Transmit Linearity Test proposal for TDD-based 802.3dm Specification

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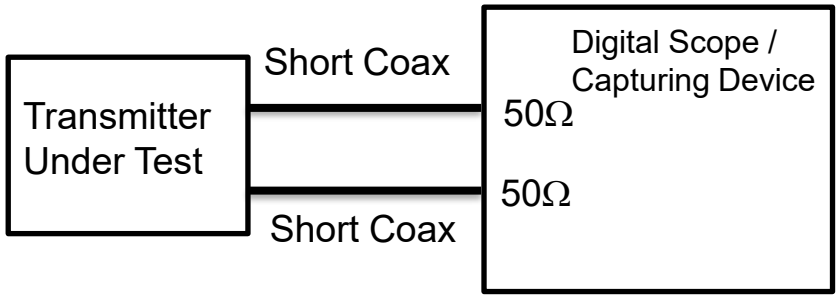
Transmitter Linearity Testing

- Transmitter Linear Testing or test mode 4 is discussed in this presentation for TDD based 802.3dm PHY.
- The testing is simplified since there is no overlap between the transmit and received signaling.
- The testing requirements, setup, and a postprocessing script are provided to qualify a transmitter for linearity.

Linearity Test Requirements

- Transmitter distortion is measured by capturing the test mode 4 waveform at rated baud rate using transmitter test fixture 1.
- The peak distortion is determined by sampling the signal output with the symbol rate clock at an arbitrary phase and processing a block of consecutive samples with the pseudo-code given in this presentation or an equivalent.
- The captured block of signal shall be at least 4000 transmitted symbols and be sampled with the minimum 10X over sampling. The transmit baud rate may be reduced to 1Gsps by repeating the symbols using the same clock edge as in normal mode of operation.
- The peak distortion values, measured at a minimum of 10 equally spaced phases of a single symbol period, shall be less than 20mV when the peak signal level is normalized to 1V. The 20mV limit applies to PAM2 transmitters. For PAM4 transmitter, the limit is 15mV.

Linearity Test Setup



10X Oversampling
Compared to baud rate

- The transmitter test fixture1 is used for Linearity measurements.
- For Coaxial applications, only one wire is connected.
- The measured signals are over post processed with the proposed MATLAB script or an equivalent.

Linearity Test Verification Script

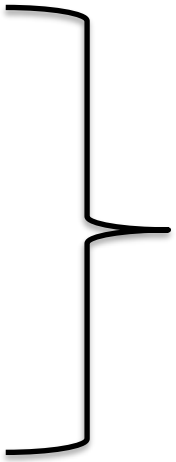
```
clear
Ns=2^11-1; % Scrambler length
Nc=70; % Canceller length
Modulation=2; % Choices are 2 or 4 for PAM2 and PAM4

% Generate scrambler sequence
scr=ones(Ns,1);
for i=12:Ns
scr(i)=mod(scr(i-11) + scr(i-9),2);
end

% Generate tm4 (test mode 4) for a given modulation
if Modulation==2
  tm4=2*scr-1;
elseif Modulation==4
  tm4=ones(Ns,1);
  map=[-1;-1/3;1;1/3];
  DS=[scr,mod(circshift(scr,3) + circshift(scr,8),2)];
  data = 2*DS(:,1)+DS(:,2);
  for n=1:length(DS)
  tm4(n) =map(data(n)+1);
  end
else
  disp('Error: The code supports either PAM2 or PAM4')
  return
end

% Test mode4 matrix
for i=1:Nc
X0(i,:)=circshift(tm4,1-i);
end

% Read captured data file
% Minimum of 4K TX symbols, 10X oversampling, high resolution capture
fid=fopen('TestMode4.bin','r');
tx = fread(fid,inf,'int16');
fclose(fid);
```



Modified the script from Clause 97 for PAM2 and PAM4 modulations

Linearity Test Verification Script, continued

```
% LPF at Nyquist
[A,B]=butter(1,1/10,'low');
tx=filter(A,B,tx);

% HPF (with this HPF, the 70-tap canceller residual linear error is 0.00)
tx = filter([1,-1],[1,-0.98],tx);

% Select one period, 10x oversampling, a row vector
tx=tx((1:Ns*10)+2e3)'; % removes HPF transients

% Level normalization
tx=tx/(max(tx)-min(tx))*2;

% Compute distortion for 10 phases
for n=1:10
tx1=tx(n:10:end);
temp=xcorr(tx1,tm4); % Align data and test pattern
index=find(abs(temp)==max(abs(temp)));
X=circshift(X0, [0, mod(index(1)+Nc-10,Ns)]);
coef=tx1/X; % Compute coefficients that minimize squared error in a cyclic block
err=tx1-coef*X; % Linear canceller
dist(n) = max(abs(err)); % Peak distortion
SNR(n)=std(tx)/std(err); % SNR
End

% Print results in mV for 10 sampling phases
format bank
peakDistortion_mV = 1000*dist'
```

PAM2 and PAM4 Encoding in the Test Script

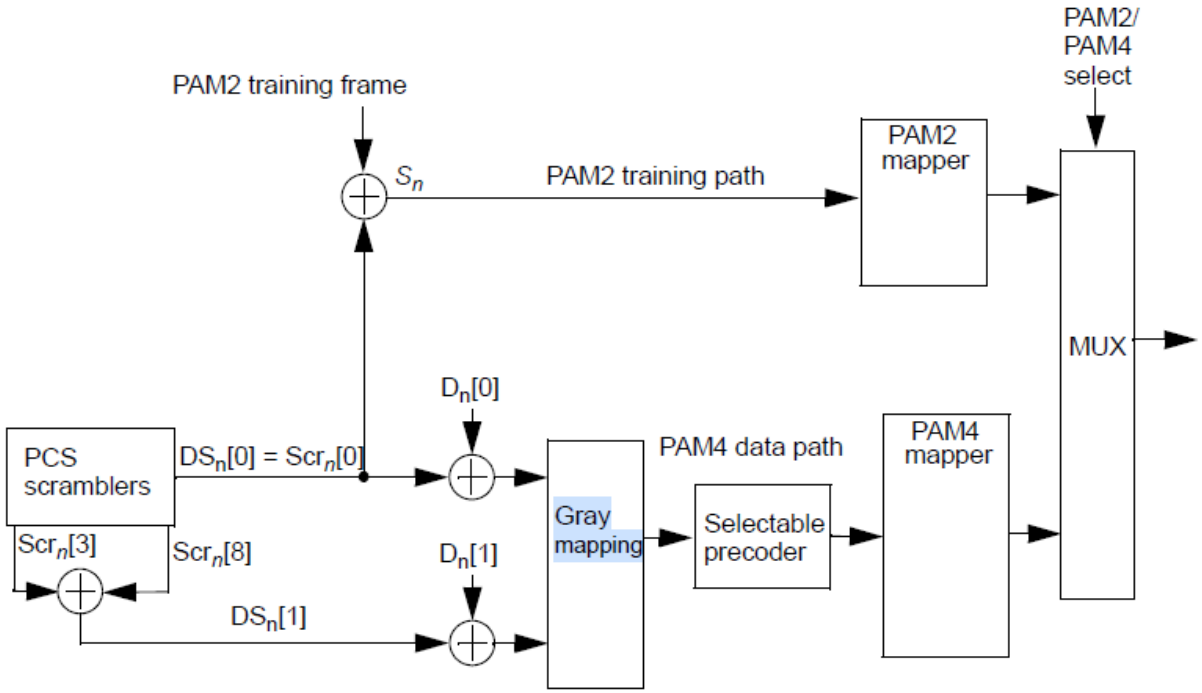


Figure 149–5—PCS Transmit function block diagram

Gray Map	PAM4
0 0	-1
0 1	-1/3
1 1	1/3
1 0	1

Verification of the Test Script

- The proposed script was simulated for multiple cable lengths and PoC filtering.
- The simulation shows 0.00mV for linear channels.
- Nonlinear model of $y=ax+bx^2+cx^3$ used to verify the non-linear distortion.
- It is observed that the PAM2 transmitters are mostly not affected by nonlinearity unless the signal shaping is used before the signal goes through a non-linear driver.
- PAM4 performance is affected by non-linearity.
- The proposed script **does not test** the effect of ingress noise. Testing for linearity with the added CW noise is more involved and often runs into setup issues. It is suggested that the effect of CW noise is verified by the implementer and not be considered as a requirement for the specification.

Thank you

Questions?