Contents

Transmitter Signal Measurements
- Monitoring
- Diagnostic/Analytical

Latest pre-correction techniques
- Adaptive pre-correction
- Memory Error Correction
- Crest Factor Reduction
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
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”
Transmitter Signal Measurements

1. Power Output

• **Calorimetric**
  – Into Dummy load – good match – min VSWR, Transmitter is out of service
  – Flow rate (gpm) x (t₂ – t₁) x coolant specific gravity factor (keep flow rate low enough that t₂ – t₁ 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

36.4 dB  27 dB  36.4 dB

Non-linear Distortion (3rd & 5th Order IM)

Linear Distortion (Amplitude & GD)

Non-linear Distortion (3rd & 5th Order IM)
Non-linear distortion 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. In NTSC, it is referred to as “LF linearity” and ICPM. Manifested by non-linear in-band and out of band inter-modulation products, there is 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

Magnitude Ripple < 0.1 dB, pp

N=5 Cheby
N=6 Elliptic
N=7 Cheby
Transmitter Signal Measurements

2. Inter-modulation

- Power Level = 100%
- SNR = 25dB
- Shoulders = 38dB
Transmitter Signal Measurements

2. Inter-modulation

Measurement Software

SNR = 25dB
Shoulders = 48dB
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

<table>
<thead>
<tr>
<th>Peak to Average</th>
<th>6.0 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual-to-Ideal Difference</td>
<td>-0.4 dB</td>
</tr>
</tbody>
</table>

Target Operating Point

Planning Factor (dB): 6.4

% of Time: 0.1

Cumulative Distribution of Peak Power vs. Average Power

% of time peak exceeds average

Peak to Average (dB above average)
Transmitter Signal Measurements
4. EVM/SNR/MER

**EVM (in %)**

\[ 100 \times \sqrt{\frac{1}{N} \times \sum (I_{err}^2 + Q_{err}^2)}/ S_{max} \]

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

**SNR (in dB)**

\[ 10 \times \log_{10} \left( \frac{\sum S_i^2 / I_{err}^2}{} \right) \]

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

**MER (in dB)**

\[ 10 \times \log_{10} \left( \frac{\sum (S_i^2 + S_q^2)}{(I_{err}^2 + Q_{err}^2)} \right) \]

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

Si and Sq 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)
Sources of SNR/MER Degradation

- Echoes Ext. to Tx: [multipath]
- Interferers ext. to Tx: [adj. co. channel]
- IQ errors ampl. and Ø: [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
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!”

Quality

5
4
3
2
1
None

Distance

NTSC

Grade A

Grade B

~ 15dB SNR

DTV

None
Transmitter Signal Measurements
4. EVM/SNR/MER

What is the best SNR?

But this assumes the Rx is connected directly to the transmitter!

0.25dB coverage margin loss

27dB Tx SNR

COVERAGE LOSS (dB)

SNR (dB)
This assumes 16dB channel SNR
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
How does **non-linear** pre-correction work?
Transmitter Signal Measurements
4. EVM/SNR/MER

How does **linear** pre-correction work?
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. The main offender inside the transmitter is the mask filter.

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.
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

Causes of SNR
Transmitter Signal Measurements
4. EVM/SNR/MER

SNR/MER measured from the EYE diagram

Inband Data Parameters: Data Eyes @ 27 dB SNR

ATSC Recommended value is > 27 dB
SNR/MER measured from the EYE diagram

Inband Data Parameters: Data Eyes @ 35+ dB SNR

ATSC Recommended value is > 27 dB
SNR/MER measured from the Constellation diagram

Inband Data Parameters: Data Constellation @ 35+ dB SNR

ATSC Recommended value is > 27 dB
SNR/MER measured from the Constellation diagram

Inband Data Parameters: Data Constellation @ 27 dB SNR

ATSC Recommended value is > 27 dB
Contents

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Latest pre-correction techniques
- Adaptive pre-correction
- Memory Error Correction
- Crest Factor Reduction
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)
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

![Graphs showing AM/AM and AM/PM characteristics](image-url)
Latest Pre-correction Techniques
Memory Error Correction
Reducing the peak envelope level

Without distorting the signal and consequently increasing 3rd Harmonic distortion
Latest Pre-correction Techniques
Crest Factor Reduction

\[ CF = 10 \cdot \log_{10} \left( \frac{\text{Maximum Power}}{\text{Average Power}} \right) \]
Latest Pre-correction Techniques
Crest Factor Reduction

Without CFR

With CFR
Latest Pre-correction Techniques
Crest Factor Reduction

Without CFR

With CFR

Marker Span
3.150000 MHz
-36.77 dB

500 [W]

560 [W]
Latest Pre-correction Techniques
Crest Factor Reduction
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 for your time and attention

For more information contact:

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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
- Hands on Demonstration