Nonlinearity Test for ACT Upstream Transmitter

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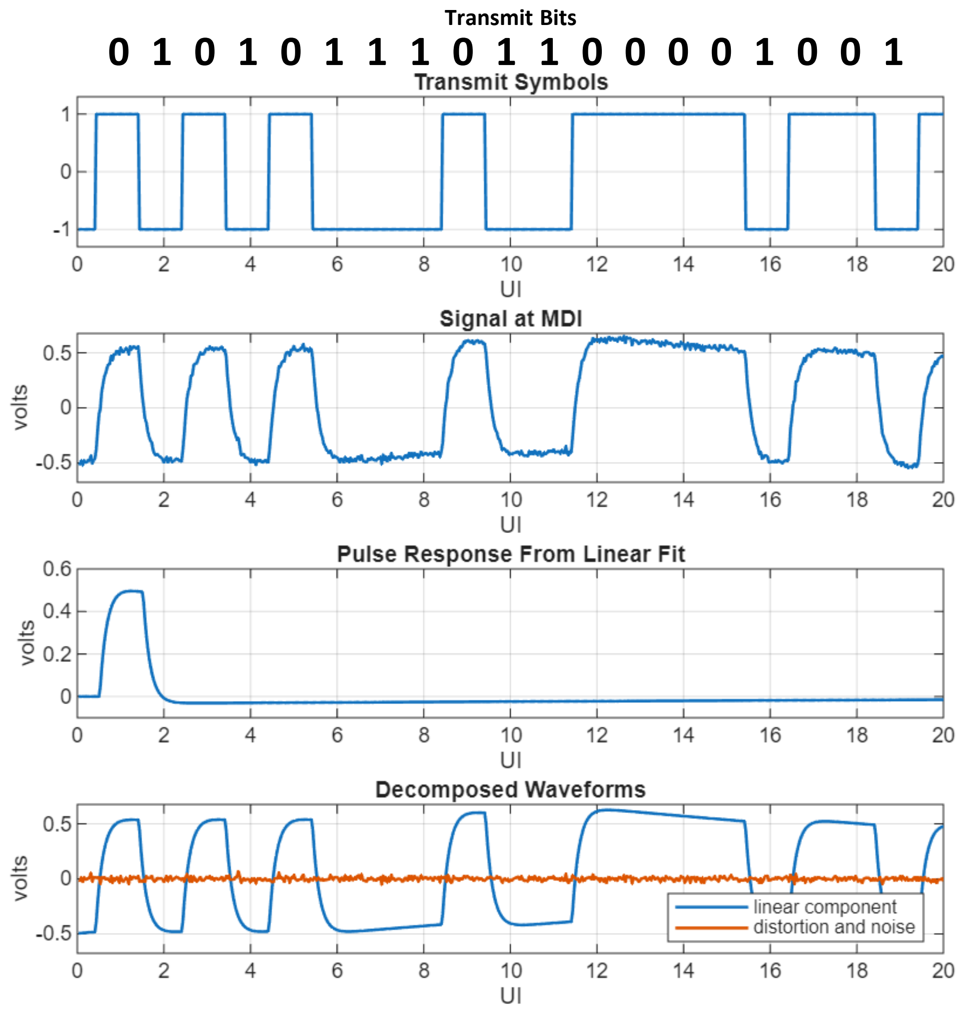
Overview

- The transmit electrical specifications includes a limit on the overall transmit nonlinearity or distortion
- In the current automotive specifications (IEEE 802.3bw, bp, ch and cy), the nonlinearity is measured as the residue of the linear fit to a waveform captured at the MDI
- The same approach is proposed for downstream trasnmitter
- Upstream transmit signal path in ACT includes differential Manchester encoding (DME), which is a nonlinear operation
- A method to use linear fit to measure distortion for a transmitter with DME is presented

Downstream: Nonlinearity Measurement

- Test procedure is defined similar to 802.3ch
- A long frame of known bits (PRBS13) is transmitted repetitively
- PAM2 maps the bits to transmit symbols
- The transmit signal is captured at MDI
- The pulse response from transmit symbols to MDI signal is calculated through linear fit
- The residue of linear fit represents distortion

2.5G



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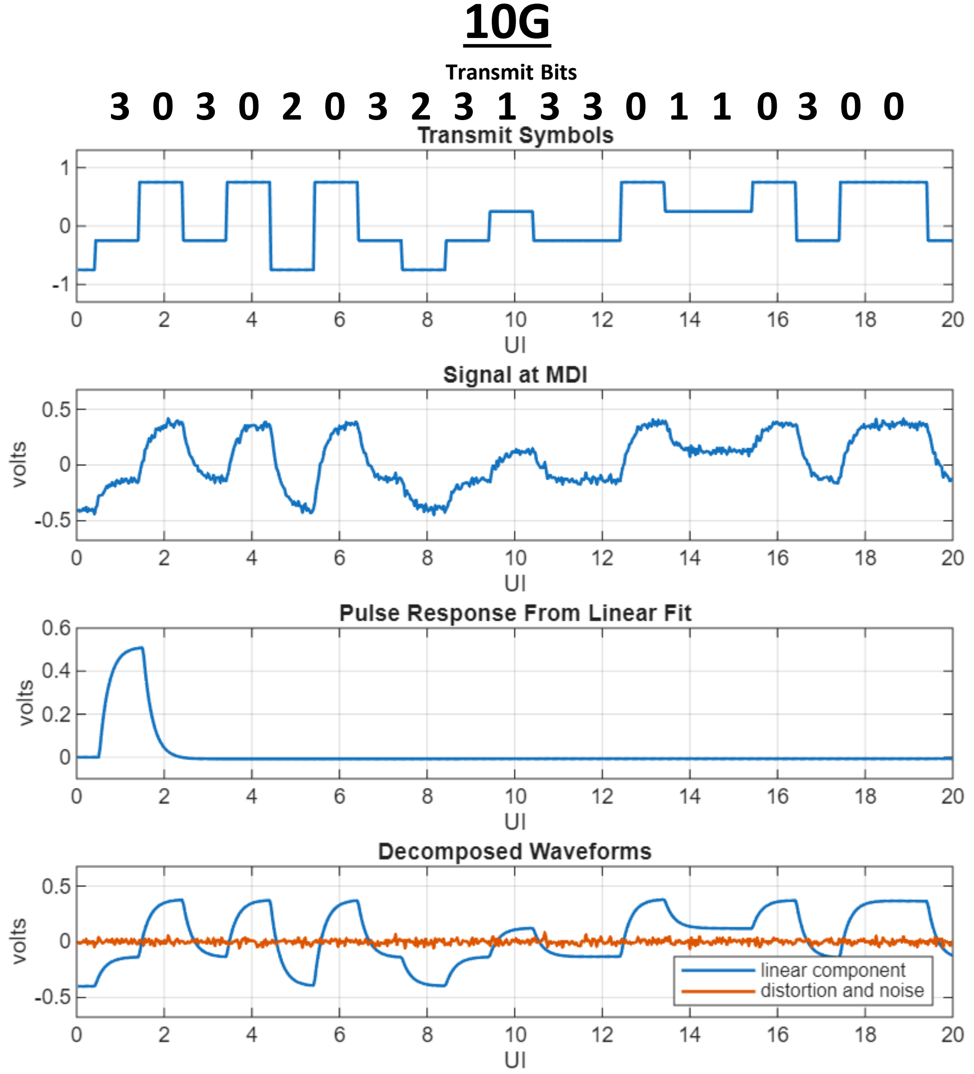
Downstream: Nonlinearity Metric

SNDR, the ratio of the power of signal to the power of residue, is chosen as a metric for nonlinearity or distortion

$$SNDR = 10log_{10}\left(\frac{P_{max}^2}{\sigma_e^2}\right)$$

- P_{max} is the maximum of the pulse response and is used as approximation for the RMS of the signal
- σ_e^2 is the total power of residue and noise



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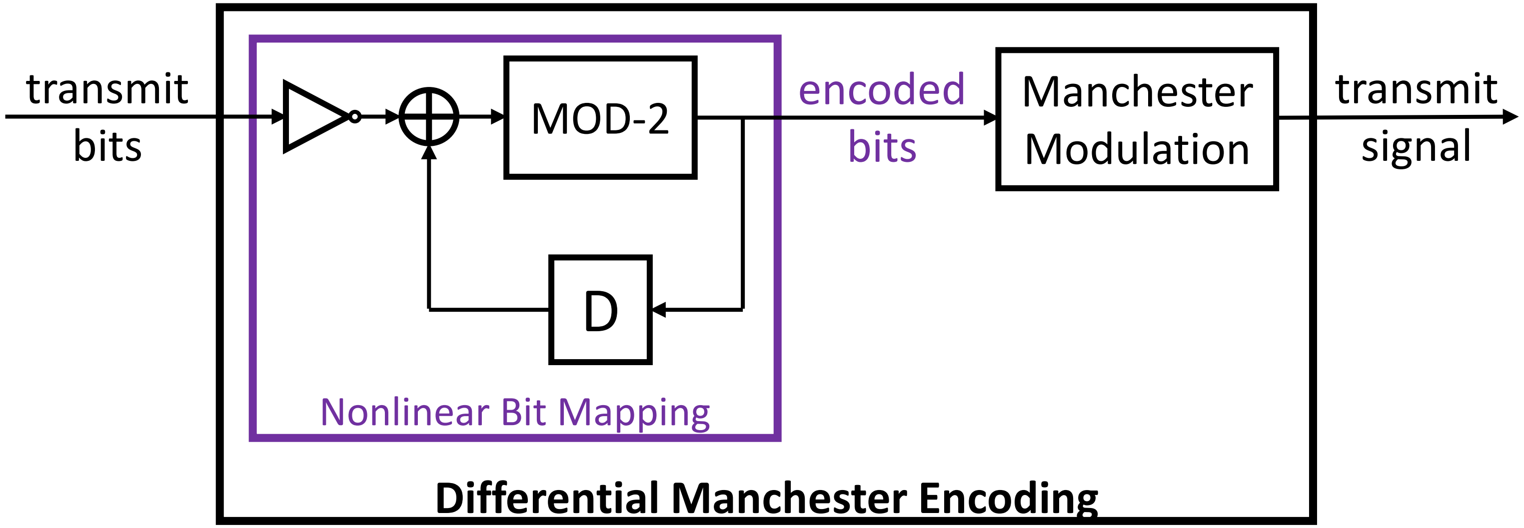
Upstream: DME and Nonlinear Bit Mapping

It is shown (sedarat 202411) that DME can be decomposed to

- A mapping of transmit bits to encoded bits – a nonlinear operation
- Simple Manchester modulation of the encoded transmit symbols – a linear operation

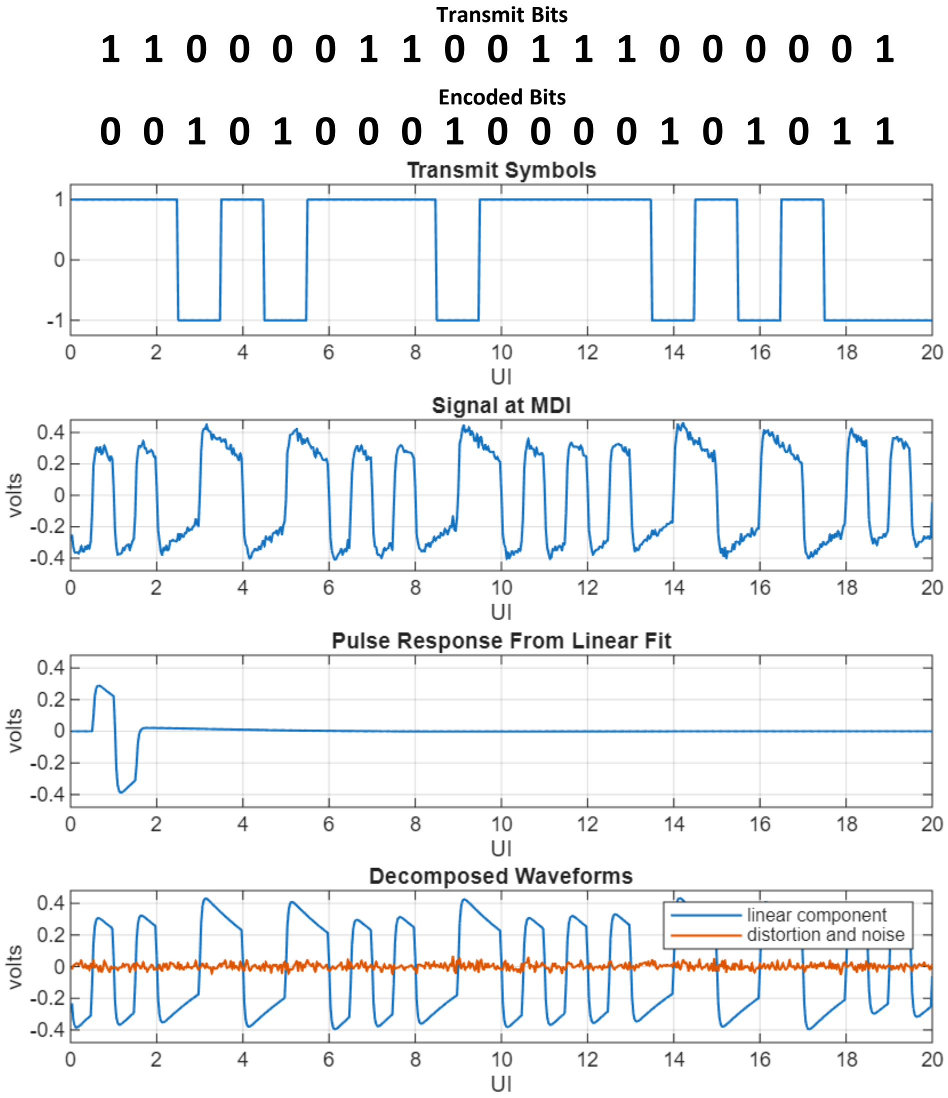


Transmit Bits	Encoded Bits		Transmit Symbol
	previous	current	
0	0	1	-1
0	1	0	+1
1	0	0	+1
1	1	1	-1

Upstream: Nonlinearity Measurement

- Transmit signal is nonlinearly related to transmit bits but linearly to encoded bits

- The encoded bits can be used as the source of the transmit symbols to do a linear fit to the capture waveform at MDI to
  - Calculate the pulse response in the transmit path
  - Calculate the residue of the linear fit



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Upstream: Nonlinearity Metric

- Similar to downstream, SNDR may be used as the metric for nonlinearity

- Droop has a more considerable effect in the upstream pulse response
  - P_{max}^2 may not be a good approximation of the signal power in upstream

- A variant of SNDR is proposed for upstream:

$$SNDR = 10log_{10}\left(\frac{\frac{1}{M}\sum_k p^2(k)}{\sigma_e^2}\right)$$

M = number of samples of the captured waveform in each symbol

200.10.2.2 Transmitter linearity

With the transmitter in test mode 4, transmitting in 100M mode, and using the transmitter test fixture 1 shown in Figure 200–17 for -T1 and Figure 200–18 for -V1, the transmit signal is captured per 85.8.3.3.4 with a minimum of *M=14*. The effective transmit baseband symbols, $x(n)$, is derived by noting that Differential Manchester encoding includes an implicit nonlinear mapping. This nonlinear operation maps the transmitted PRBS13 bits d_{in} to another set of pseudo-random bits d_{out}, which in turn maps to the implicit transmit baseband symbols $x(n)$ all according to Table-000.

Transmit Bits	Encoded Bits		Baseband Symbols
	previous	current	
$d_{in}(n) = \text{PRBS13}$	$d_{out}(n-1)$	$d_{out}(n)$	$x(n)$
0	0	1	-1
0	1	0	+1
1	0	0	+1
1	1	1	-1

Table-000 – Mapping table to generate the implicit transmit symbols from the PRBS13 transmit bit

Given the implicit transmit symbols $x(n)$, and the captured waveform $y(k)$, compute the linear fit pulse response $p(k)$ and the standard deviation of linear fit error $e(k)$ according to 85.8.3.3.5 and using $N_p = 100$ and $D_p = 2$. The transmitter SNDR distortion is defined as:

$$SNDR = 10log_{10}\left(\frac{\sigma_p^2}{\sigma_e^2 + \sigma_n^2}\right)$$

Where $\sigma_p^2 = \frac{1}{M}\sum_k p^2(k)$, and σ_e and σ_n are the standard deviation of $e(k)$ and noise, respectively. The transmitter SNDR distortion shall exceed 30 dB.

Summary

- Transmit linearity test, as defined for downstream direction, may not be directly extended to upstream because DME is a nonlinear operation
- This difficulty can be overcome using the encoded bits as the source of transmit symbols in the linear fit operation
- A variant of SNDR, which uses average pulse power, is proposed for a more accurate calculation of the transmit signal power
- Future consideration: average pulse power may also be a good choice to calculated SNDR for downstream transmitter

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Thank You