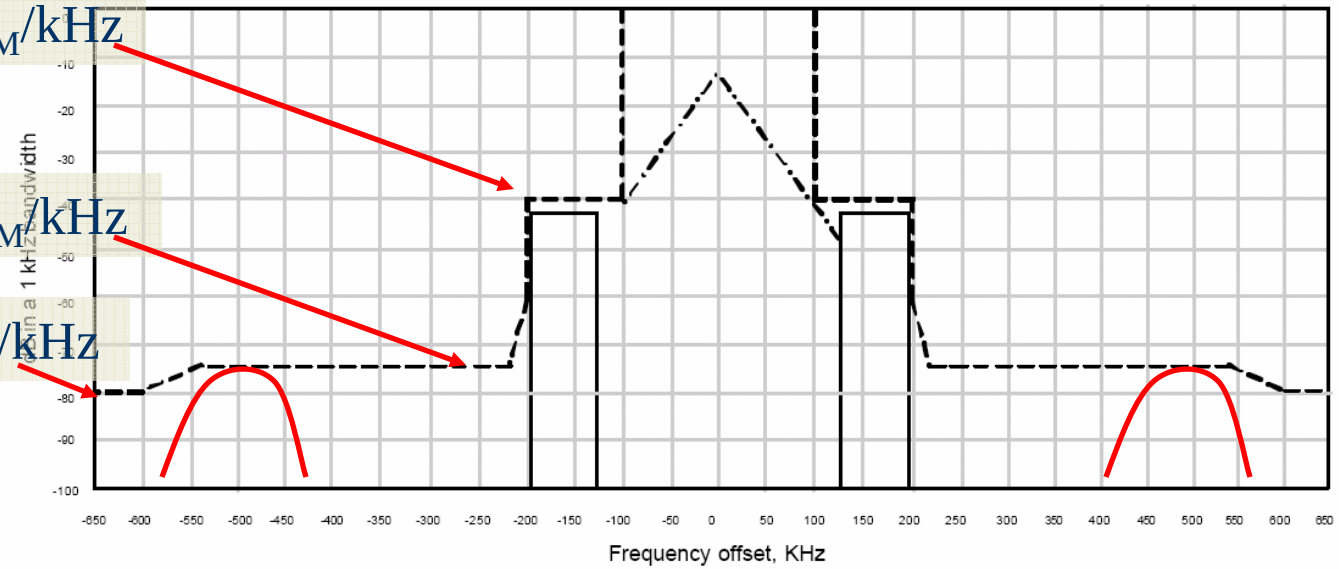
iBiquity RF Mask

-40 dBc$_{FM}$/kHz

-74.4 dBc$_{FM}$/kHz

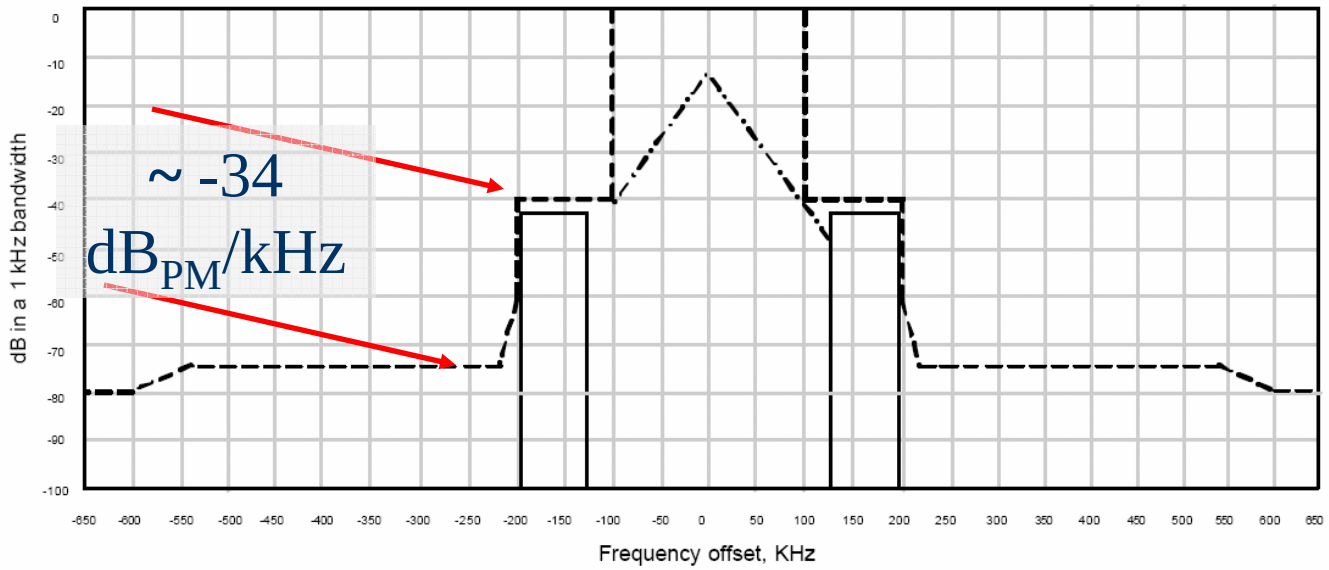
-80 dBc$_{FM}$/kHz



Frequency, F, Offset Relative to Carrier	Level, dB/kHz
200-215 kHz offset	[-61.4 - (|frequency in kHz|-200 kHz) · 0.867] dB
215-540 kHz offset	-74.4 dB
540-600 kHz offset	[-74.4 - (|frequency in kHz|-540 kHz) · 0.093] dB
>600 kHz offset	-80 dB

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

iBiquity RF Mask



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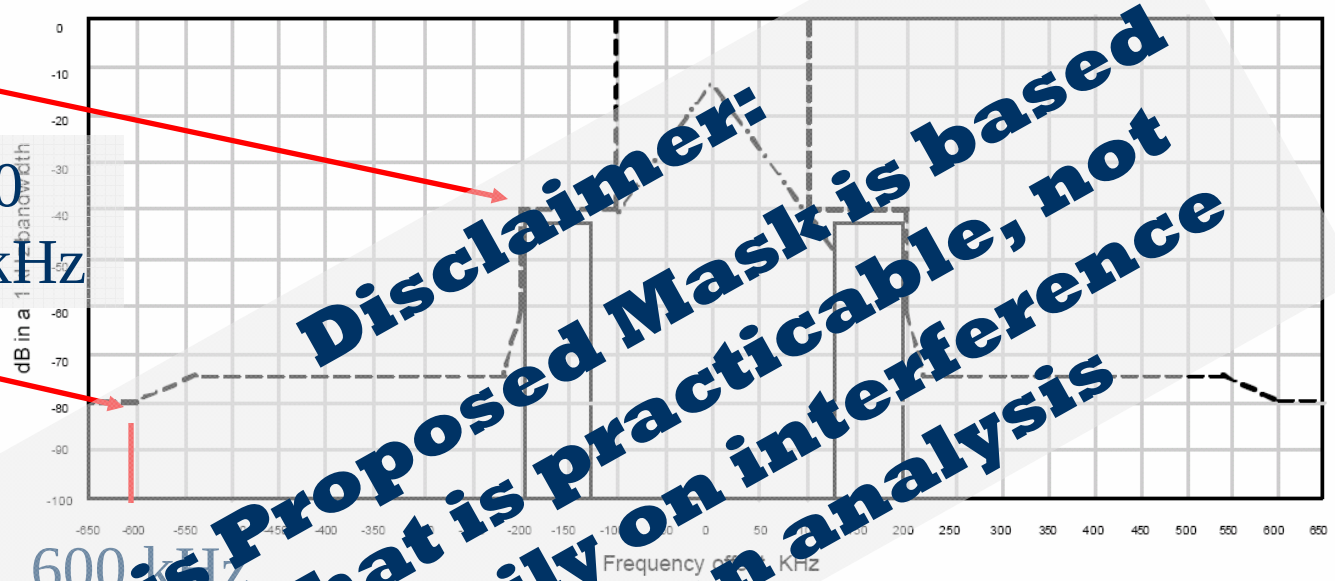
iBiquity RF Mask

~ -40 dB_{PM}/kHz



600 kHz

Disclaimer:
This Proposed Mask is based on what is practicable, not necessarily on interference protection analysis

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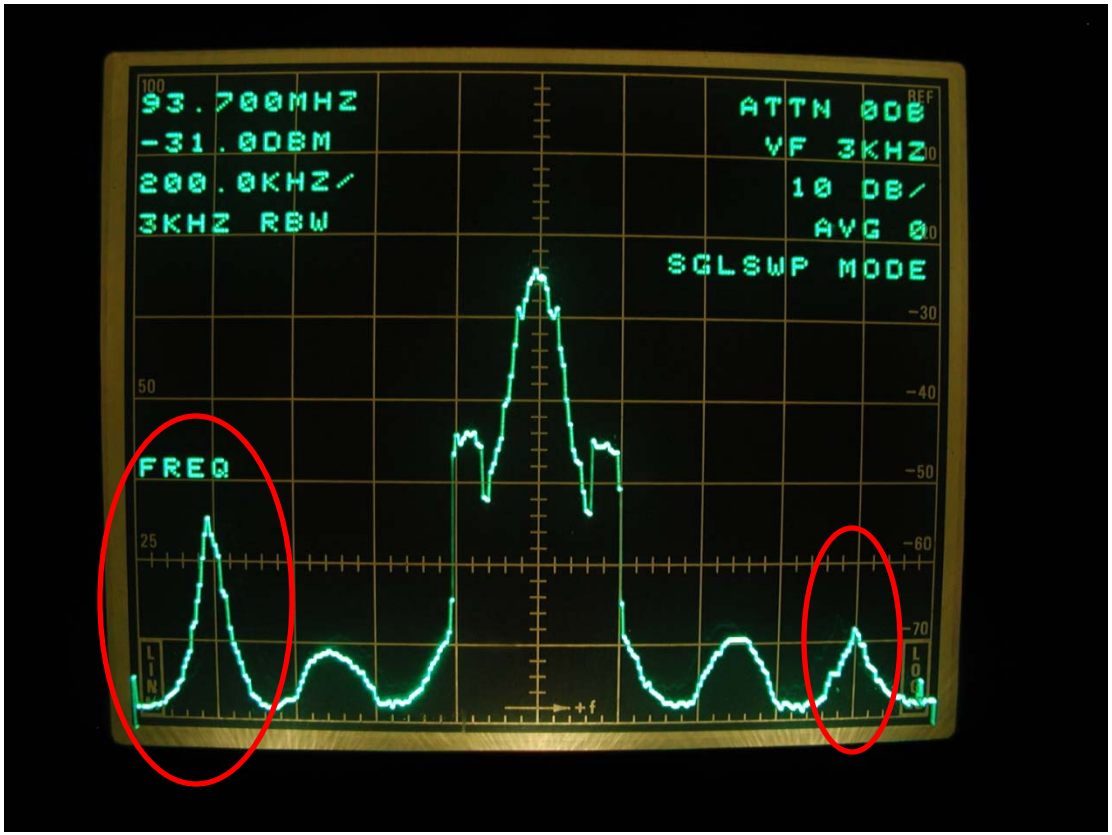
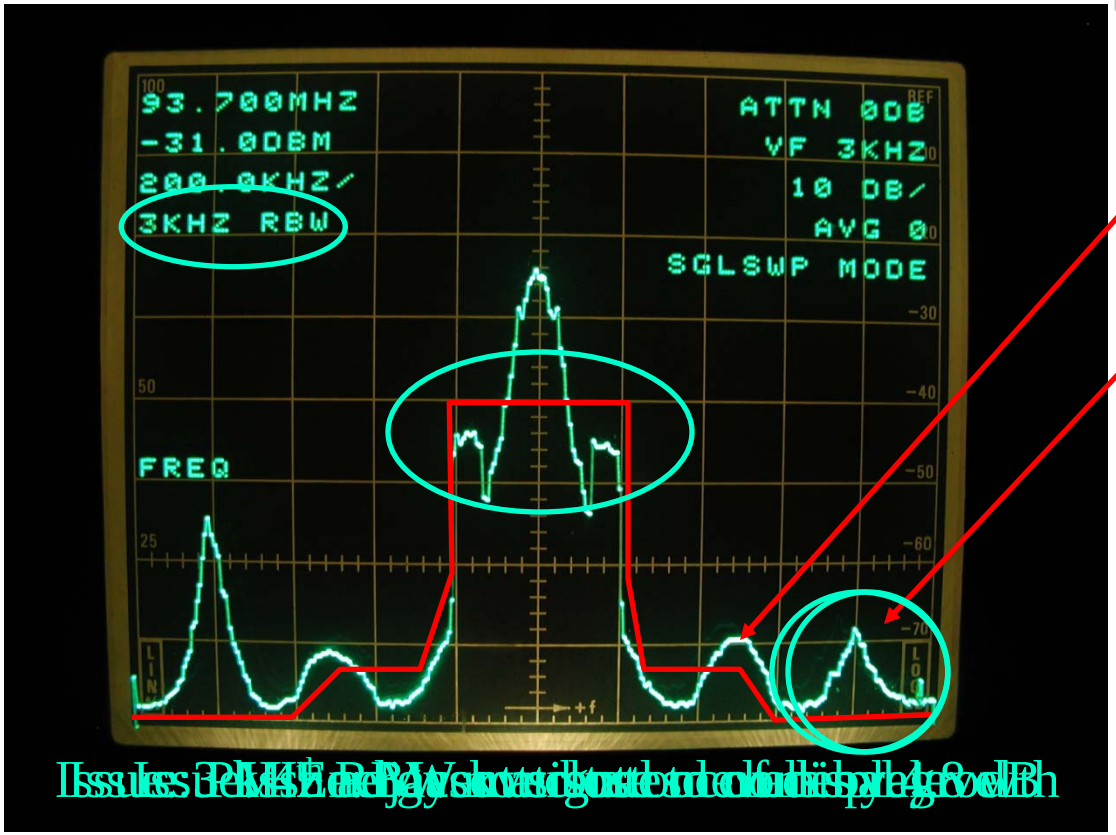
Table 3: iBiquity FM Hybrid Mode Noise and Spurious Emission Limits

Why Regrowth Matters



Field Measurement with 4th Adjacent Signals

What's Wrong with this Picture?



Should Be
< –74.4 dBc_{FM}
in 1kHz

Should Be
< –80dBc_{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

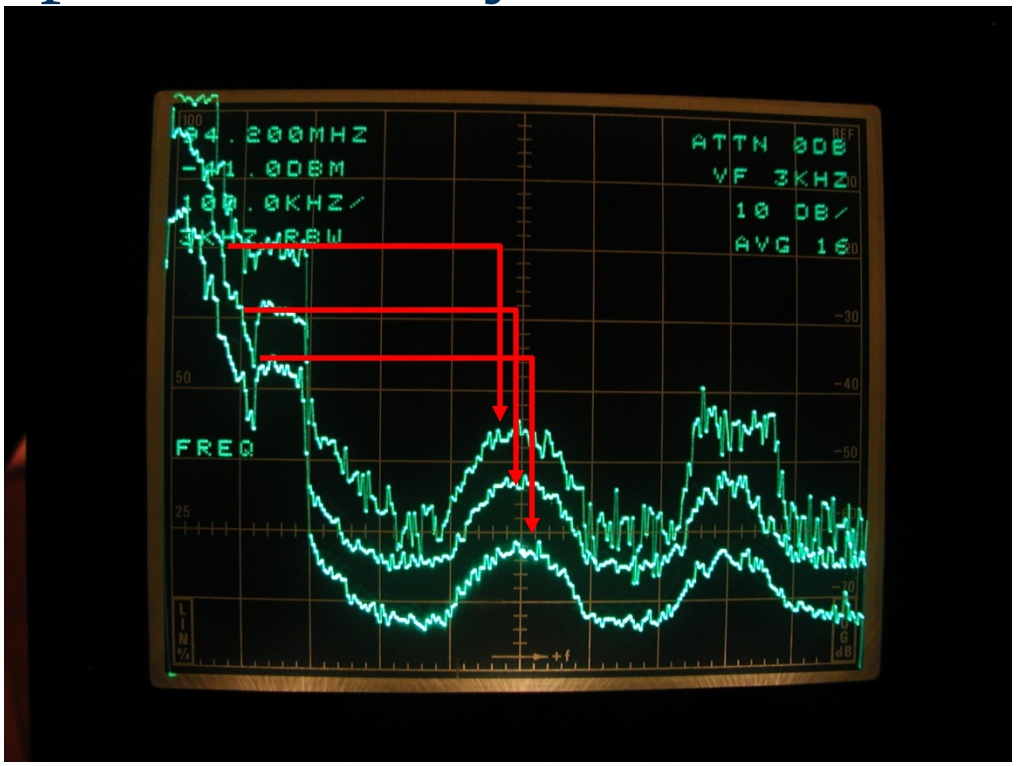
- Spectrum Analyzer
  - Variations among detectors
    - The noise-like waveform problem
    - Level understated by ~2dB

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



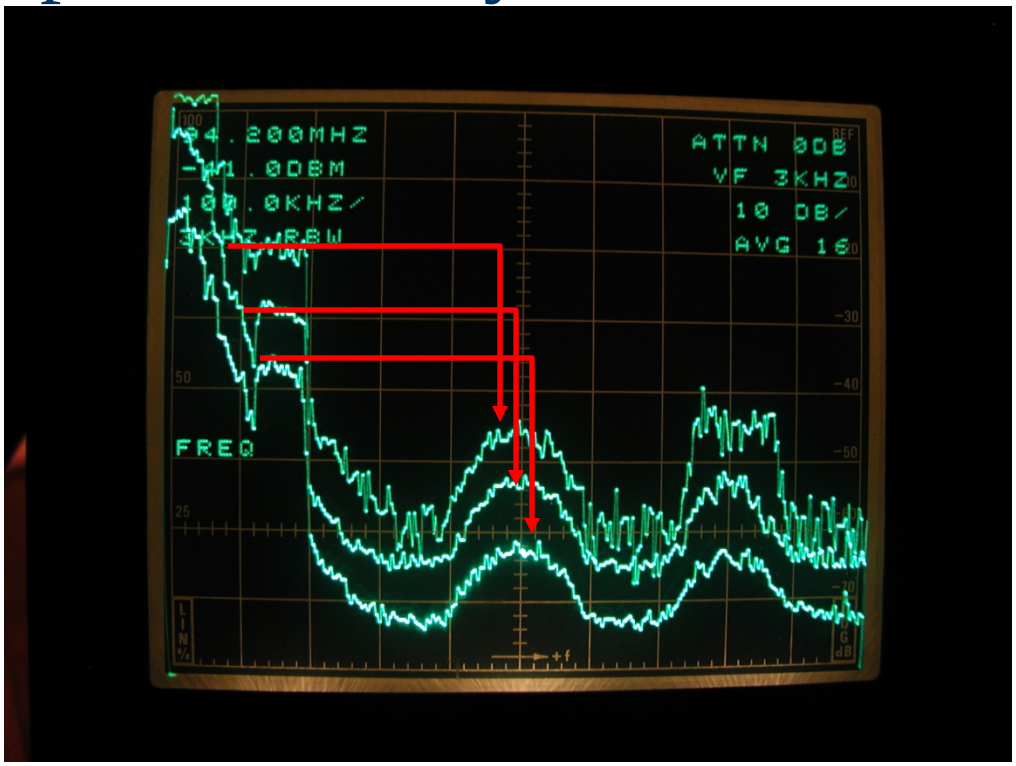
Peak Hold

Peak Average

Max-Min Average

Measurements

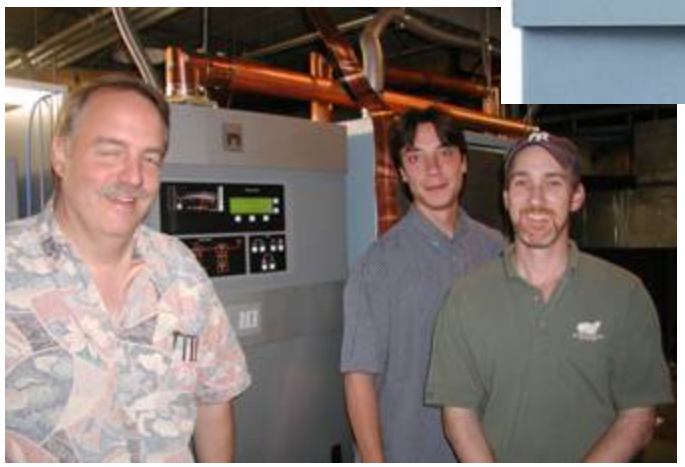
- Spectrum analyzers



Any sampling mode shows relation between PM and regrowth

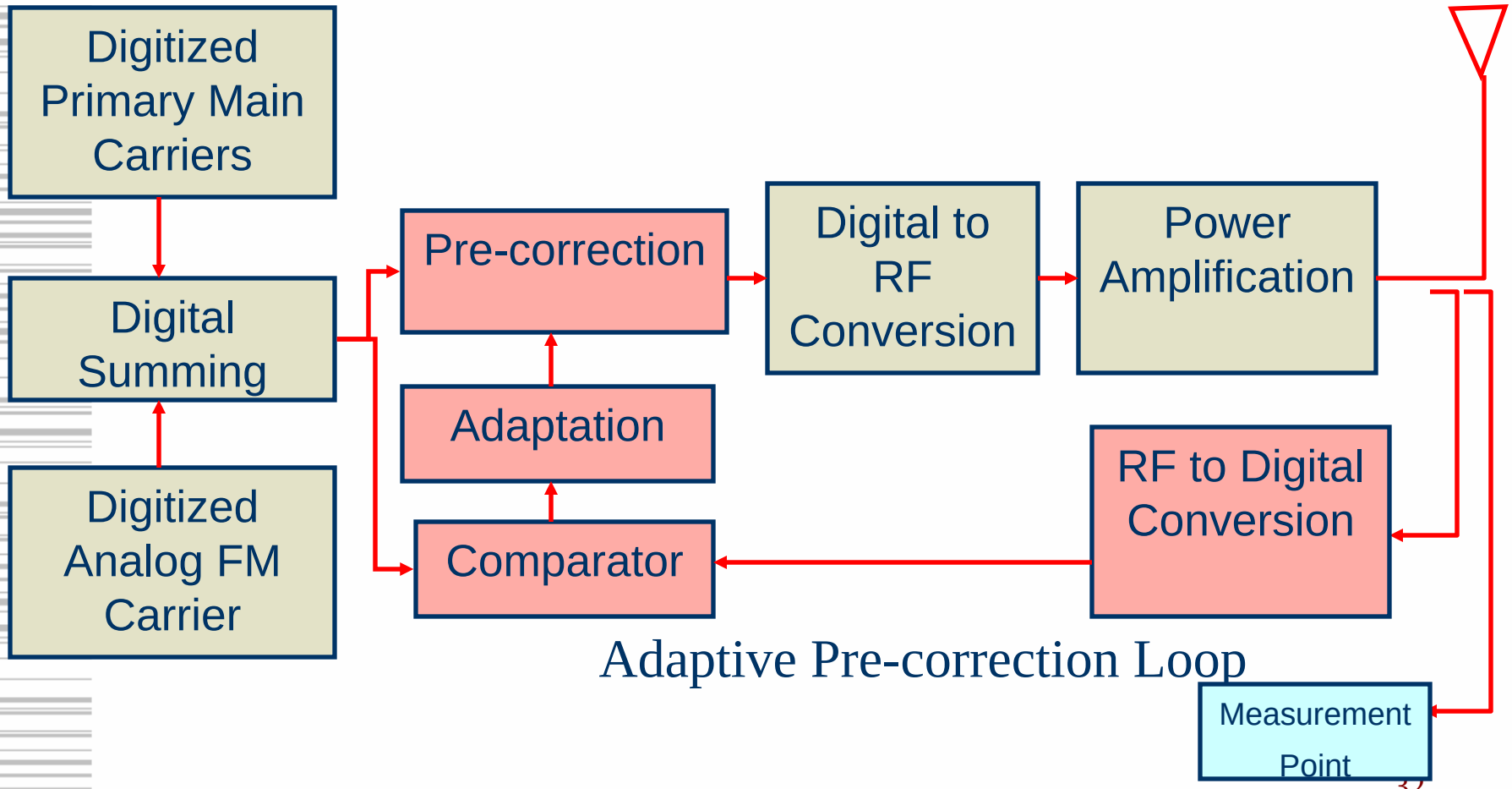
Measurements

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



nautel

KUVO Nautel Flow

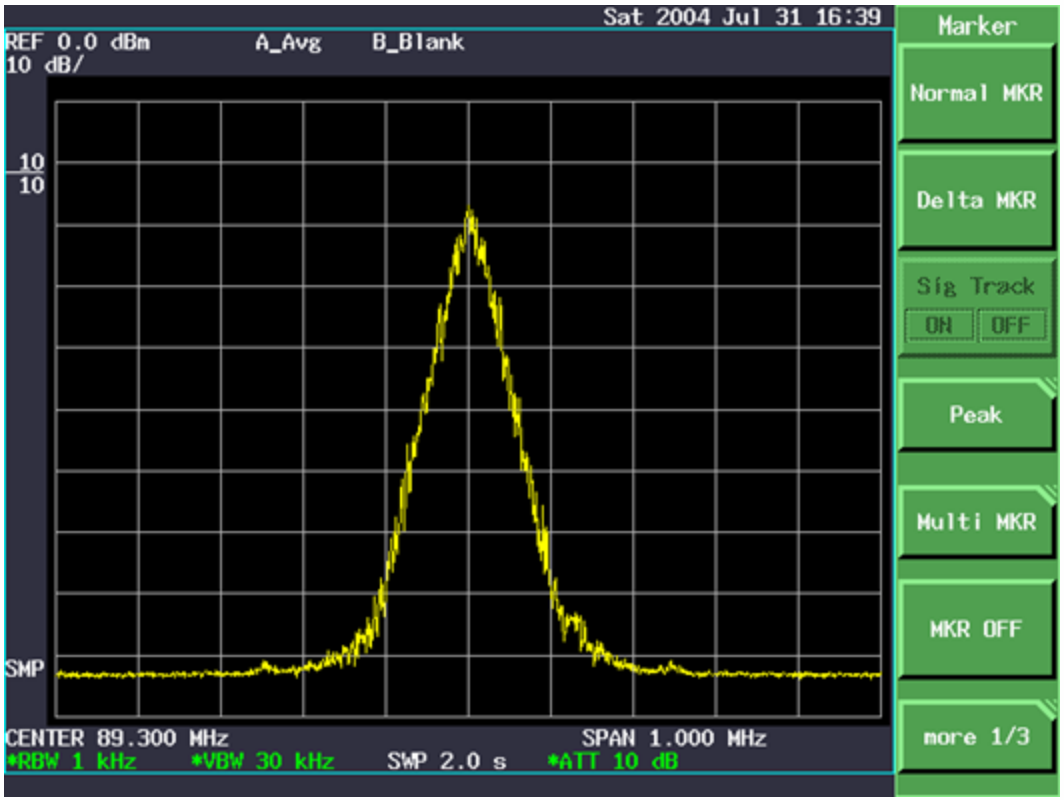


Adaptive Pre-correction Loop

Measurements

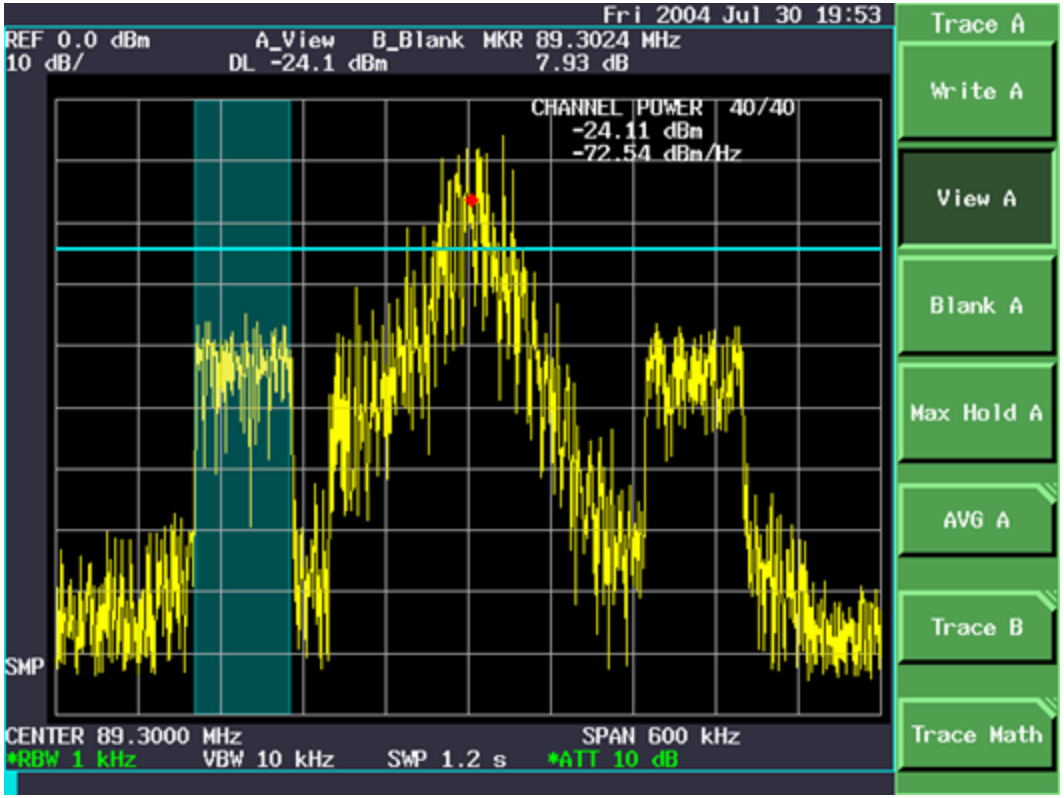
- KUVO

FM only



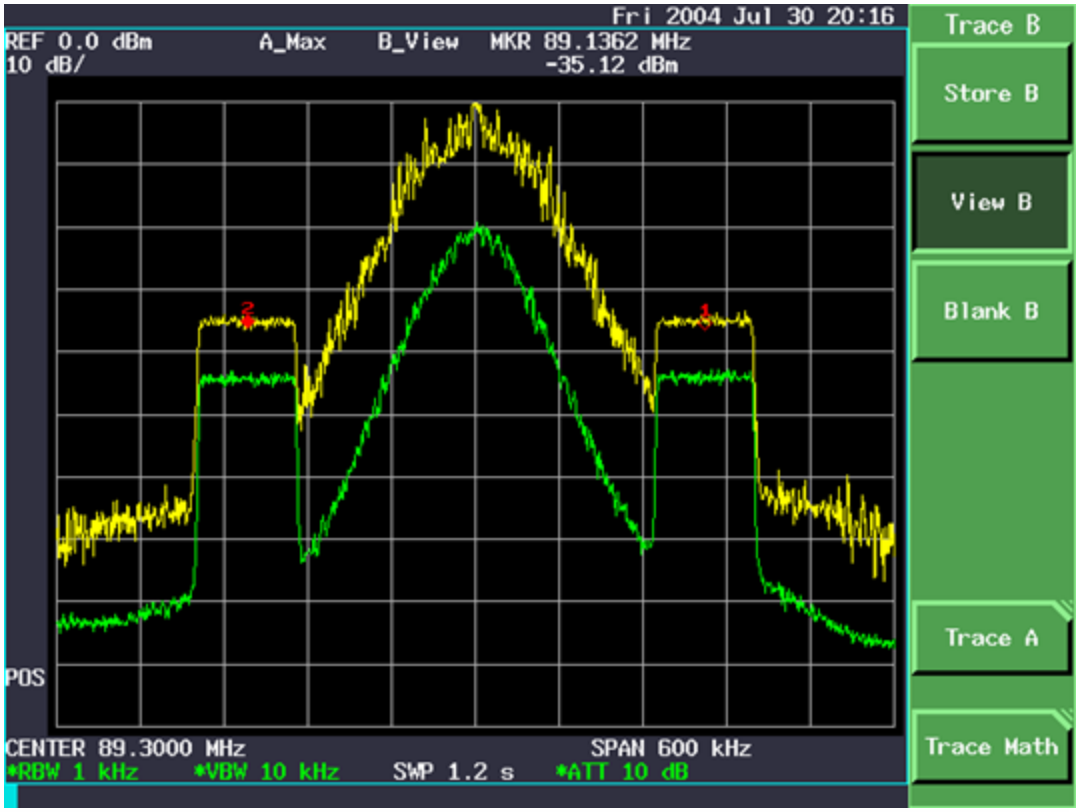
Measurements

- Channel Power
  - Analyzer utility
  - Computes power in a bandwidth



Measurements

- Positive Peaks
  - Averaged
- Sample
  - Averaged



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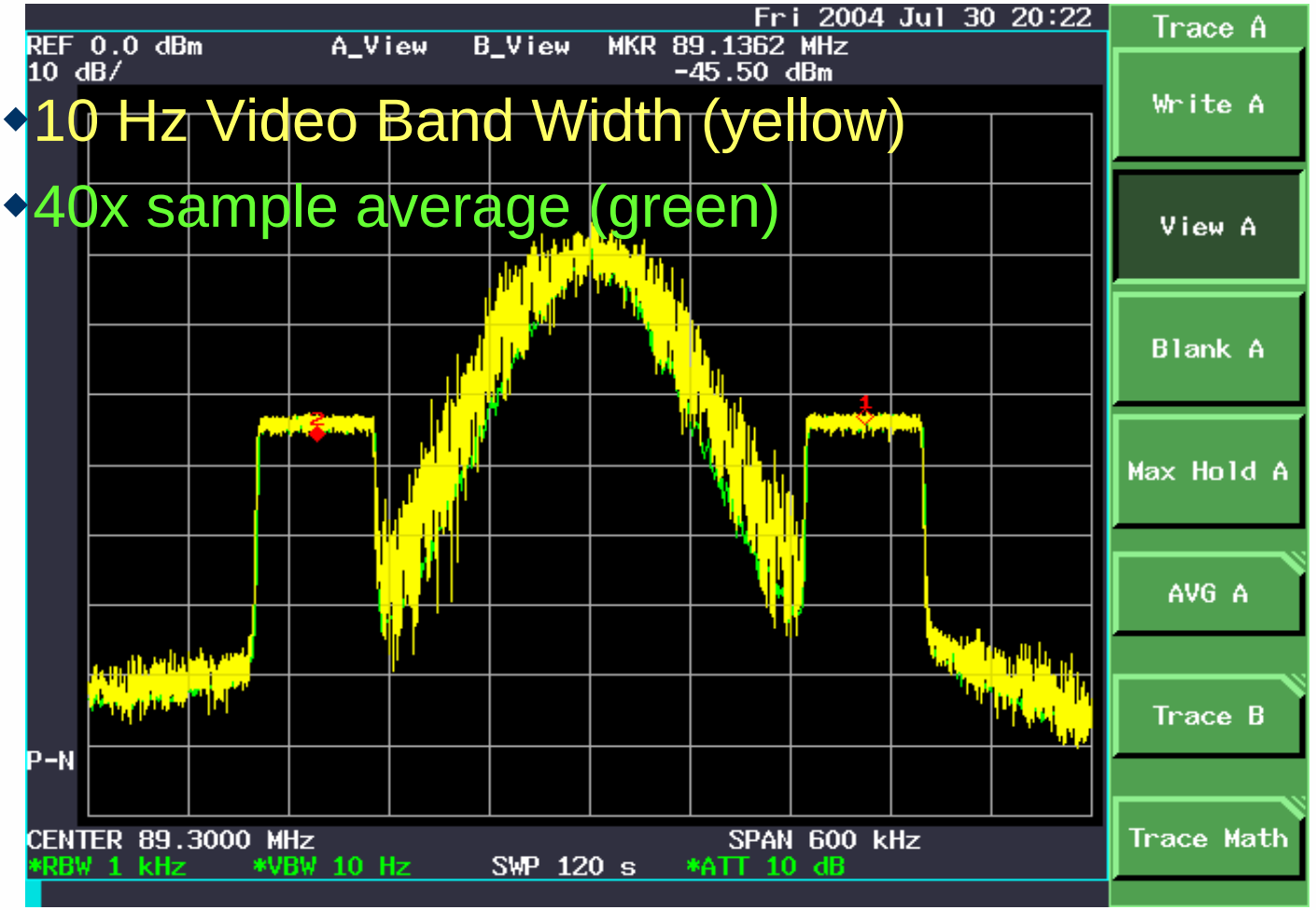
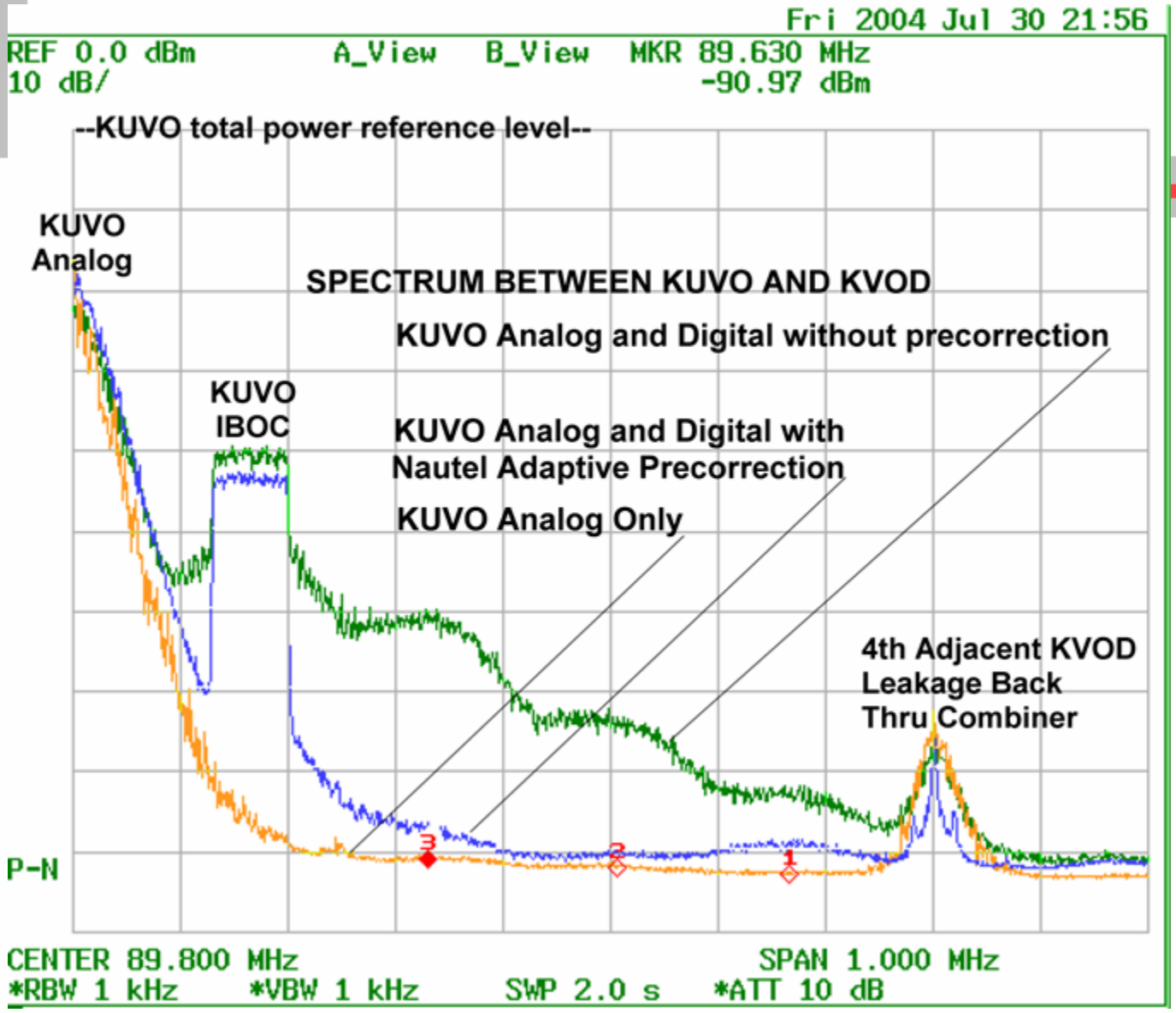
Measurements

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



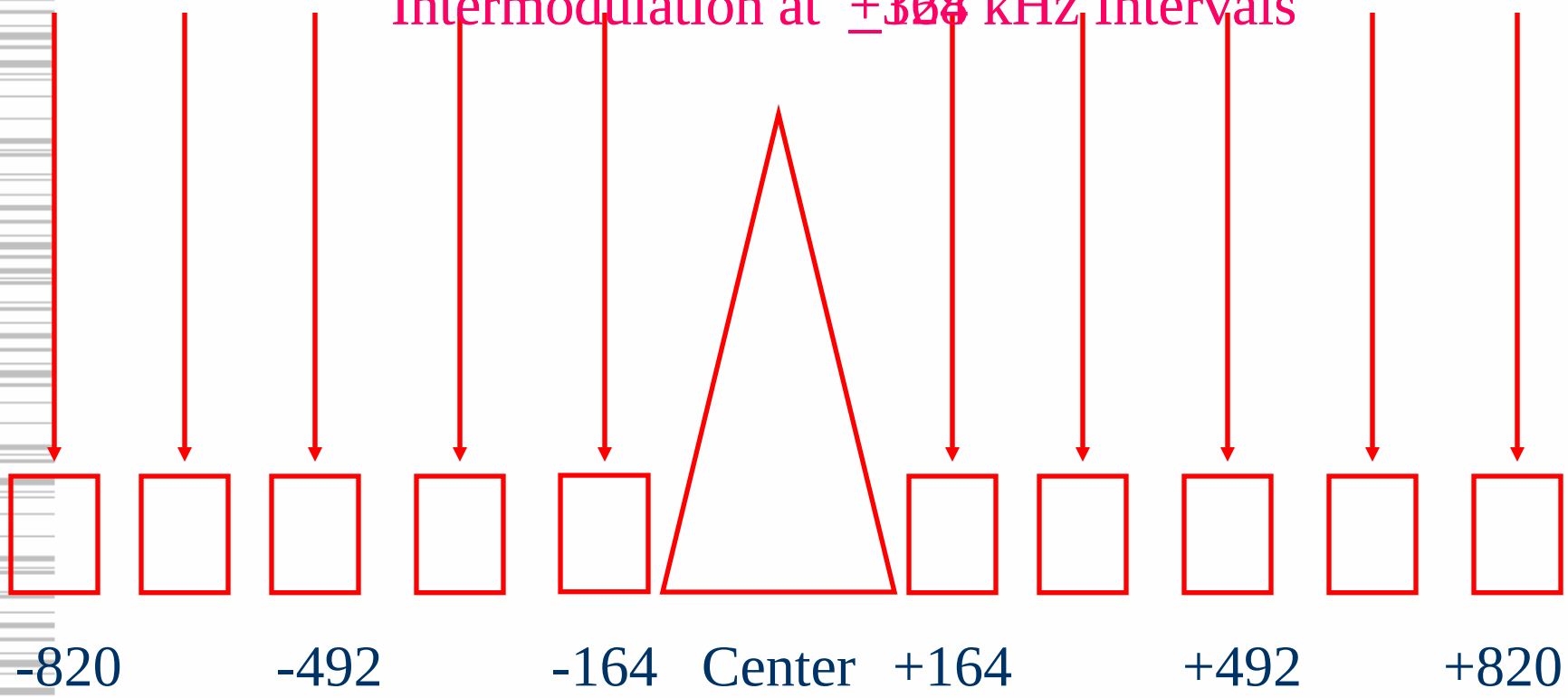

Fri 2004 Jul 30 21:56
REF 0.0 dBm
10 dB/
A_View
B_View
MKR 89.630 MHz
-90.97 dBm
--KUVO total power reference level--
KUVO
Analog
SPECTRUM BETWEEN KUVO AND KVOD
KUVO Analog and Digital without precorrection
KUVO
IBOC
KUVO Analog and Digital with
Nautel Adaptive Precorrection
KUVO Analog Only
4th Adjacent KVOD
Leakage Back
Thru Combiner
P-N
CENTER 89.800 MHz
SPAN 1.000 MHz
*RBW 1 kHz
*VBW 1 kHz
SWP 2.0 s
*ATT 10 dB

Common Amplification

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

Common Amplification

Intermodulation at ±328 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

The KVOD Crew

nautel

Mike Woods,

Chris Mahaney

Broadcast Signal Lab

Thank You

www.broadcastsignallab.com