Understanding *Adaptive Equalization* for Digital Television Transmitters

Presented to -

PBS Technology Conference

Presented by -
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Adaptive Digital Equalization

- What is it?

- Why do you need it?

- How does it work in the real world?

- What can you do to make it work the best?

# What is *Adaptive Equalization*?

- System for monitoring and compensating for linear and nonlinear distortion in the transmission system

- Maintains low distortion 8VSB signal

- Works even when you're not at the transmitter so changes in RF system performance are tracked and equalization adjustments are automatically made

What is Linear Distortion?

- Linear distortion exists when a system does not have the following characteristics:
  - Constant amplitude vs. frequency
  - Linear phase vs. frequency (i.e. constant group delay)
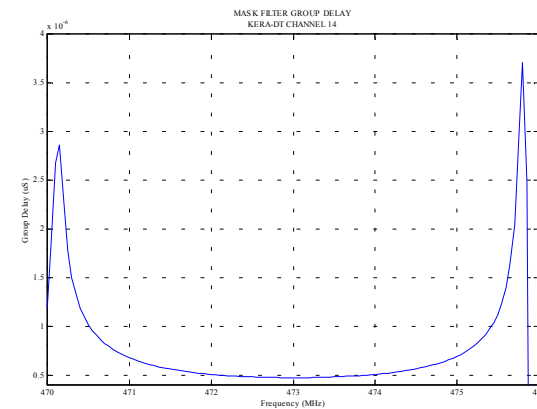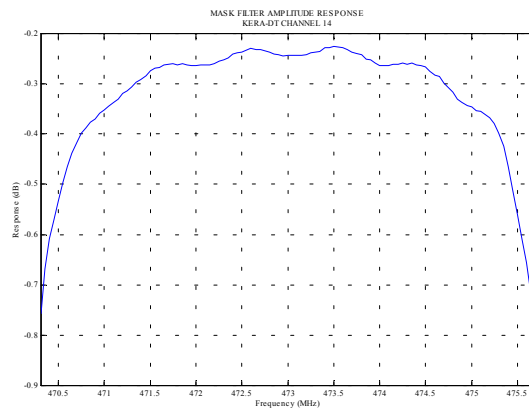
The Most Common Causes of Linear Distortion in 8VSB

- Tuned circuits:
  - Mask filter
  - Cavity amplifiers
  - Antennas

- VSWR
  - Antenna icing
  - Imperfect transmission line
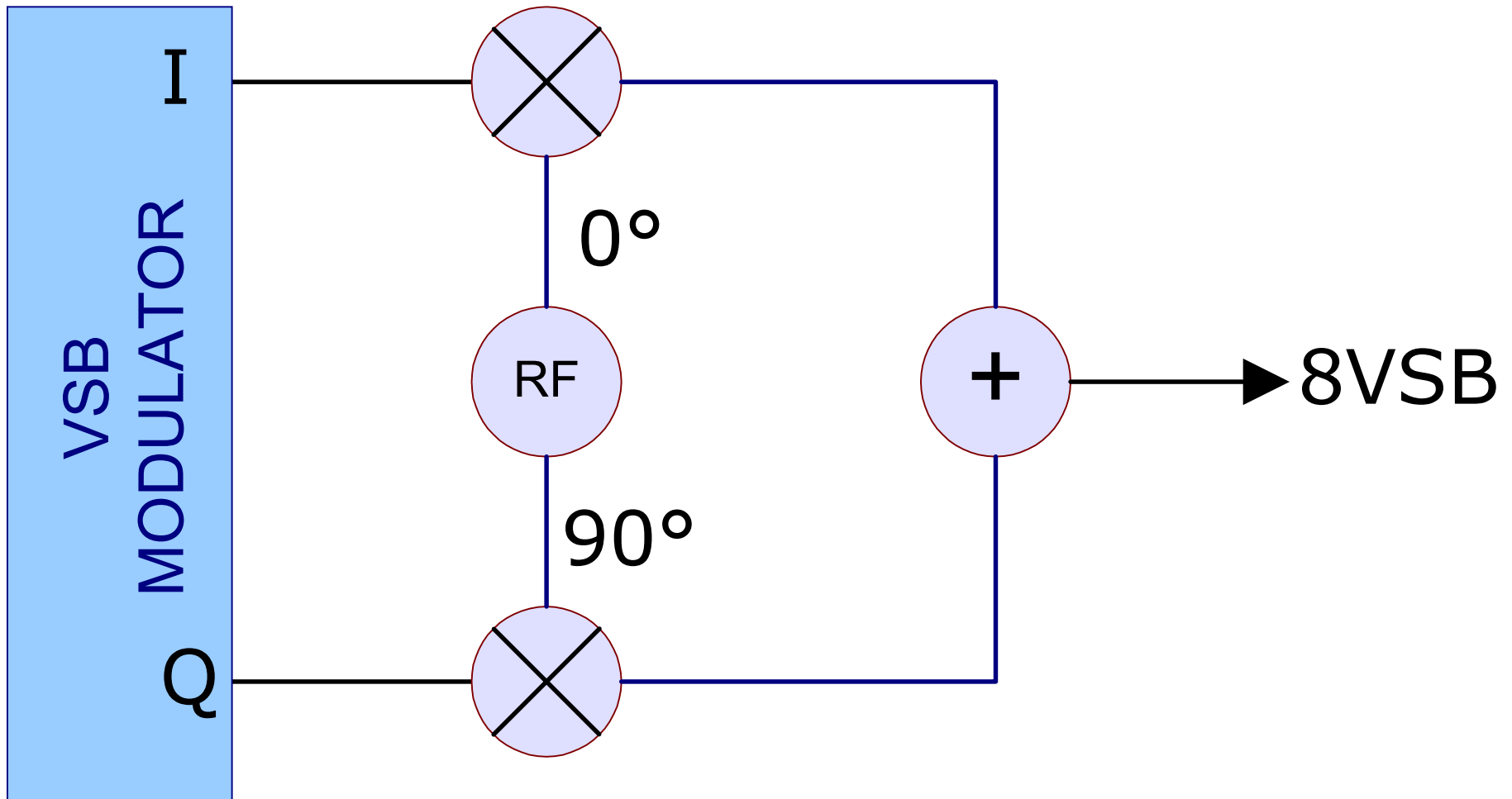
Why is Linear Distortion Bad?

- Linear distortion eats up the signal to noise margin of digital systems
  - Receiver equalizer must work harder to remove transmission system distortion
  - Linear distortion due to reflections at transmission site are harder for receiver to correct
  - Reduces coverage area

How to Recognize Linear Distortion ?

- Linear distortion causes random noise in the complex domain thus increasing EVM
  - Noise is independent of signal amplitude
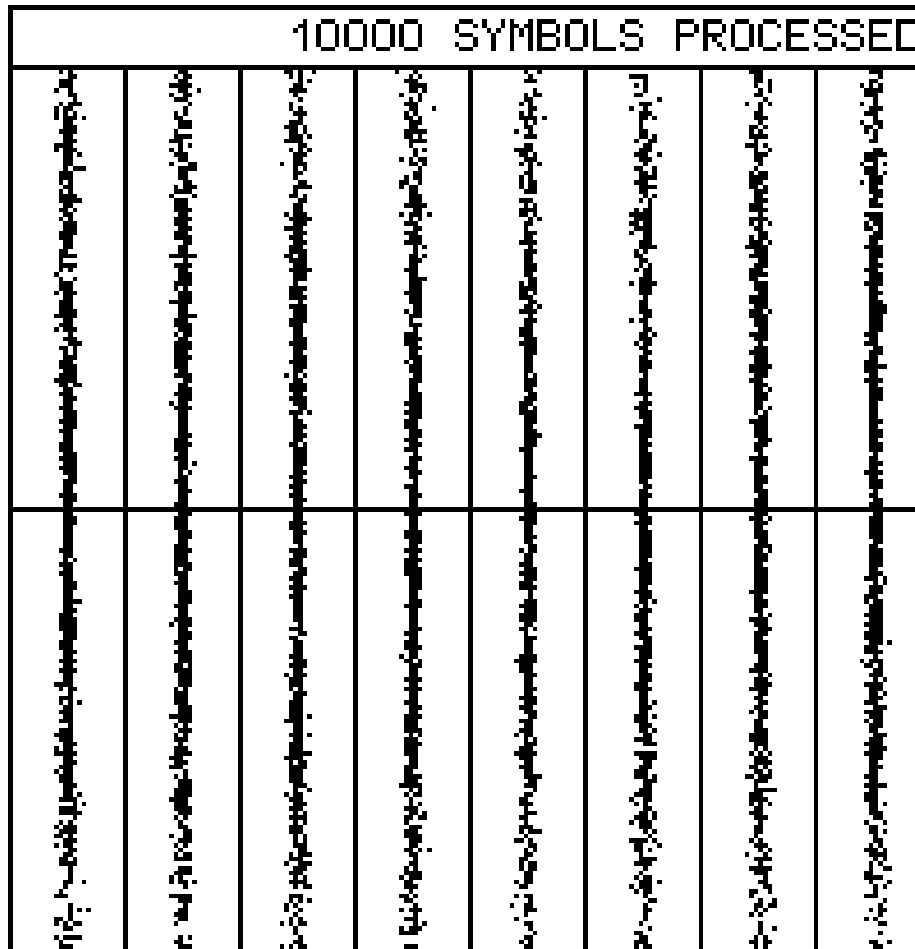 - Constellation diagram will be 8 fat lines instead of 8 skinny lines

Understanding Vector Modulation

Understanding Vector Modulation
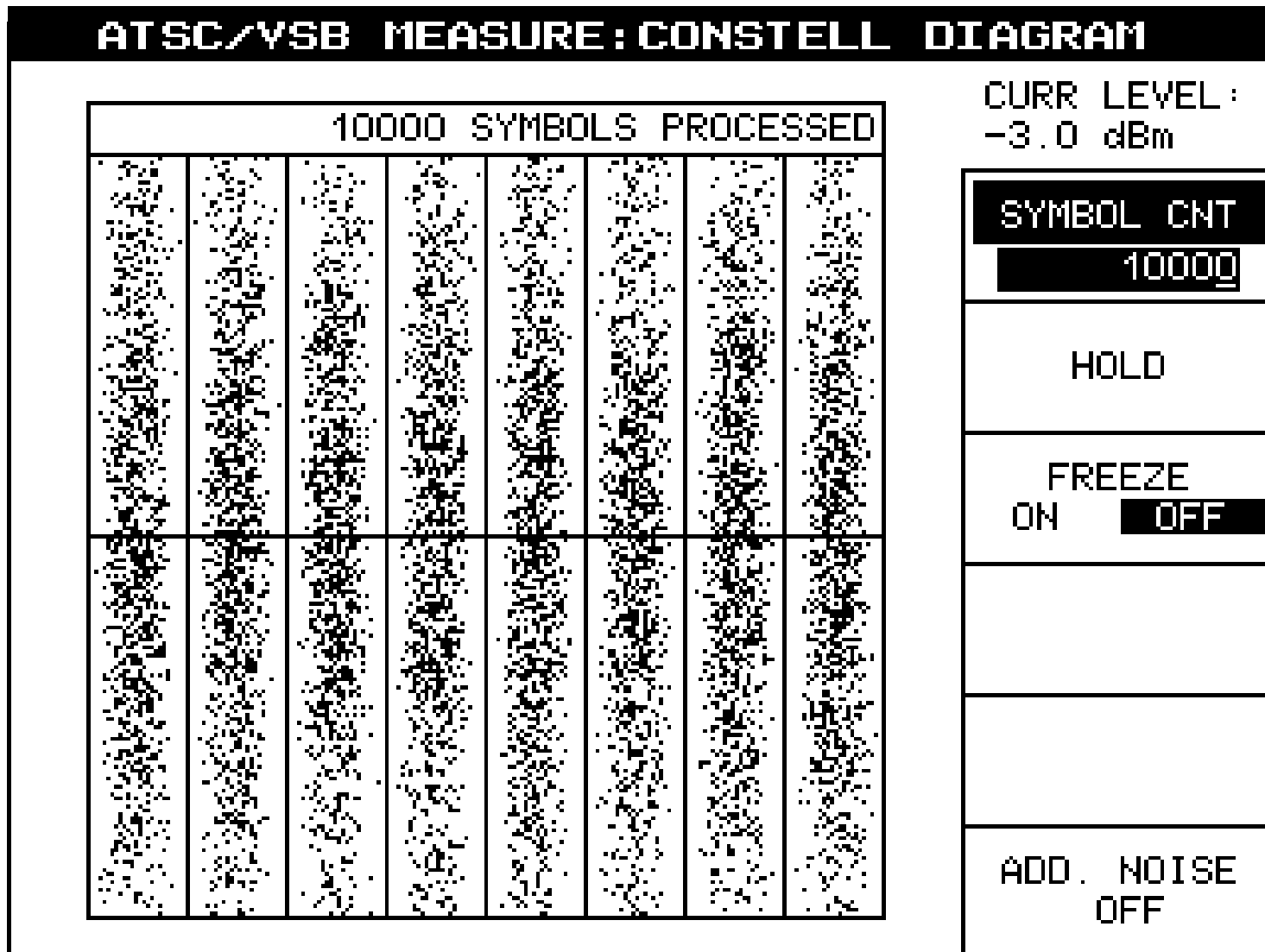
How to Recognize Linear Distortion ?

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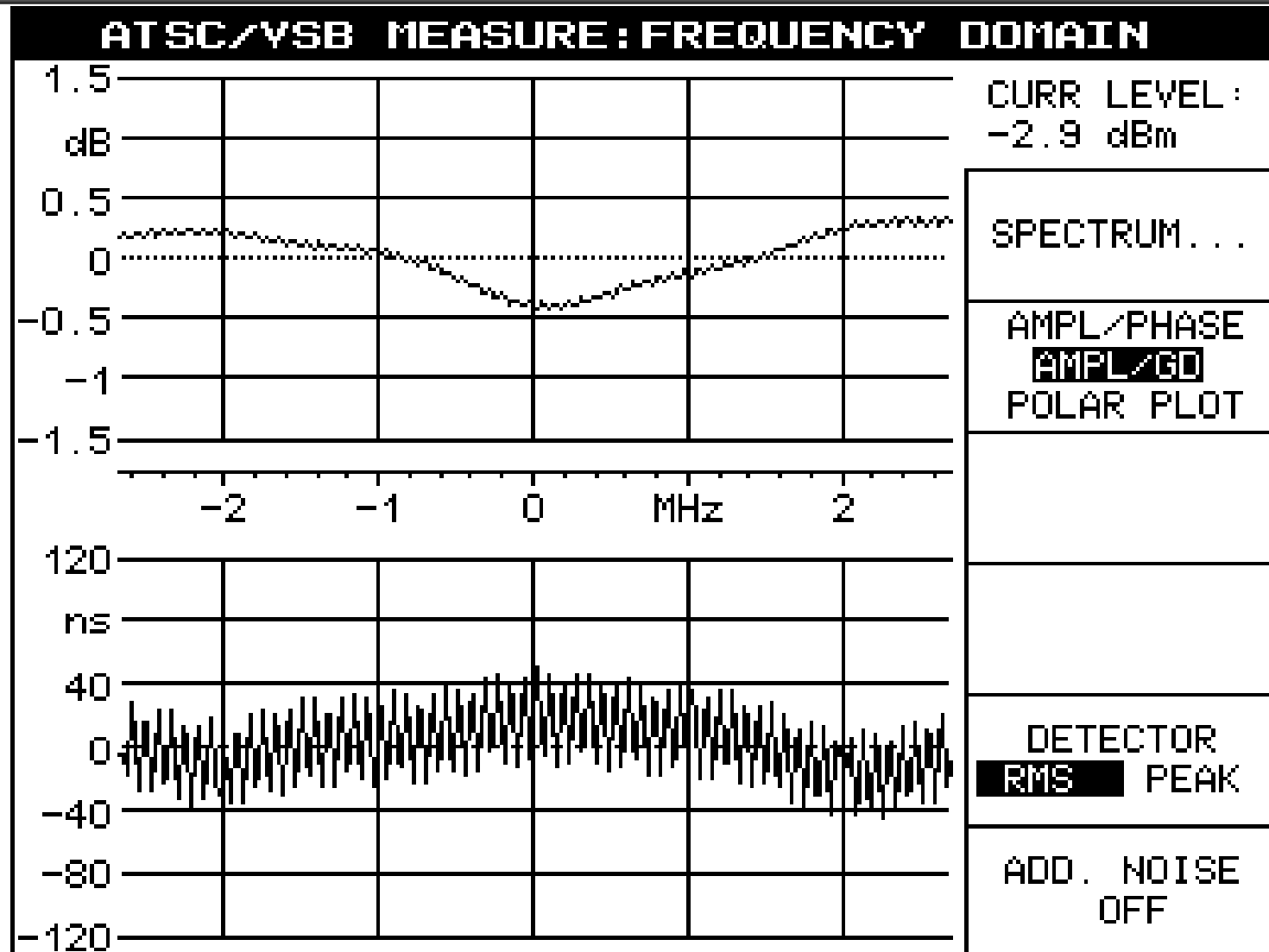
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ATSC/VSB MEASURE:VSB PARAMETERS

┌─────────────────┬──────────┬─────────────────┬──────────────┐
│ CENTER FREQ     │ CHANNEL  │ ATTEN : 40 dB   │              │
│ -21.50 MHz      │          │ -3.0 dBm        │              │
├─────────────────┴──────────┴─────────────────┼──────────────┤
│                                               │ CONSTELL     │
│ TRANSMISSION:                                 │ DIAGRAM...   │
│                                               │              │
│   PHASE JITTER (RMS)            --- °         ├──────────────┤
│   SIGNAL/NOISE RATIO          23.0 dB         │ FREQUENCY    │
│                                               │ DOMAIN...    │
│ SUMMARY:                                      │              │
│                                               ├──────────────┤
│   MOD ERROR RATIO (RMS)       22.8 dB         │ TIME         │
│   MOD ERROR RATIO (MIN)      <12.8 dB         │ DOMAIN...    │
│   ERROR VECTOR MAG (RMS)       4.7 %          │              │
│   ERROR VECTOR MAG (MAX)     >15.1 %          ├──────────────┤
│                                               │  VSB PARA    │
│                                               │ PILOT VALUE. │
│                                               ├──────────────┤
│                                               │              │
│                                               │              │
│                                               ├──────────────┤
│                                               │ ADD. NOISE   │
│                                               │    OFF       │
└───────────────────────────────────────────────┴──────────────┘
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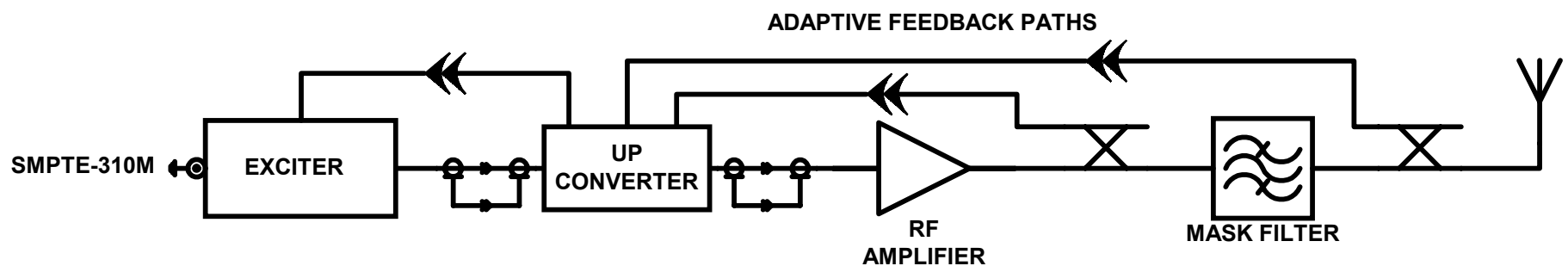
How Can Linear Distortion be Controlled?

- Linear distortion can be reduced or eliminated by measuring signal to noise (SNR) degradation and compensating for the transfer function of RF system through predistortion
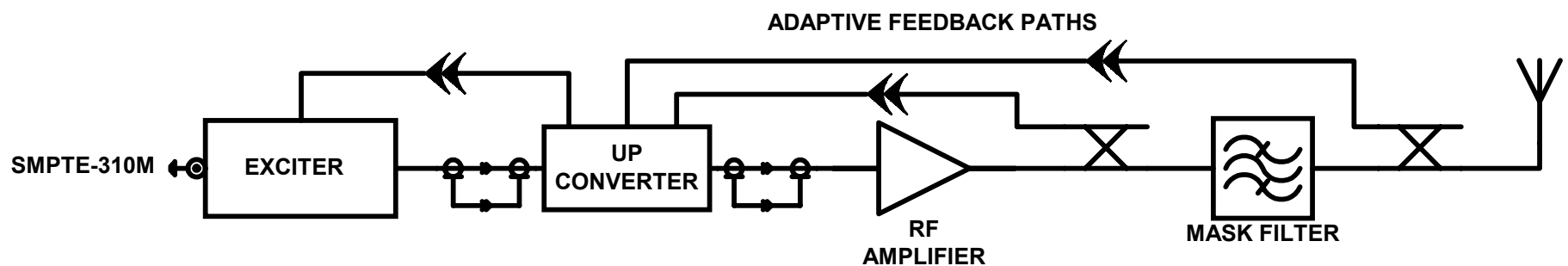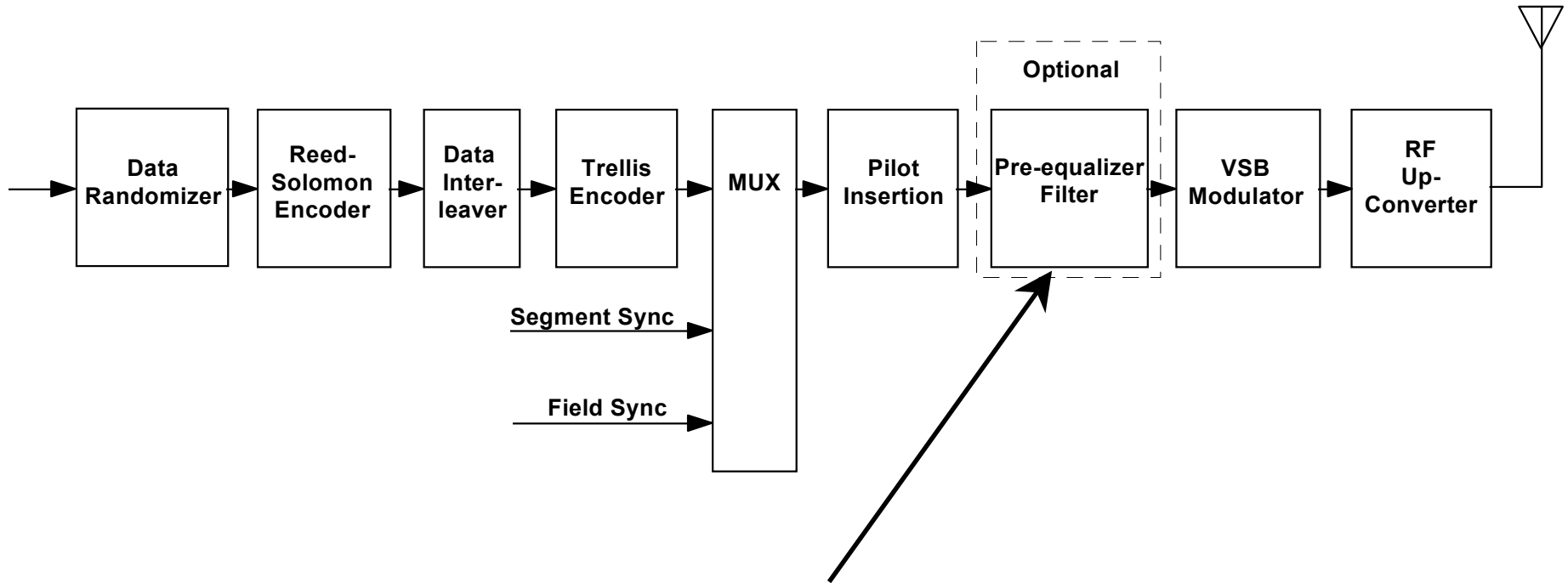
ADAPTIVE FEEDBACK PATHS

SMPTE-310M → EXCITER → UP CONVERTER → RF AMPLIFIER → MASK FILTER →

Adaptive Equalization to Correct Linear Distortion

- Adapative Equalization Process
  - Capture output of exciter
  - Capture output of mask filter
  - Demodulate transmitter output to same domain as exciter
  - Subtract both versions and adjust predistortion filter for least error

ADAPTIVE FEEDBACK PATHS

SMPTE-310M ——→ | EXCITER | → | UP CONVERTER | → ▷ RF AMPLIFIER → MASK FILTER → antenna

ADC Proprietary Information

Adaptive Equalization to Correct Linear Distortion

Optional

| Data Randomizer | Reed-Solomon Encoder | Data Inter-leaver | Trellis Encoder | MUX | Pilot Insertion | Pre-equalizer Filter | VSB Modulator | RF Up-Converter |

Segment Sync

Field Sync

- PREDISTORTION FILTER

What is Nonlinear Distortion?

- Nonlinear distortion exists when a system does not have the following characteristics:

  - Constant gain vs. output power

  - Constant phase vs. output power

The Most Common Causes of Nonlinear Distortion in 8VSB

- Active circuits
  - AGC amplifiers
  - Solid state power devices
 - IOT amplifiers

Why is Nonlinear Distortion Bad?

- Nonlinear distortion eats up the signal to noise margin of digital systems
  - No receiver can correct for nonlinear distortion
  - Causes spectral regrowth both inside the channel and outside the channel
  - Reduces coverage area

How to Recognize Nonlinear Distortion ?

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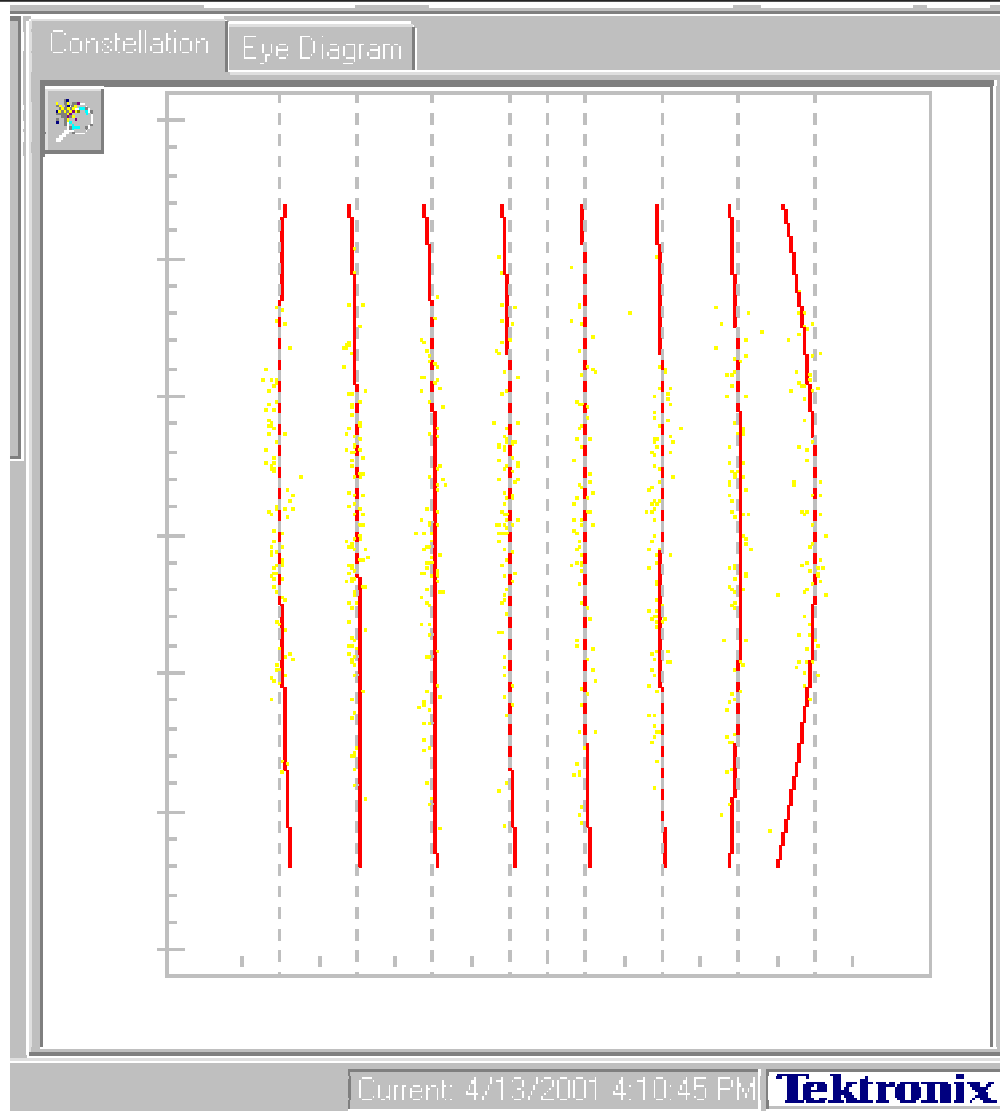
ADC Proprietary Information
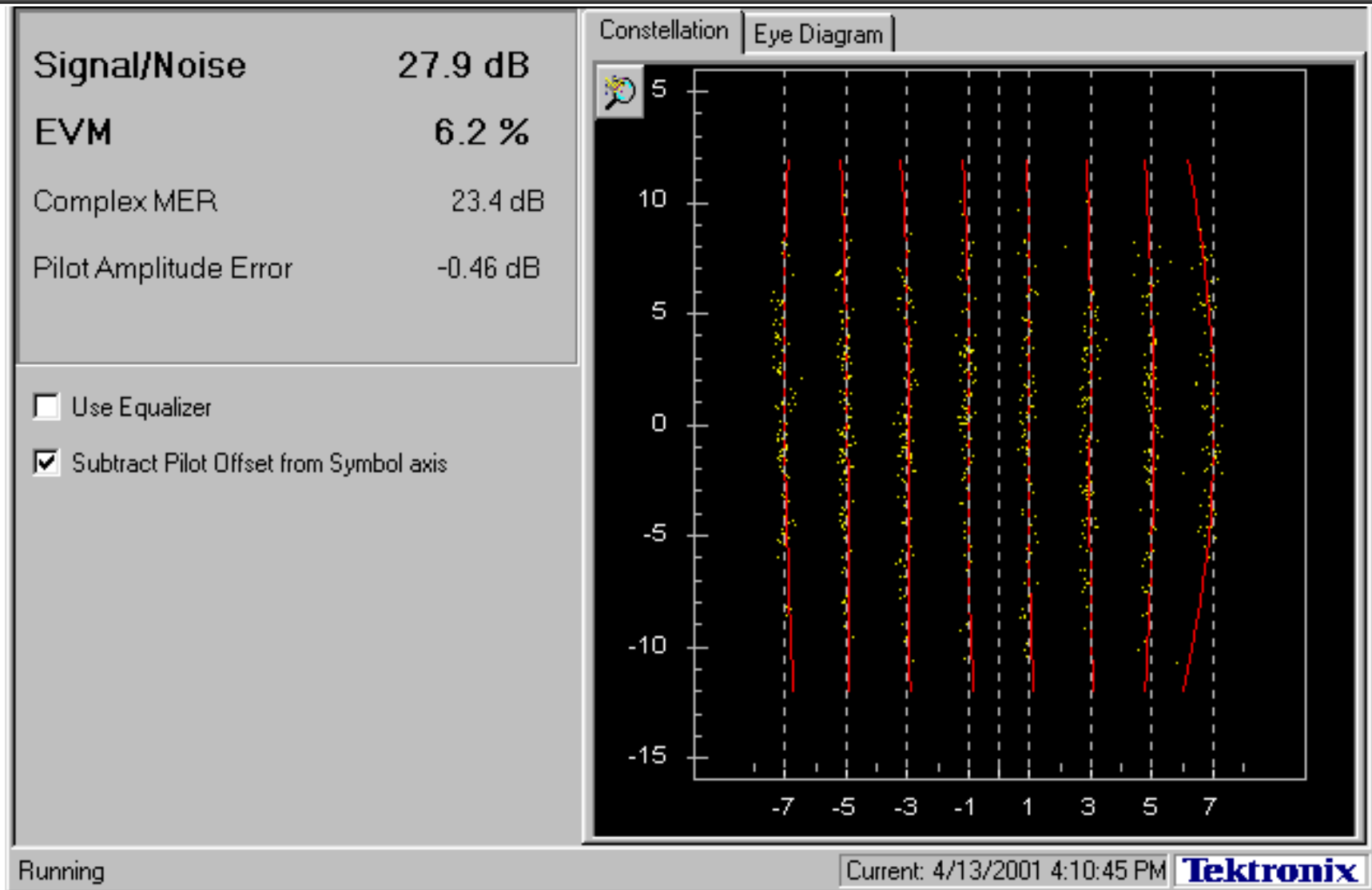
How Can Nonlinear Distortion be Controlled?

- Nonlinear distortion can be reduced or eliminated by measuring the error in the constellation as a function of output power and creating a predistortion system to compensate

ADAPTIVE FEEDBACK PATHS

SMPTE-310M   EXCITER   UP CONVERTER   RF AMPLIFIER   MASK FILTER
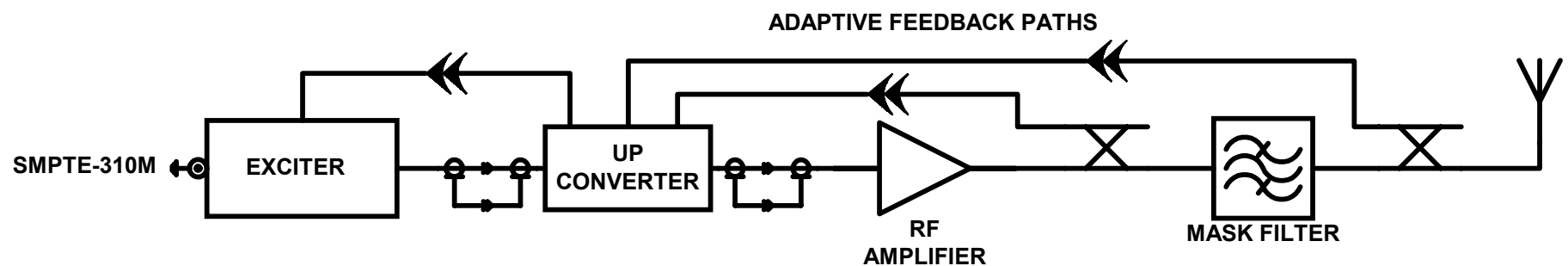
# Adaptive Equalization to Correct Nonlinear Distortion

- Adapative Equalization Process
  - Capture output of exciter
  - Capture output of RF amplifier
  - Demodulate transmitter output to same domain as exciter
  - Compute phase and gain error at all envelope levels and adjust predistortion system for least error

ADAPTIVE FEEDBACK PATHS

SMPTE-310M — EXCITER — UP CONVERTER — RF AMPLIFIER — MASK FILTER
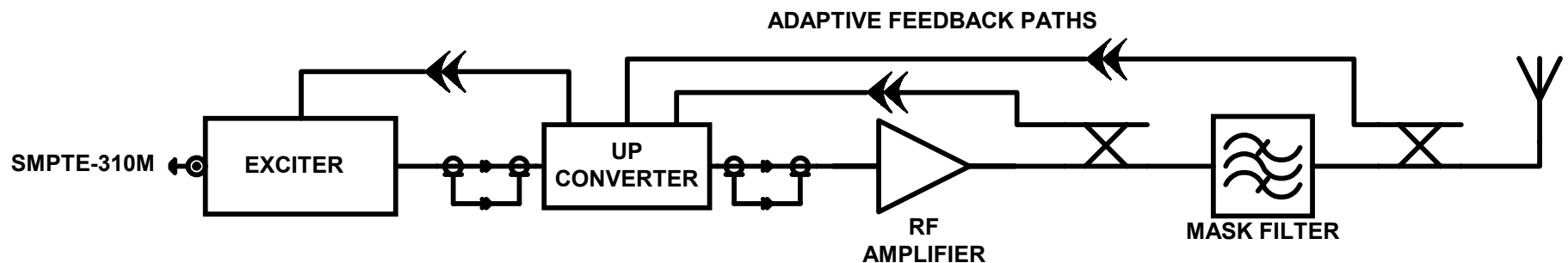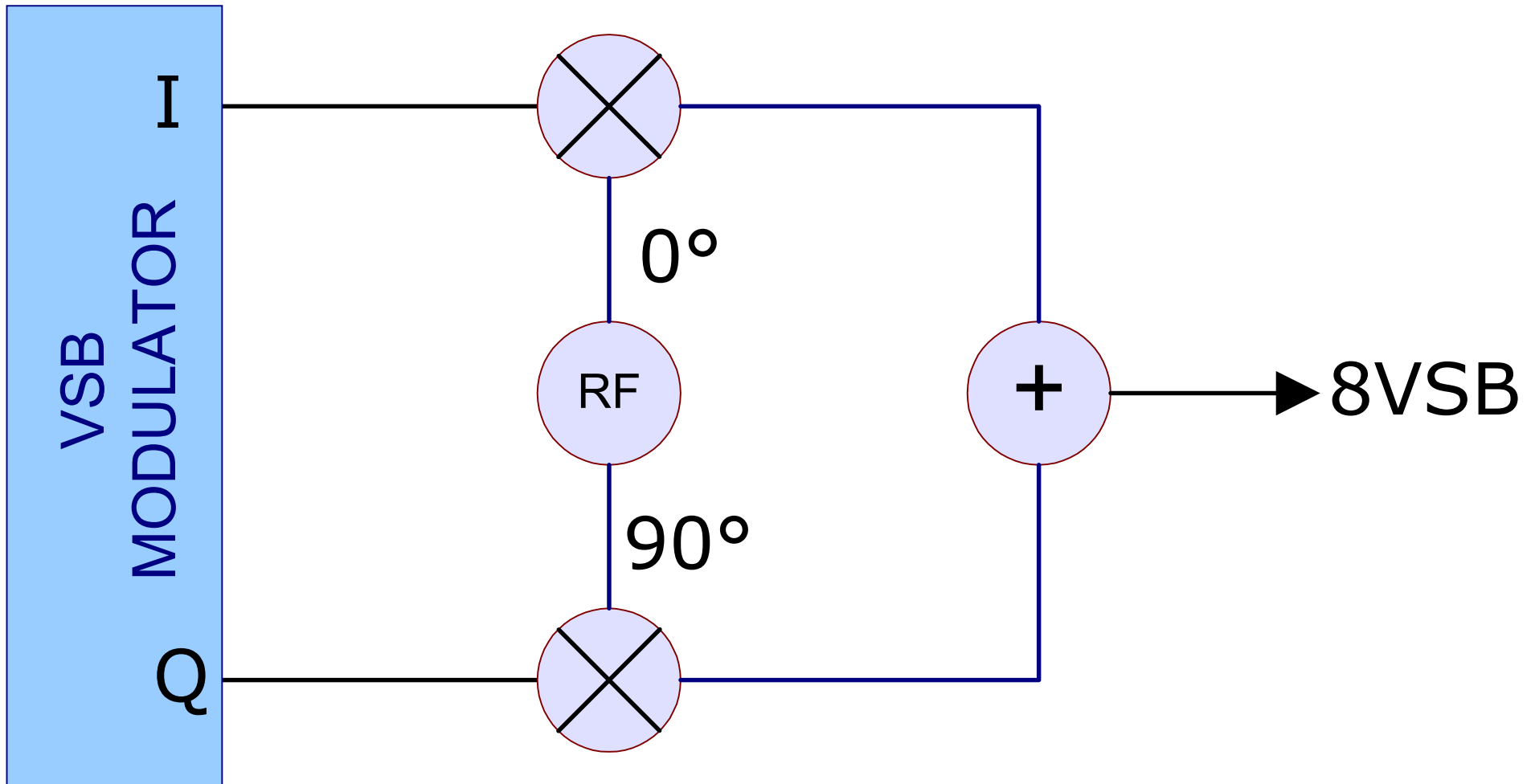
How To Correct Nonlinear Distortion
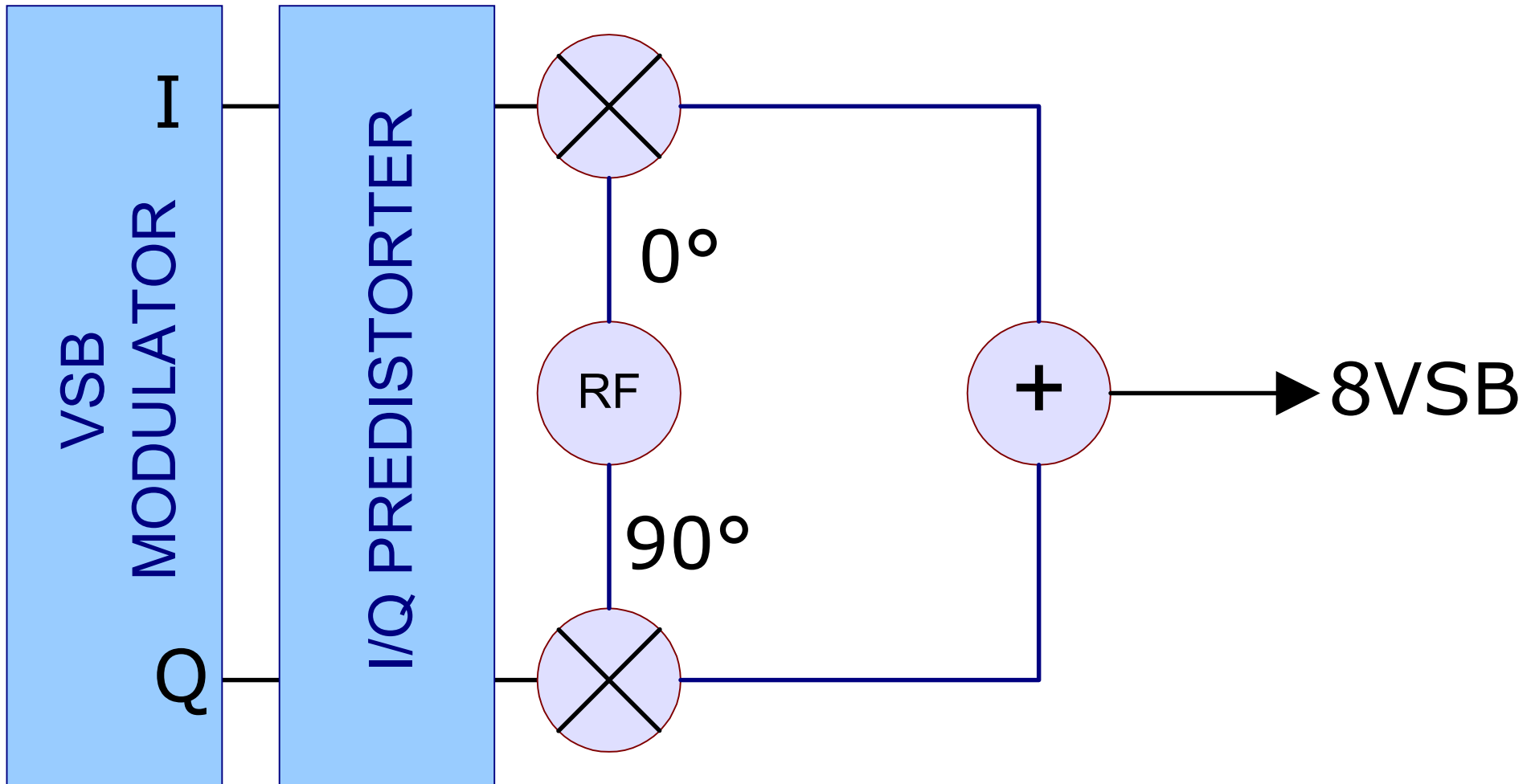
Maximizing Performance of Adaptive Systems

- Eliminate as much VSWR as possible

- Reduce temperature variations of mask filter

- Maintain the quality of the adaptive sample points and cabling

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Dan Dickey

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