RF Measurements in a CATV System

What LEVEL should be measured for Analog and Digital CATV Systems? What Performance Metrics should be Measured for the Health of the Signal?

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RF Measurements at Endpoints

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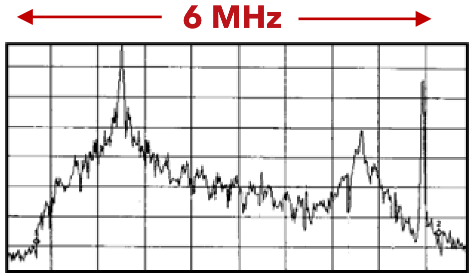
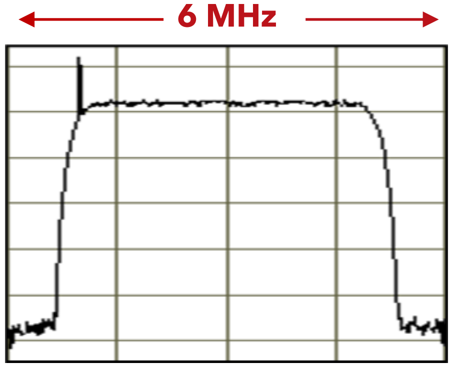
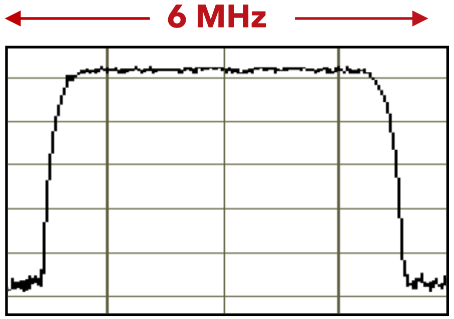
- Analog RF signals should be between 5 and 15 dBmV.
  - Measured at the input to the tuner device (Analog Television, Processor, Demodulator, etc.)
  - FCC Minimum is 0 dBmV, or 3 dBmV at the end of 100′ of cable
- Digital RF Signals (8VSB and QAM64 / 256) should be between -5 dBmV and +5 dBmV.
  - Measured at the input to the device (Digital Tuner, Processor, Demodulator, etc.)
  - In mixed Analog/Digital Systems, Digital signals should combine with Analog signals 6-10 dB lower than Analog Video Carrier



5 to 15 dBmV



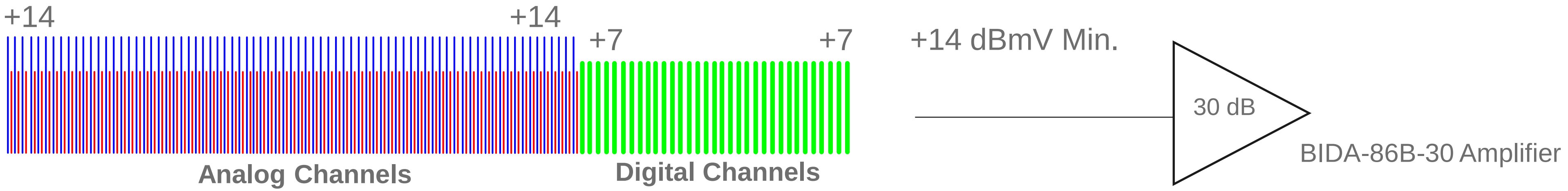
-5 to +5 dBmV



-5 to +5 dBmV

RF Measurements into Amplifiers

- Amplifier Input Minimum Level = Amplifier Output High Level – Gain
  - Example: BIDA 86B-30; 30 dB gain, 36/44 dBmV rated output
    - 44 dBmV output – 30 dB Gain = 14 dBmV Input Level, Minimum
    - If more than 2 dB higher input level, use Plug-In modules to reduce levels
  - Example: BIDA-86B-43; 43 dB gain, 36/44 dBmV rated output; +1 dBmV Input Level
- If incoming RF signals are all Analog or all Digital, all signals must be flat (equal level) as possible.
- If incoming RF signals are a mix of Analog and Digital, Digital signals must be 6-10 dB lower than Analog Video Carrier. All signals must be relatively flat (equal level), in relation to other signals of the same type (analog/digital).



Units of Measure – dBmV vs Microvolt

dBmV	uV	uW
-12	251.2	0.0008
-9	354.8	0.0016
-6	501.2	0.0033
-3	707.9	0.0066
0	1000	0.013
3	1414	0.026
6	1990	0.053
9	2810	0.105
12	3980	0.21
15	5620	0.42
20	10,000	1.33
30	31,620	13.3
40	100,000	133.3
50	316,200	1,333.3
60	1,000,000 (1V)	13,333.3

Typical Digital Input Range to Tuner (-6 to 9 dBmV)

Typical Analog Input Range to Tuner (0 to 15 dBmV)

Reference Voltage Level:
0 dBmV = 1000 microvolts (1 mV) across 75 Ω

Conversion Factors
0 dBm = +48.75 dBmV across 75 Ω
0 dBW = +78.75 dBmV across 75 Ω
0 dBmV = +60 dBuV across 75 Ω

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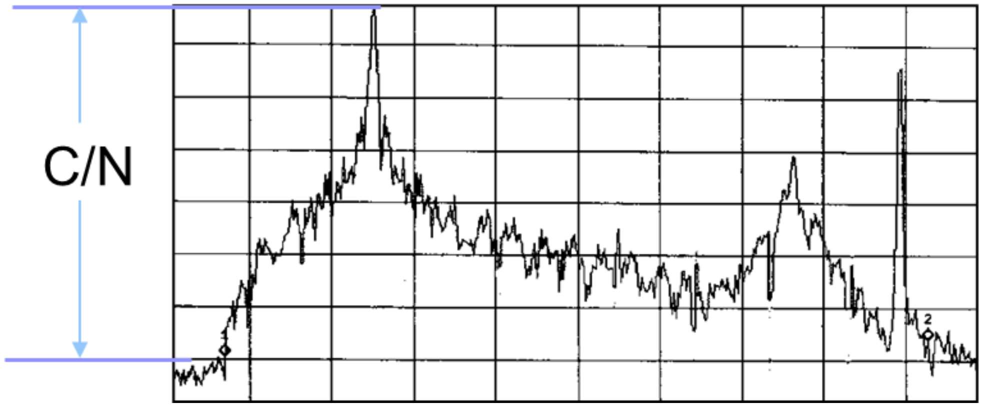
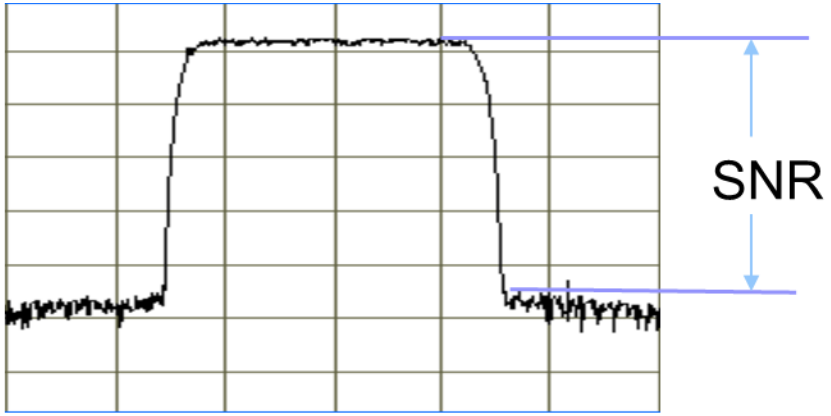
Amplifier Contributions - NOISE

- Noise – unwanted or erroneous signals
- To avoid snowy pictures (Analog) or poor MER (Digital), the desired signal must be strong enough to override the noise.
- Significant noise contributions include:
  - Thermal noise – generated by all electronics, dependent upon temperature
  - Amplifiers – amount of noise added above thermal noise is the noise figure
- NOISE is added to the signal at the Input to Amplifiers. Lower input levels cause more noise to be added to the signal.





Carrier-to-Noise (C/N)

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- C/N – wanted video carrier compared to the system noise level
- For a single Amplifier
  - C/N = 59 – NF + Input Level
    - 59 = thermal noise level in dBmV of 75 Ω resistor
    - BIDA Series = 8.5 dB NF
      - 30 dB gain = 15 dBmV input = ~65 dB C/N
      - 43 dB gain = +1 dBmV input = ~51 dB C/N
      - 50 dB gain = -6 dBmV input = ~44 dB C/N
- For an amplifier cascade
  - C/N (cascade) = C/N – 10 log(N)
    - C/N = single amp contribution
    - N= Number of amplifiers in cascade

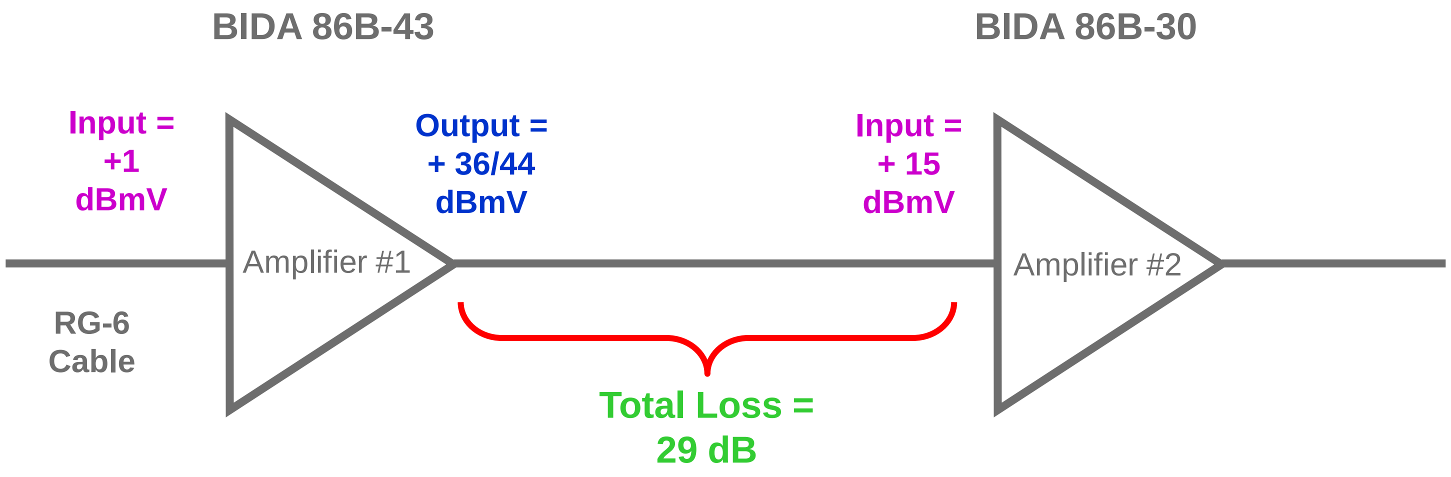
** Every doubling of amplifiers drops overall C/N by 3dB
*FCC Minimum C/N for Analog signals to any outlet = 43 dB

Amplifier Cascade Factor

CASCADE (N)	C/N + SSO 10*LOG(N)	CSO 15*LOG(N)	CTB & XMOD 20*LOG(N)
1	0.00	0.00	0.00
2	3.01	4.52	6.02
3	4.77	7.16	9.54
4	6.02	9 03	12.04
5	6.99	10.48	13.98
6	7.78	11.67	15.56
7	8.45	12.68	16.90
8	9.03	13.55	18.06
9	9.54	14.31	19.08
10	10.00	15.00	20.00
11	10.41	15.62	20.83
12	10.79	16.19	21.58
13	11.14	16.71	22.28
14	11.46	17.19	22.92
15	11.76	17.64	23.52
16	12.04	18.06	24.08
17	12.30	18.46	24.61
18	12.55	18.83	25.11
19	12.79	19.18	25.58
20	13.01	19.52	26.02
21	13.22	19.83	26.44
22	13.42	20.14	26.85
23	13.62	20.43	27.23
24	13.80	20.70	27.60
25	13.98	20.97	27.96

Carrier-to-Noise (C/N) Example

Noise Figure = 8.5 dB



C/N = 59 - NF + Input Level
C/N #1 = 59 - 8.5 + 1
= 50.5 + 1
= 51.5 dB

C/N = 59 - NF + Input Level
C/N #2 = 59 - 8.5 + 15
= 50.5 + 15
= 65.5 dB

dB difference = 65.5 - 51.5 = 14.0 dB
dB subtraction figure = 0.17 dB (Refer to 10 Log chart in BRG P. 126)
Lowest CNR = 51.5 – 0.17 = 51.33 dB
The Resultant Overall CNR = 51.3 dB

10 Log Function Derate Chart

(use for CNR and SSO)

diff (dB)	SUBTRACTION VALUES 0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	3.01	2.96	2.91	2.86	2.81	2.77	2.72	2.67	2.63	2.58
1	2.54	2.50	2.45	2.41	2.37	2.32	2.28	2.24	2.20	2.16
2	2.12	2.09	2.05	2.01	1.97	1.94	1.90	1.87	1.83	1.80
3	1.76	1.73	1.70	1.67	1.63	1.60	1.57	1.54	1.51	1.48
4	1.46	1.43	1.40	1.37	1.35	1.32	1.29	1.27	1.24	1.22
5	1.19	1.17	1.15	1.12	1.10	1.08	1.06	1.04	1.01	0.99
6	0.97	0.95	0.93	0.91	0.90	0.88	0.86	0.84	0.82	0.81
7	0.79	0.77	0.76	0.74	0.73	0.71	0.70	0.68	0.67	0.65
8	0.64	0.63	0.61	0.60	0.59	0.57	0.56	0.55	0.54	0.53
9	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42
10	0.41	0.40	0.40	0.39	0.38	0.37	0.36	0.35	0.35	0.34
11	0.33	0.32	0.32	0.31	0.30	0.30	0.29	0.28	0.28	0.27
12	0.27	0.26	0.25	0.25	0.24	0.24	0.23	0.23	0.22	0.22
13	0.21	0.21	0.20	0.20	0.19	0.19	0.19	0.18	0.18	0.17
14	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14
15	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11
16	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09
17	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07
18	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
19	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
20	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
21	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
22	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
23	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
24	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
25	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

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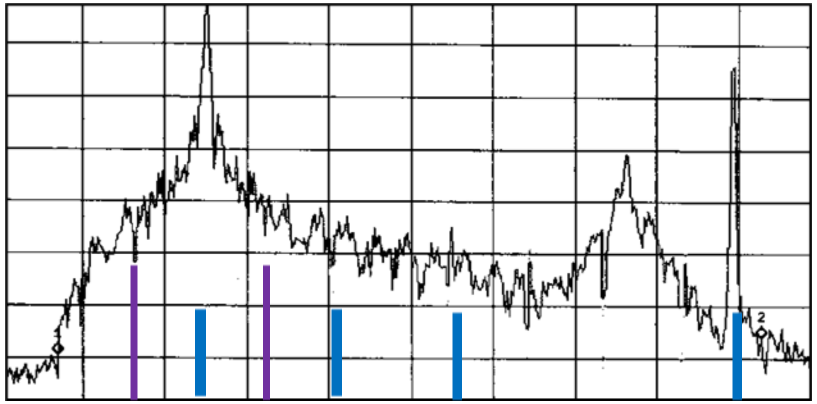
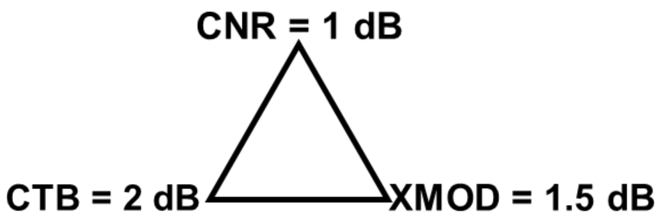
Amplifier Contributions – Distortions (Analog)

- Intermodulation Products
  - Distortions generated by the amplifiers due to their non-linearity. Frequencies are added and subtracted yielding new interfering frequencies (or beats).
  - Distortions are added to RF signals at the Output of the Amplifiers. Higher Output levels cause more Distortions to be added to the signals.
- CTB – Composite Triple Beat (grainy or wormy)
  - Summation of triple order distortions in decibels
- CSO – Composite Second Order (VHF Channels – diagonal lines)
  - Summation of second order distortions (1.25 MHz above visual carriers) in decibels



Amplifier Contributions – Distortions (Analog)

- **XMOD** – Cross Modulation (buzzing in sound, sound lines in pictures)
  - Modulation from one or more television channels imposed on another channel or channels
  - Measured in decibels
- **Hum** (rolling bars: 1=60 Hz; 2=120 Hz. Usually bad capacitor in PS)
  - Amplitude modulation of the carrier by a signal whose frequency is usually a harmonic of the power line frequency
  - Measured in dBc – decibels relative to carrier
- The "**Delta of Life**" – a balancing act
  - CNR is 1:1 ratio, for every dB change on Amp input, C/N changes 1 dB
    - 1 dB lower input, C/N gets Worse by 1 dB
  - CTB is 2:1 ratio, for every dB change on Amp output, CTB changes 2 dB
    - 1 dB lower output, CTB gets Better by 2 dB; XMOD gets Better by 1.5 dB
  - XMOD is 1:5:1 ratio, for every 1 dB change on output, XMOD changes 1.5 dB



Distortions Example

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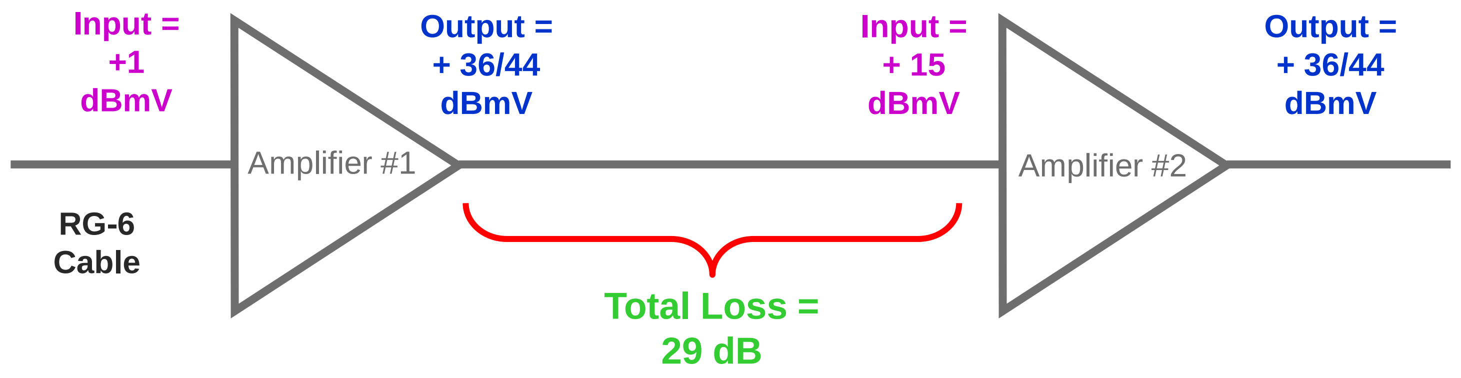
BIDA 86B-43P
CTB @ 36/44 dBmV OUTPUT = -60 dB

BIDA 86B-30P
CTB @ 36/44 dBmV OUTPUT = -62 dB



dB Difference – 62 – 60 = 2 dB
dB Subtraction Figure = 5.08 dB (Refer to 20 LOG chart in BRG p. 125)
Lowest CTB = 60 – 5.08 = 54.92 dB
The Resultant overall CTB = 55 dB

**Every doubling of amplifiers drops overall CTB by 6 dB
* FCC Minimum for Distortions in Analog system to any outlet = -51 dB

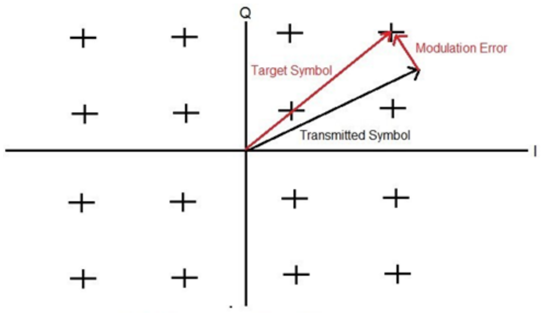
20 Log Function Derate Chart

(use for CTB and XMOD)

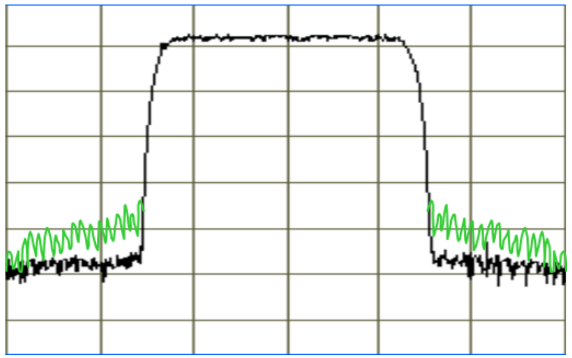
diff (dB)	SUBTRACTION VALUES 0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	6.02	5.97	5.92	5.87	5.82	5.77	5.73	5.68	5.63	5.58
1	5.53	5.49	5.44	5.39	5.35	5.30	5.26	5.21	5.17	5.12
2	5.08	5.03	4.99	4.95	4.90	4.86	4.82	4.78	4.73	4.69
3	4.65	4.61	4.57	4.53	4.49	4.45	4.41	4.37	4.33	4.29
4	4.25	4.21	4.17	4.13	4.10	4.06	4.02	3.98	3.95	3.91
5	3.88	3.84	3.80	3.77	3.73	3.70	3.66	3.63	3.60	3.56
6	3.53	3.50	3.46	3.43	3.40	3.36	3.33	3.30	3.27	3.24
7	3.21	3.18	3.15	3.12	3.09	3.06	3.03	3.00	2.97	2.94
8	2.91	2.88	2.85	2.83	2.80	2.77	2.74	2.72	2.69	2.66
9	2.64	2.61	2.59	2.56	2.53	2.51	2.48	2.46	2.44	2.41
10	2.39	2.36	2.34	2.32	2.29	2.27	2.25	2.22	2.20	2.18
11	2.16	2.13	2.11	2.09	2.07	2.05	2.03	2.01	1.99	1.97
12	1.95	1.93	1.91	1.89	1.87	1.85	1.83	1.81	1.79	1.77
13	1.75	1.74	1.72	1.70	1.68	1.67	1.65	1.63	1.61	1.60
14	1.58	1.56	1.55	1.53	1.51	1.50	1.48	1.47	1.45	1.44
15	1.42	1.41	1.39	1.38	1.36	1.35	1.33	1.32	1.31	1.29
16	1.28	1.26	1.25	1.24	1.22	1.21	1.20	1.19	1.17	1.16
17	1.15	1.14	1.12	1.11	1.10	1.09	1.08	1.06	1.05	1.04
18	1.03	1.02	1.01	1.00	0.99	0.98	0.96	0.95	0.94	0.93
19	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84
20	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.77	0.76	0.75
21	0.74	0.73	0.73	0.72	0.71	0.70	0.69	0.69	0.68	0.67
22	0.66	0.66	0.65	0.64	0.64	0.63	0.62	0.61	0.61	0.60
23	0.59	0.59	0.58	0.57	0.57	0.56	0.56	0.55	0.54	0.54
24	0.53	0.53	0.52	0.51	0.51	0.50	0.50	0.49	0.49	0.48
25	0.48	0.47	0.46	0.46	0.45	0.45	0.44	0.44	0.43	0.43
26	0.42	0.42	0.42	0.41	0.41	0.40	0.40	0.39	0.39	0.38
27	0.38	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.35	0.34
28	0.34	0.34	0.33	0.33	0.32	0.32	0.32	0.31	0.31	0.31
29	0.30	0.30	0.30	0.29	0.29	0.29	0.28	0.28	0.28	0.27
30	0.27	0.27	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.24
31	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.22	0.22	0.22
32	0.22	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19
33	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.17
34	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.15
35	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14
36	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
37	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
38	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10
39	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
40	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

Distortions and Noise in Digital

- Distortions and noise in Digital systems manifest as CIN (Composite Intermodulation Noise)
  - This is a combination of Composite Intermodulation Distortions (CID = CTB, CSO, and XMOD in analog) and Thermal Noise
  - CIN appears as elevated noise floor
- CIN will decrease MER (Modulation Error Ratio) of the digital signal
  - MER is the ratio, in decibels, of average symbol power to average error power
  - $MER_{(dB)}$ = 10 x log (average symbol power/average error power)



Modulation Error Ratio



It’s All About MER at the Drop

- Once the QAM signal leaves the Headend (MER about 40 dB), it is subject to degradation due to distribution, related problems. MER is reduced by all of the following
  - Noise, due to improper Amp input levels or Ingress (CNR)
  - Non-Linear Distortion from Amplifiers. Maintain amp input/output levels according to specifications and channel loading. (CTB, CSO, XMOD, CPD)
  - Reflections, due to impedance mismatches and improper or missing terminations on Splitters, Combiners, Taps; Damaged coax cable, and improperly installed F-connectors. (Micro-reflections, Amplitude Ripple & Tilt, Group Delay).
  - Spurious Signals – caused by Ingress, Local Pickup, or Malfunctioning Active Equipment (In-Channel Ingress, Lase Clipping, Data Collisions)

The “**Cliff**” Point for QAM 64 is about **22 dB** and for QAM 256 about **28 dB**

The “**Cliff**” Point is when the Forward Error Correction runs out of the ability to replace missing or damaged data with “corrected” data. Severe tiling or picture freeze up will occur. Recommended to run with at least 3 dB margin above Cliff Point.

BER and MER

- BER (Bit Error Rate) is the ratio of errored bits to the total number of bits transmitted, received, or processed over a defined length of time
  - Example: 3 errored bits in a total of 1,000,000 transmitted bits will result in a BER of 3/1,000,000 = 0.000003 = 3x106
- MER (Modulation Error Ratio) is the ratio, in decibels, of average symbol power to average error power
  - MER(dB) = 10 x log (average symbol power/average error power)
  - MER is influenced by everything present in the signal's transmission path such as:
    - Phase Noise
    - CNR (Carrier-to-Noise Ratio)
    - CTB Distortion (Composite Triple Beat)
    - CSO Distortion (Composite Second Order)
    - Cross Modulation (XMOD)
    - Micro-reflections (Ghosting)
    - Amplitude tilt/ripple
    - Group Delay
    - Ingress

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TECH TIP

Picture Quality	MER (8VSB)	MER (QAM 64)	MER (QAM 256)
Excellent	**Greater than 30 dB**	**Greater than 38 dB**	**Greater than 38 dB**
Good	**25 to 30 dB**	**30 to 38 dB**	**35 t0 38 dB**
Marginal	**18 to 25 dB**	**23 to 30 dB**	**30 to 35 dB**
Non-Functional	**Less than 18 dB**	**Less than 23**	**Less than 30 dB**

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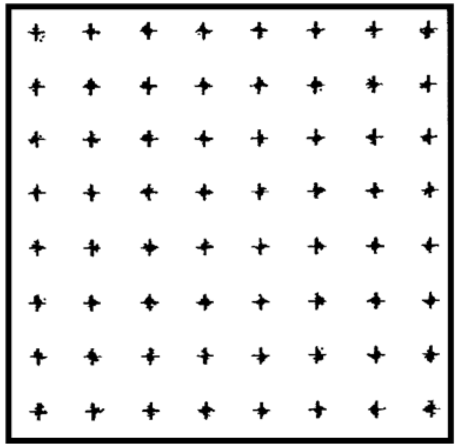
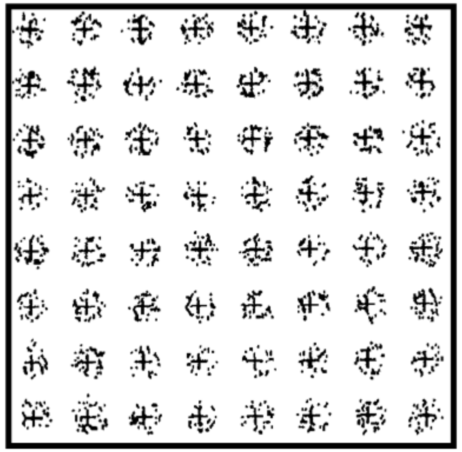
QAM 64 Constellation Analysis



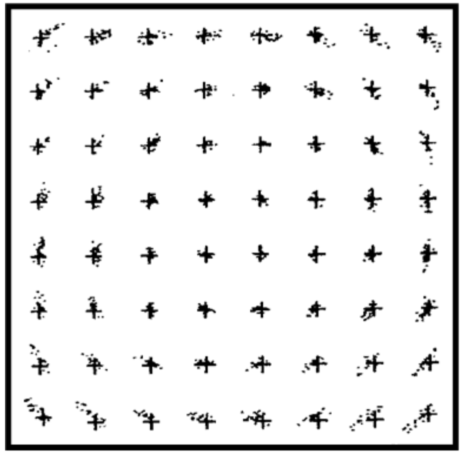
[1] Good Constellation

Pattern of dots in this constellation diagram are very close to the center (crosshairs), indicating a normal constellation with no noise or distortion issues.



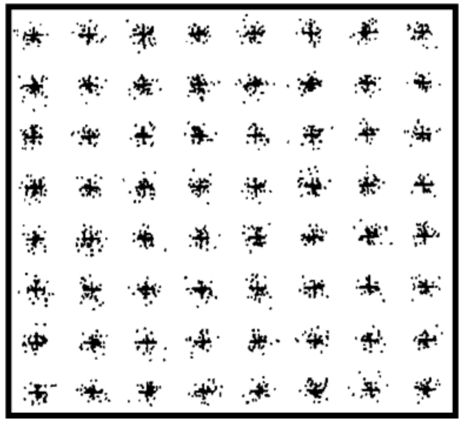
[3] CTB/CSO Constellation

Caused by coherent noise, poor CTB and CSO will cause circular patterns in each cell.



[2] Phase Shift Constellation

Circular effect where points in each cell are stretched out perpendicular to a radius line, in proportion to the distance from the center of the diagram, giving an overall appearance of circles around the center of the diagram.
Usually caused by residual FM - typically a headend problem.



[4] Poor CNR Constellation

Fuzzy circular pattern in each cell, occupying most of the cells. Picture quality may remain good, but slight further degradation of the signal may cause loss of picture all together.

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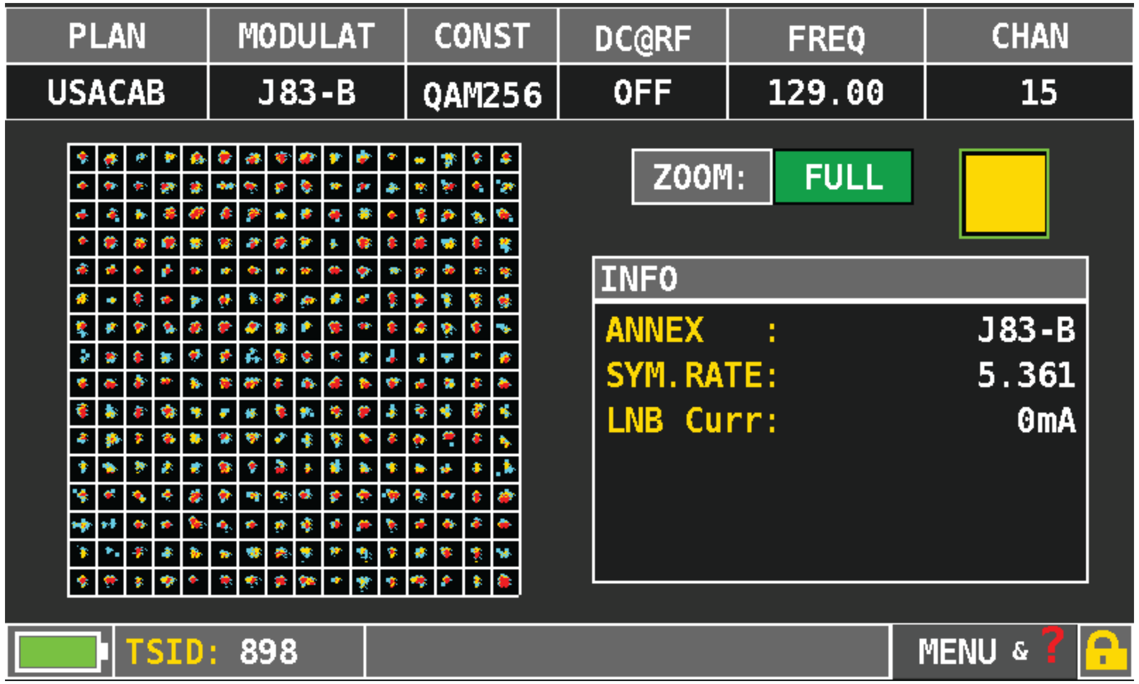
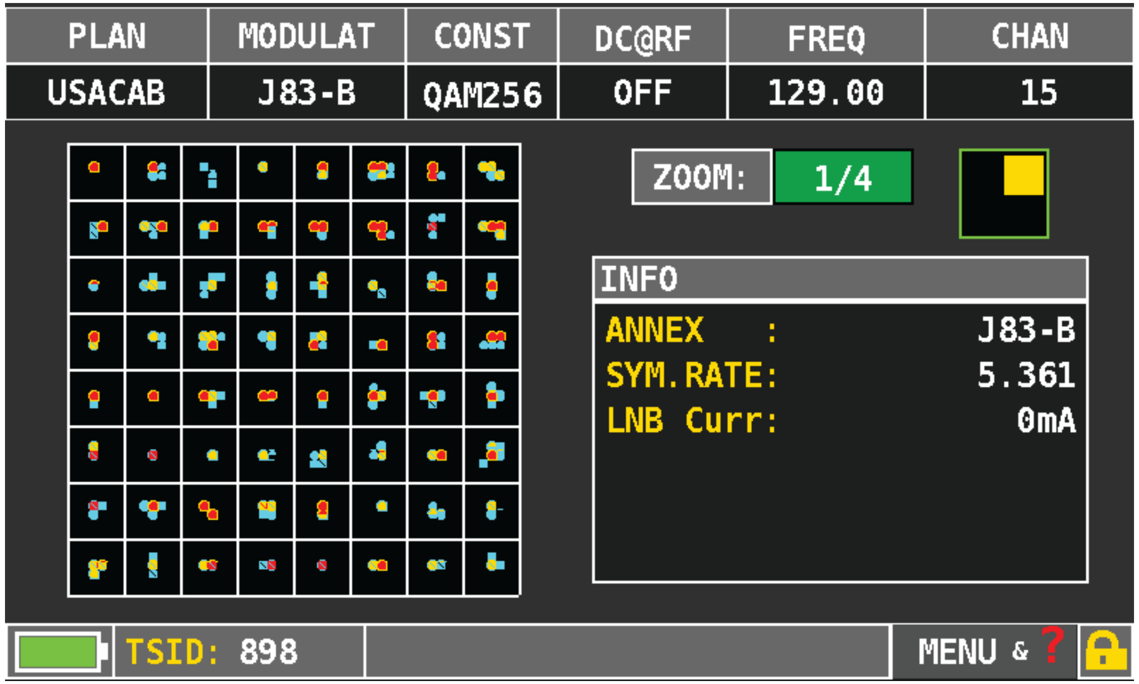
QAM 256 Constellations

Constellation: Full



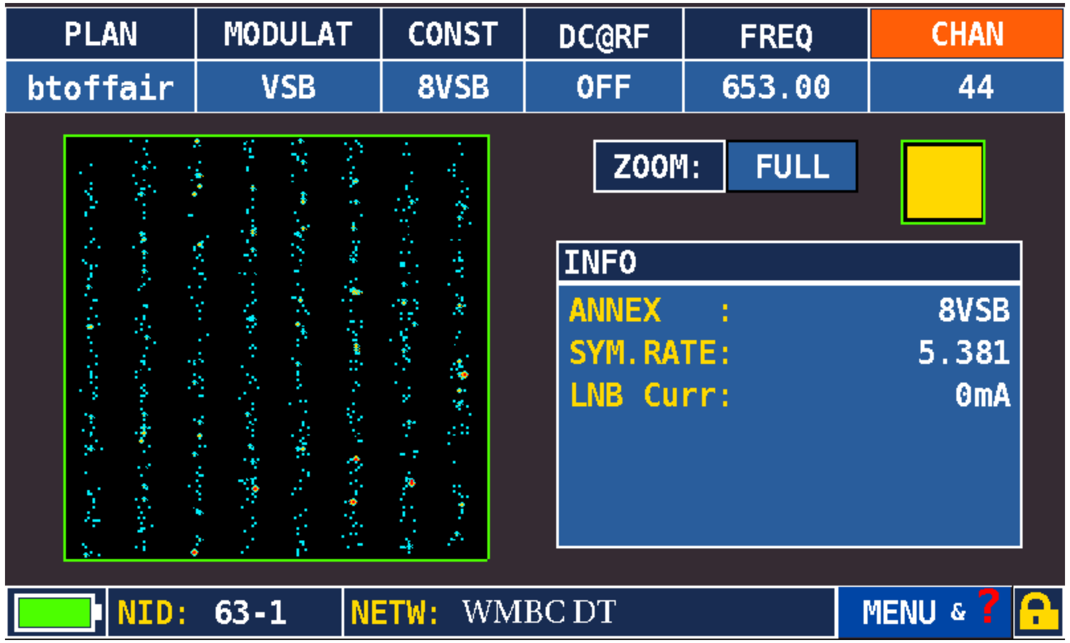
Constellation: Zoom



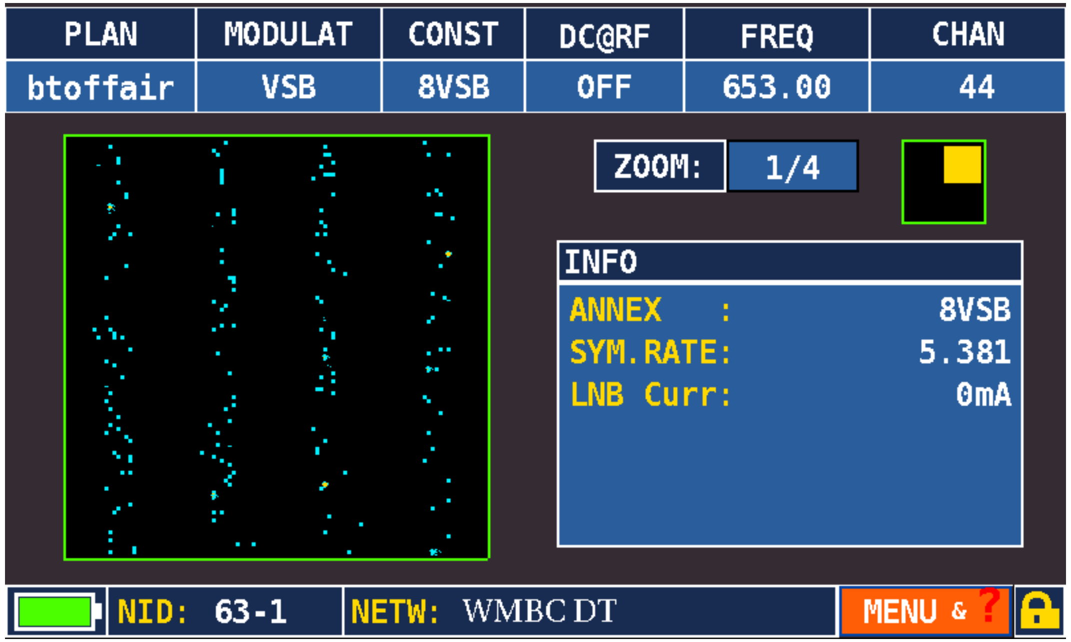
8VSB Constellation Diagrams (Waterfalls)

BLONDER TONGUE LABORATORIES

Constellation: Full



Constellation: Zoom



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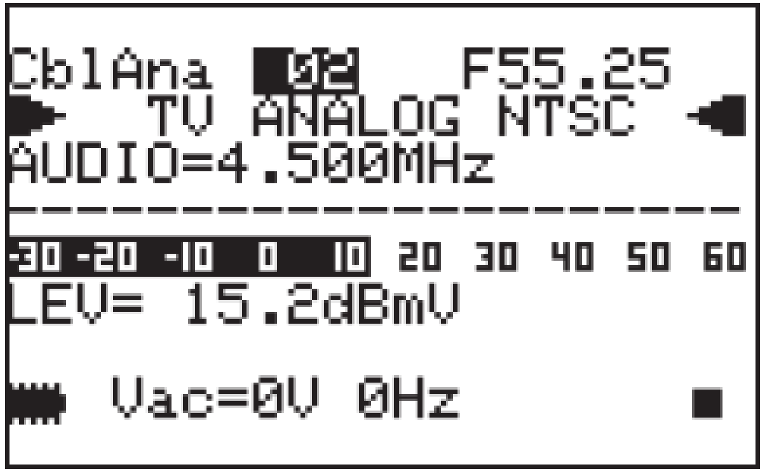
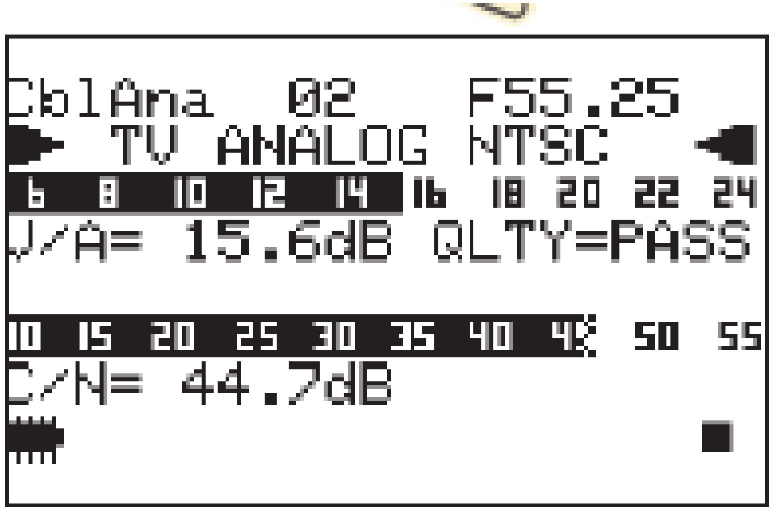
Measurement Metrics - Analog

- For Analog systems, C/N and CTB are primary measurement metrics for the health of the system
  - Use a Field Strength Meter and a Spectrum Analyzer to measure





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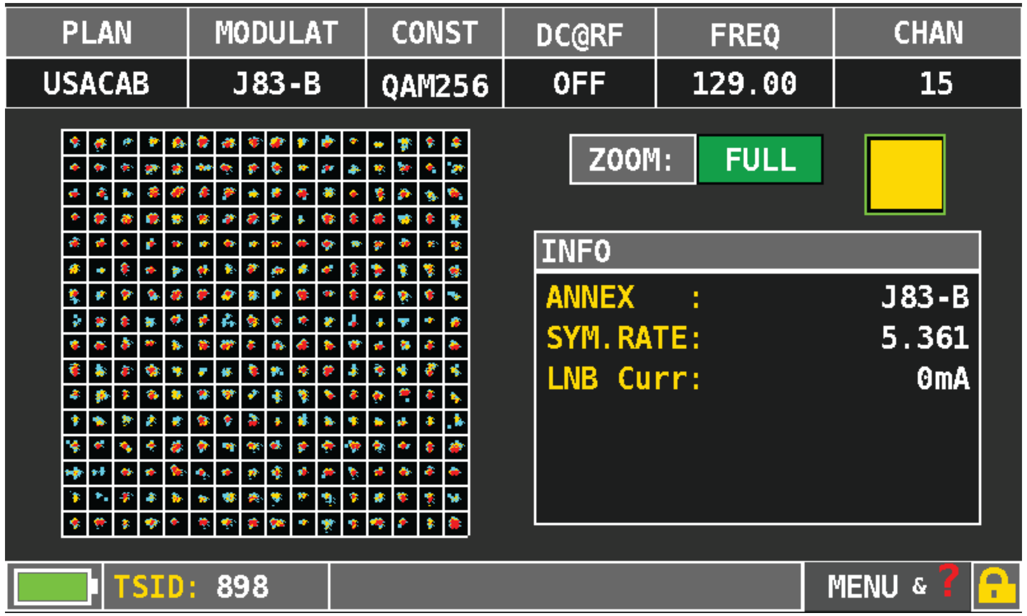
Measurement Metrics - Digital

- For Digital systems, MER and BER are primary measurement metrics for the health of the system
  - Use Digital Field Strength Meter, QAM Analyzer, Spectrum Analyzer, and Constellation Meter to measure



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