DIGITAL PREDISTORTION LINEARIZING OUR AMPLIFIERS

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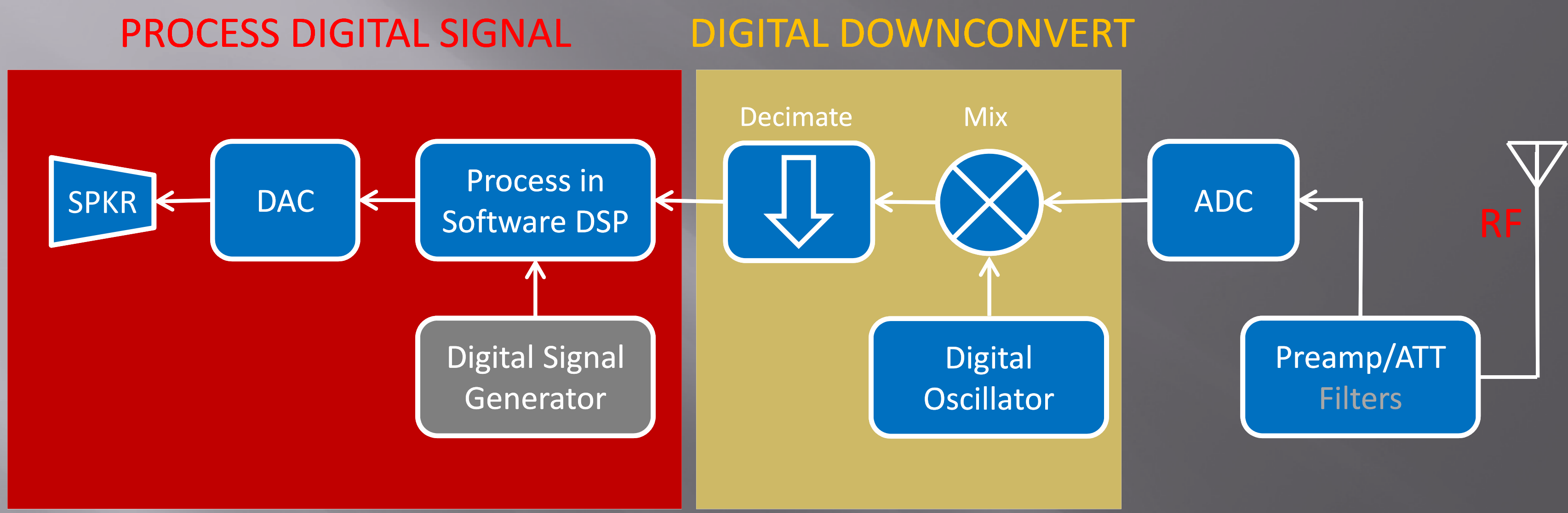
HAM RADIO FRIEDRICHSHAFEN 2014

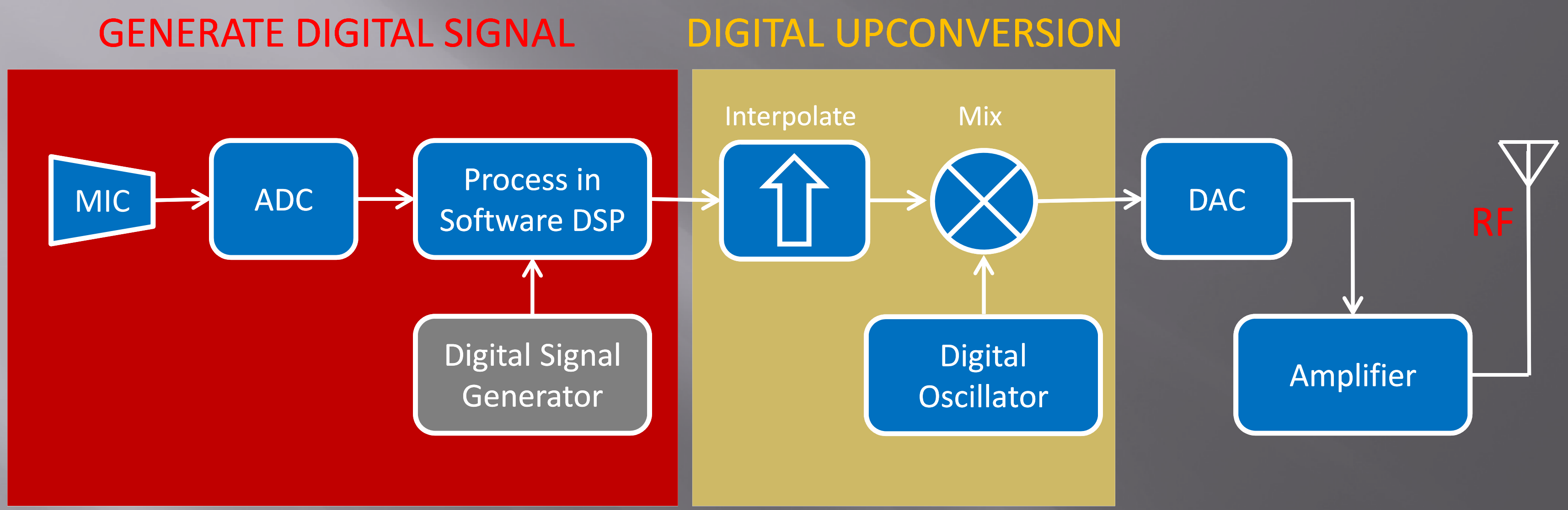
DIGITAL DOWN-CONVERSION RECEIVER
(DDC)



- Mix With Complex Oscillator To Generate Baseband (0 Hz IF) Signal
- Decimate Down From The Sample Rate Of The Oscillator & ADC (122.88 Mhz)

- Process The Complex Digital Signal (I,Q) To Generate Audio
  - Sample rates are easily processed in software (48K – 384K)

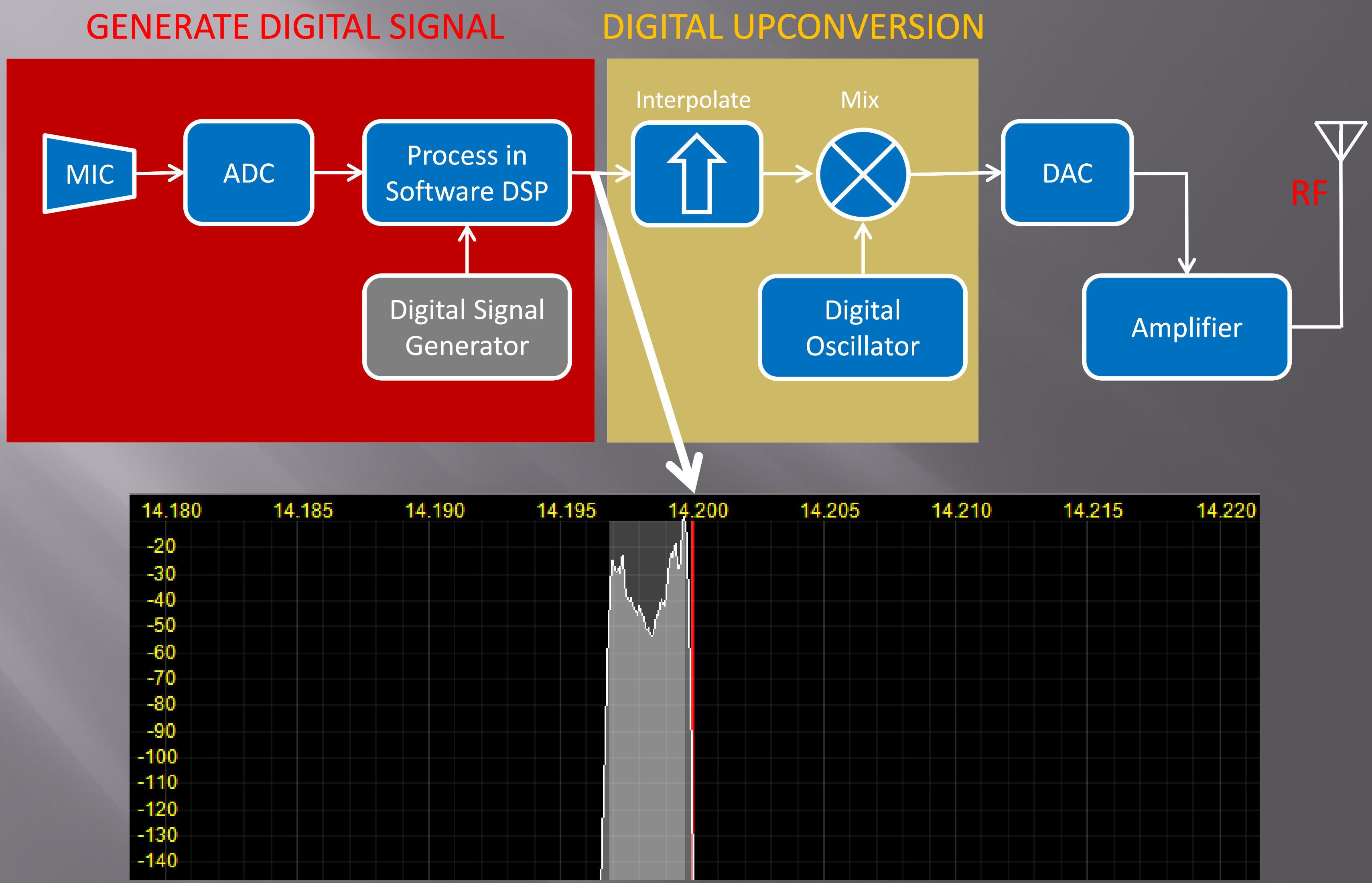
DIGITAL UP-CONVERSION TRANSMITTER
(DUC)



- Complex Digital Signal (I,Q) Generated From Audio Data
  - Sample rates are easily processed in software (48K – 384K)

- Interpolate Up To The Sample Rate Of The DAC & Oscillator (122.88 Mhz)
- Mix With Complex Oscillator To Generate The RF-Frequency Digital Signal

DIGITAL UP-CONVERSION TRANSMITTER
(DUC)



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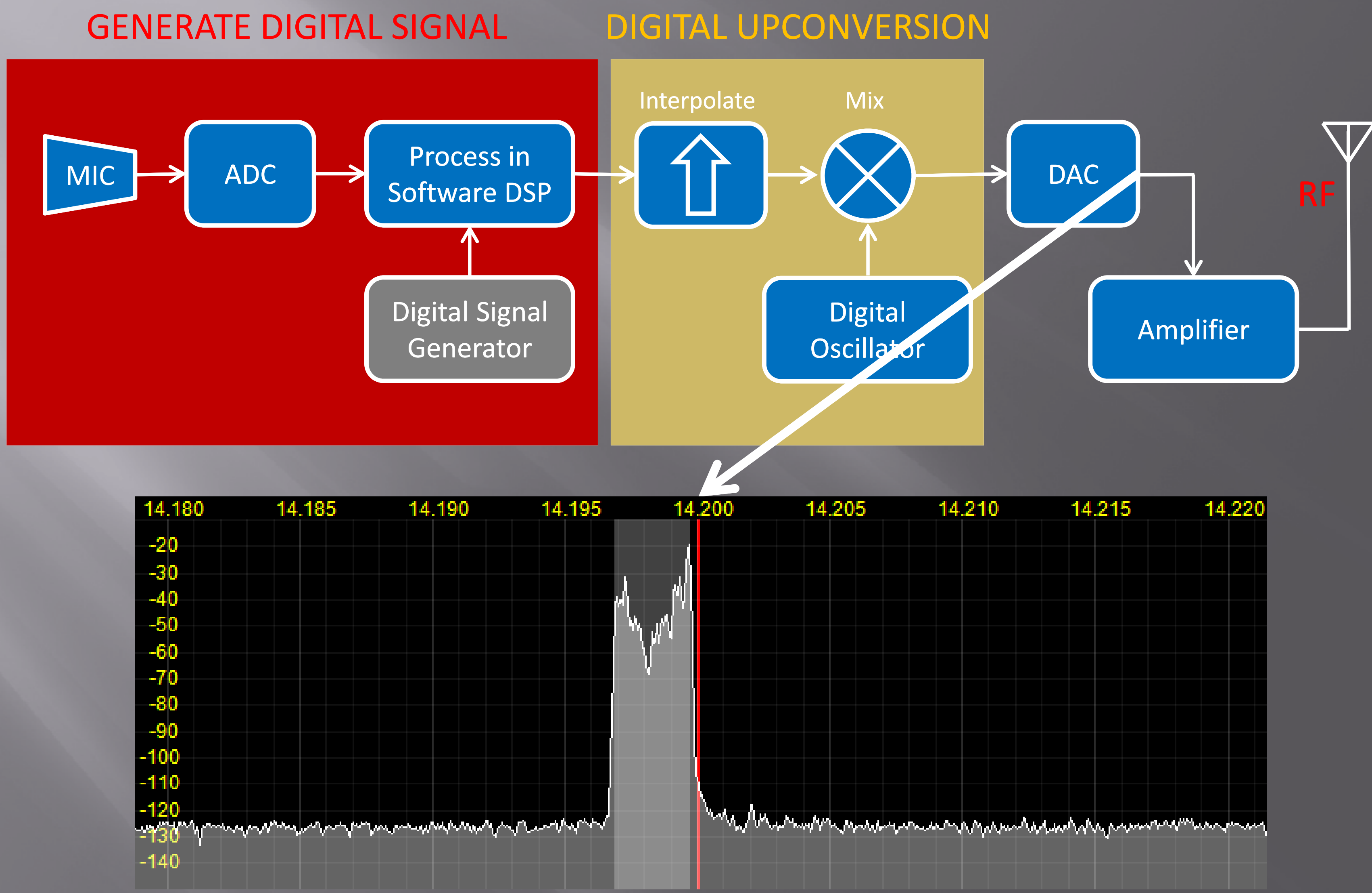

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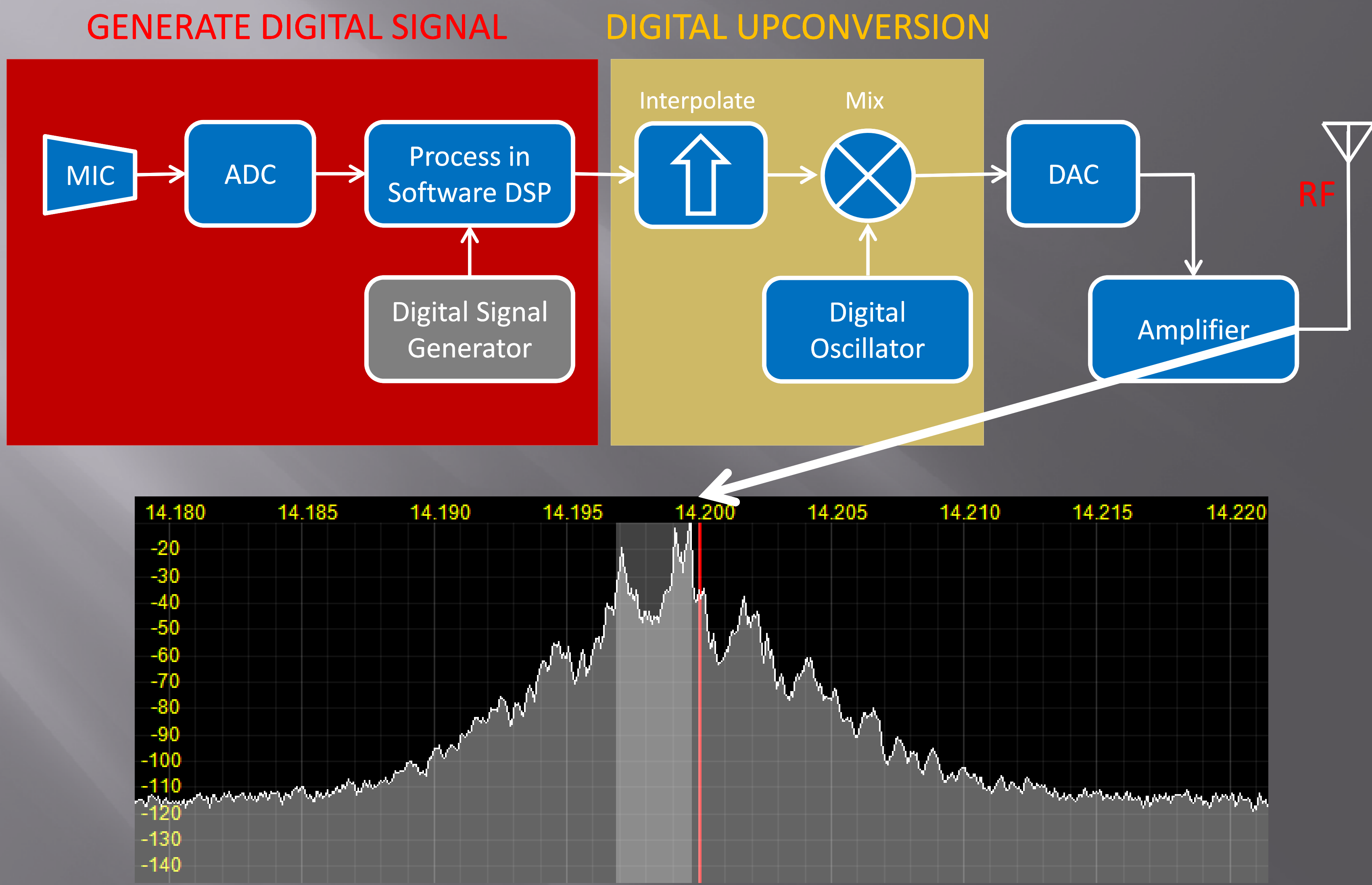

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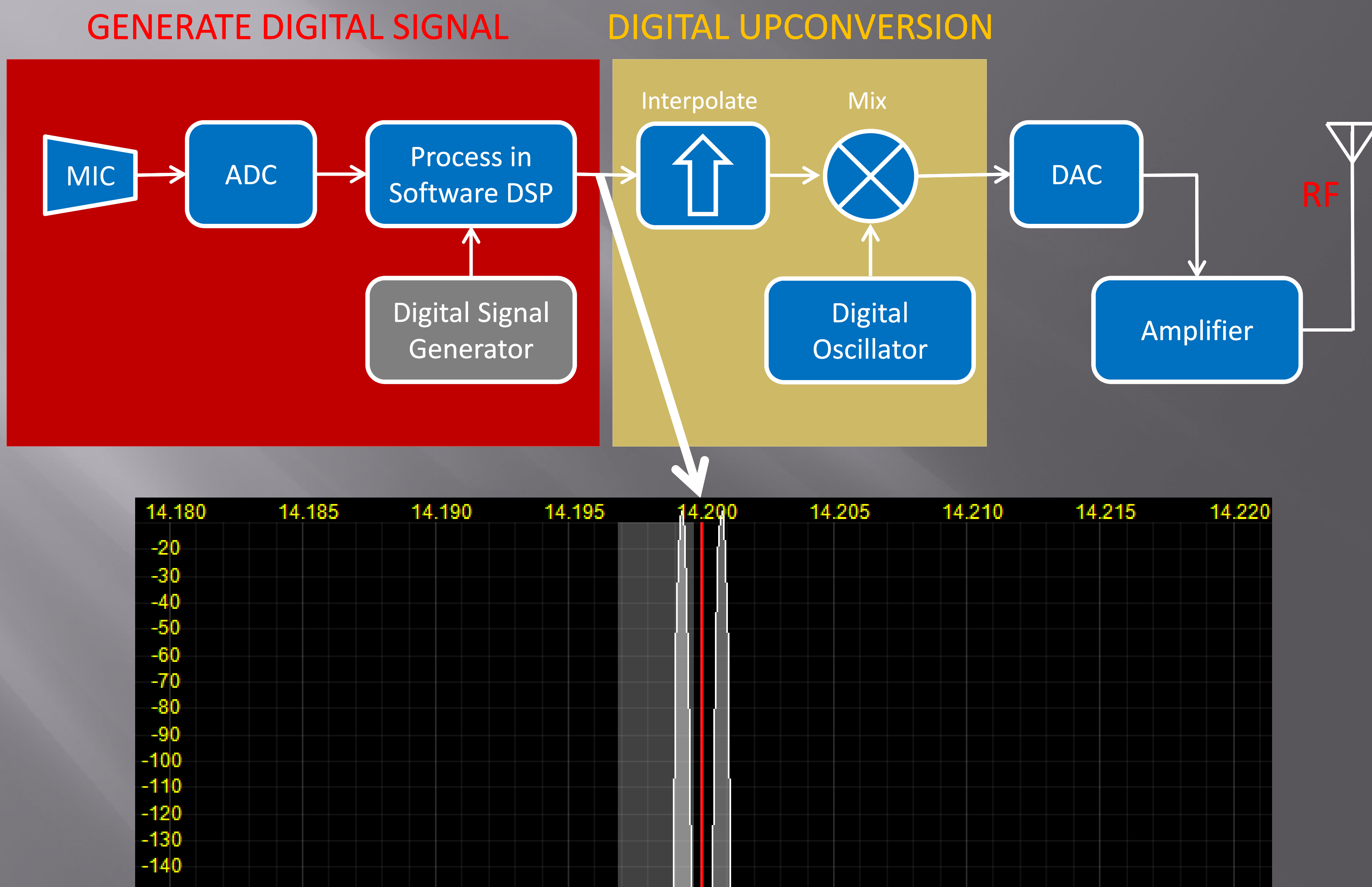

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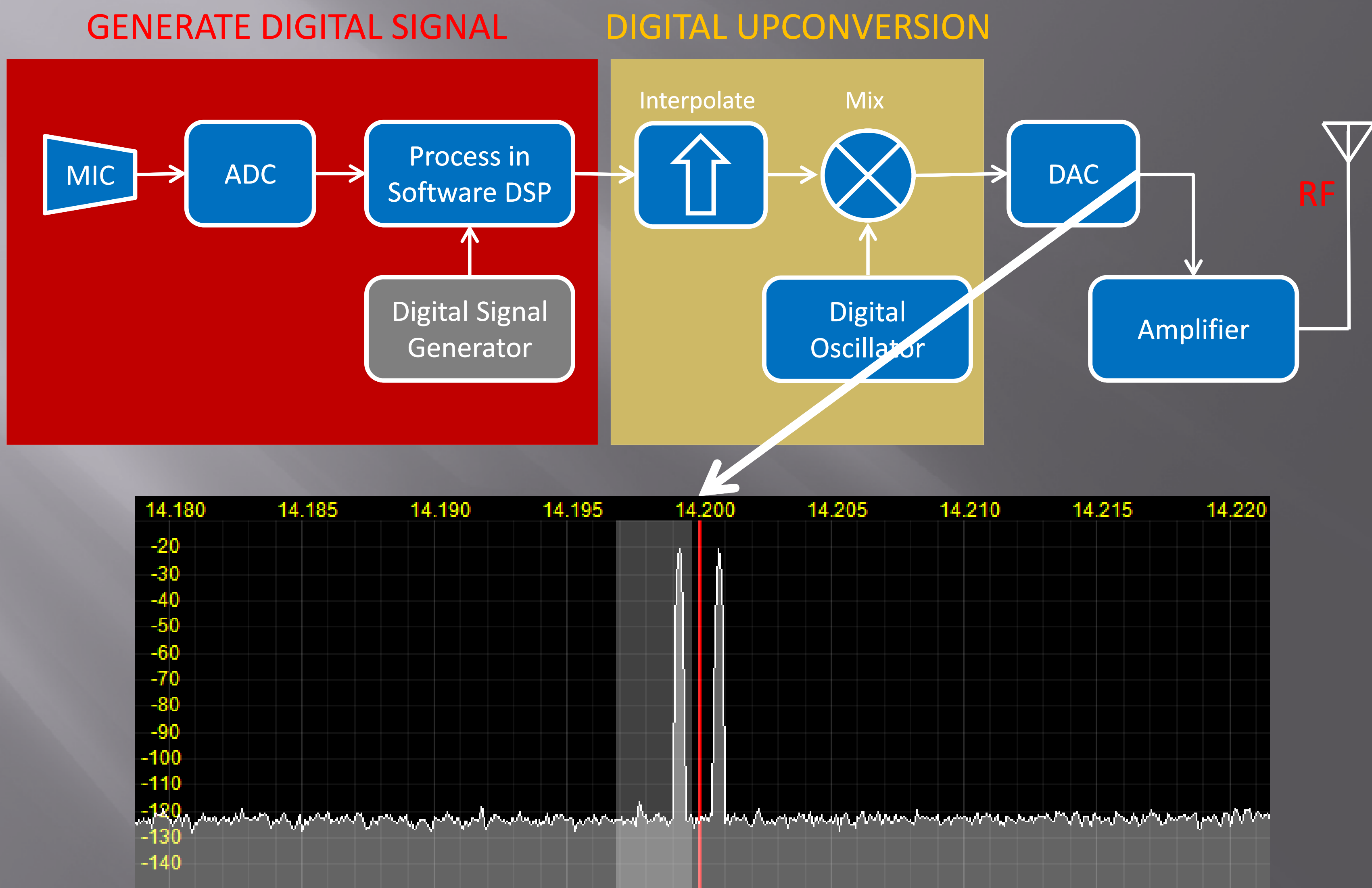

DIGITAL UP-CONVERSION TRANSMITTER
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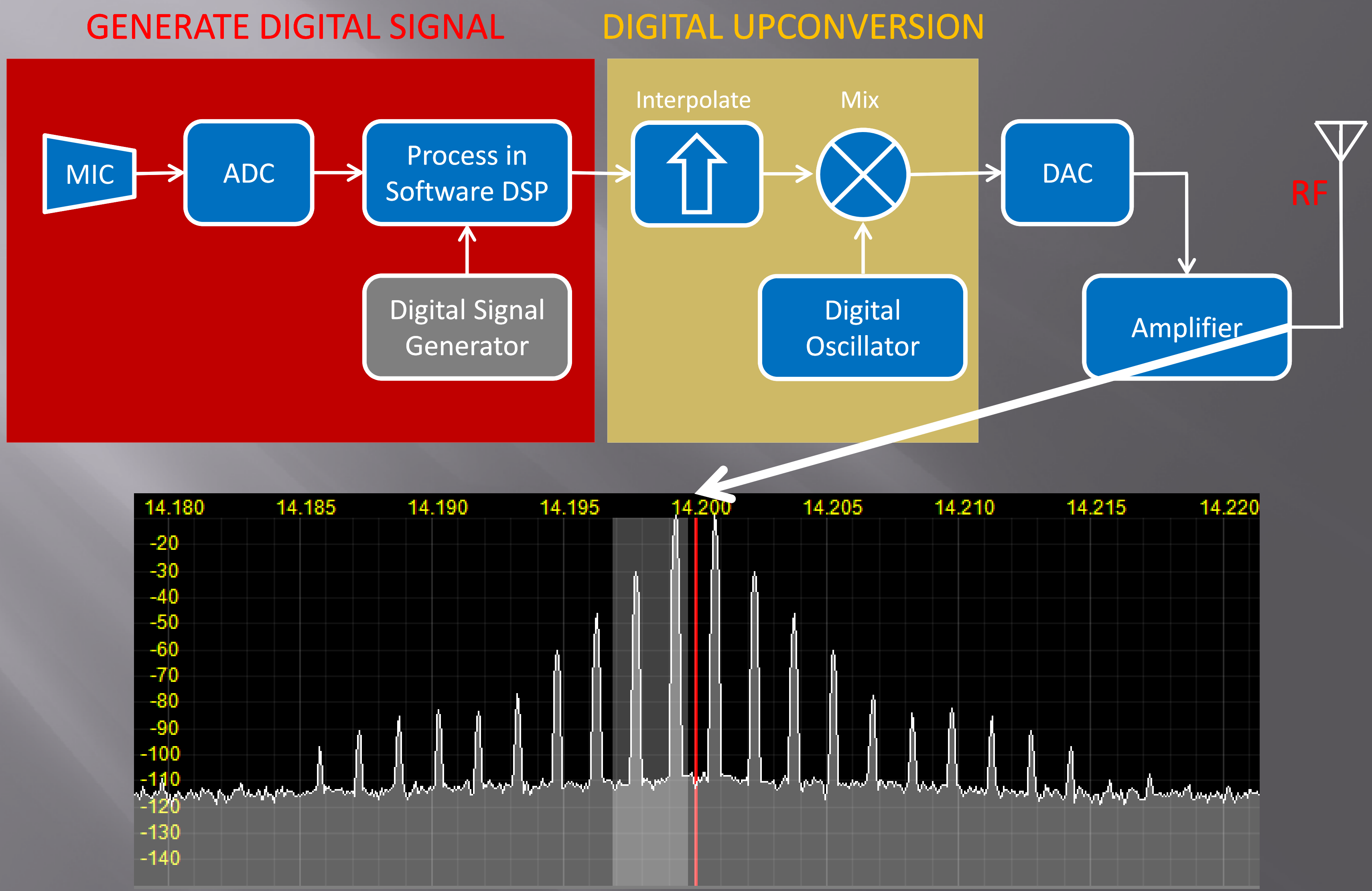
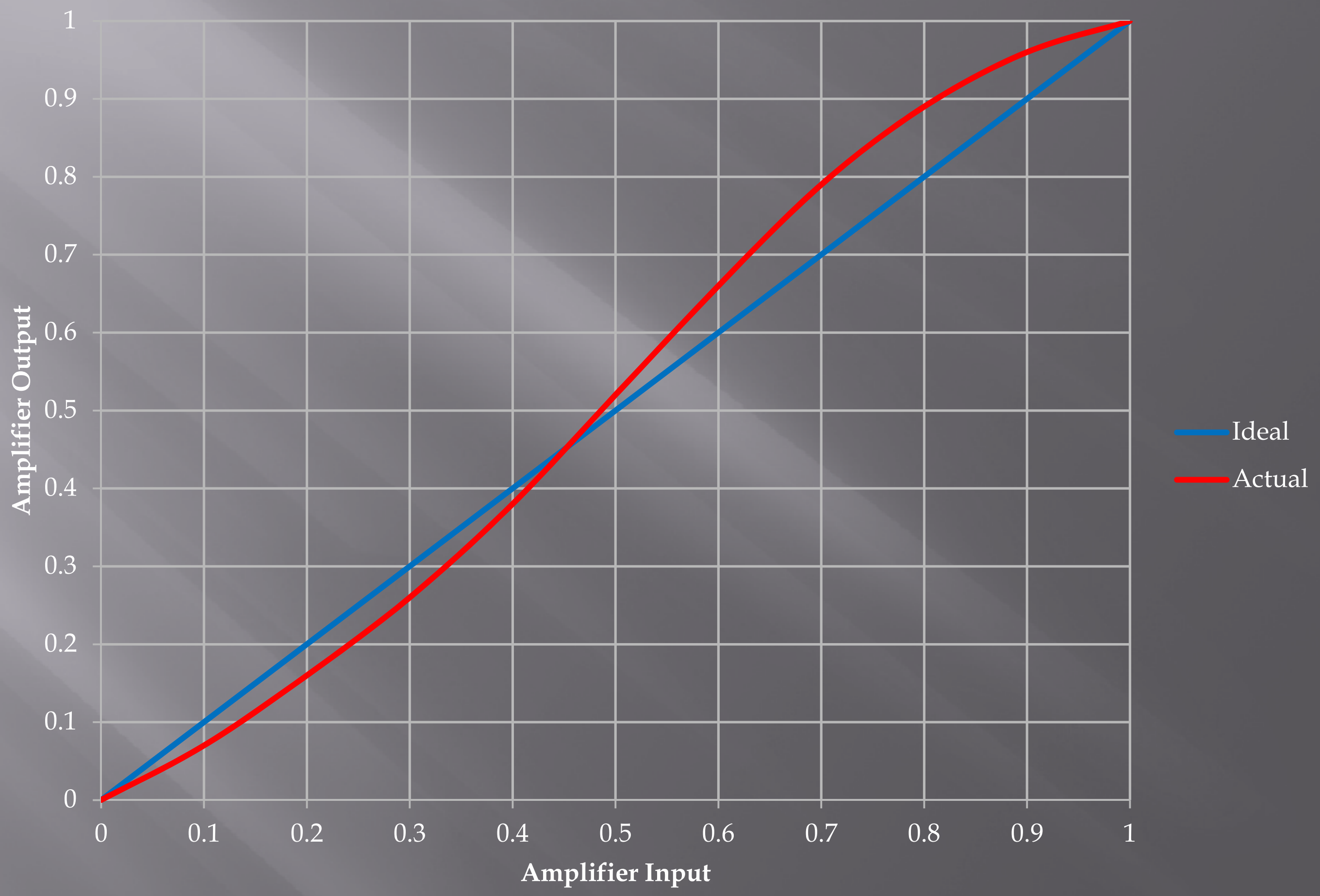


WHY ?

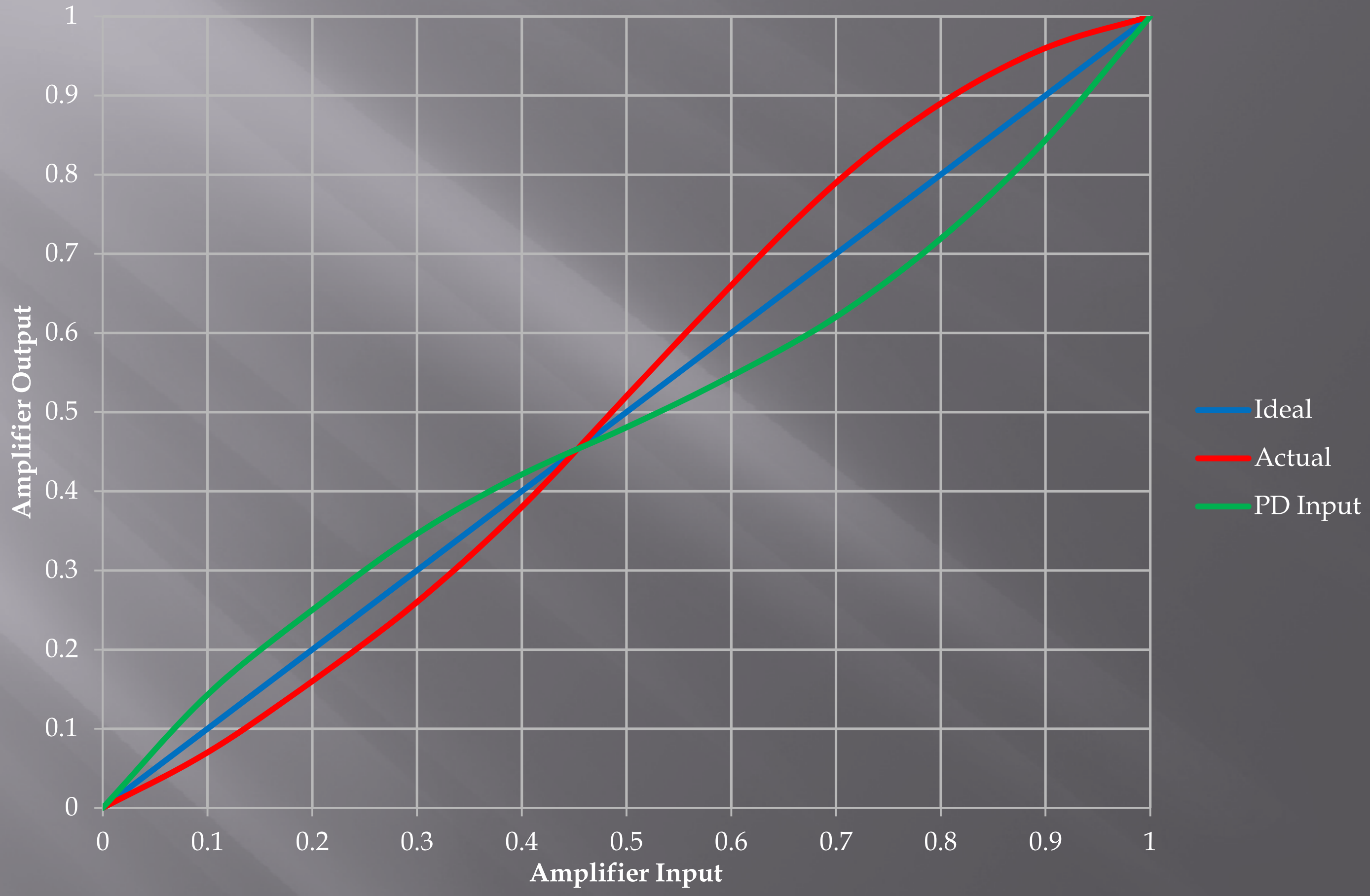
WHY ?

Because the amplifier is NOT perfectly linear!

AMPLITUDE NON-LINEARITY

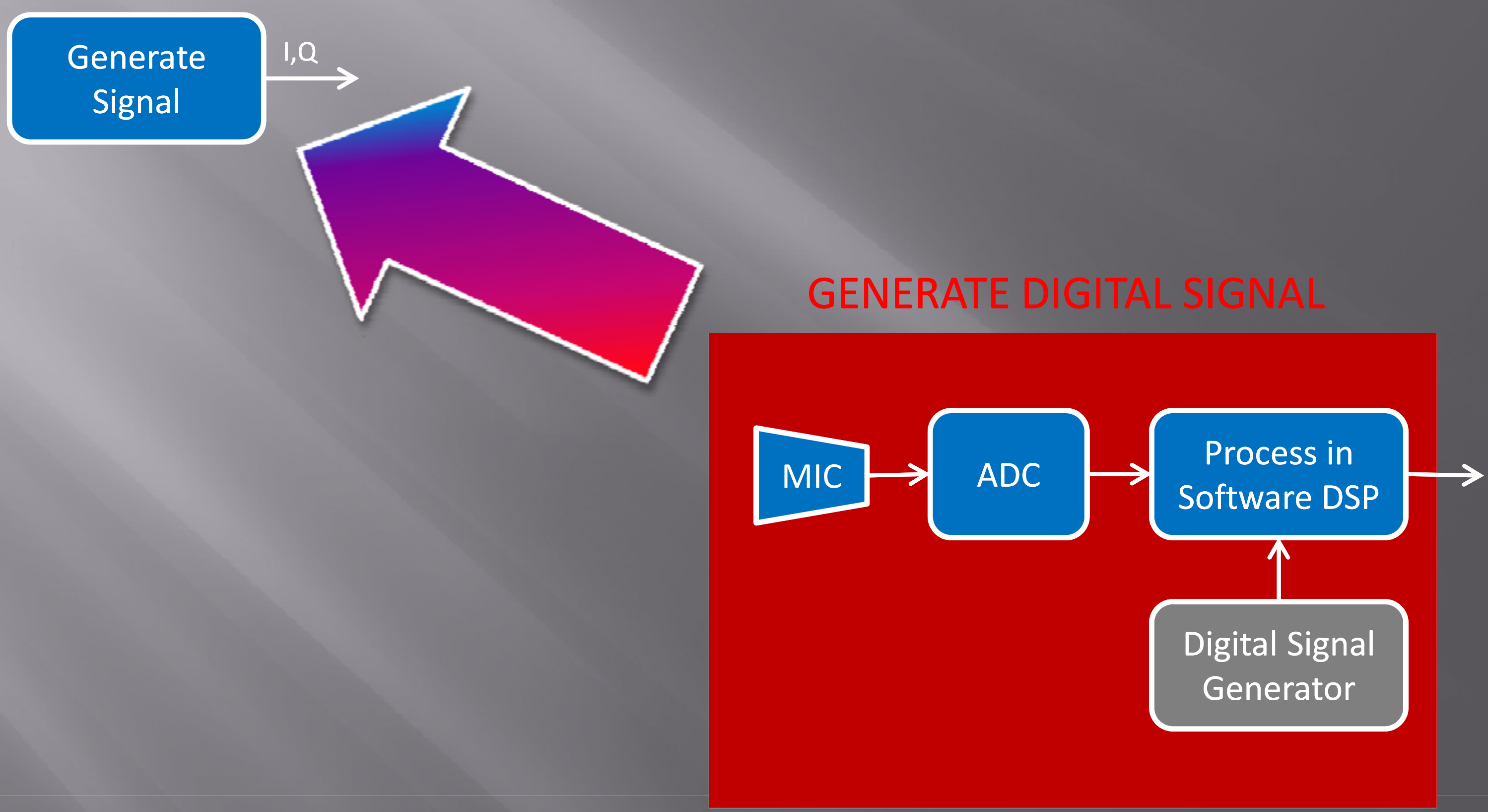


CORRECTION BY PREDISTORTION



ADAPTIVE BASEBAND PREDISTORTION

Basic Concept



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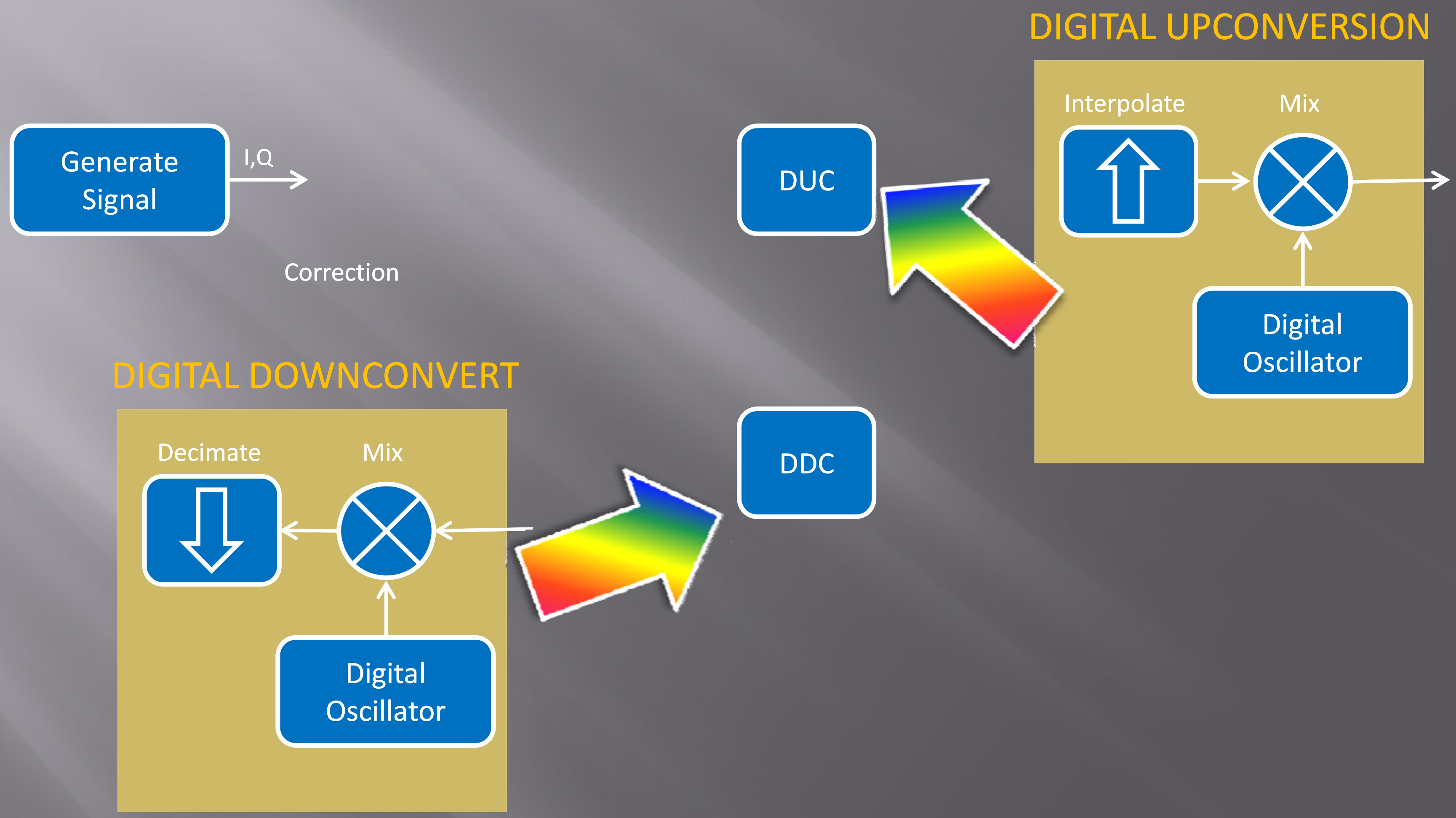

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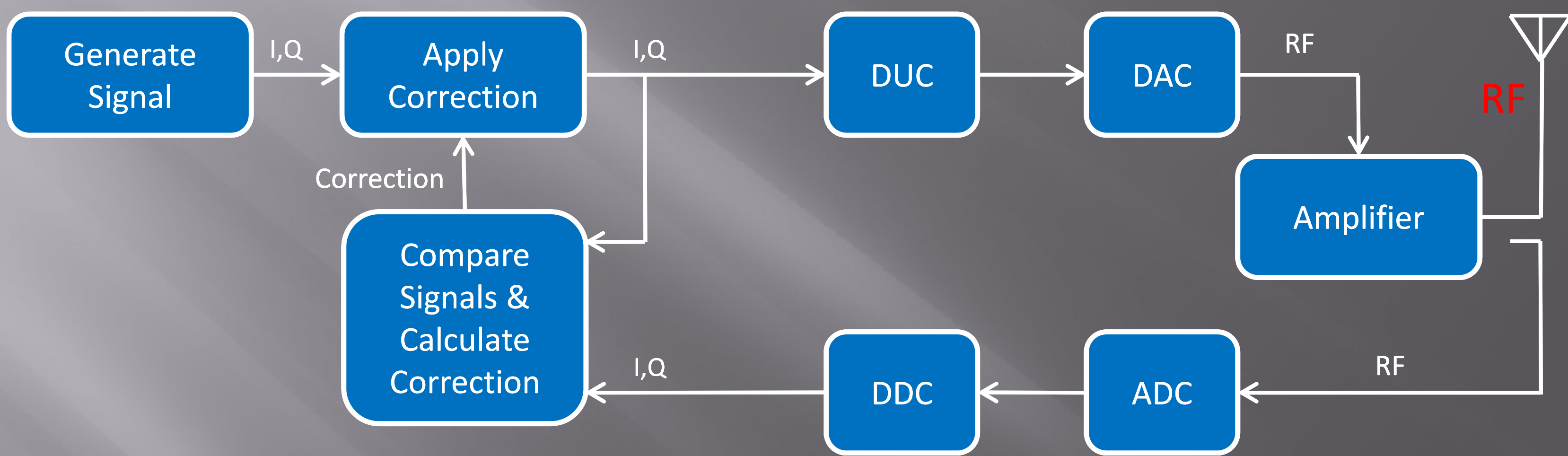
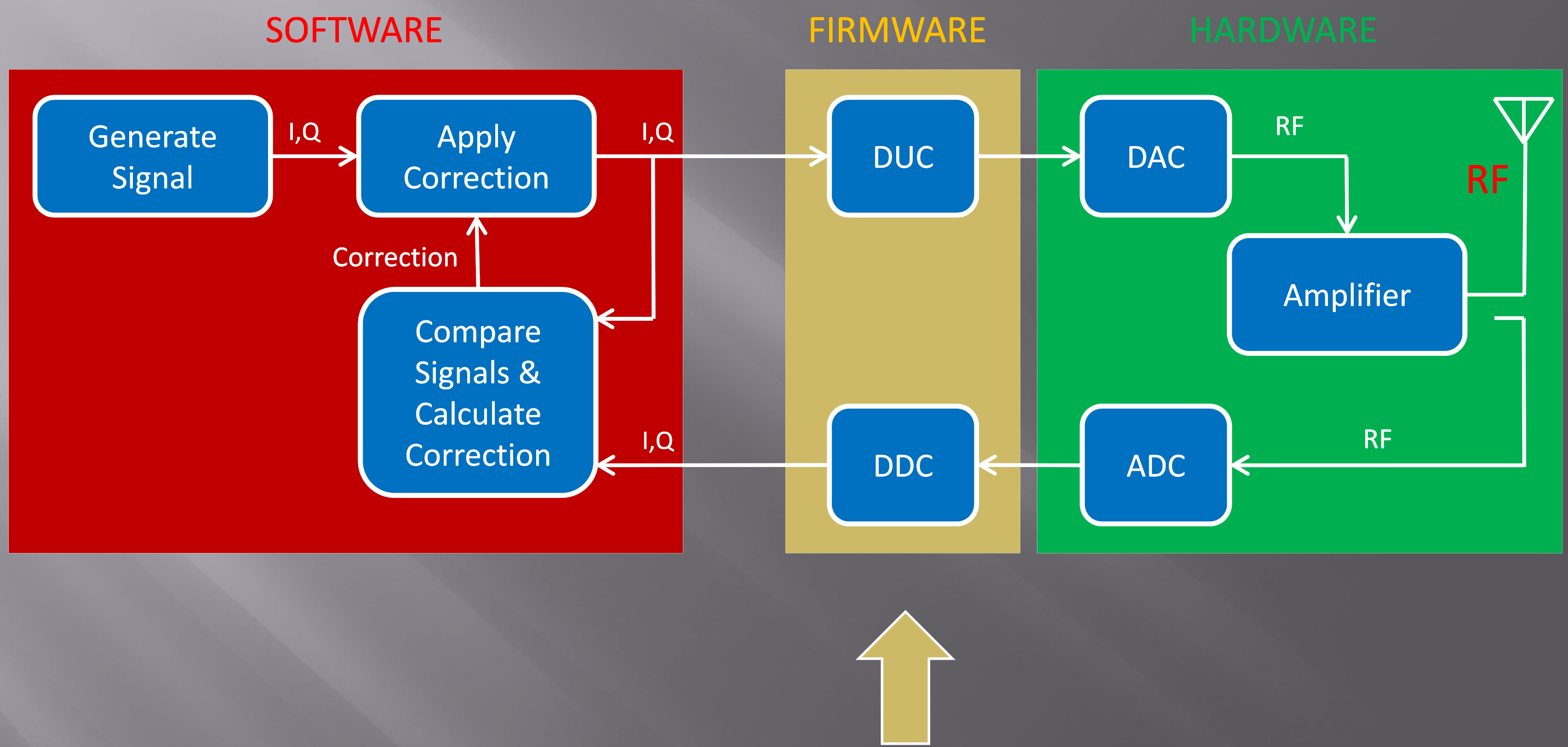
Basic Concept



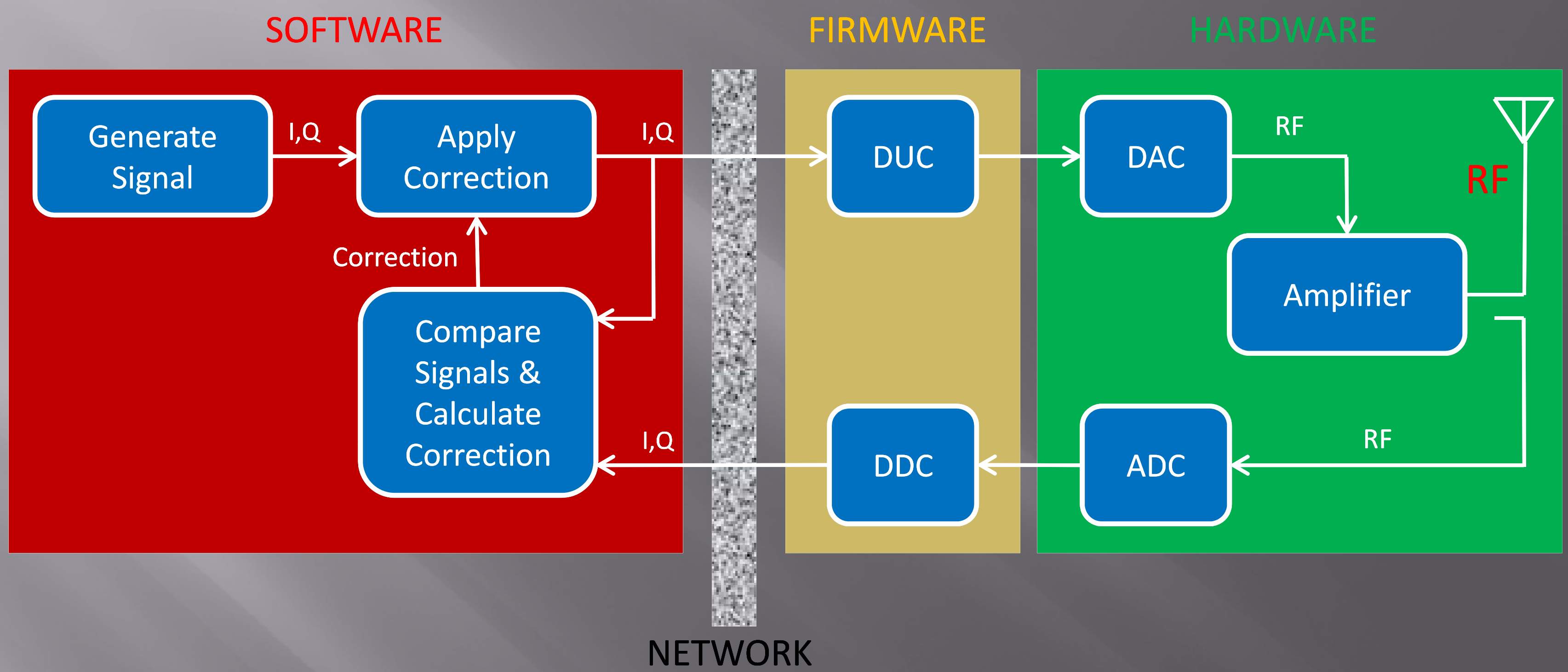
- Apply Correction to the out-bound signal
- Calculate Correction by Comparing the Input & Output of the Amplifier
  - BASEBAND – I,Q Before Up-Conversion / I,Q After Down-Conversion
  - ADAPTIVE – Repeat the process to Adapt to Changing Conditions

ADAPTIVE BASEBAND PREDISTORTION



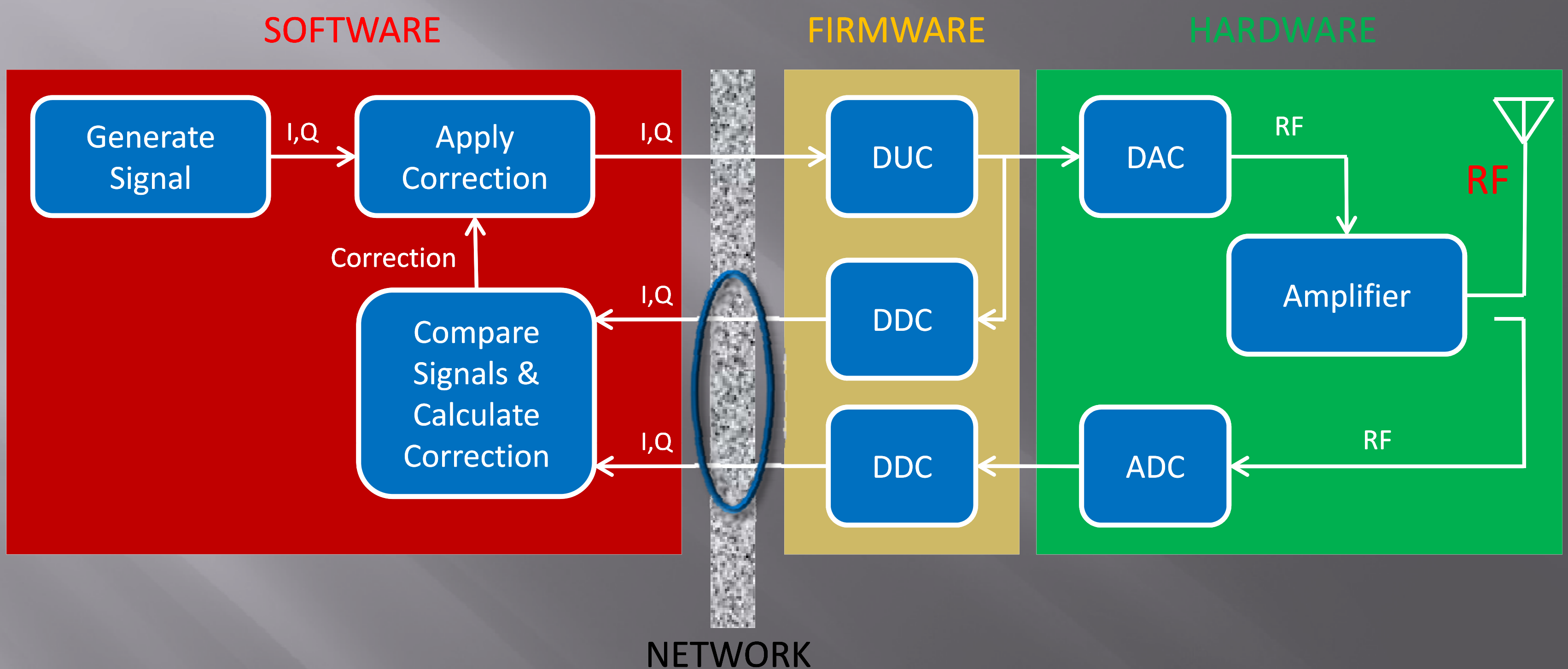
VERY flat frequency response!

ADAPTIVE BASEBAND PREDISTORTION



- Samples from the amplifier Input and Output must be matched in time
- Network delays create variability in timing of amplifier Output samples

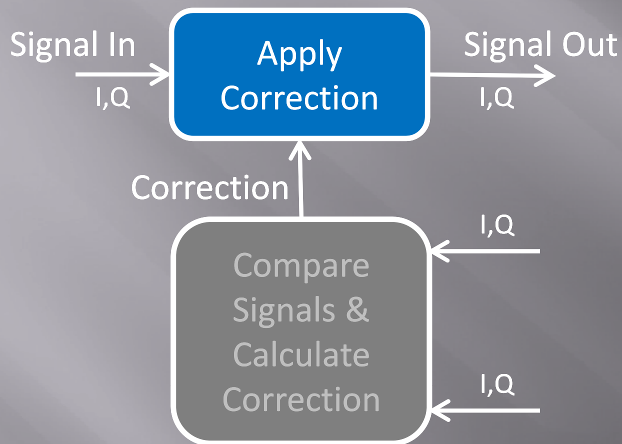
ADAPTIVE BASEBAND PREDISTORTION



- Samples from the amplifier Input and Output are synchronized
- The Input I,Q and Output I,Q are interleaved in network packets

ADAPTIVE BASEBAND PREDISTORTION

APPLYING CORRECTION



FOR EACH iq_sample

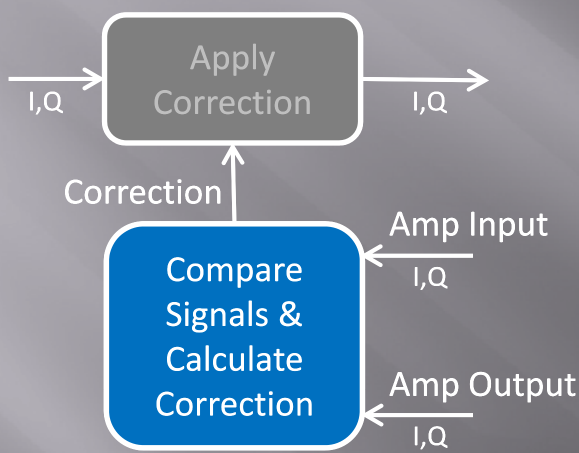
$$mag = sqrt\,(i^2 + q^2)$$
$$g = gain\_correct\ (\,mag\,)$$
$$\varphi = phase\_correct\ (\,mag\,)$$
$$i\_out = g * (\,i * \cos(\varphi) - q * \sin(\varphi)\,)$$
$$q\_out = g * (\,i * \sin(\varphi) + q * \cos(\varphi)\,)$$

Multiply by the gain correction

Rotate the phase

ADAPTIVE BASEBAND PREDISTORTION

CALCULATING CORRECTION



FOR EACH pair_of_iq_samples

$\text{in\_mag} = \text{sqrt}\,(i_{in}^2 + q_{in}^2)$

$\text{out\_mag} = \text{sqrt}\,(i_{out}^2 + q_{out}^2)$

$g = \text{scale} * (\text{in\_mag} / \text{out\_mag})$

$\varphi = \arctan\left((- i_{in} * q_{out} + q_{in} * i_{out}) / (i_{in} * i_{out} + q_{in} * q_{out}) \right)$

save_gain_correction

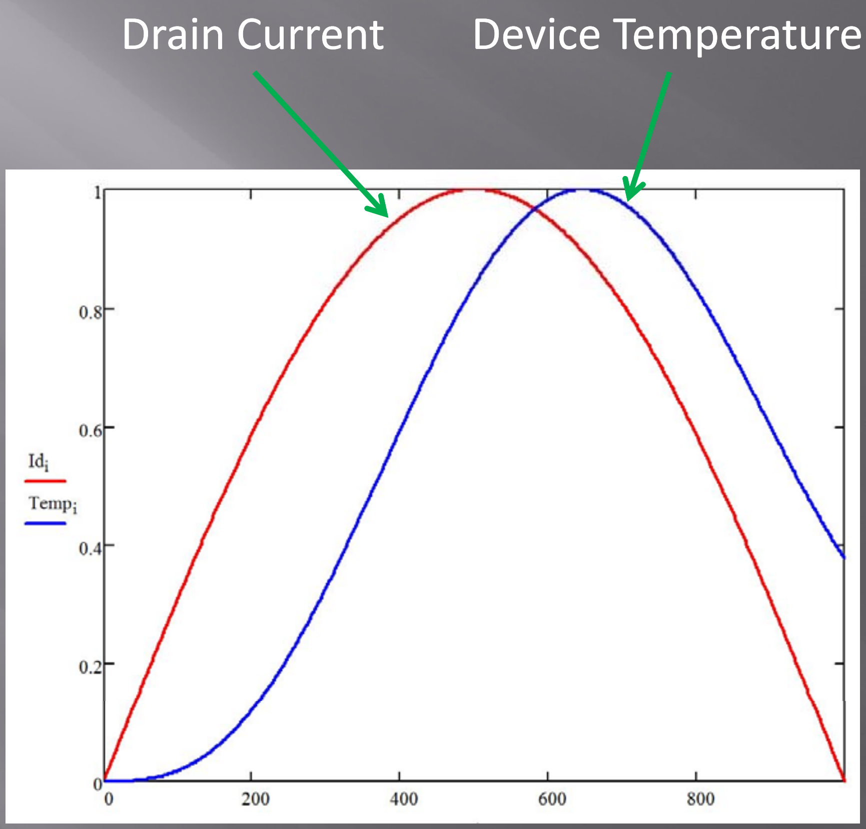
save_phase_correction

“scale” compensates for amplifier gain and feedback attenuation

MEMORY EFFECTS

THE PREDISTORTION ENEMY !

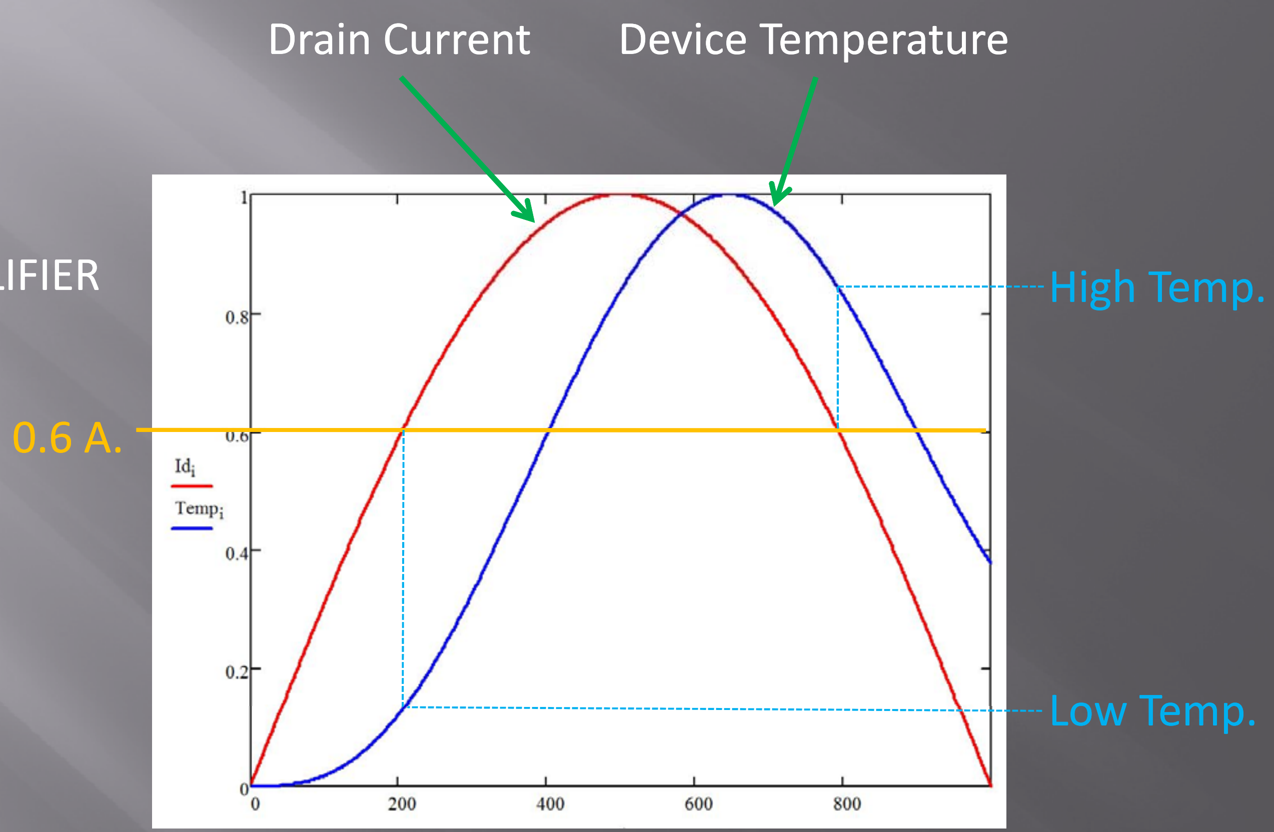
EXAMPLE:
CLASS B AMPLIFIER



MEMORY EFFECTS

THE PREDISTORTION ENEMY !

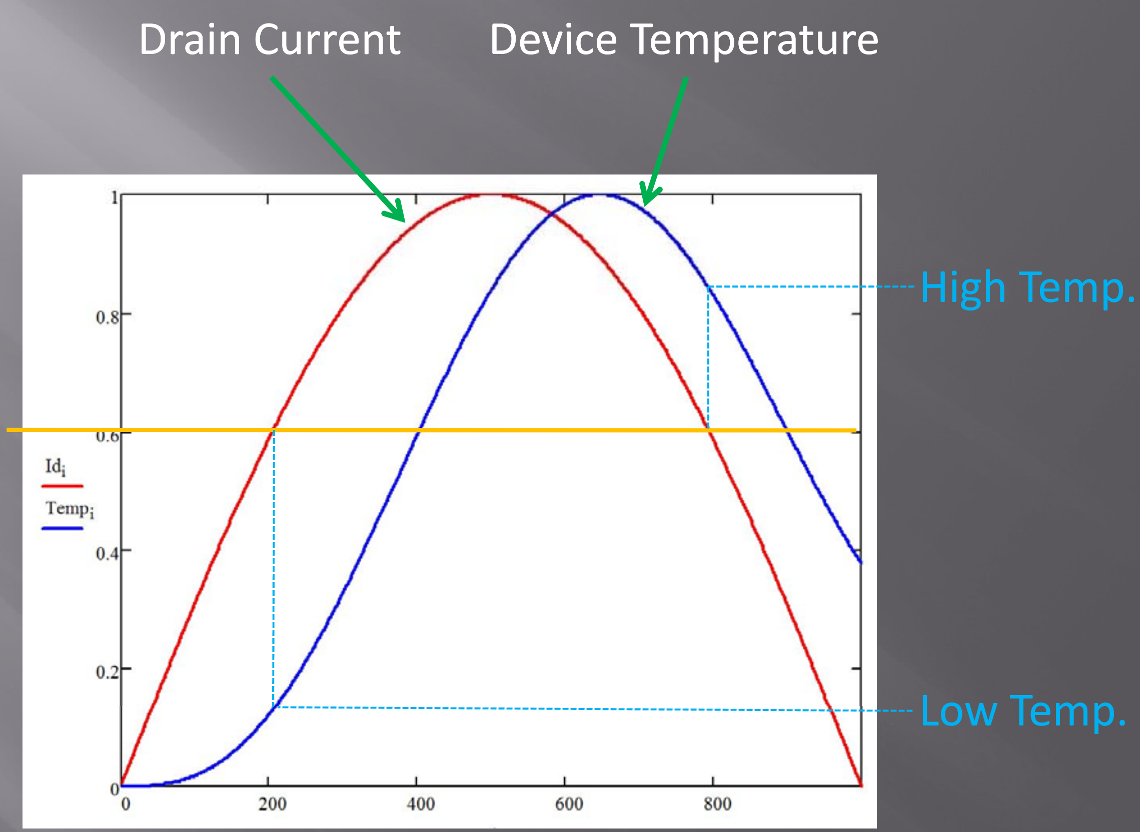
EXAMPLE:
CLASS B AMPLIFIER



MEMORY EFFECTS

THE PREDISTORTION ENEMY !

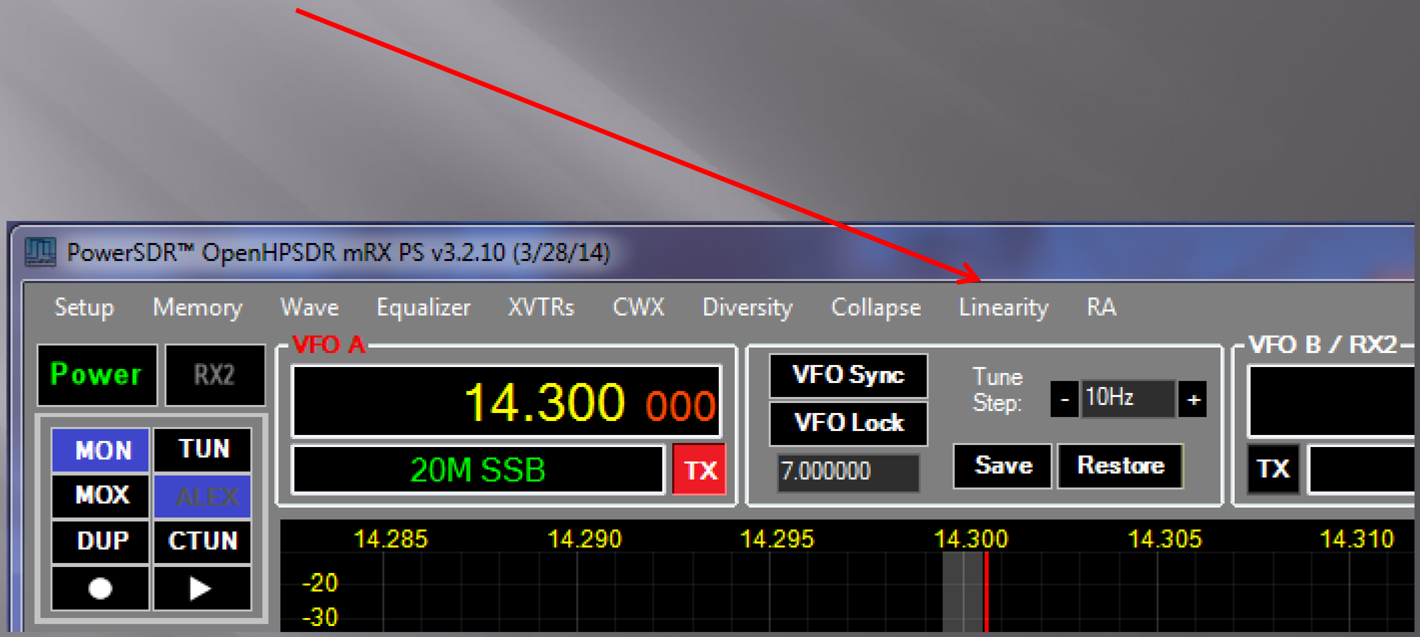
EXAMPLE:
CLASS B AMPLIFIER



Same Input Mag/Phase → Different Output Mag/Phase
Why? The amplifier "remembers" the past inputs!

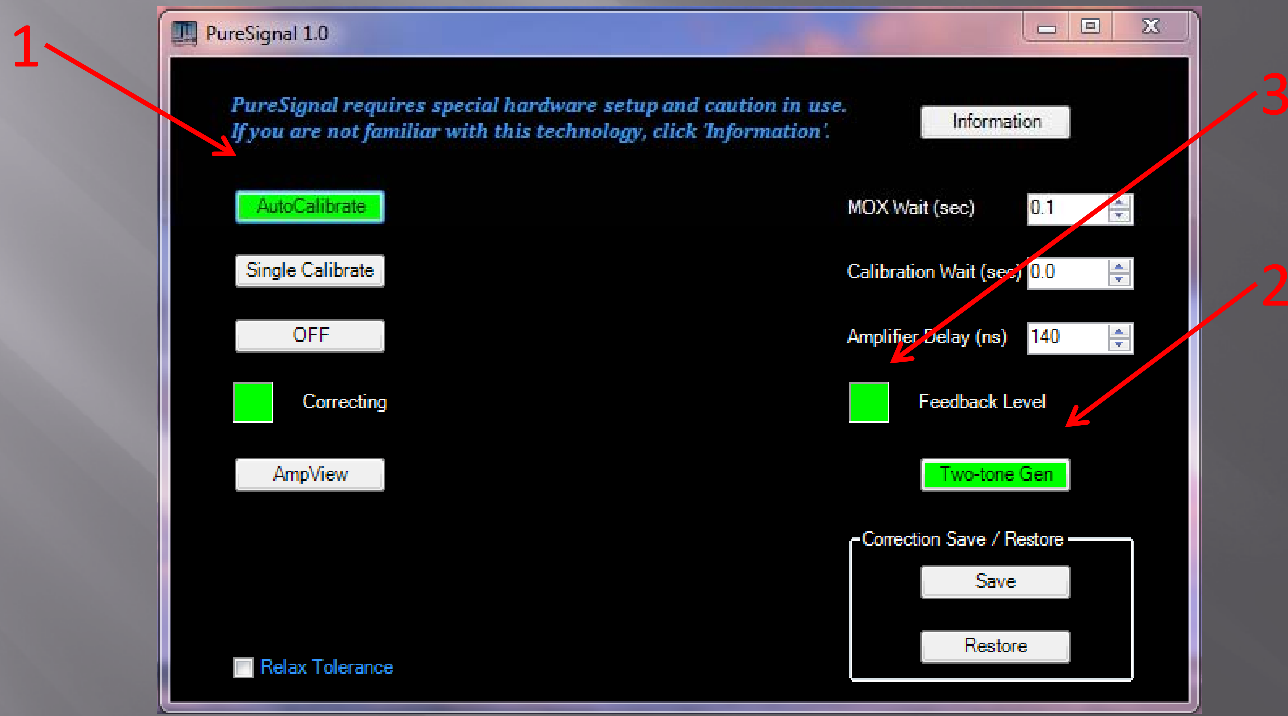
USING PURESIGNAL

1. Install your coupler.
2. Click “Linearity” to open the PureSignal form.

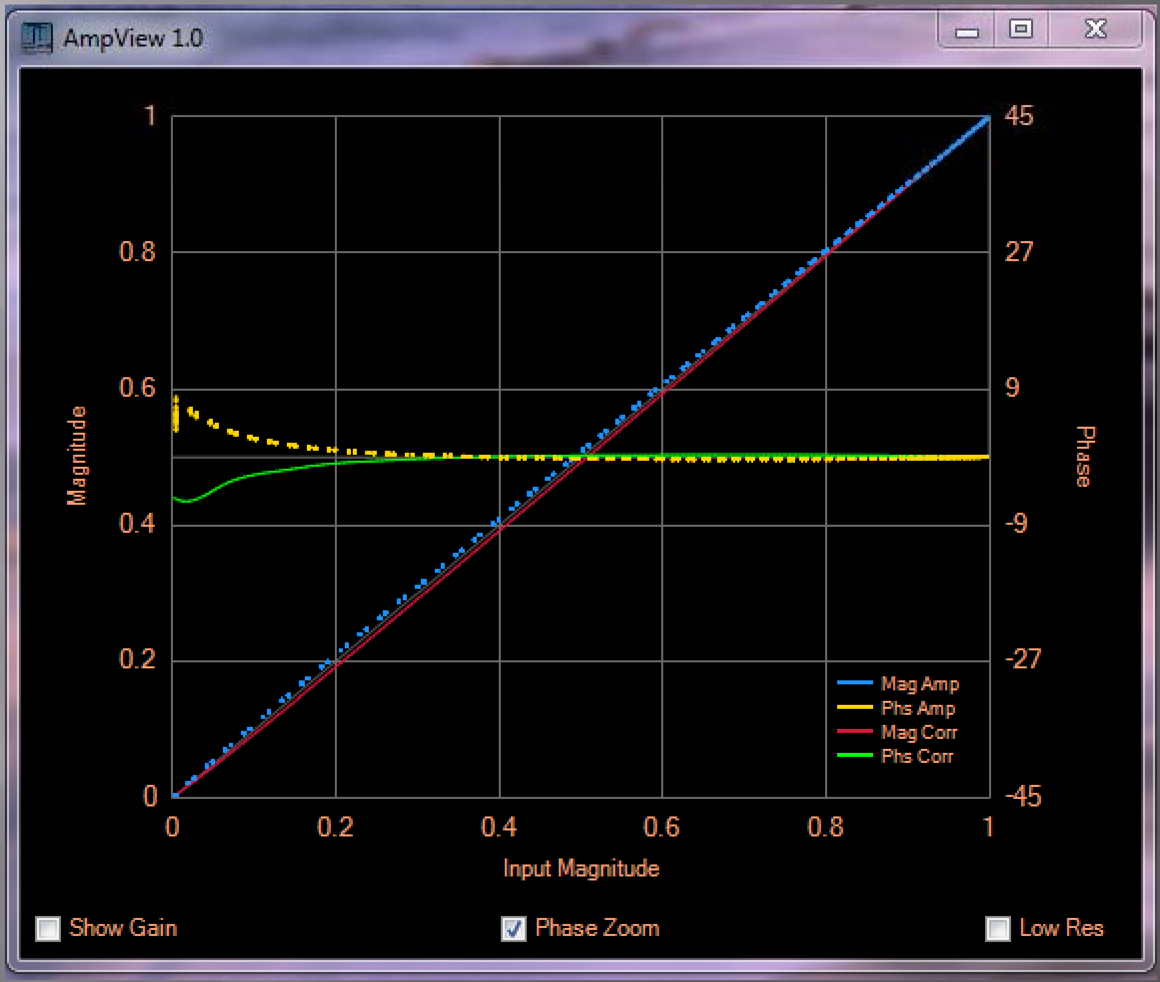


USING PURESIGNAL

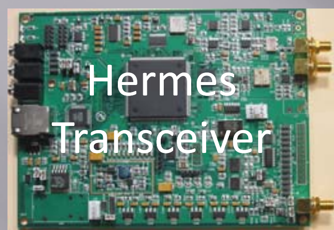
1. Click AutoCalibrate to activate PureSignal
2. Transmit audio or turn on the two-tone generator.
3. Adjust your attenuators for a GREEN Feedback Level indication.
4. If desired, adjust other controls per the “Information” document.
5. (Optional) Relax and click AmpView just to see what’s happening.



USING AMPVIEW

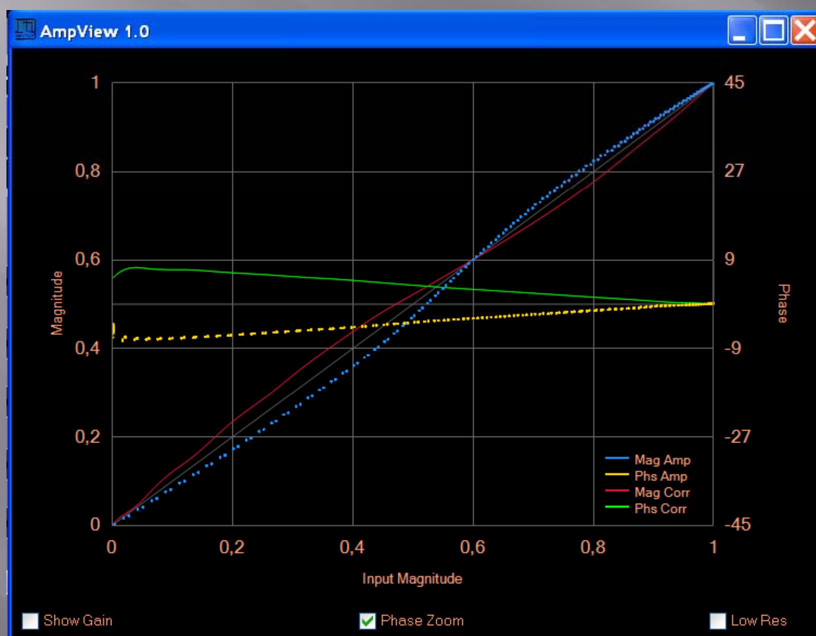


PURESIGNAL RESULTS
Kurt, DL9SM



→ SD2918 Class A → NXP, 2x BLF578

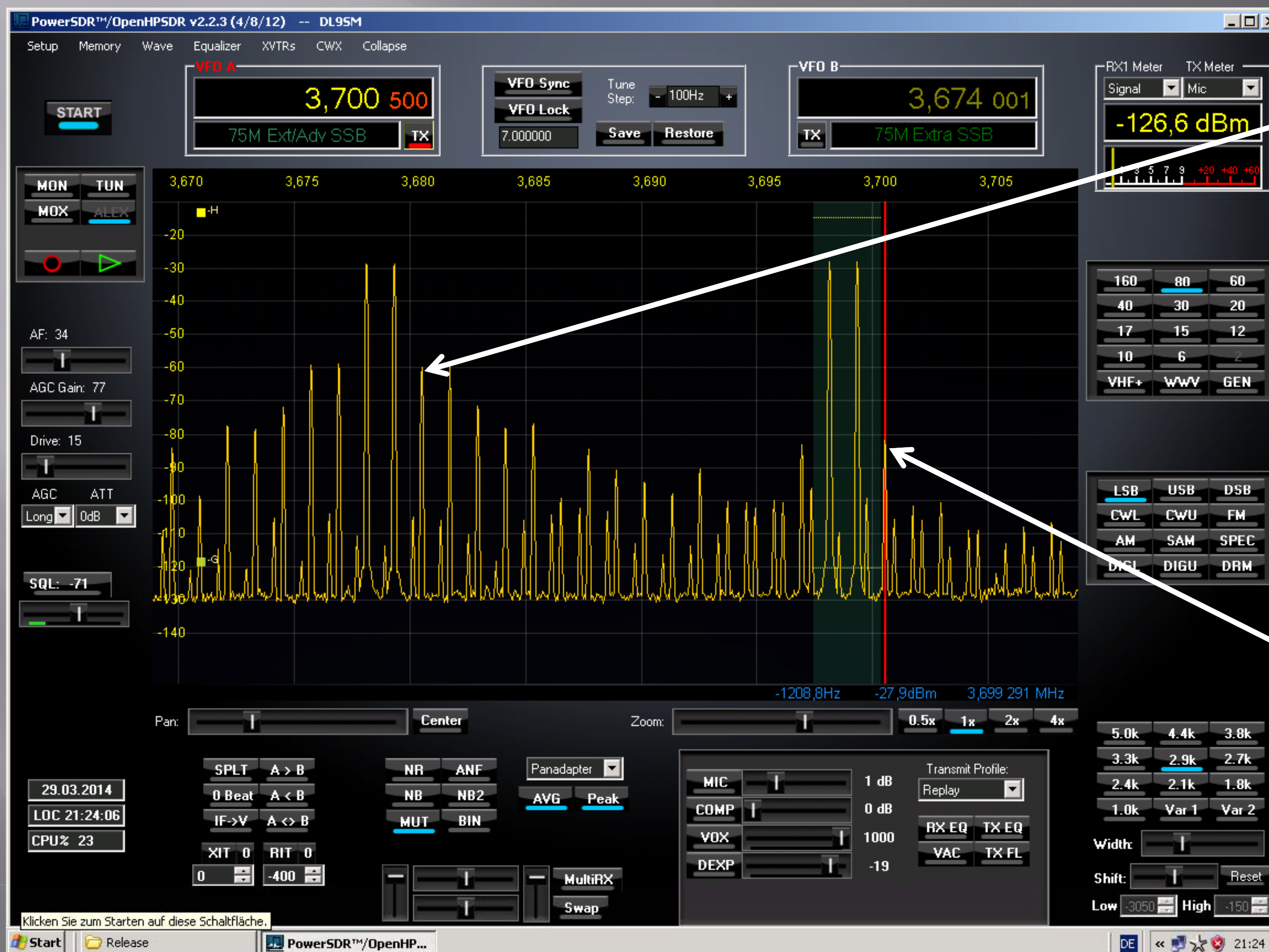
- 50V LDMOS Final
- Low Idq = 0.7A/device
- >1200W Capability



- 80M, 1 KW
- Low memory effects visible

PURESIGNAL RESULTS

Kurt, DL9SM



- PureSignal OFF
- IMD3 ~ -31dBt

- PureSignal ON
- IMD3 ~ -53dBt

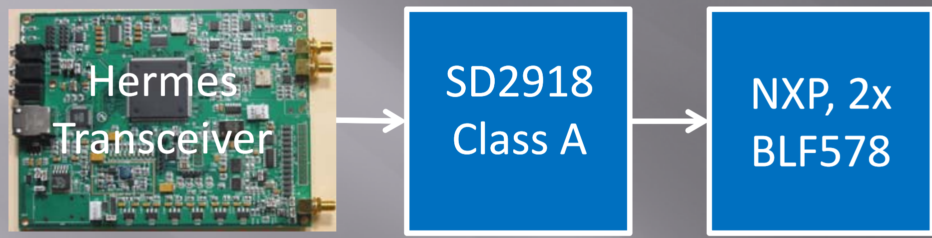
PURESIGNAL RESULTS
Kurt, DL9SM

- PureSignal OFF
- IMD ~ -30dB

- PureSignal ON
- IMD ~ -52dB

PURESIGNAL RESULTS

Kurt, DL9SM



- 50V LDMOS Final
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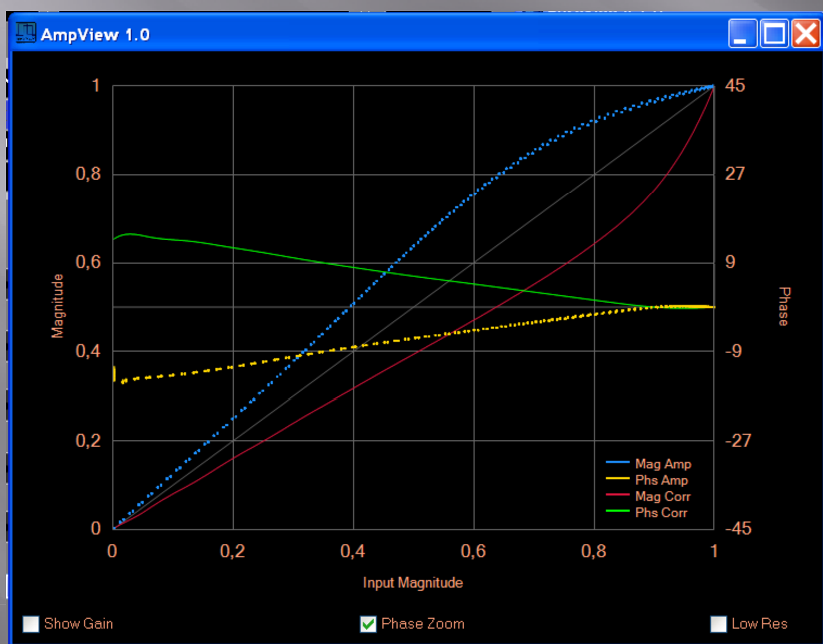
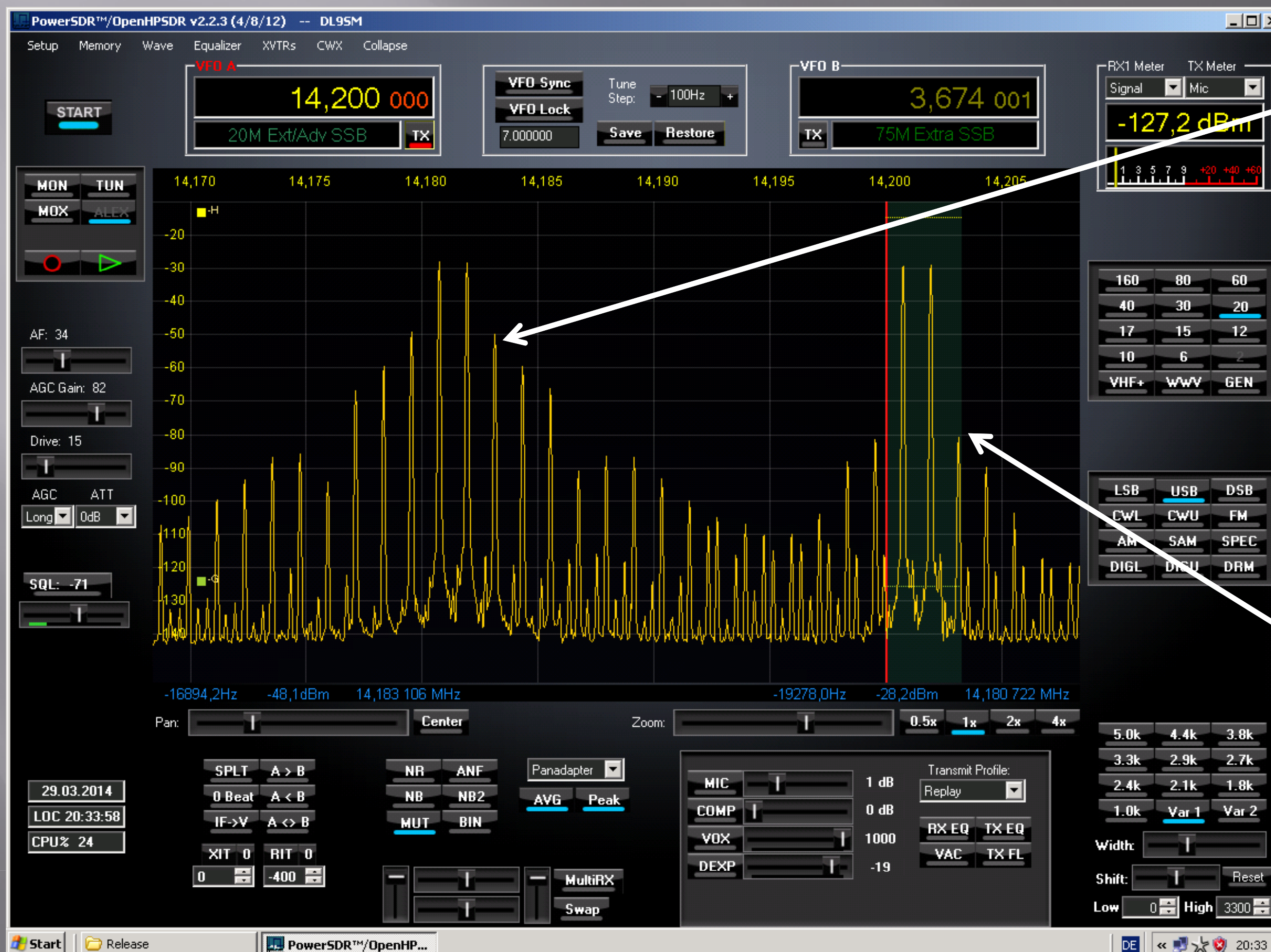


- 20M, 1 KW
- Most non-linear band for this amp
- Low memory effects visible
- Should correct well

PURESIGNAL RESULTS

Kurt, DL9SM



- PureSignal OFF
- IMD3 ~ -21dB

- PureSignal ON
- IMD3 ~ -51dB

PURESIGNAL RESULTS
Kurt, DL9SM

- PureSignal OFF
- IMD ~ -31dB

- PureSignal ON
- IMD ~ -51dB

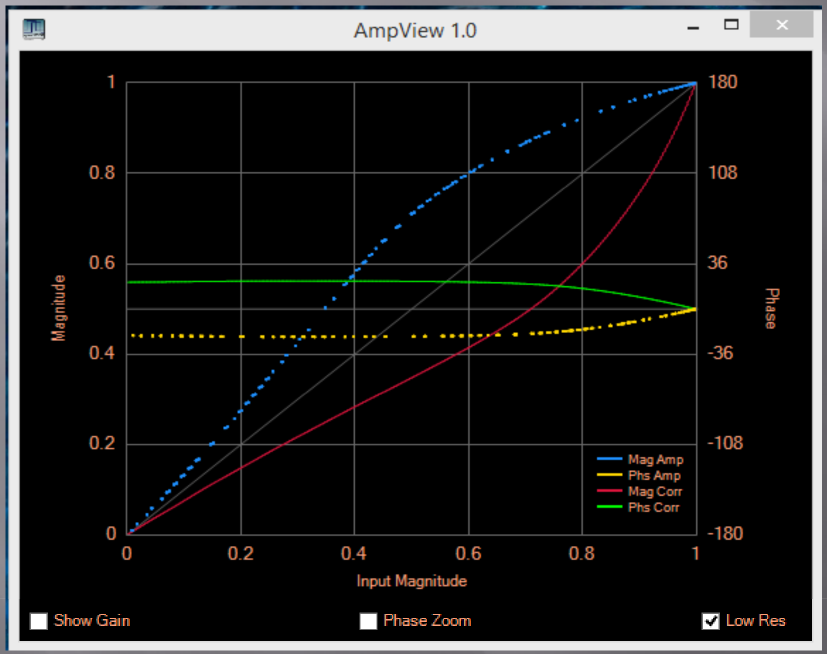
PURESIGNAL RESULTS
Clyde, K2UE

ANAN-100D

2M Xvtr

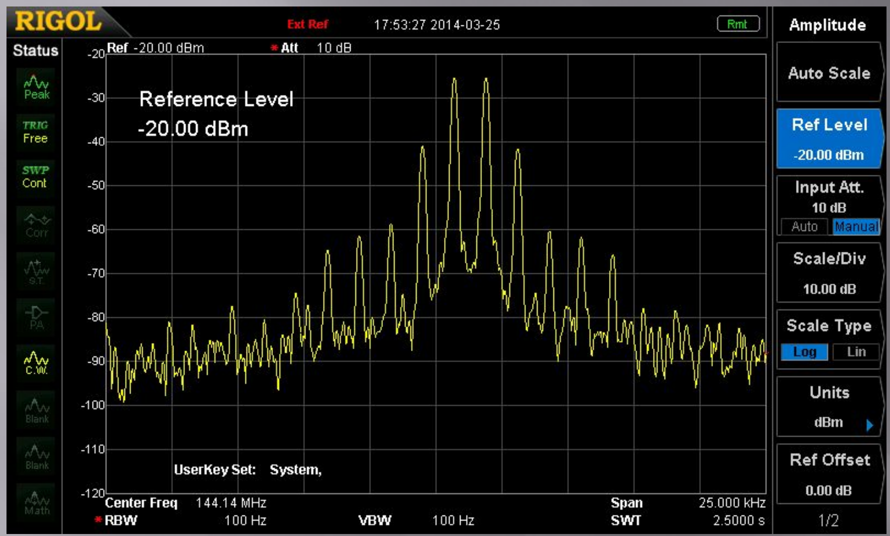
M[2] 2M-1K2

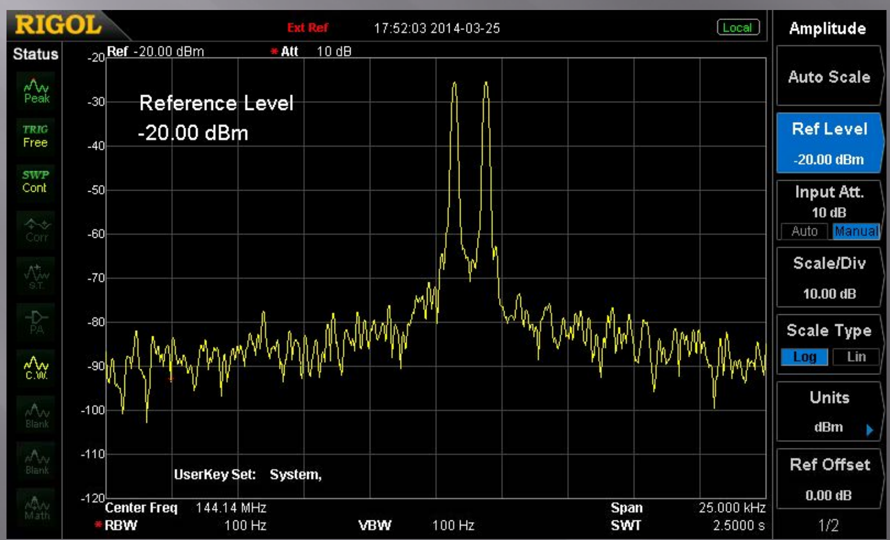
- ANAN Low-Pwr Xvtr Output
- Full-duplex Transverter
- 1200W 2M Amplifier



- 2M Amplifier is VERY non-linear
- LDMOS, Very low memory effects
- Should be very correctable!

PURESIGNAL RESULTS
Clyde, K2UE

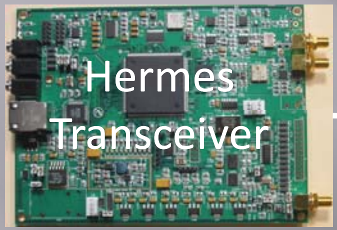




- PureSignal OFF
- IMD3 ~ -16dBt

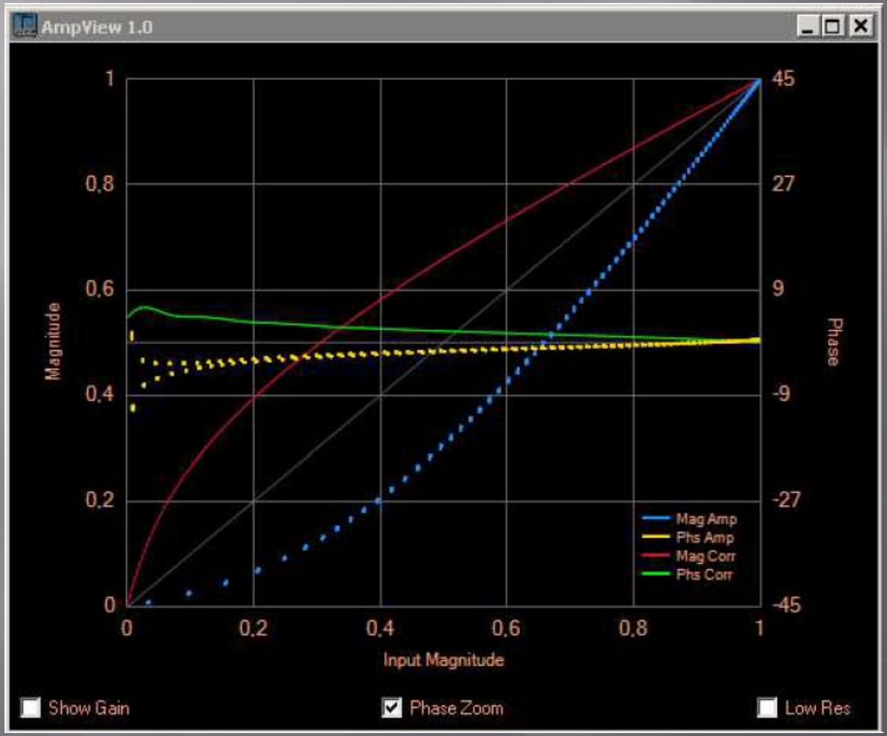
- PureSignal ON
- IMD3 ~ -48dBt

PURESIGNAL RESULTS
Helmut, DC6NY



Freescale MRFE6VP6300HR5

- Push-Pull LDMOS
- 1.8 – 70 Mhz.
- 300+ Watts
- Class AB or Class B



- 40 Meters
- Class B Operation
- Idq = 20 mA
- Drain efficiency = 80%

PURESIGNAL RESULTS
Helmut, DC6NY

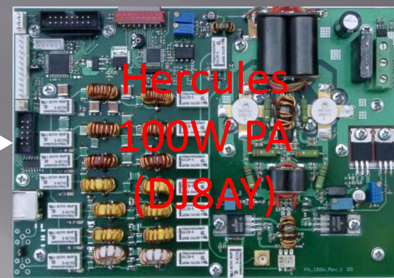
- 40 Meters, Class B
- PureSignal OFF
- IMD3 = -16 dBc
- IMD5 = -28 dBc

- PureSignal ON
- IMD3 = -51 dBc
- IMD5 = -64 dBc
- ~ 35 dB Improvement

PURESIGNAL RESULTS

Focko, DJ5JB

Two P-P Stages
TI OPA2674C



2x RD16HHF1 MOSFET
2x MRF492 BJT

2x 3-500Z
(Grounded-grid)

MIXED TECHNOLOGY

- 80M, 900 Watts
- IMD3 -28 → -55 dBc
- IMD5 -34 → -70 dBc

PURESIGNAL

What's Next?

- Exploration of algorithms to actively correct memory effects
    - Probably difficult for modes such as SSB and AM
    - Probably requires a different mathematical formulation than is currently used in Telecom
    - Some simulation already in place
    - More days and hours required!