ATSC 3.0 Waveform Impact on your 8-VSB Transmitter

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Featuring GatesAir's

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Topics / Agenda

- Basis for Today's Discussion
- Peak Power is key
- CCDF and why it's instructive
- 8-VSB CCDF
- OFDM CCDF's
  - Tone Reservation (TR)
  - Active Constellation Extension (ACE)
- Conclusion

IOT's

IOT Amplifier

L-3's Inductive Output Amplifier is a high-efficiency tube operating in the UHF-TV frequency range of 470 to 810 MHz. The amplifier can be used in digital or analog transmitters at power levels up to 130 KW peak for digital and 80 kW NTSC vision-only analog. The tube is configured to be an exact replacement for the D2130 IOT when used in an e2v IMD2000/2001 series of cavities. Imperial-Flex-Fitting (threaded 5/8-24) couplings are included with the tube for installation.

The IOTD 130D is the companion of the IOTD 130 that is used exclusively in L-3 trolley assemblies.

RATINGS

	MIN	MAX	UNITS
Heater Voltage	5	7	V
Heater Current, Operating	20	30	A
Heater Current, Surge	---	60	A
Heater Warm-Up Time	300	---	sec
Beam Voltage	22	36	kV
Beam Current	---	2.5	A
Quiescent Current	0.4	0.6	A
Body Current	---	60	mA
Solenoid Current	22	27	A
Collector Dissipation	---	55	kW
Load VSWR	---	1.5:1	---
Bias Voltage (Referenced to Cathode)	-50	-150	V
Grid Current	---	±150	mA
Ion Pump Current, Beam On	---	20	µA
Ion Pump Voltage (Referenced to Cathode)	3	4	kV
Drive Power for Visual Service Peak Sync	---	500	W
Peak Sync. Vision-Only Output Power	---	80	kW
Aural-Only Output Power	---	35	kW
Peak Sync Vision O/P Power Common Mode	---	55	kW
Aural Output Power Common Mode	---	5.5	kW
Peak/Average Output Power (8VSB)	---	130/30	KW/kW
Peak/Average Input Power (8VSB)	---	1500/250	W

6.4 dB

7.8 dB

FET's

BLF888D; BLF888DS

UHF power LDMOS transistor

Rev. 4 — 18 February 2016

AMPLEON

Product data sheet

1. Product profile

1.1 General description

A 600 W LDMOS RF power transistor for broadcast Doherty transmitter applications. The excellent ruggedness of this device makes it ideal for digital and analog transmitter applications.

Table 1. Application information

RF performance at V_{DS} = 50 V in an ultra wide Doherty application.

Test signal	f	$P_{L(AV)}$	G_p	η_D	IMD_{shldr}	PAR
	(MHz)	(W)	(dB)	(%)	(dBc)	(dB)
DVB-T (8k OFDM)	470 to 860	115 to 134 [1]	17	40 to 48 [1]	−38 to −44 [2]	8 [3]

[1] Depending on selected channel.

[2] Depending on exciter used.

[3] PAR (of output signal) at 0.01 % probability on CCDF; PAR of input signal = 9.5 dB at 0.01 % probability on CCDF.

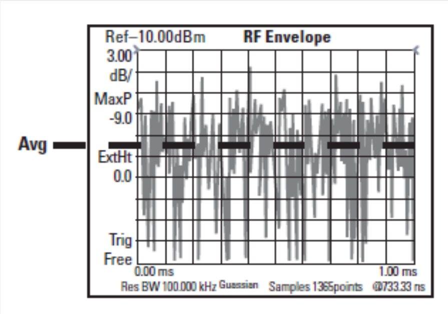
Definition of CCDF (1)

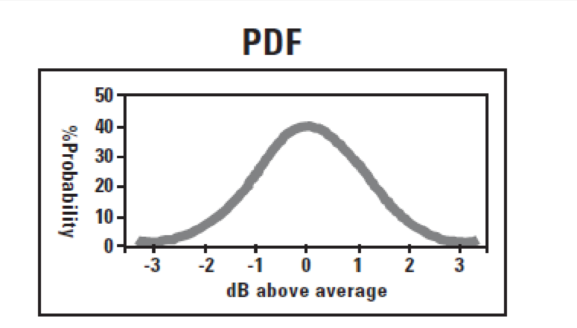
- (Power) Complementary Cumulative Distribution Function
- Measures how far and how often a signal exceeds the average power.
- Consider digitally modulated waveforms as a noise-like *set of data with statistics*.
- We are interested in the Probability Density Function (PDF) of the RF envelope.

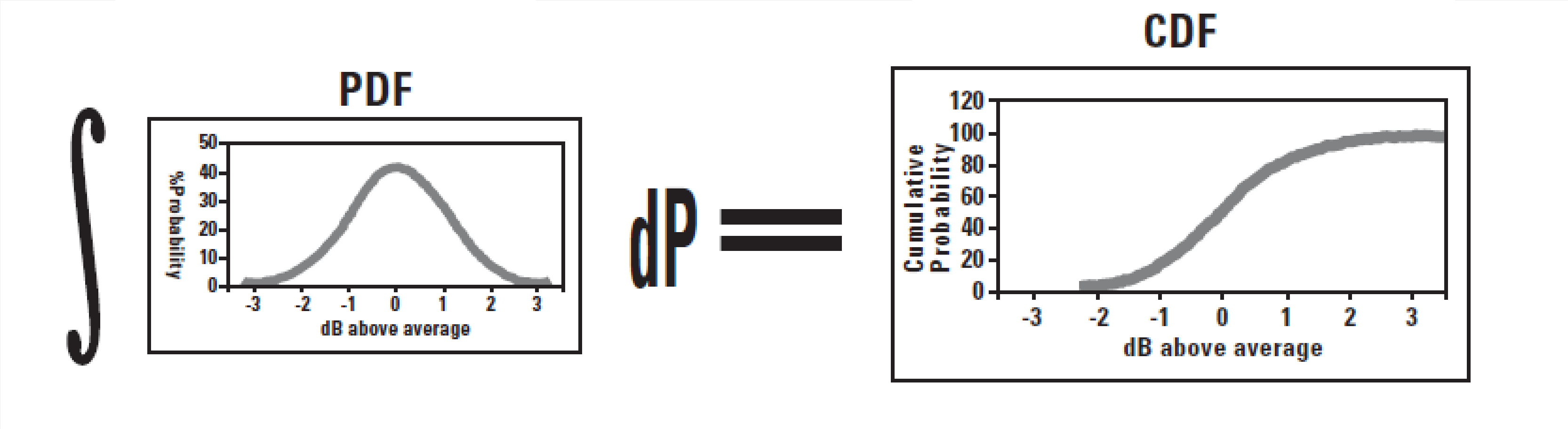
Definition of CCDF (2)

- The PDF doesn’t tell us too much, but it’s integral, the Cumulative Density Function (CDF), does.
- CDF emphasizes minimum values.
- CCDF (CDF’s complement) emphasizes peak amplitude excursions.
- A power amplifier’s linearity is very well characterized by it’s <u>ability to faithfully reproduce peaks.</u>
- Transmitter models: DHD60<u>P</u>2, CD2100<u>P</u>1

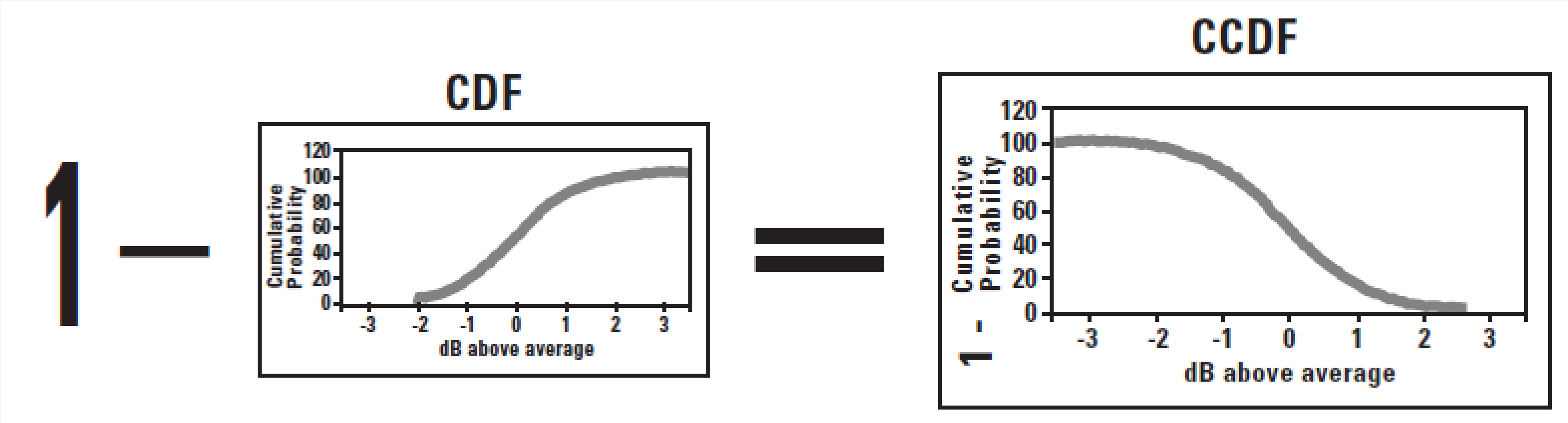
Definition of CCDF





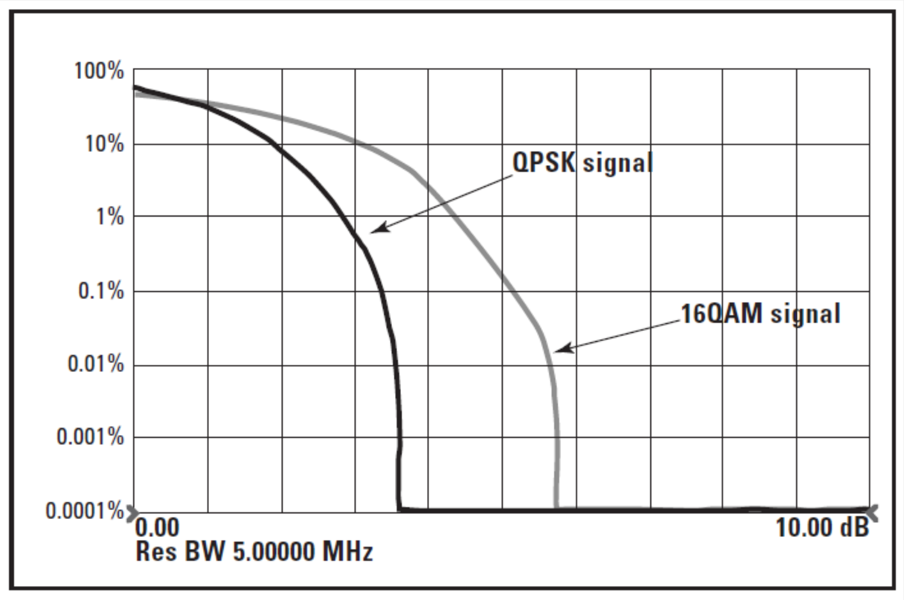


Definition of CCDF



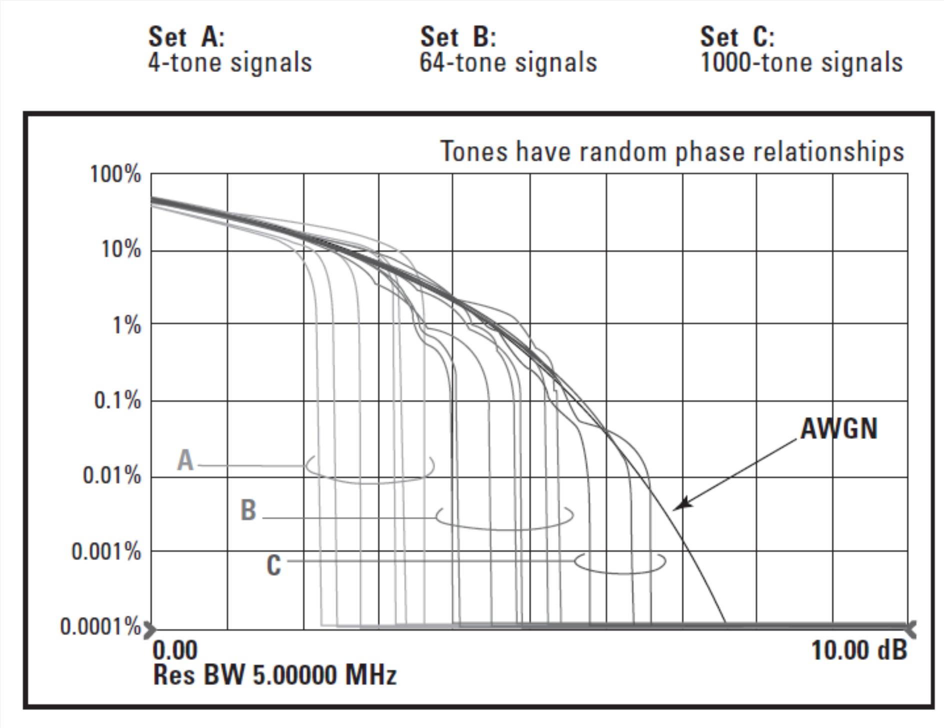
- A logarithmic y-axis provides better resolution for low probability events.

Examples of CCDF Curves



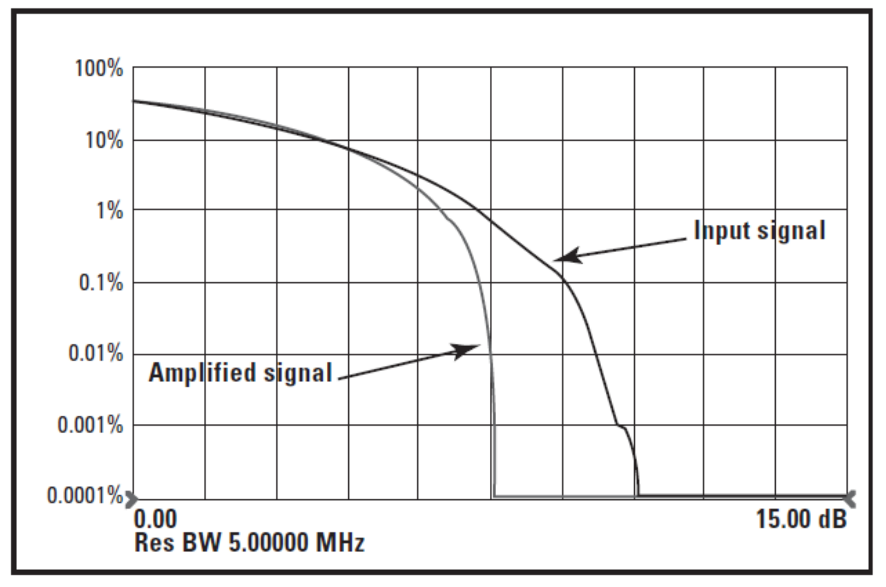
- QPSK: 2 bits / symbol
- 16 QAM: 4 bits / symbol
  - 2x bit rate throughput
  - But a more stressful CCDF (higher peak to average ratio)
- Power Amplifiers for 16 QAM have different design needs than QPSK.
- 40 % more peak capability

OFDM CCDF curve build-up



- A single CW signal has a peak that is ≅ average.
  - It's CCDF curve would be a point at 100%, 0 dB.
  - Two CW signals create a time domain waveform with fluctuating amplitude.
  - Note how CCDF curve of a given waveform approaches AWGN as # of carriers increase.

CCDF Reveals PA Compression



- Clipping of the waveform is difficult to measure in the time domain, but very evident in the CCDF.
- By characterizing the PA and knowing the signal characteristics, we can predict achievable, repeatable performance.
- 0.1% is a good benchmark.
- PA designers use 0.01%

Difference between Crest Factor and CCDF?

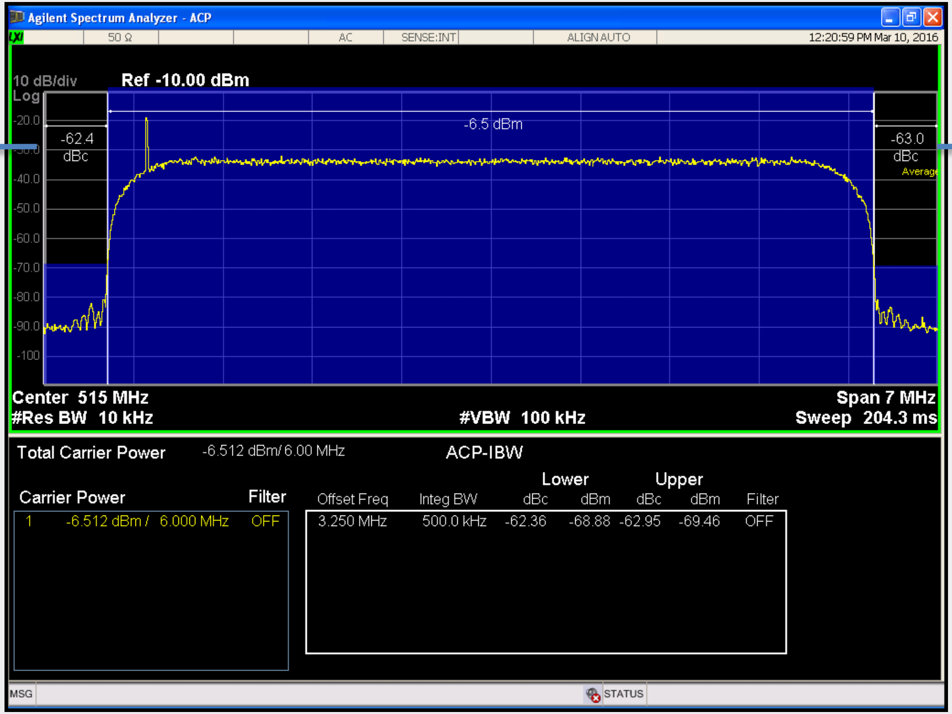
- You may often hear these terms intermingled or in the same conversation.
- We have explained CCDF…. Relates to Power and is statistical.
- Crest Factor usually refers to voltage.
  - Uses a single measured peak voltage value as compared to the RMS voltage.
    - Important for pre-correction limits.
    - Important for RF systems.
    - Important for receiver tuners.

Establish 8-VSB Baseline

8 VSB, exciter only (very linear), spectral response

-62.4 dBc

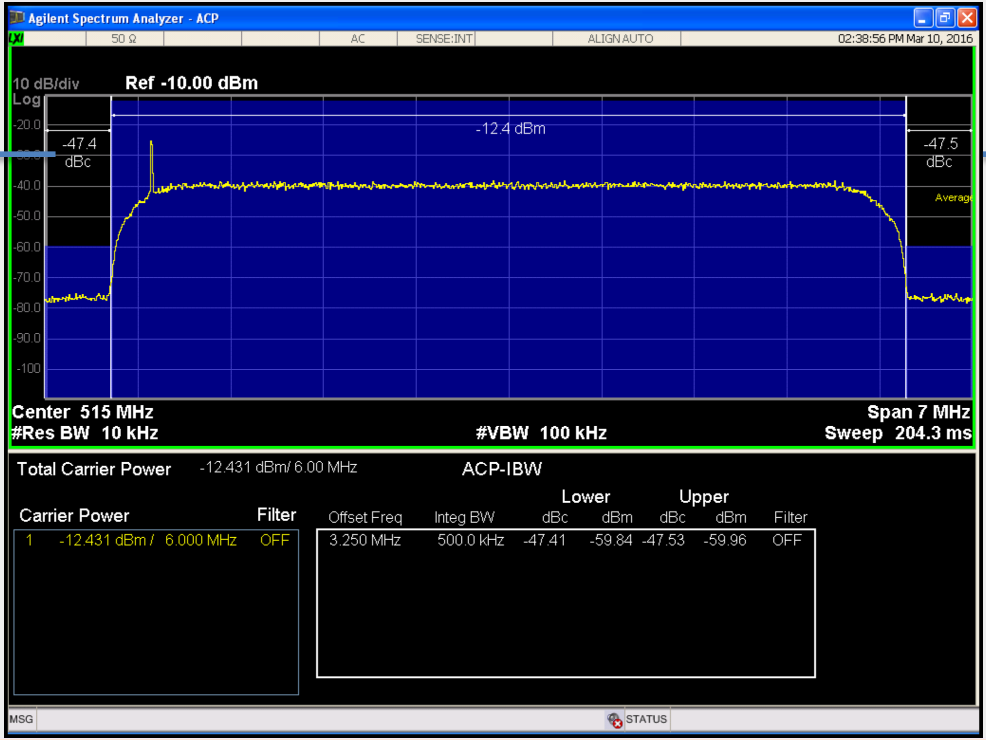
-63 dBc



8 VSB, exciter only CCDF

8 VSB, Doherty amplifier at FCC mask limit

-47.4 dBc



-47.5 dBc

8 VSB, Doherty PA at FCC mask limit

8-VSB, linear and amplified

LET'S LOOK AT OFDM

6 MHz DVB-T2 (64 QAM) used for example data

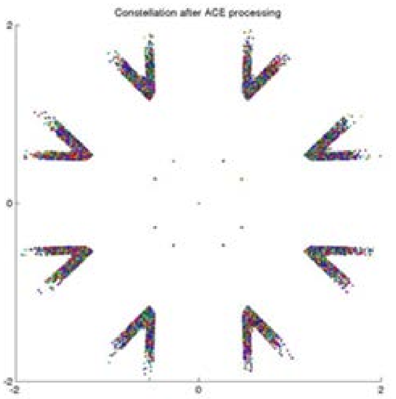
Background on Crest Factor Reduction (CFR)

- CFR techniques are used in today's exciters to "clip" or limit the amount of peaking / peak expansion applied to a signal
  - Peak expansion is necessary for effective precorrection
  - Too much peak expansion can be destructive

Tone Reservation and Active Constellation Extension

- TR: Reserve certain carriers from carrying data. Alter amplitude and phase of those carriers to cancel out peaking.

- ACE: Dynamically moves outer constellation points within constraints to minimize the peak magnitude.



256-QAM, CR 3/15

OFDM, exciter only, internal CFR backed off

unleash

OFDM, exciter only, w/ Tone Reservation (TR), CFR backed off

Exciter Ref:
8.37 dB

unleash

OFDM, exciter only, w/ Active Constellation Extension (ACE), No CFR

Exciter Ref:
8.37 dB

unleash

OFDM, exciter only, w/ TR and ACE, CFR backed off

Exciter Ref:
8.37 dB

Delta
0.42 dB

unleash

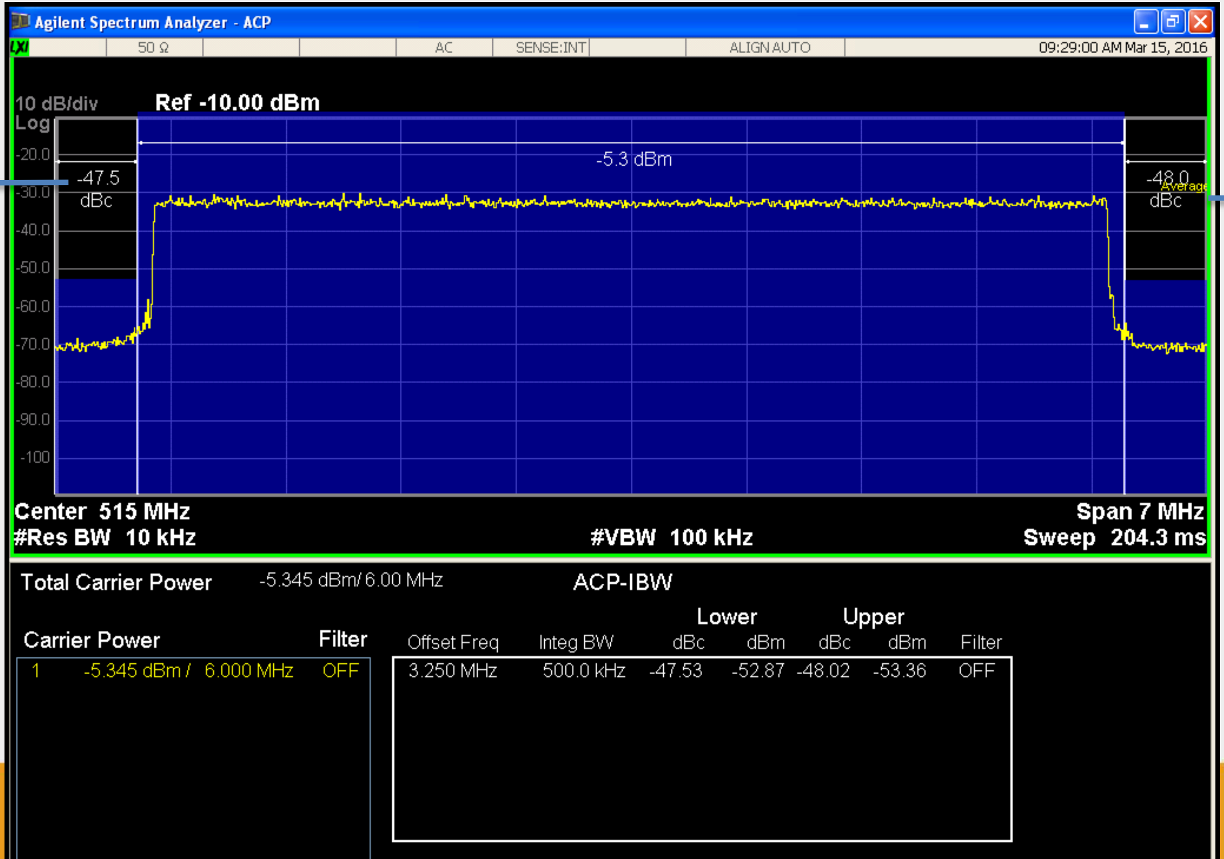
OFDM, Exciter only, CFR backed off vs. CFR on (default)

CFR backed off (slide 21)

CFR engaged at normal parameters

OFDM, thru PA to FCC shoulder limit, no TR or ACE

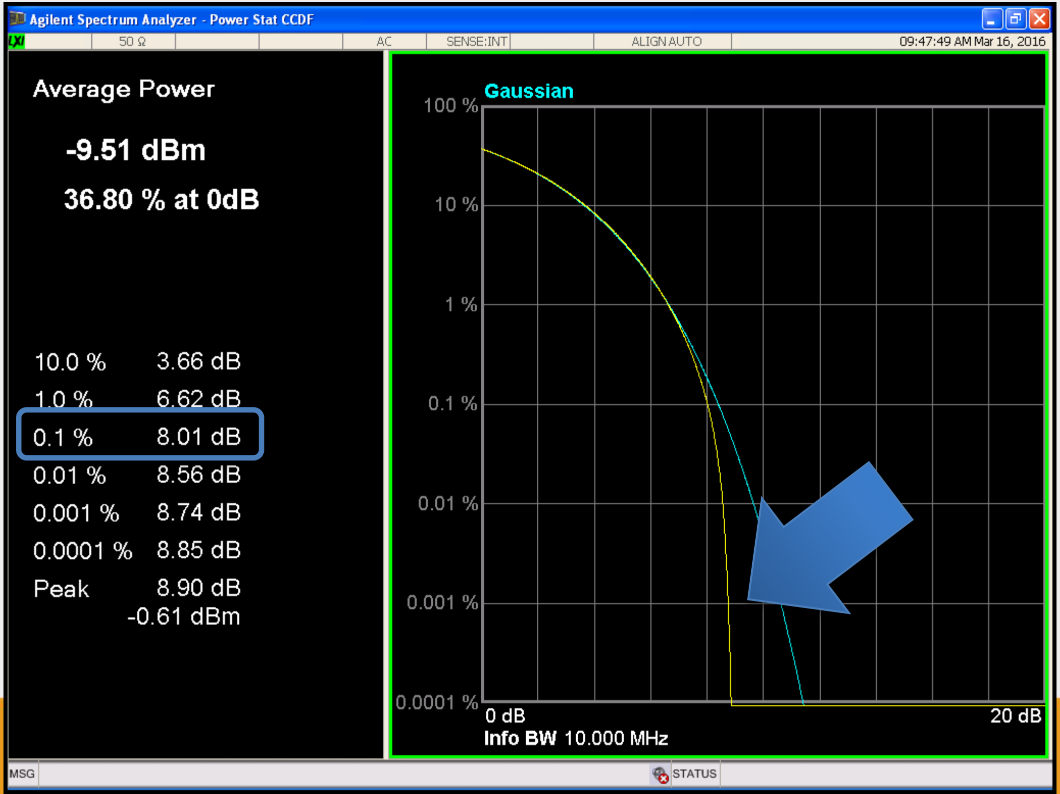
-47.5 dBc



-48 dBc

OFDM, thru PA to FCC shoulder limit, no TR or ACE

Only 0.06 dB Delta From Exciter alone w/ TR & ACE



unleash

OFDM, thru PA, FCC shoulder limit, CFR enabled, w/ Tone Reservation

No TR or ACE (Reference)

w/ Tone Reservation

OFDM, thru PA, FCC shoulder limit, CFR enabled, w/ ACE

No TR or ACE (Reference)

w/ ACE (0.05 dB better than TR)

OFDM, thru PA, FCC shoulder limit, CFR enabled, w/ TR and ACE

No TR or ACE (Reference)

(0.1 dB better than ACE alone)

Class A vs. Doherty

Class A PA using TR

Doherty PA using TR

Conclusion on peak reduction methods

- Literature on TR and ACE methods allude to peak reductions on the order of 1 – 2 dB (or more) for OFDM waveforms.
- The benefit observed on real-world broadcast PA's driven to limits are on the order of 0.3 to 0.5 dB.
- While helpful, they don't *appreciably* close the gap between 8-VSB and OFDM.

8-VSB and OFDM thru PA @ mask

The basis for the 2 dB difference in power

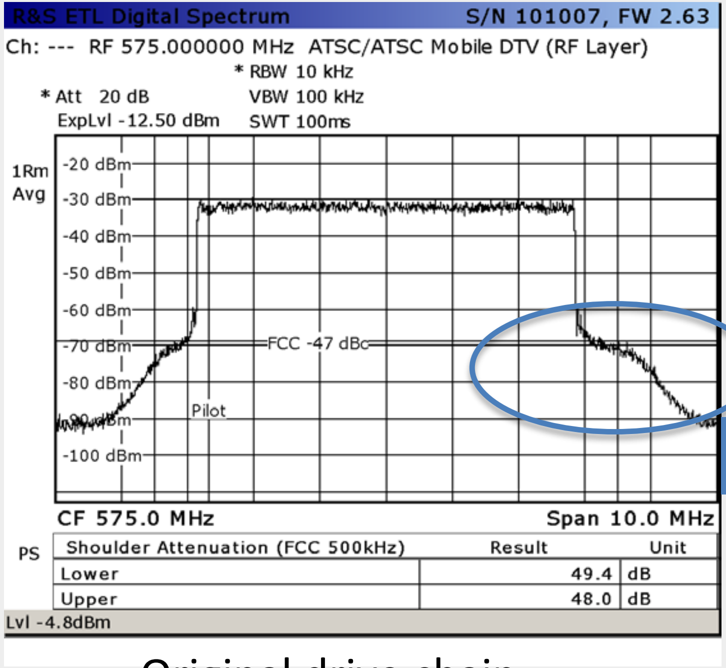
Real World: WJW Transmitter

- A 3-IOT transmitter
- Commissioned 1999
- Shut down in 2009
  - WJW went back to VHF
- 8-VSB
  - Transmitter rated at 67 kW
  - Operated at 40.2 kW
- Futurecast OFDM Waveform
  - TPO 28 kW
  - -3.8 dB / - 1.6 dB

WJW with OFDM waveform

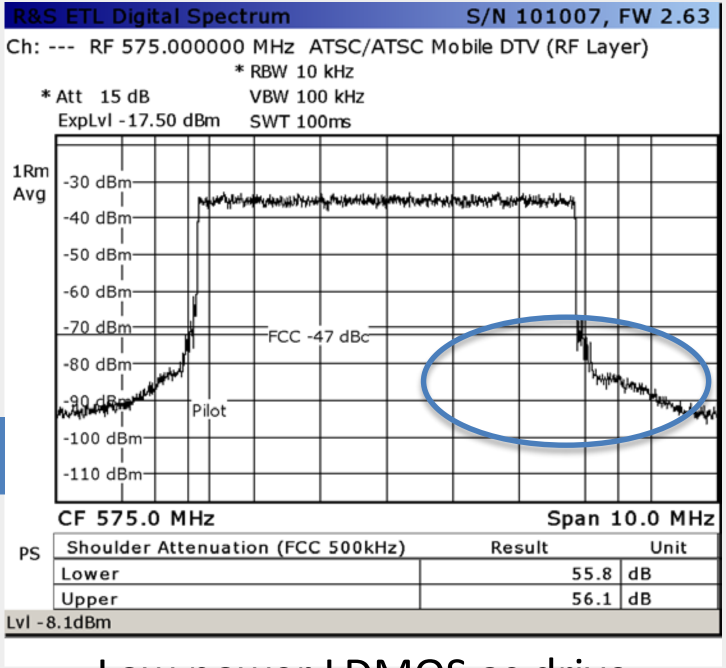
- Transmitter used pre-drivers and IPA's from it's NTSC lineage.
- 28 V transistors, many cascaded stages.
- These amplifiers don't have the high linear peak capability compared to their average power as state-of-the-art (50 V) LDMOS devices.
- As an experiment, a low power transmitter was used to bypass the entire drive chain and drive one IOT.

What can be accomplished with modern LDMOS drive?



Original drive chain

$6.4 - 8\,dB$



Low power LDMOS as drive

What’s the impact?

- We’ve shown where the well known ≅ 2 dB difference in powers between 8-VSB and OFDM comes from.
- Optional peak reduction techniques help, but won’t reduce the impact significantly.
- Depending on transmitter vintage and sizing as is, it is likely it will not be able to produce the same power in ATSC 3.0
- Dipole factor and down-band moves from repack could help reduce needed transmitter power.

Acknowledgements

- Ed Westenfeld
- Keysight Technologies App. Note
  - "Characterizing Digitally Modulated Signals with CCDF Curves"

Thank You