

ATSC TV Digital Transmission performance and measurement



Perry Priestley - Linear Industries, Inc. November 2010

Contents

- ▶ **Transmitter Signal Measurements**
 - ▶ Monitoring
 - ▶ Diagnostic/Analytical
- ▶ Latest pre-correction techniques
 - ▶ Adaptive pre-correction
 - ▶ Memory Error Correction
 - ▶ Crest Factor Reduction



Transmitter Signal Measurements

Two viewpoints -

- Monitor

- Diagnostic/Analytical



Transmitter Signal Measurements

Monitoring

- Pilot Carrier Frequency
 - Phase Noise
 - Symbol Clock Frequency
 - Jitter
-
- Once every 18-24 month
 - Related to Encoder mux clock, PLL, ext. 10MHz ref., Temp Stab oven...
 - Test equipment required:
 - Agilent 88441A, Tektronix RFA 300, R&S EFL/ETL

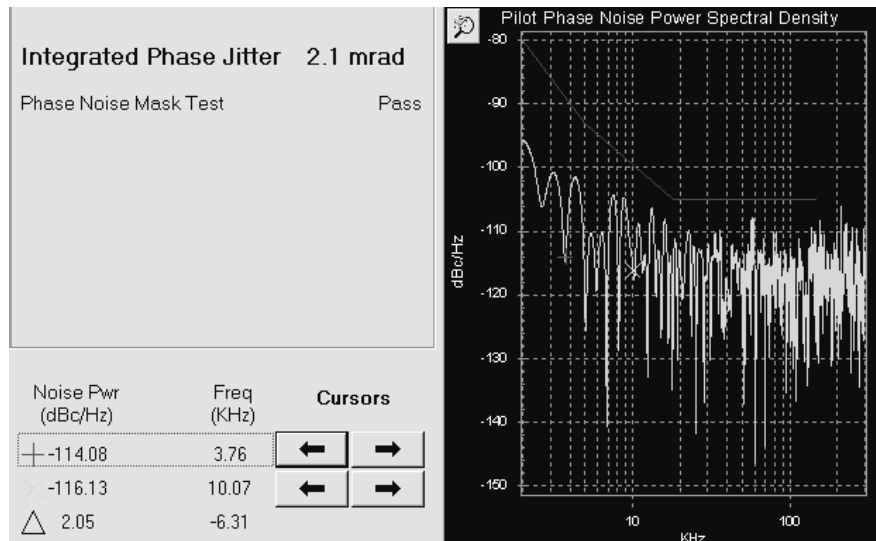


Transmitter Signal Measurements

Monitoring

– Phase Noise

- Specification -20kHz; noise level should be 104dB referenced to carrier i.e. 104dB/c
- Best SNR/MER with a noise level less than >100dB across the entire band from 1KHz to 100kHz.



Transmitter Signal Measurements

Diagnostic/Analytical

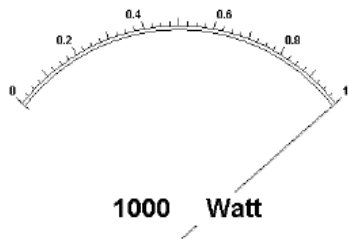
- Transmitter Power Output (TPO - average 6 MHz)
- FCC Emission Mask (Out of band measurement – Intermodulation)
- Peak to Average Power Ratio (CCDR)
- Signal Quality
 - EVM
 - SNR
 - MER



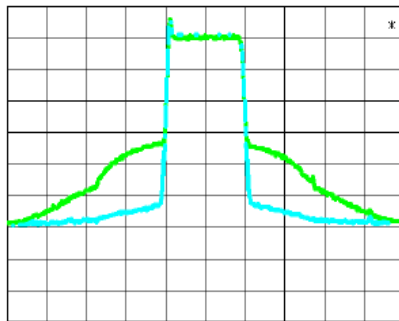
Transmitter Signal Measurements

The Four “Figures of Merit”

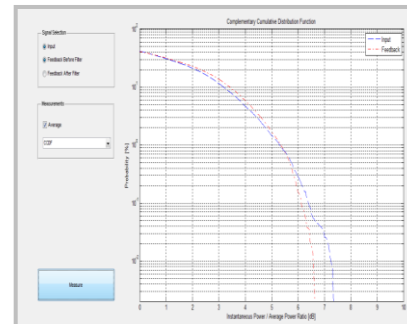
Power Output



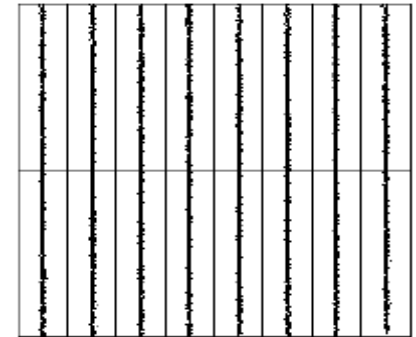
Intermodulation



CCDF



MER



Transmitter Signal Measurements

1. Power Output

- **Calorimetric**
 - Into Dummy load – good match – min VSWR, Transmitter is out of service
 - Flow rate (gpm) x $(t_2 - t_1)$ x coolant specific gravity factor
(keep flow rate low enough that $t_2 - t_1$ is at least 1degree > 1kW)
 - Accuracy ~ 4% or 0.18dB
- **Power Meter**
 - Accurate directional coupler
 - High Quality Power meter
 - Calibrated cables
- **Calibrated Spectrum Analyzer**
 - Accurate directional coupler
 - Calibrated cables and attenuators – don't overload the front end of the SA

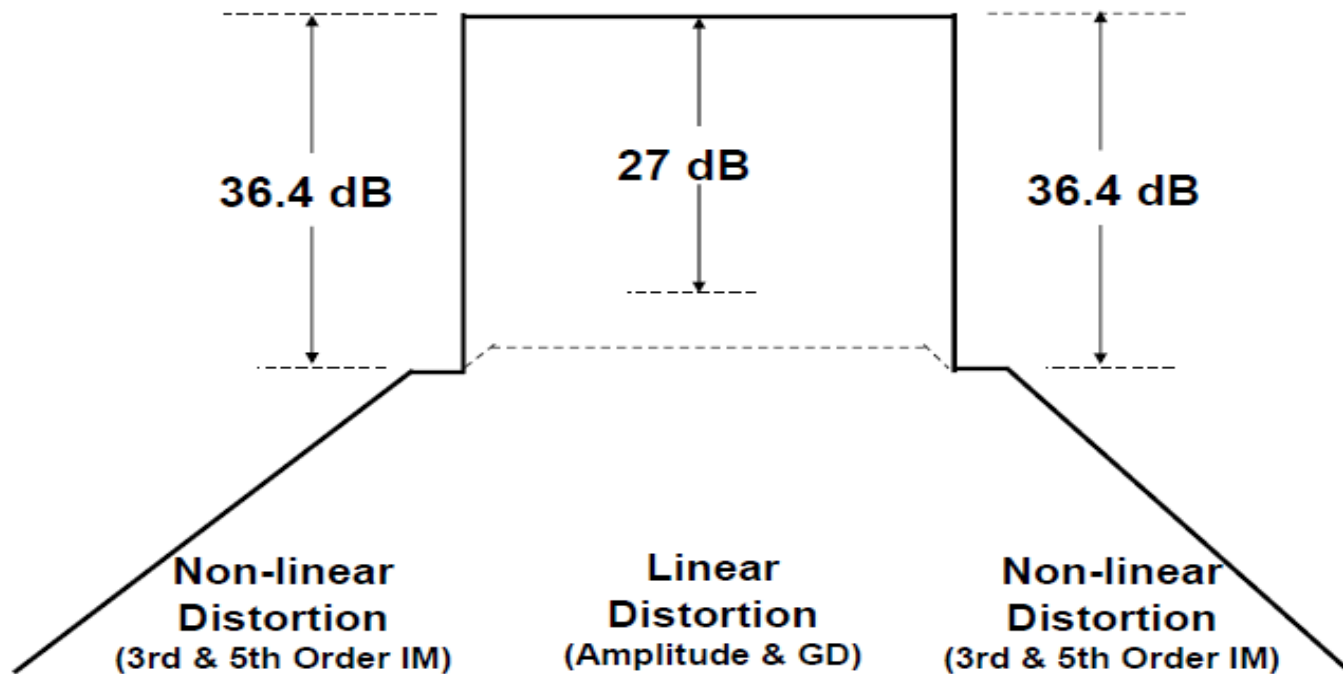


Transmitter Signal Measurements

2. Inter-modulation

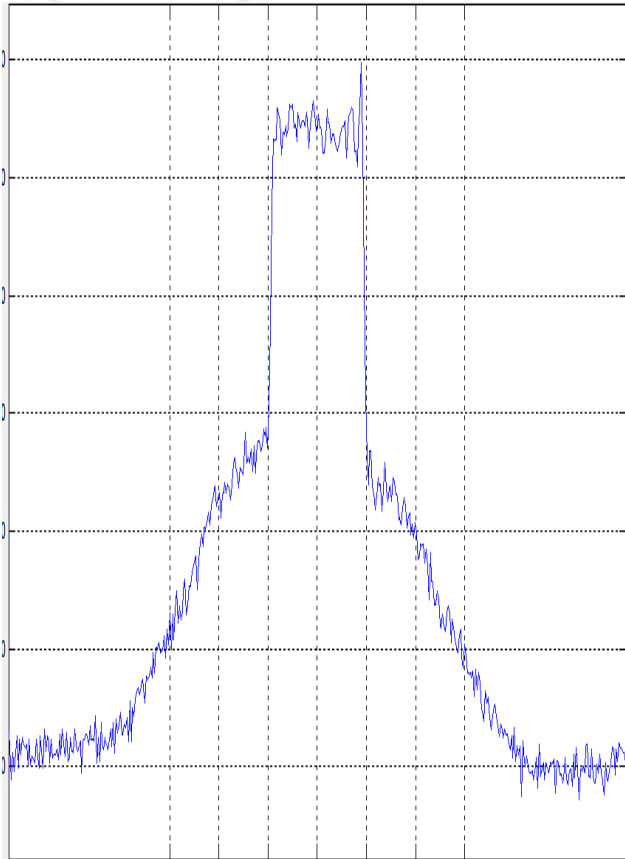
- ➡ Out of channel emission or “Shoulders” or “Shelves”

Tx Compliance Spectrum



Transmitter Signal Measurements

2. Inter-modulation



What is Non-Linear Distortion?

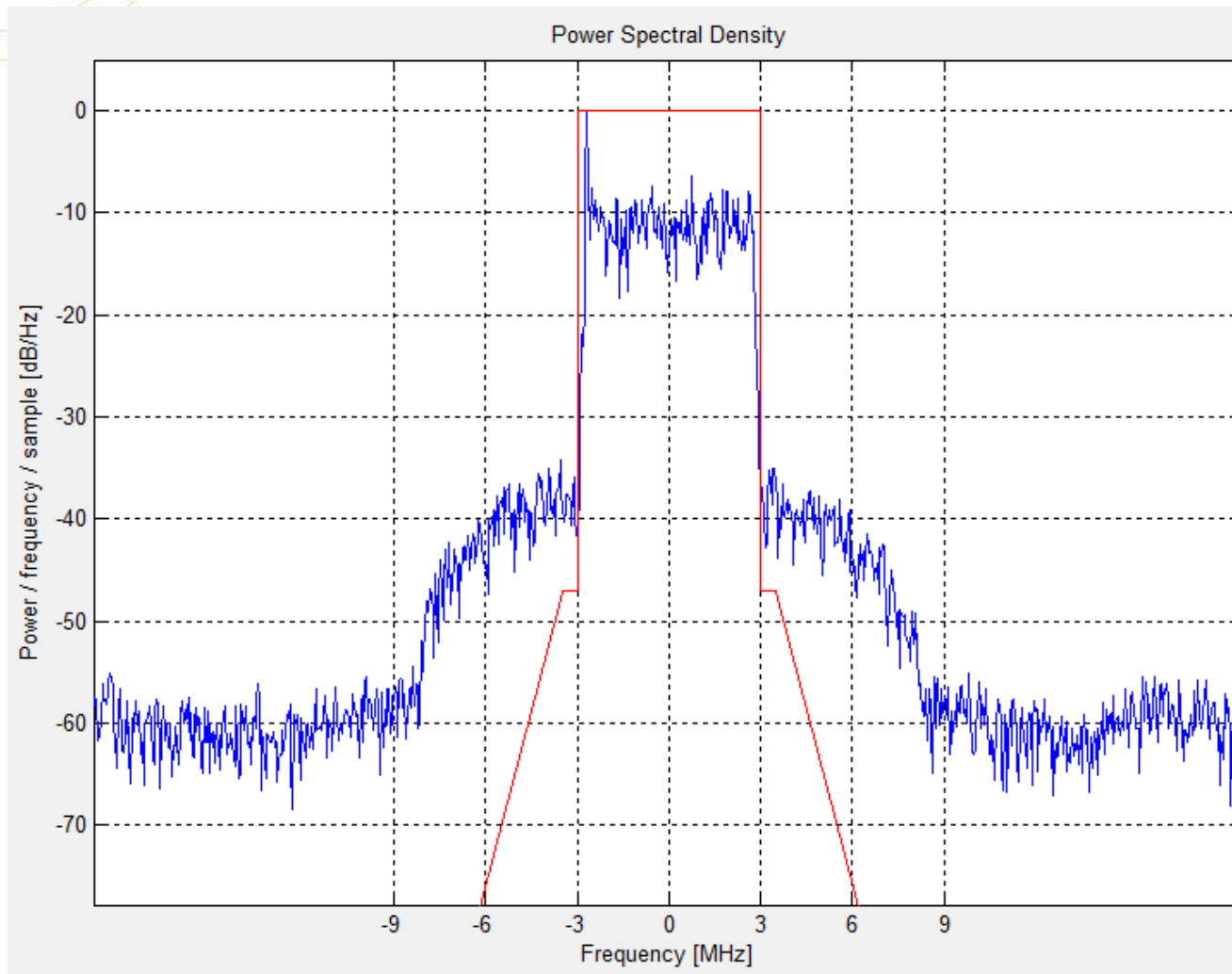
- In NTSC same as “LF linearity” and ICPM
- Manifested by non-linear in-band and out of band inter-modulation products
- Non-linearity is created when the amplifier’s gain and/or phase response changes because of changing input signal amplitude
- The presence of non-linear distortion will reduce the receiver’s ability to automatically correct for linear distortion

No mechanism to correct these errors at the receiver !



Transmitter Signal Measurements

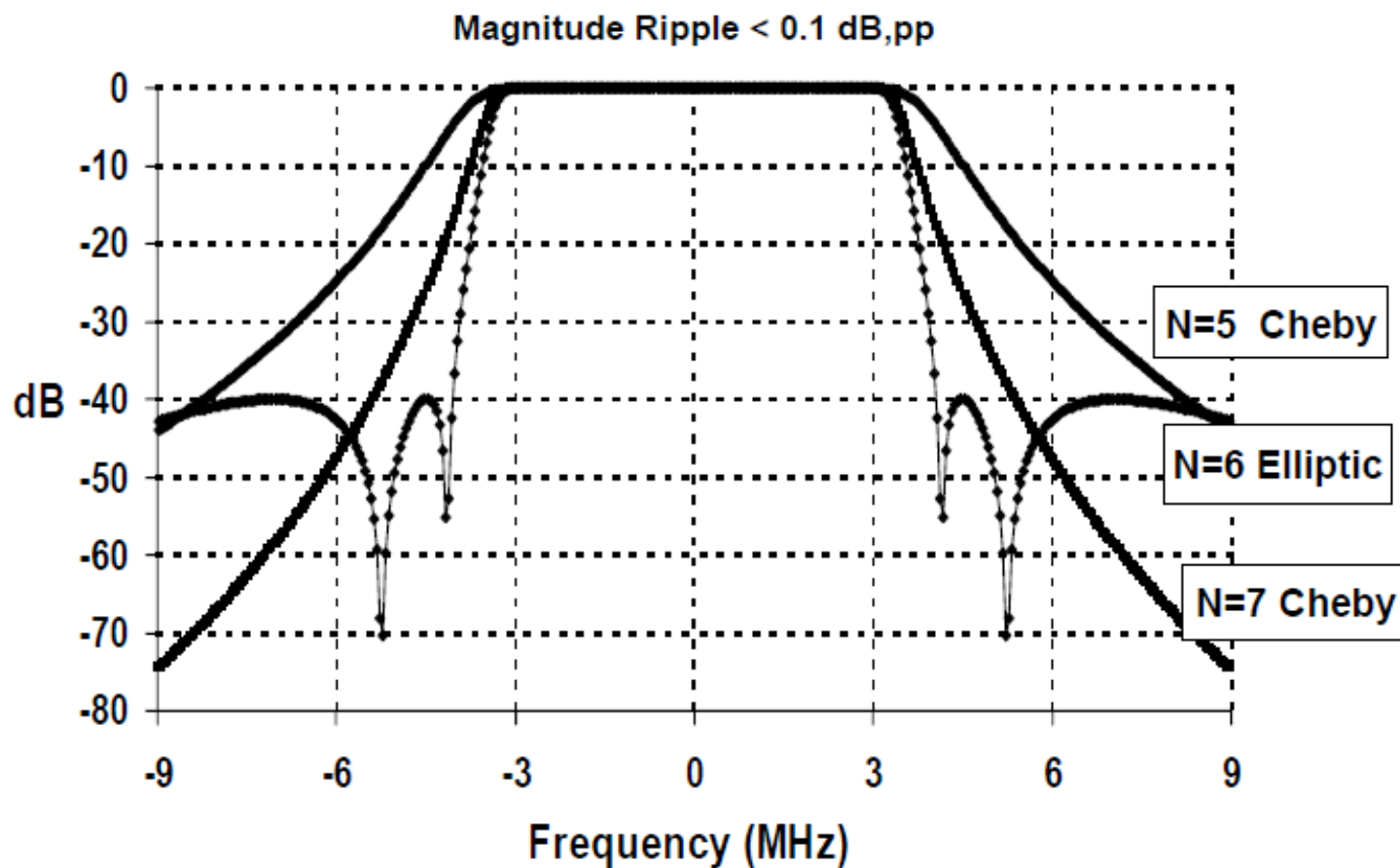
2. Inter-modulation



Transmitter Signal Measurements

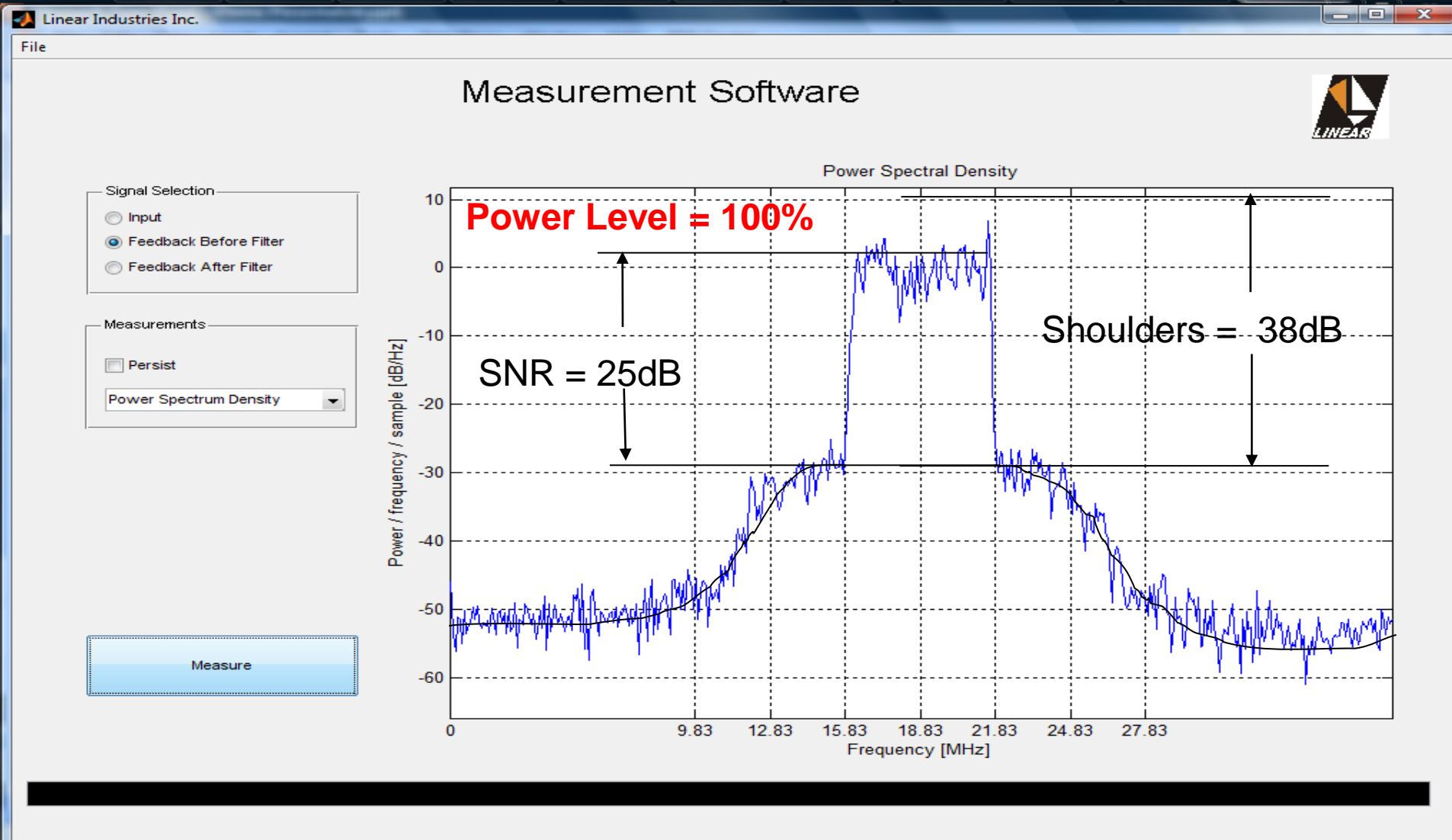
2. Inter-modulation

High Power Bandpass Filters: Stopband Magnitude



Transmitter Signal Measurements

2. Inter-modulation



Transmitter Signal Measurements

2. Inter-modulation

Linear Industries Inc.

File

Measurement Software



Signal Selection

Input

Feedback Before Filter

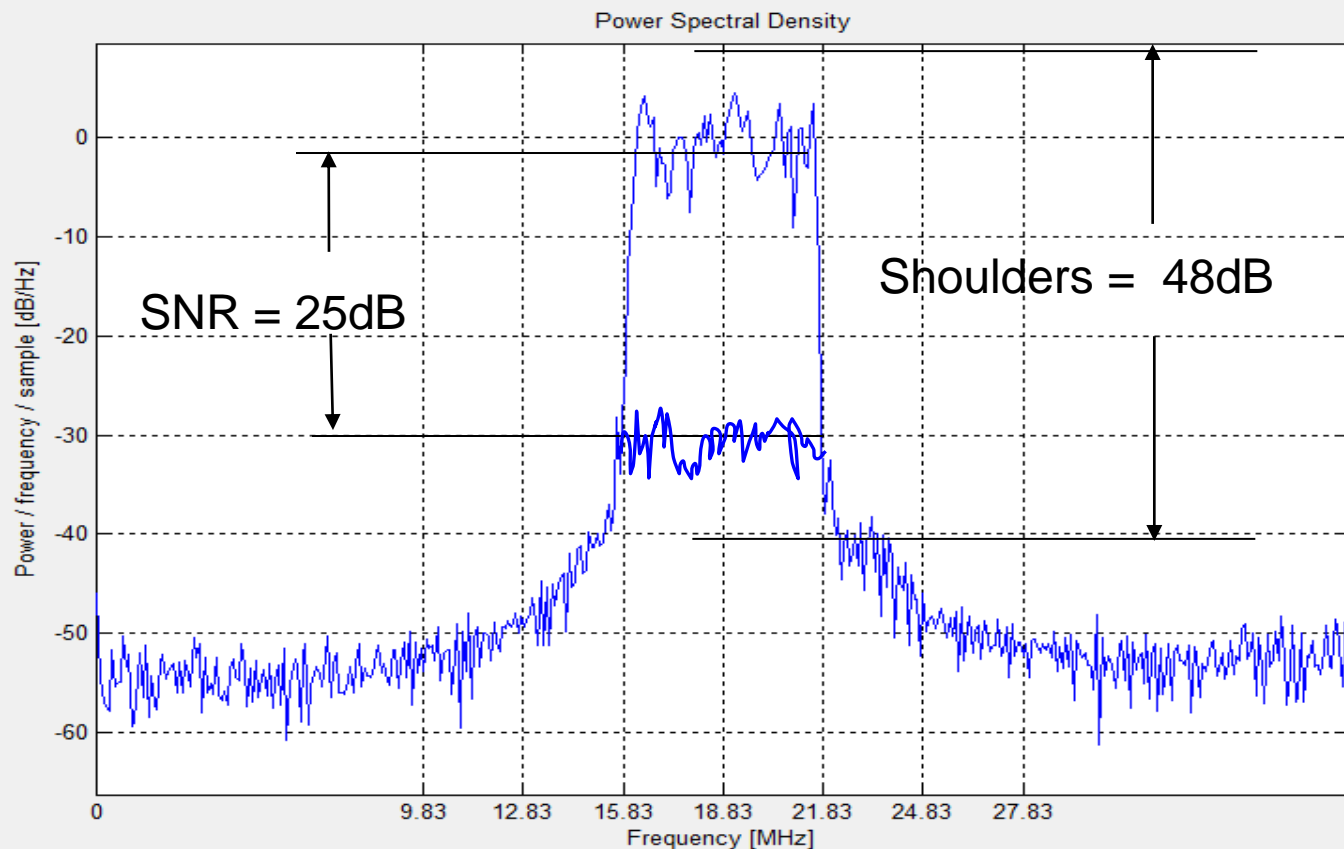
Feedback After Filter

Measurements

Persist

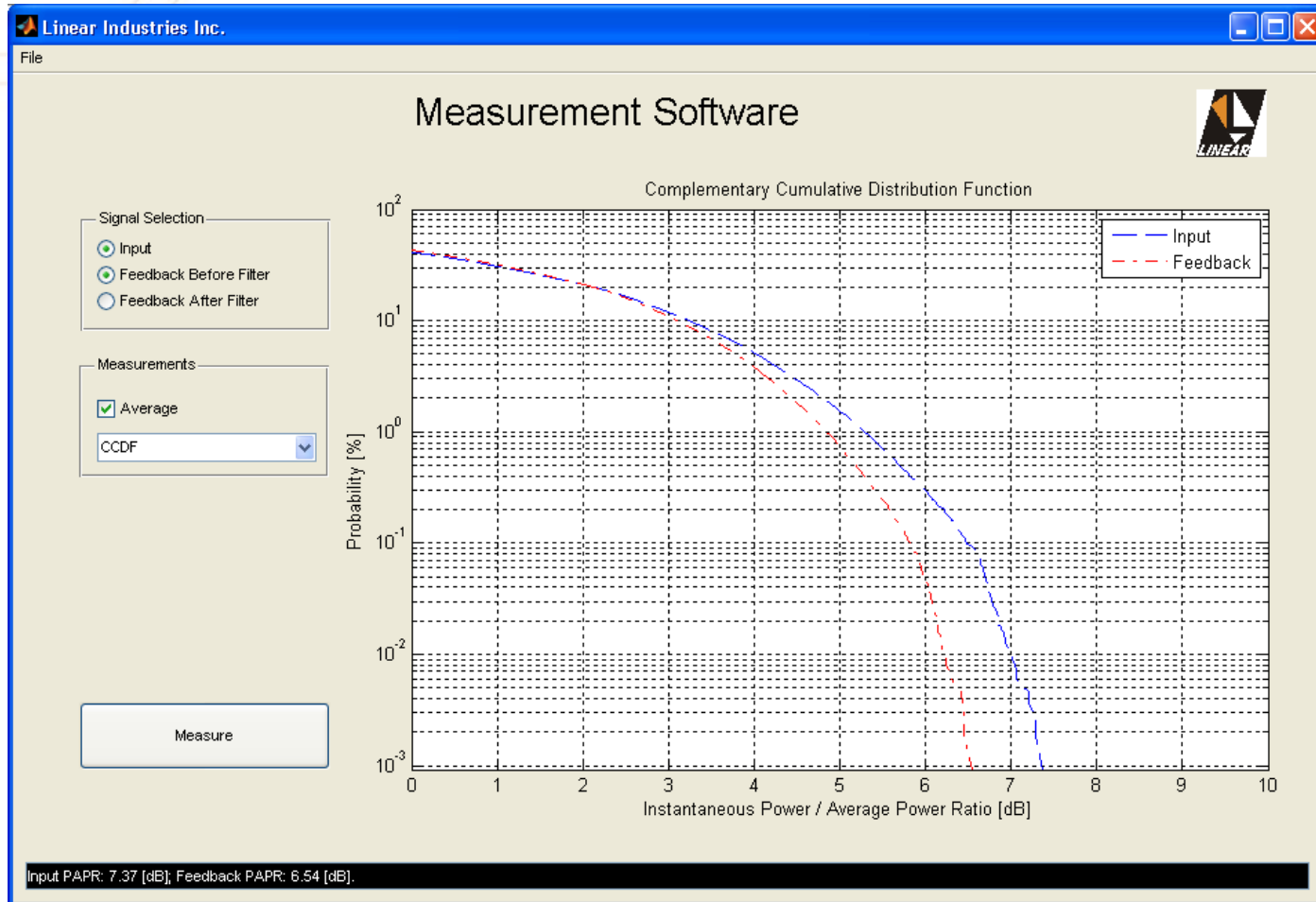
Power Spectrum Density

Measure



Transmitter Signal Measurements

3. CCDF



Transmitter Signal Measurements

3. CCDF

► Complimentary Cumulative Distribution Factor

- **Represents** the probability (vertical axis) of the Instantaneous Power in dB above the average power, where the in the horizontal axis is the transmitter output power and Zero = 100% TPO.

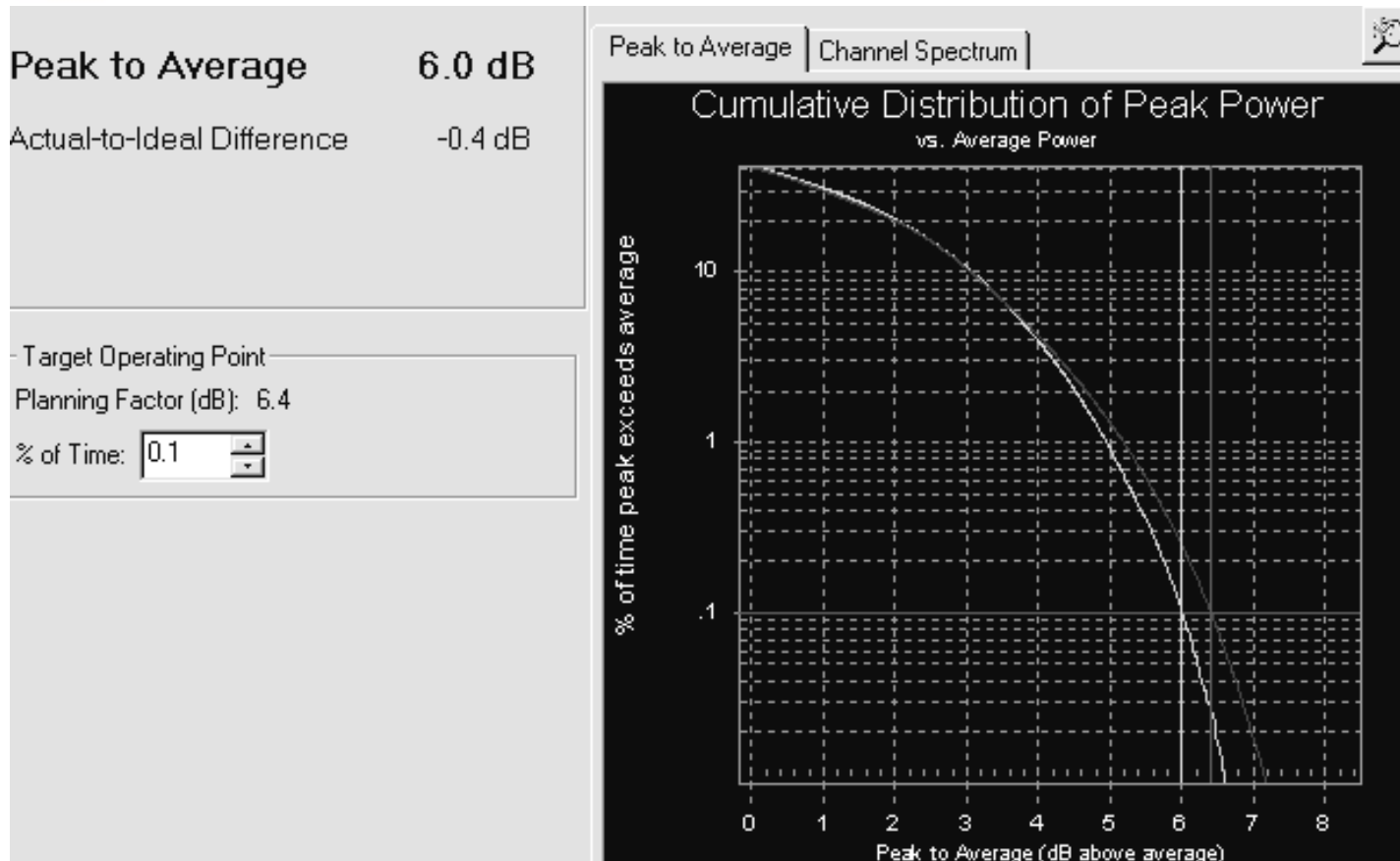
PAPR: Stands for Peak to Average Power Ratio and represents the ratio between the maximum peak power and the average power. Quoted in dB.



Transmitter Signal Measurements

3. CCDF

► Complimentary Cumulative Distribution Factor



Transmitter Signal Measurements

4. EVM/SNR/MER

EVM (in %)

$$100 * \text{SQRT} \left(\left(\frac{1}{N} \right) * \text{SUM} (I_{\text{err}}^2 + Q_{\text{err}}^2) \right) / S_{\text{max}}$$

I err of 2.25% and Q err of 2.25% gives an EVM of 3%

SNR (in dB)

$$10 * \text{LOG}_{10} \left(\frac{\text{SUM}(S_i^2)}{I_{\text{err}}^2} \right)$$

I err = 4.45% and gives a SNR of 27dB

MER (in dB)

$$10 * \text{LOG}_{10} \left(\frac{\text{SUM} (S_i^2 + S_q^2)}{I_{\text{err}}^2 + Q_{\text{err}}^2} \right)$$

I err of 4.45% and Qerr of 4.45% gives an MER of 27dB

*S_i and S_q are ideal Signal values of the I and Q channels
I err and Q err are deviations in received signals from the ideal (i.e. noise)*



Transmitter Signal Measurements

4. EVM/SNR/MER

Sources of SNR/MER Degradation

- Echoes Ext. to Tx: [multipath]
- Interferers ext. to Tx: [adj. co. channel]
- IQ errors ampl. and ϕ : [decoder, encoder, modulator]
- Phase jitter: [oscillator stability, encoder decoder errors]
- Non-linear amplitude distortion: [ampl and F/B etc..]
 - Third harmonic distortion; Side-band re-insertion [Insufficient shoulder attenuation through non-linear correction and mask filter attenuation]
- Linear phase distortion or frequency magnitude response error and Frequency group delay error
 - Typically caused by filters, combiners, transmit antennas and receive antennas



Transmitter Signal Measurements

4. EVM/SNR/MER

Why is SNR important?

The better the SNR at the transmission system the greater noise margin at the receiver

SNR is a critical issue determining coverage margin

- ▶ Particularly related to older generation receivers
- ▶ The better the SNR the higher probability of good coverage

DTV receivers have Adaptive Equalization to correct uncontrollable linear and multipath propagation effects

HOWEVER --- receivers margin is wasted if it is improving controllable SNR at the transmission system output

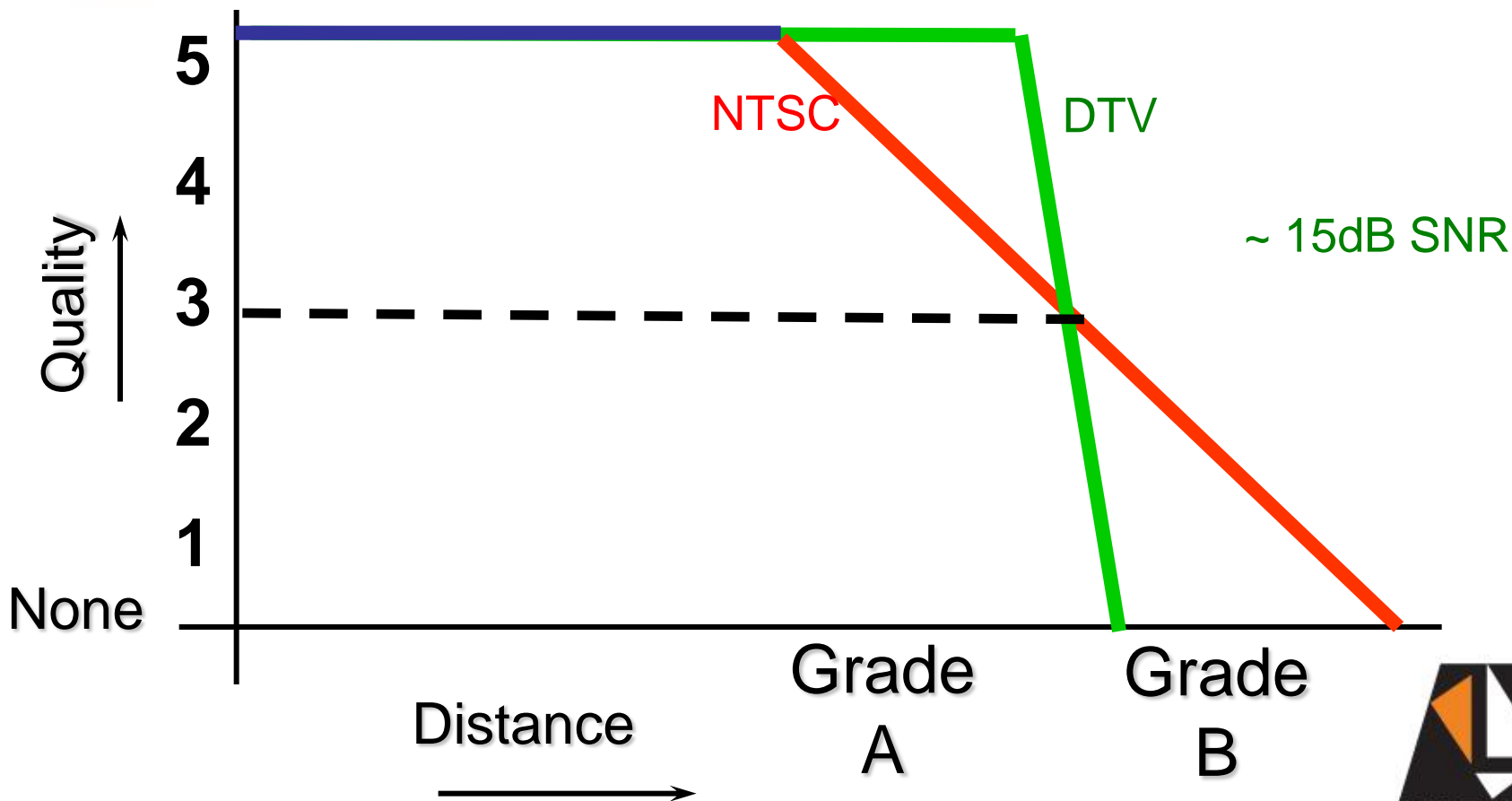
- ▶ The best service margin will result from the best pre-equalized transmission system SNR



Transmitter Signal Measurements

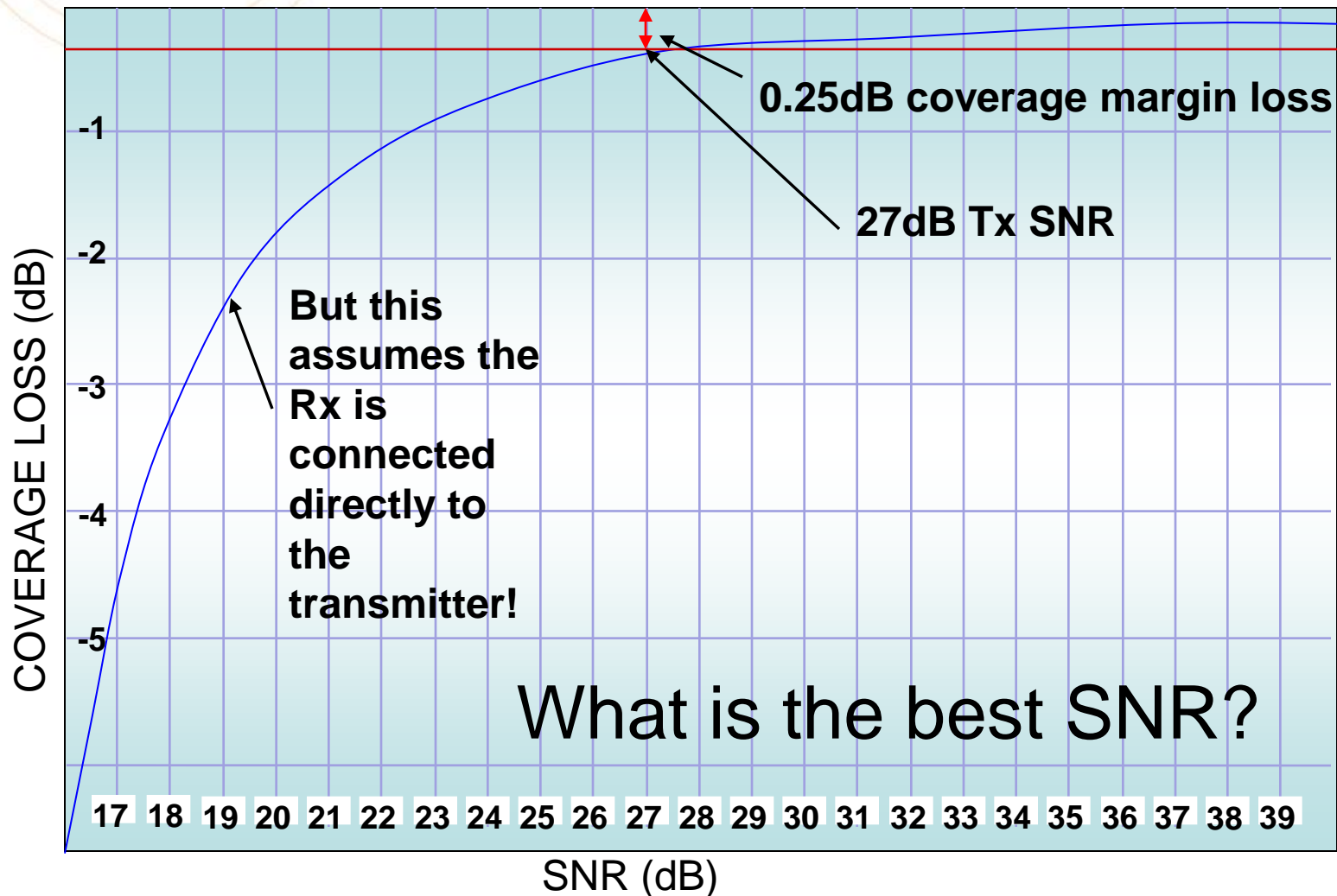
4. EVM/SNR/MER

The “Cliff Effect” – “all or nothing!”



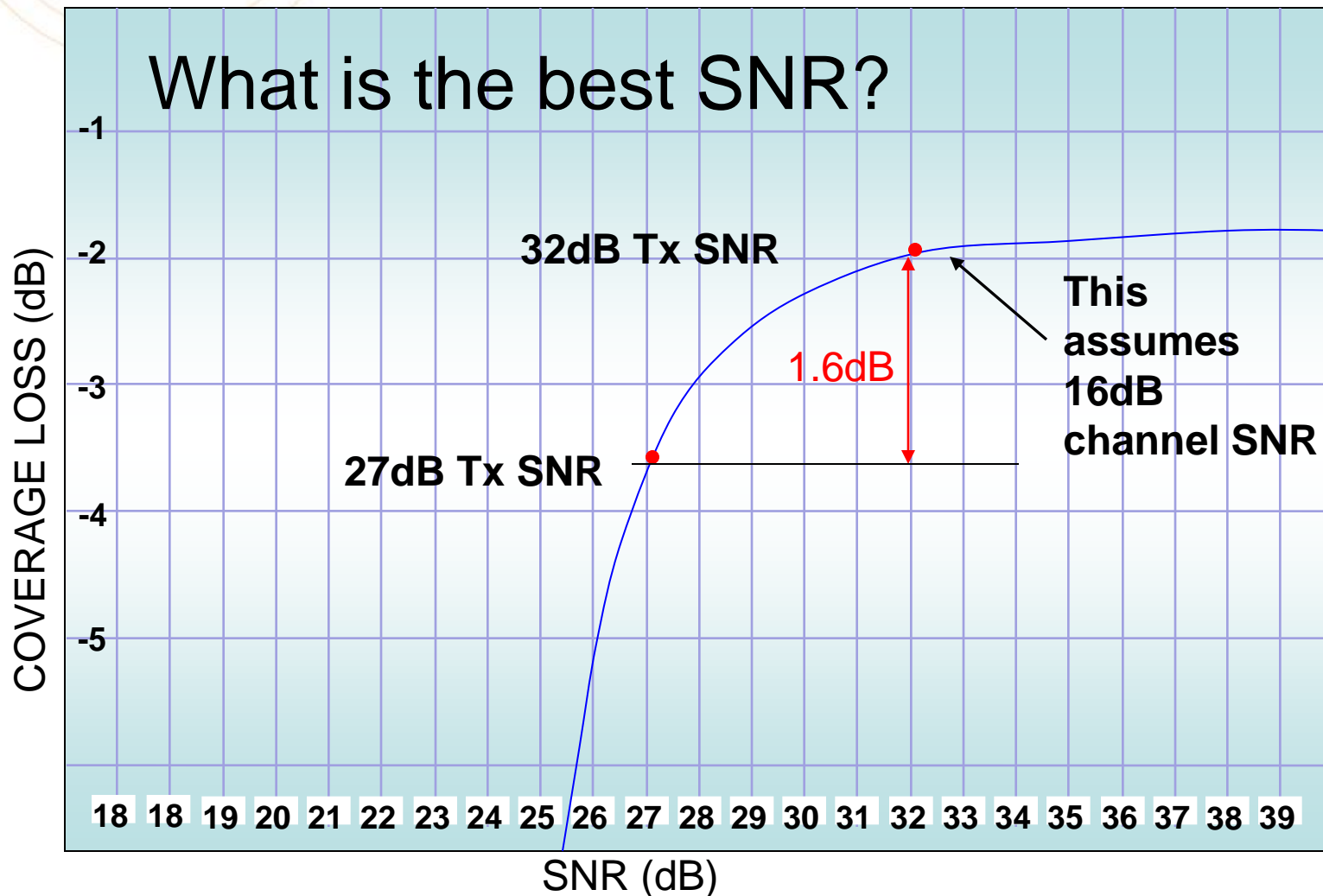
Transmitter Signal Measurements

4. EVM/SNR/MER



Transmitter Signal Measurements

4. EVM/SNR/MER



Transmitter Signal Measurements

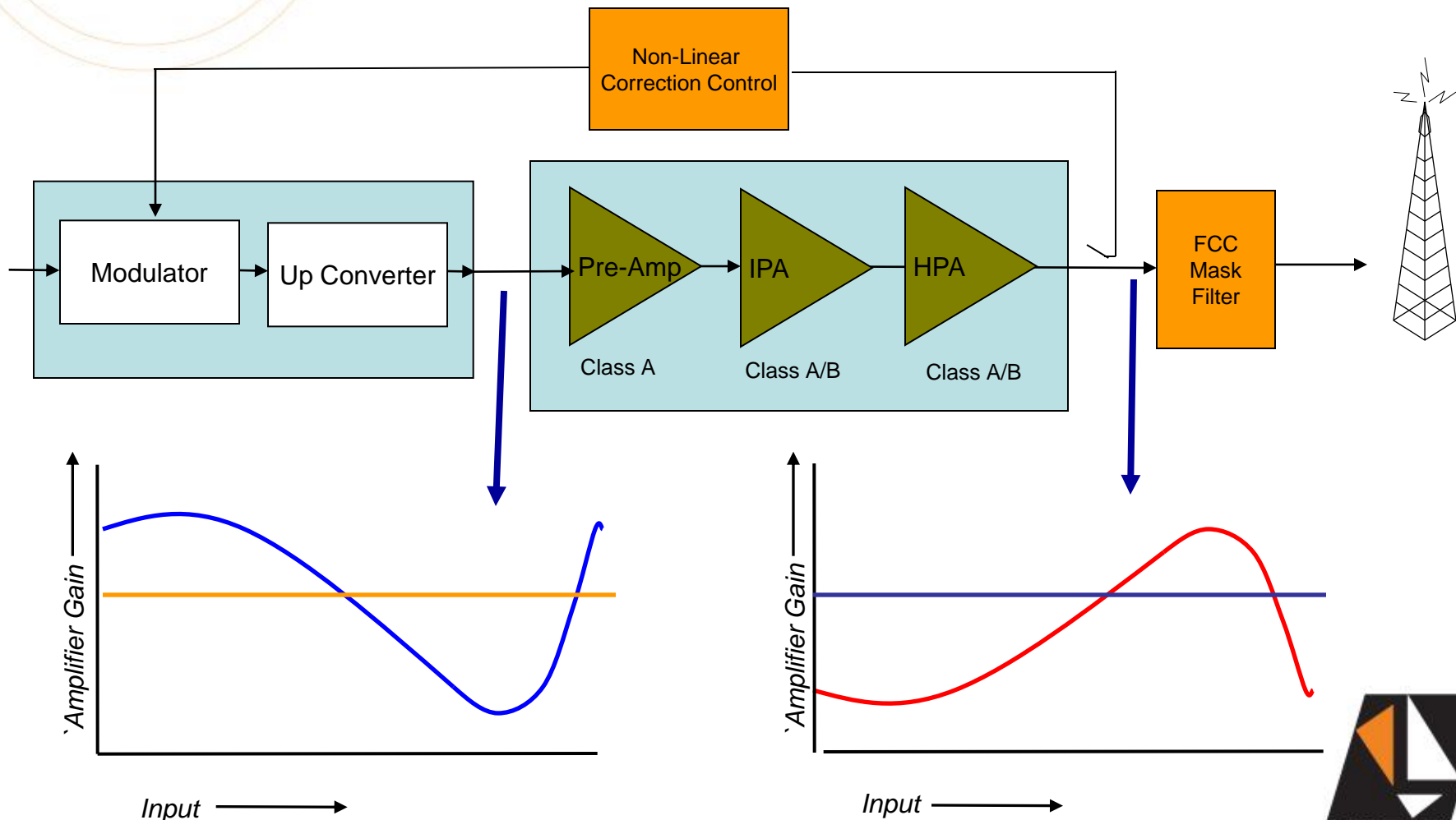
4. EVM/SNR/MER

- ▶ Threshold SNR of ideal ATSC demodulator (receiver) ~ 15dB
- ▶ 27dB SNR/MER assumed level for maximum coverage
 - ▶ But based on Rx being connected directly Tx!
- ▶ Real world SNR degraded by:
 - ▶ Filter, antenna, co-channel and adjacent interference, echoes, Rx equalizer white noise (dependant on echoes), Rx inter-modulation and cross-modulation,.
 - ▶ Also Rx input antenna miss-match
 - ▶ Unlicensed devices can also degrade SNR
- ▶ Improving SNR to better than 32dB could improve coverage by 1.6dB
- ▶ Broadcasters who maximize Tx SNR will enjoy better coverage in noisy and interference prone links
- ▶ Significant improvement in DTV service availability



Transmitter Signal Measurements

4. EVM/SNR/MER

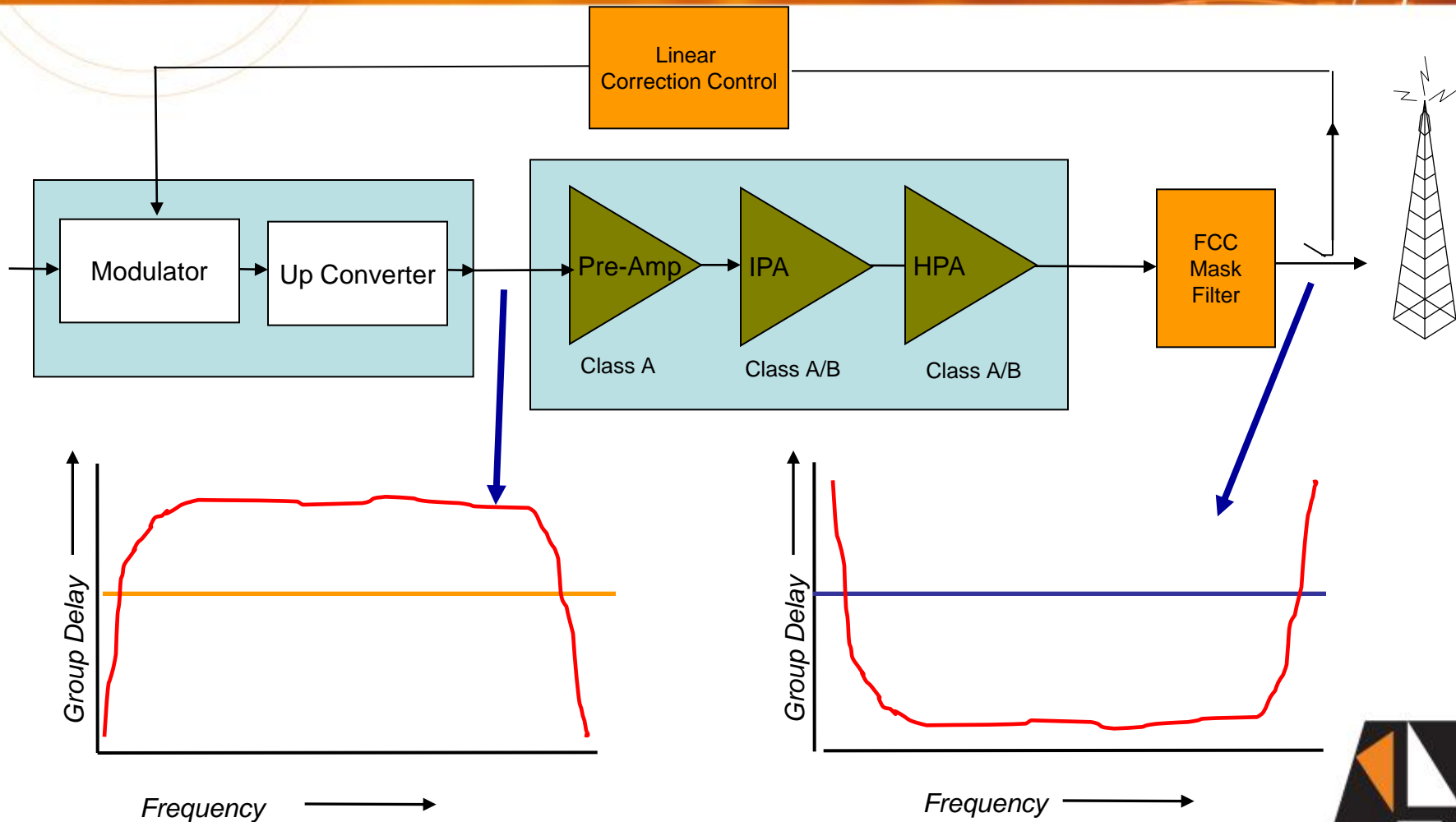


How does non-linear pre-correction work?



Transmitter Signal Measurements

4. EVM/SNR/MER

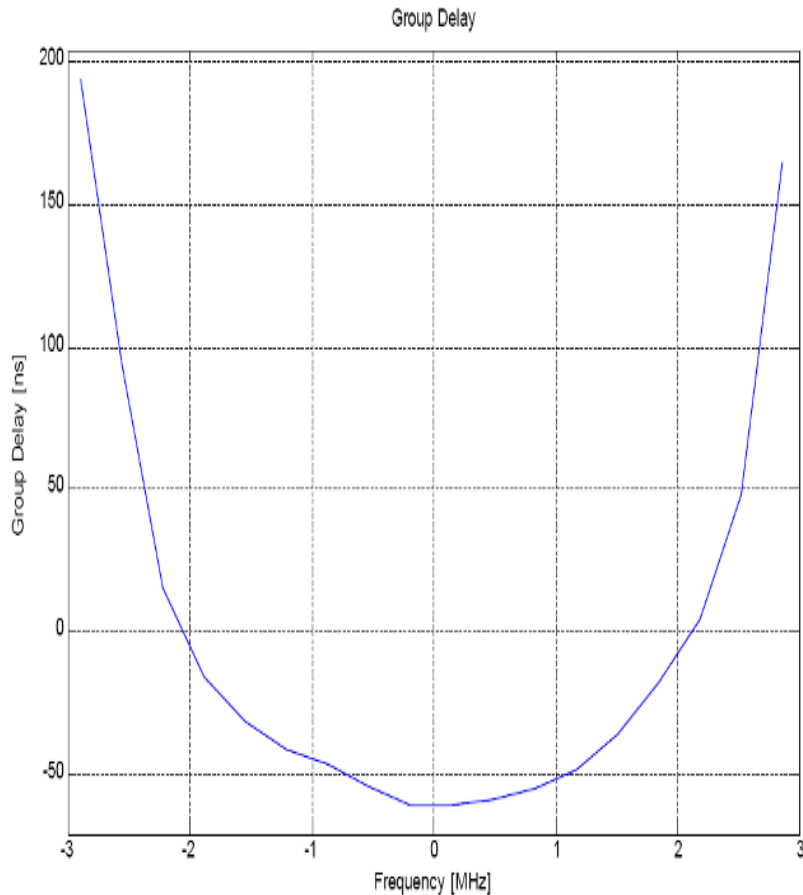


How does linear pre-correction work?



Transmitter Signal Measurements

4. EVM/SNR/MER



What is linear distortion?

- ➔ Linear distortion can be created throughout the DTV transmission path from the transmitter to the receiver
- ➔ Inside the transmitter it is created by frequency response errors and group delay variations
- ➔ Main offender inside the transmitter is the mask filter



Transmitter Signal Measurements

4. EVM/SNR/MER

What is linear distortion?

- ➔ Receivers do correct for linear distortion and
- ➔ Linear distortion in the mask filter is small compared to transmission path linear distortions; multipath / frequency selective fading

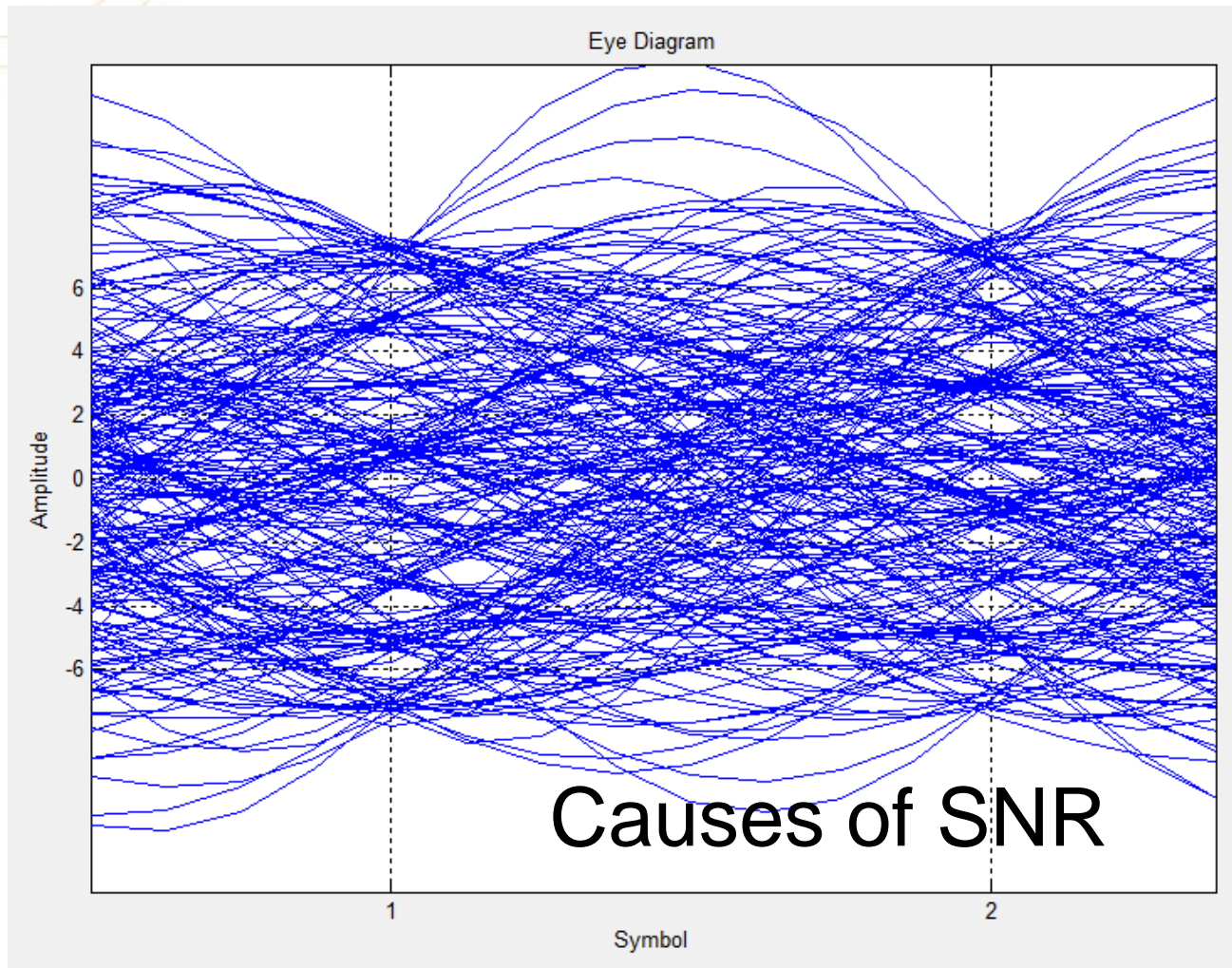
However, linear distortion can have a profound effect on measured SNR.

If linear distortion components are not minimized, then the more harmful non-linear distortion components may go unnoticed because the linear distortion tends to dominate in the SNR



Transmitter Signal Measurements

4. EVM/SNR/MER

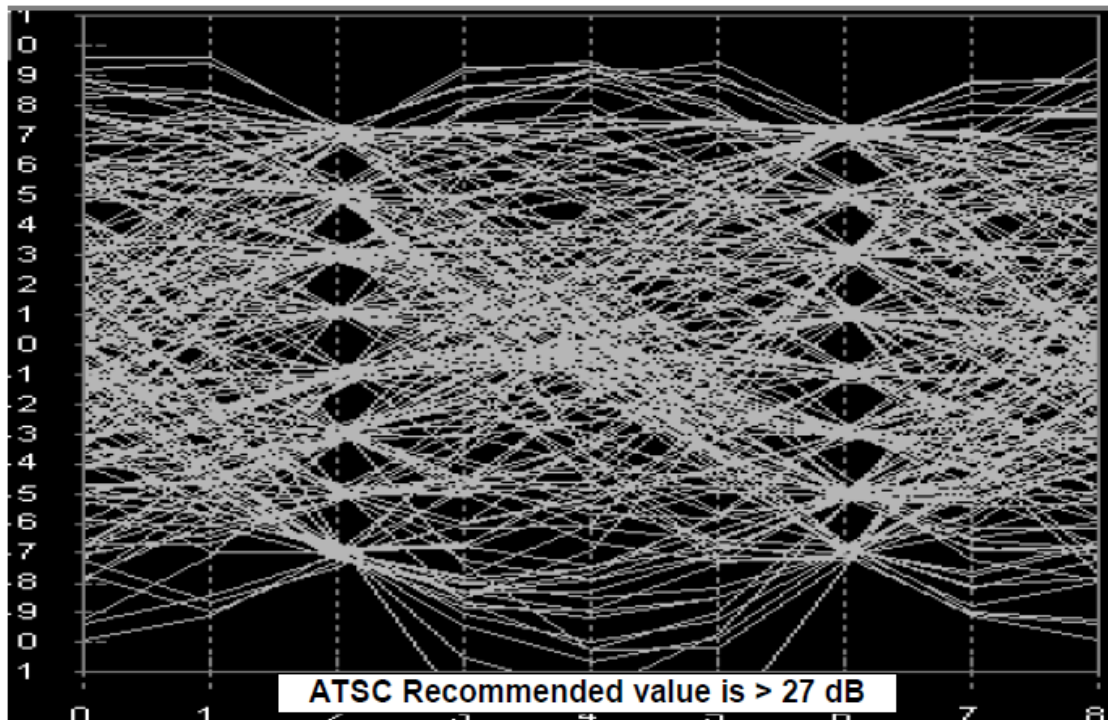


Transmitter Signal Measurements

4. EVM/SNR/MER

- ➡ SNR/MER measured from the EYE diagram

Inband Data Parameters: Data Eyes @ 27 dB SNR

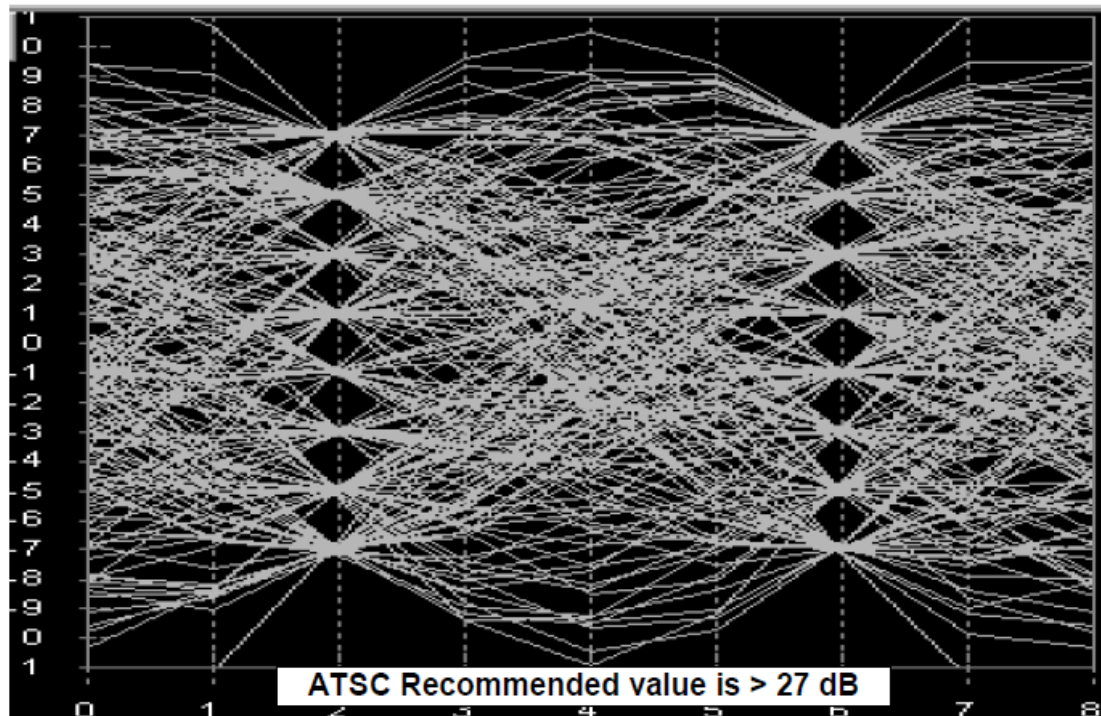


Transmitter Signal Measurements

4. EVM/SNR/MER

- ➡ SNR/MER measured from the EYE diagram

Inband Data Parameters: Data Eyes @ 35+ dB SNR

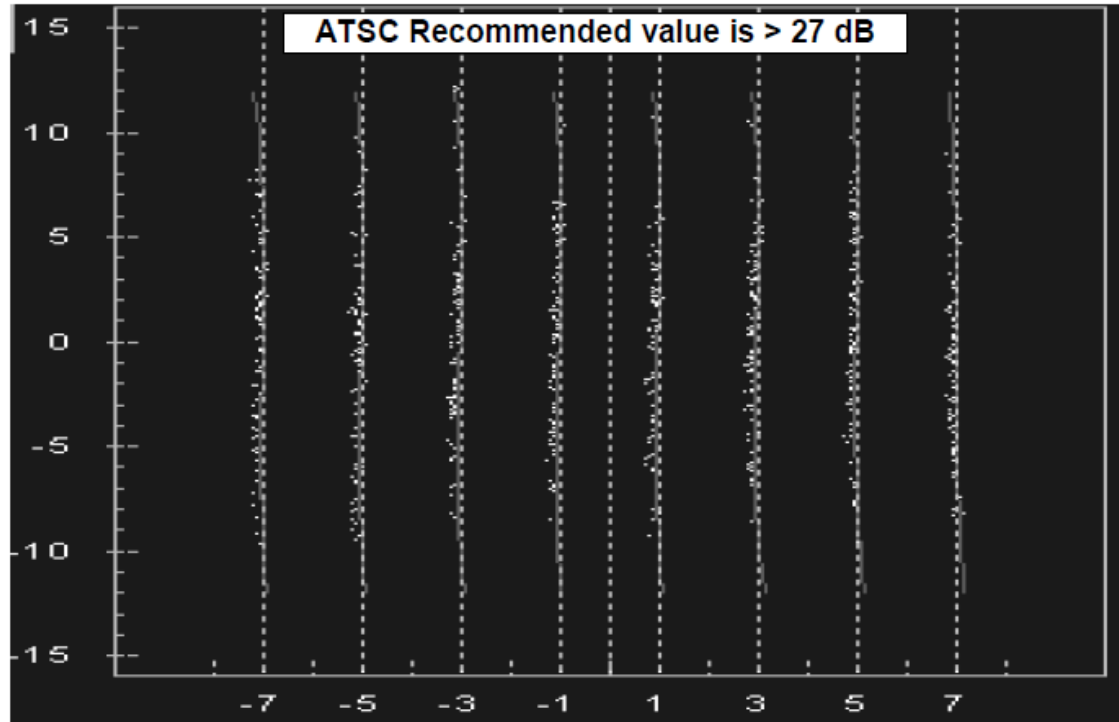


Transmitter Signal Measurements

4. EVM/SNR/MER

- ➡ SNR/MER measured from the Constellation diagram

Inband Data Parameters: Data Constellation @ 35+ dB SNR

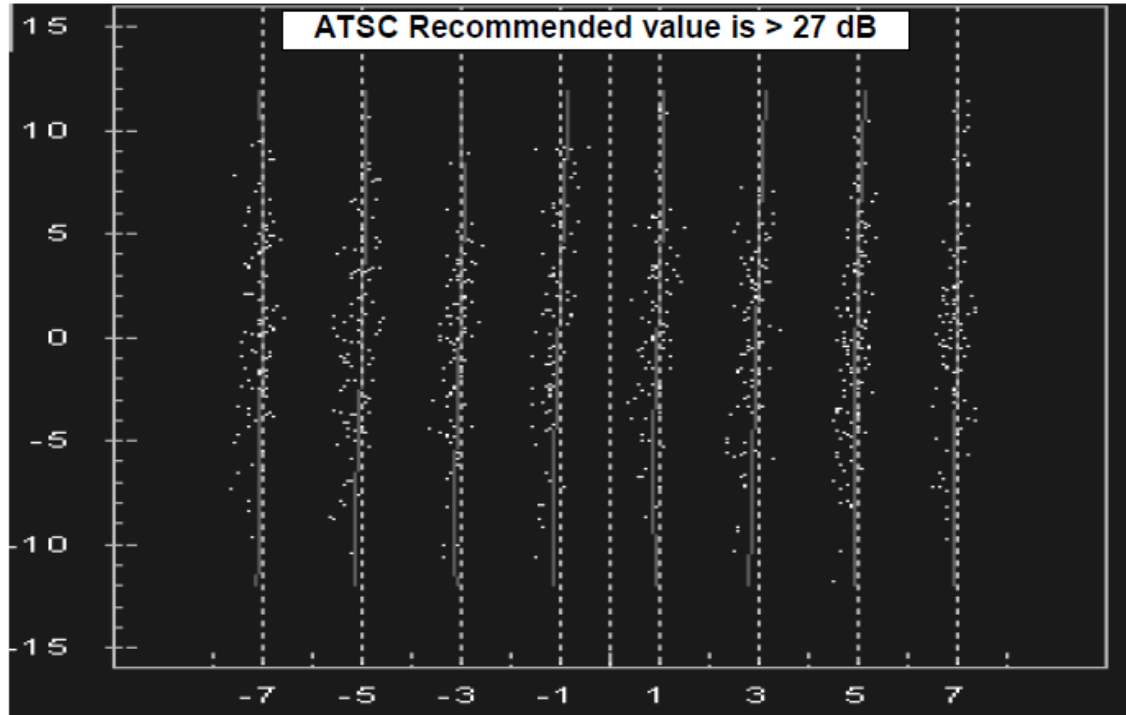


Transmitter Signal Measurements

4. EVM/SNR/MER

➡ SNR/MER measured from the Constellation diagram

Inband Data Parameters: Data Constellation @ 27 dB SNR



Contents

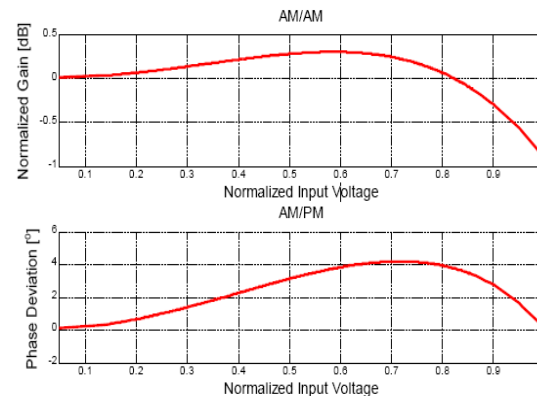
- ▶ Transmitter Signal Measurements
 - ▶ Monitoring
 - ▶ Diagnostic/Analytical
- ▶ Latest pre-correction techniques
 - ▶ Adaptive pre-correction
 - ▶ Memory Error Correction
 - ▶ Crest Factor Reduction



Latest Pre-correction Techniques

▶ Three key digital performance enhancements that significantly benefit coverage and cost of operating a digital transmitter:

1. Adaptive pre- correction
 - Linear and Non-linear
2. Memory Error Correction (MEC)
3. Crest Factor reduction (CFR)



Latest Pre-correction Techniques

Adaptive Correction

➤ Adaptive Correction

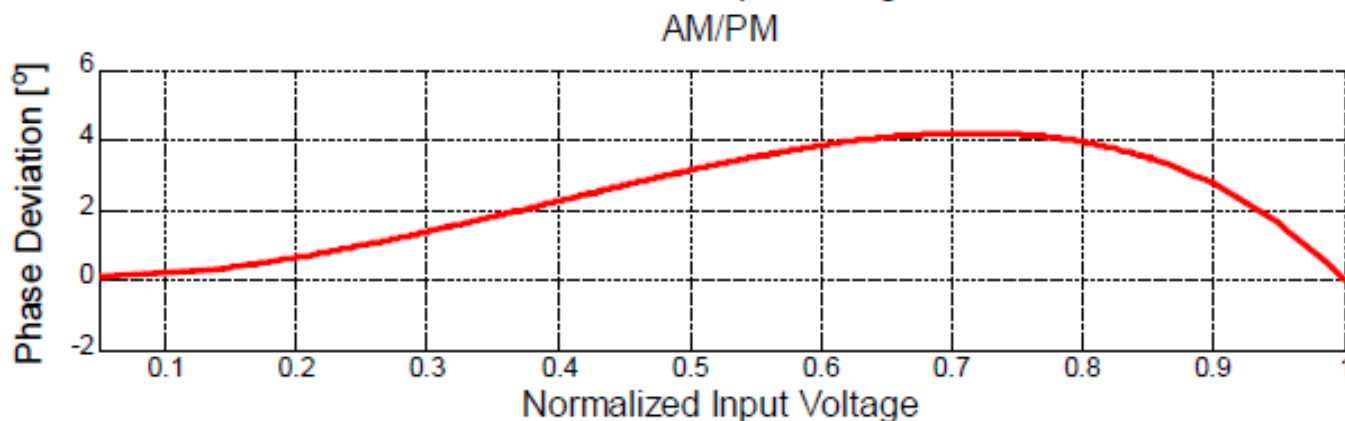
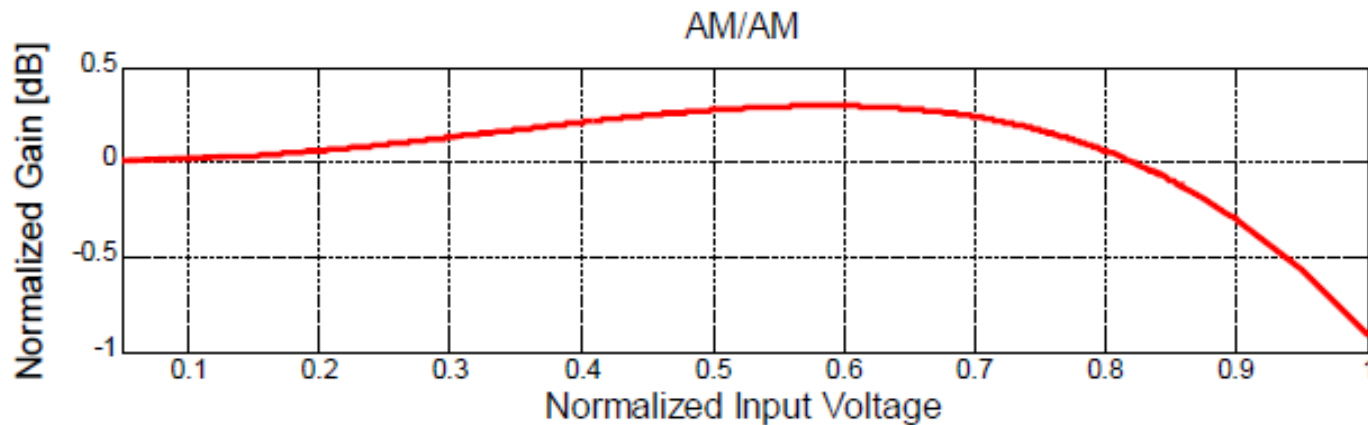
- Key issues: Fast enough that it captures the errors over a short period and can include Memory Error correction
- Includes sophisticated algorithms that can be adapted specifically for “Tube” or “Solid State”
- Manual as well as automatic operation
 - Manual recommended in most circumstances
 - Automatic should be no more than 4 times a day
 - With notification of errors before action
- Separate Linear and Non-linear
- Correction On/Off switch
- Can be activated during operation
 - Does not effect power or performance



Latest Pre-correction Techniques

Memory Error Correction

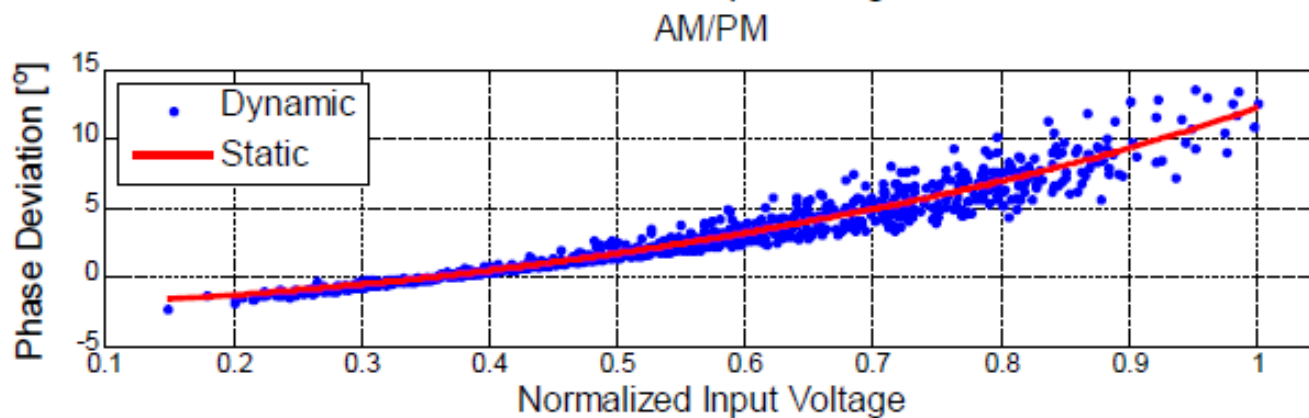
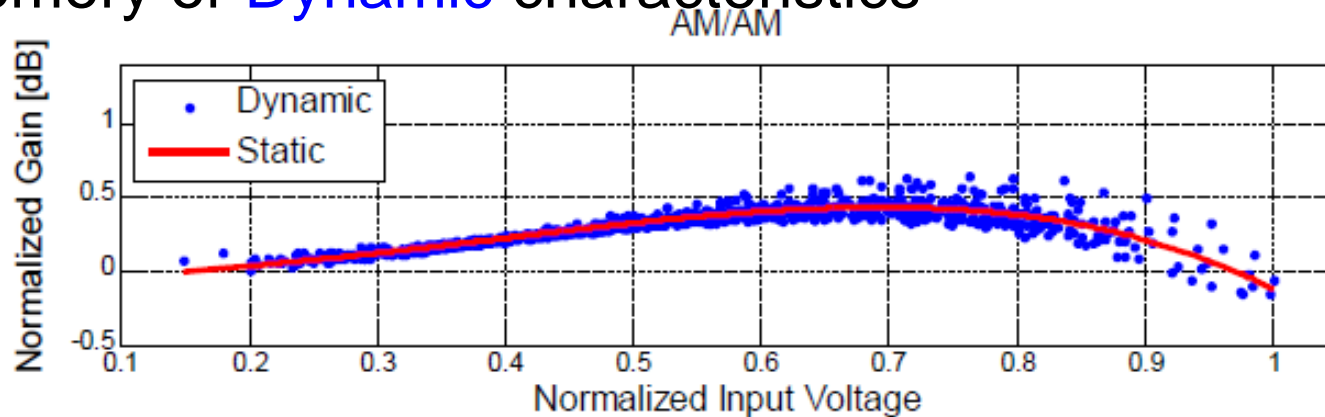
- ▶ PA “Memoryless” or **Static** Characteristic



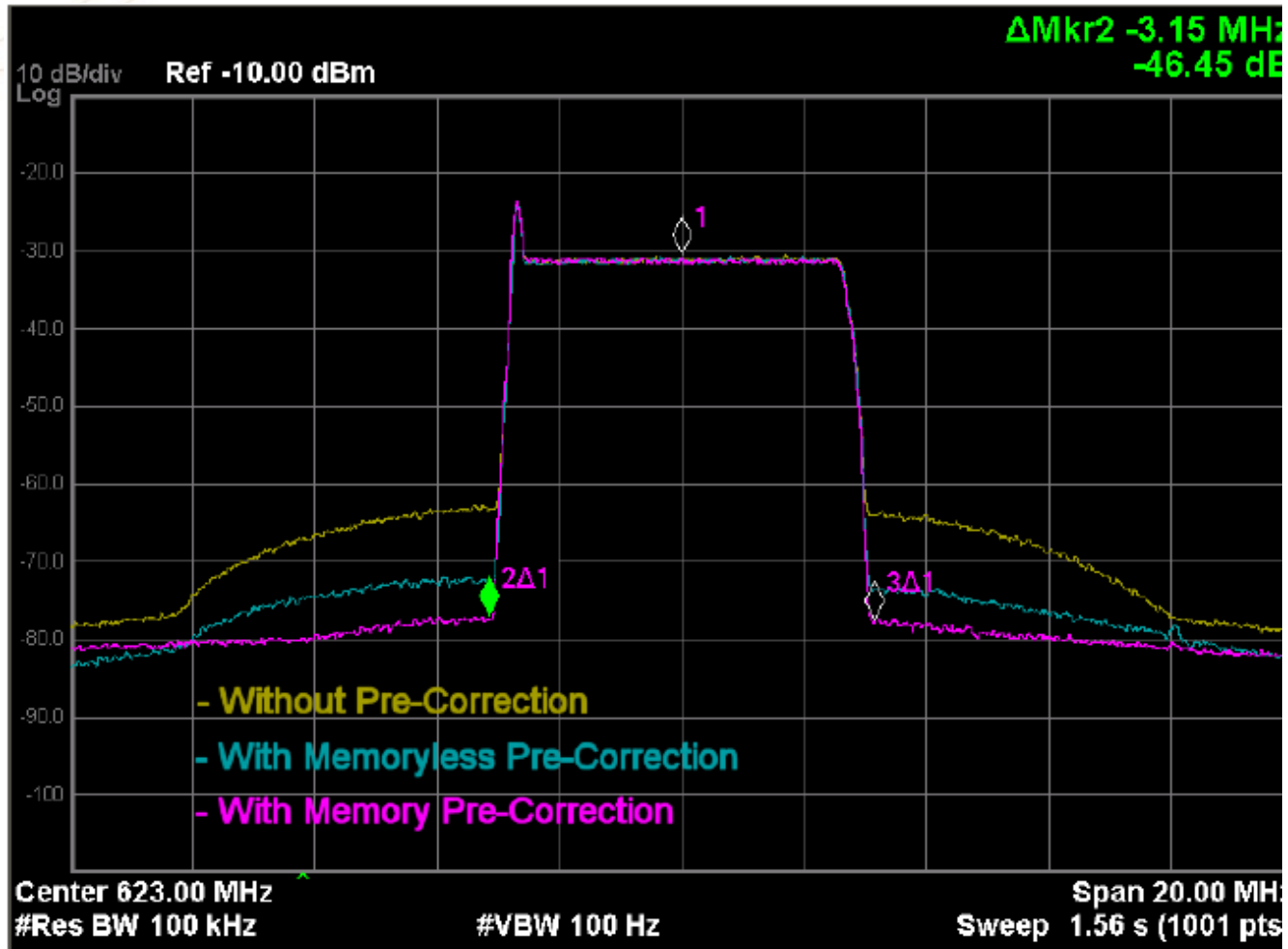
Latest Pre-correction Techniques

Memory Error Correction

- ▶ PA “Memoryless” or **Static** Characteristic and PA Memory or **Dynamic** characteristics



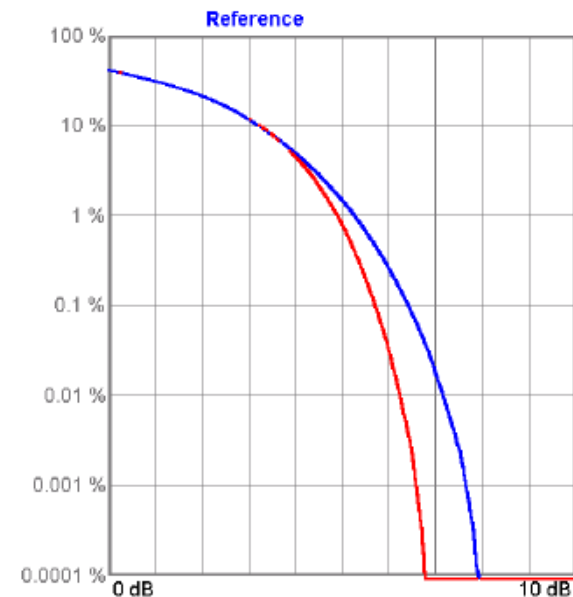
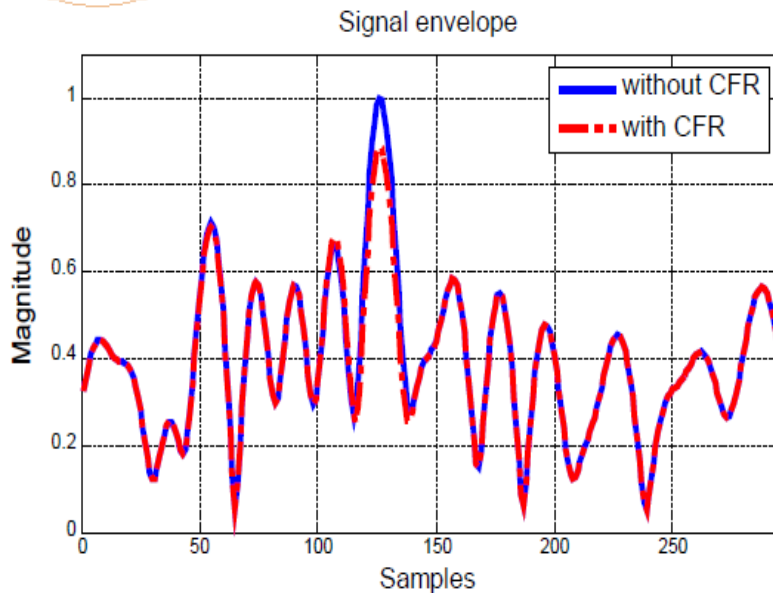
Latest Pre-correction Techniques Memory Error Correction



Latest Pre-correction Techniques

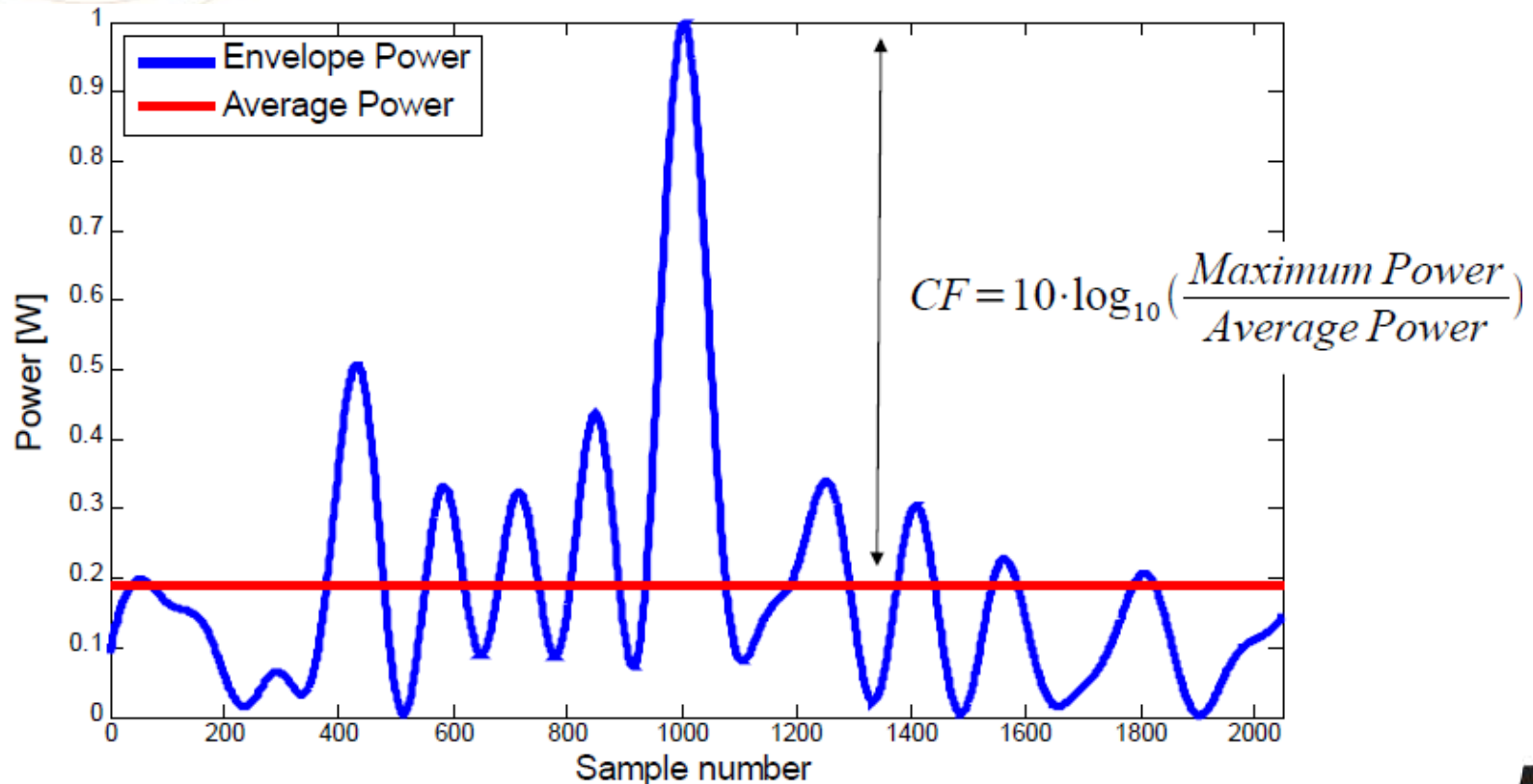
Crest Factor Reduction

- ▶ Reducing the peak envelope level
 - ▶ Without distorting the signal and consequently increasing 3rd Harmonic distortion



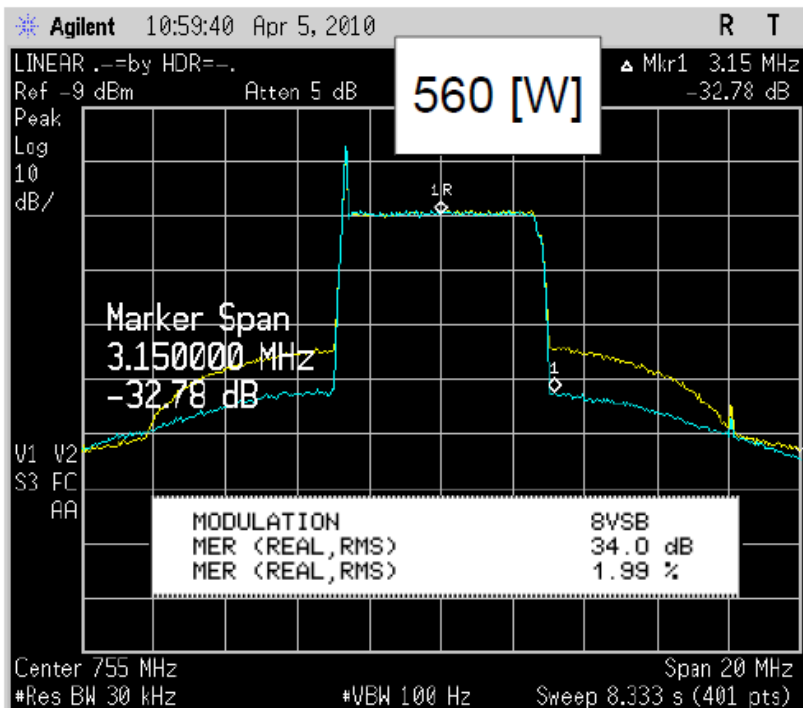
Latest Pre-correction Techniques

Crest Factor Reduction

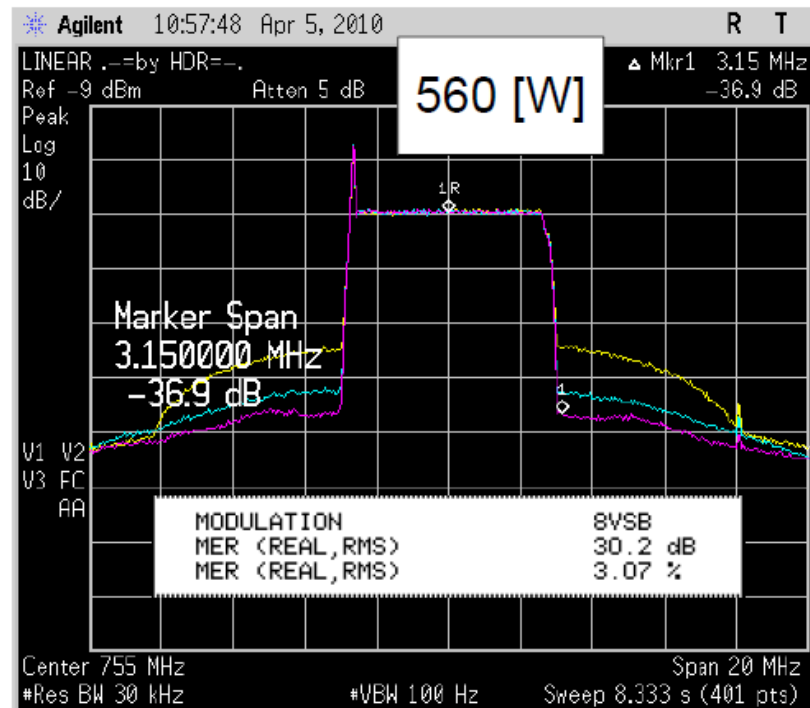


Latest Pre-correction Techniques Crest Factor Reduction

Without CFR

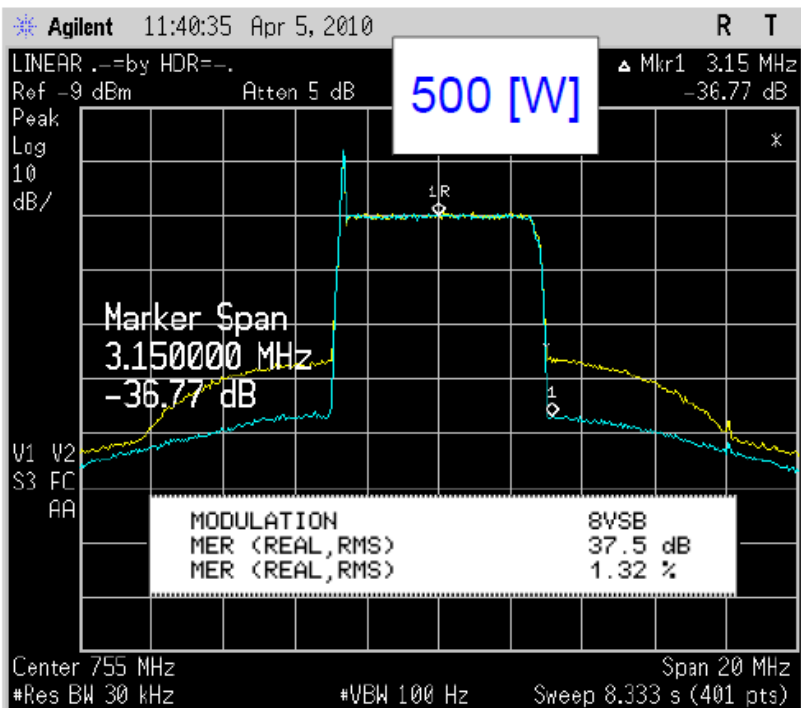


With CFR

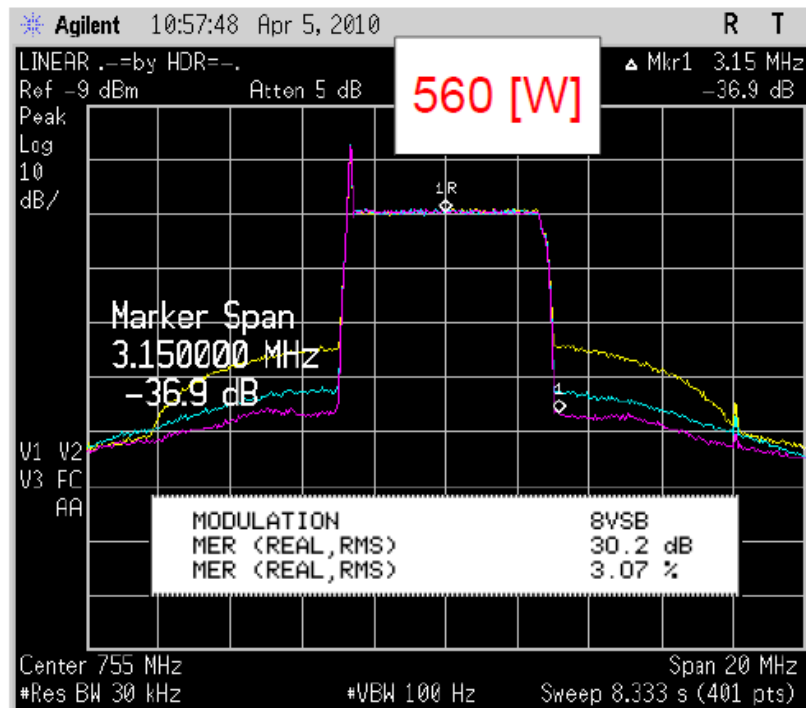


Latest Pre-correction Techniques Crest Factor Reduction

Without CFR



With CFR



Latest Pre-correction Techniques Crest Factor Reduction



Conclusion

- ▶ Recent enhancements can significantly benefit coverage and cost of operating a digital transmitter:
 - ▶ HIGHEST POWER AMPLIFIER EFFICIENCY
 - ▶ 14 -> 19%
 - ▶ HIGHEST WATTS / DOLLAR
 - ▶ ANALOG PEAK SYNC / 8 VSB DIGITAL AVERAGE POWER RATIO OF 1.9dB (or 65% of peak sync power)



Thank you

Thank you for your time and attention

For more information contact:

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410 750 2165



Hands on Demonstration

LCD display - Visual Interface for SETUP and MEASUREMENTS

Command buttons for data entry and pre-correction control



90-240VAC
41-63 Hz VAC input
and switch

Sample ports for adaptive
non-linear pre-and linear
pre-correction inputs

UHF 20dBm RF
output and -30dB
sample ports

SMPTE310M/ASI
compatible inputs



10MHz Ref.
input and
output ports

USB Interface
for pre-
correction

Ethernet and
Web server port

