

TX distortion measurement and limit for 1000BASE-T1

San Antonio, TX
November 03, 2014

Ahmad Chini
achini@broadcom.com

Outline

- Test mode 4 is specified to measure TX distortion in 1000BASE-T. The same approach is adopted with some modifications to measure TX distortion for 1000BASE-T1.
 - The test pattern uses same modulation adopted for 1000BASE-T1 data mode and the 11-bit scrambler used in 1000BASE-T test mode 4.
 - The set up for TX distortion measurement is similar to 1000BASE-T but with HPF integrated in the processing code.
 - The disturber level and frequency are adjusted to match 1000BASE-T1 specifications.
 - An example processing code to measure distortion is provided along with a suggestion for distortion limit.

Test mode 4 pattern generation

- The 11-bit scrambler generator used is same as 1000BASE-T. The 3 binary bits as defined are used to select one of eight 2D-PAM3 symbols per mapping table below (same as data mode mapping).

$$g(x) = 1 + x^9 + x^{11} \quad \longrightarrow \quad \text{Updated at 375MHz}$$

$$x0_n = Scrn[0]$$

$$x1_n = Scrn[1] \wedge Scr_n[4]$$

$$x2_n = Scrn[1] \wedge Scr_n[5]$$



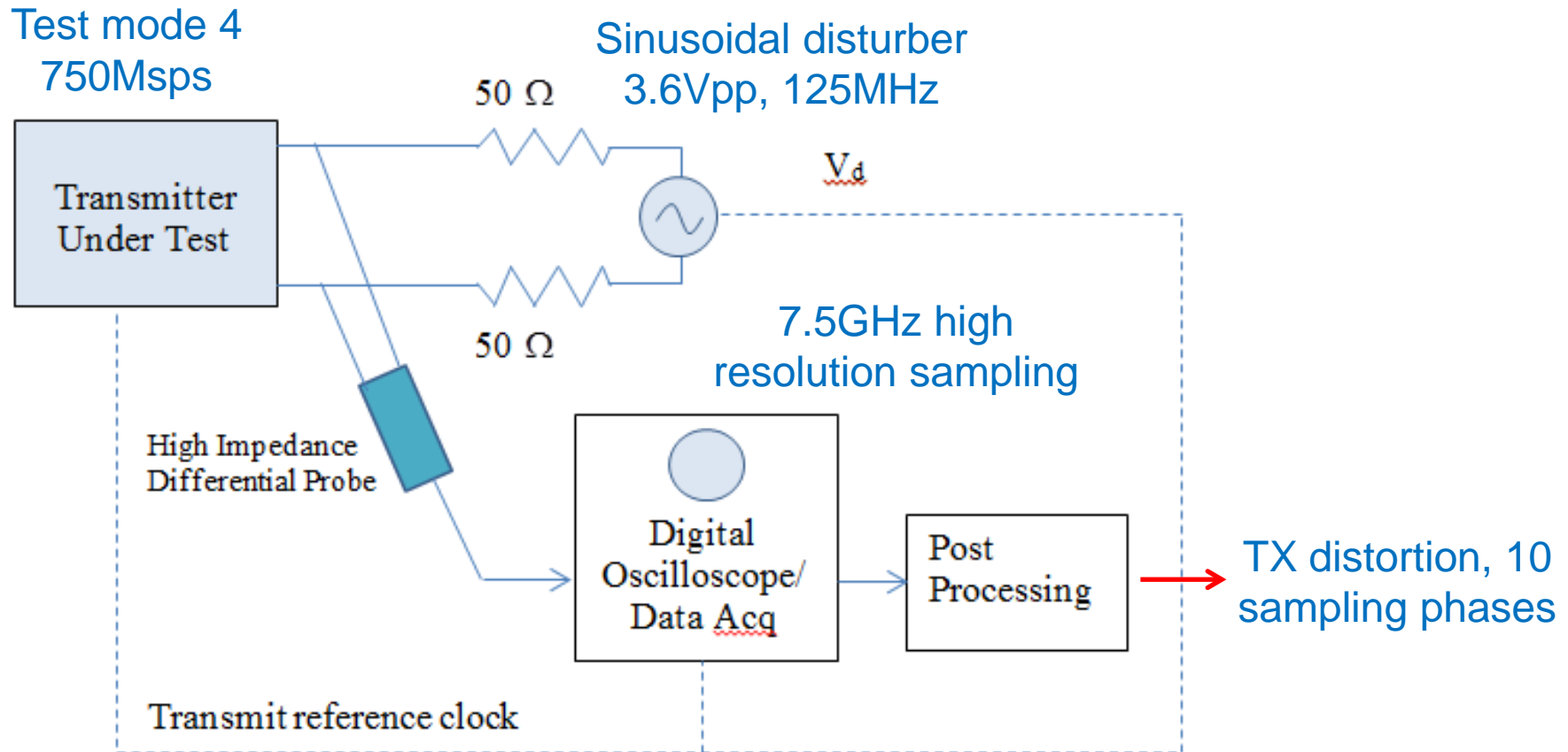
Modified from 1000BASE-T
to improve correlation for
2D-PAM3 mapping

$x2_n$	$x1_n$	$x0_n$	T1	T0
0	0	0	-1	-1
0	0	1	0	-1
0	1	0	-1	0
0	1	1	-1	+1
1	0	0	+1	0
1	0	1	+1	-1
1	1	0	+1	+1
1	1	1	0	+1

\longrightarrow T0 sent first

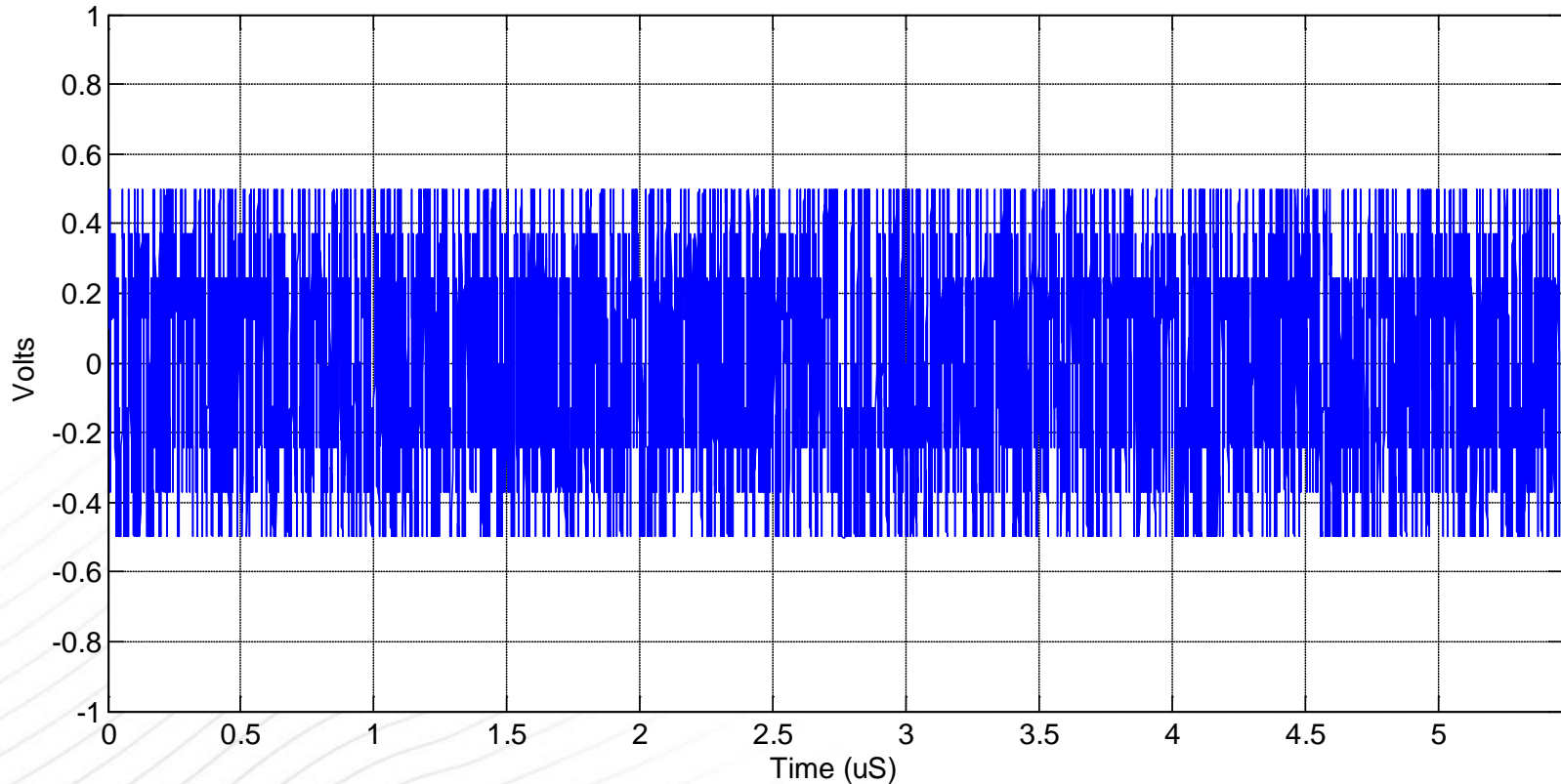
Transmitter should time
the transmitted symbols
from a 750MHz \pm 0.01%
clock in the MASTER
timing mode.

Transmit distortion test set up



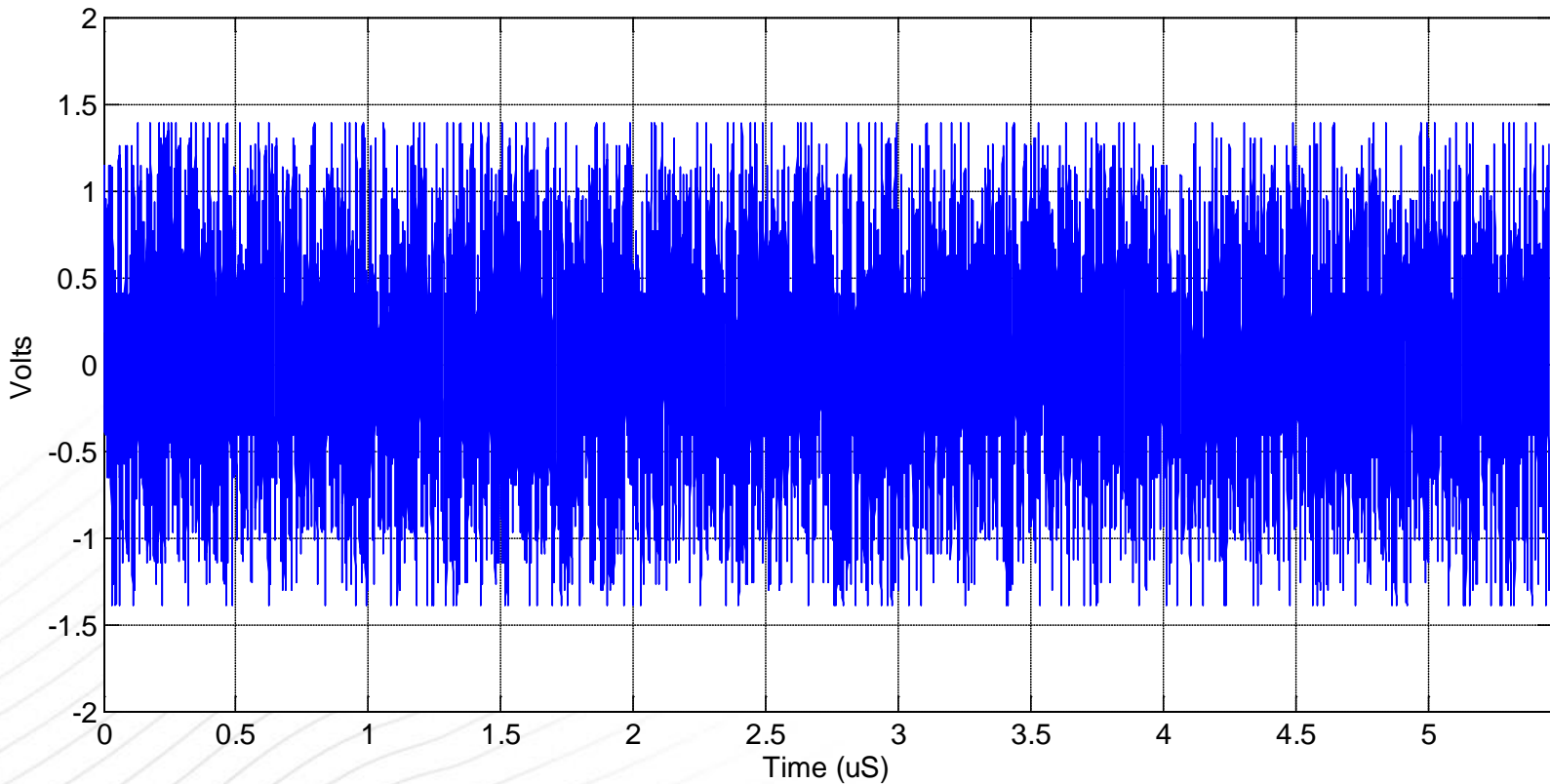
- The transmit clock of 750MHz and the disturber of 125MHz and the sampling clock of the digital oscilloscope are frequency locked.

Example Test Mode 4 waveform, without disturber (1 cycle)



- Same PSD shaping and signal level as data mode is used.
- One cycle is $2 \cdot (2^{11} - 1) = 4094$ transmit symbols.

Example Test Mode 4 waveform, with 3.6Vpp sinusoidal disturber (1 cycle)



- The 3.6Vpp disturber level is adjusted from 5.4Vpp specified for 1000BASE-T and considering maximum TX level of 1.35Vpp in 1000BASE-T1 as compared to 2Vpp in 1000BASE-T.

Example Matlab script for post processing

```
% Example code assumes frequency lock for PHY, data capturing clock and disturber
clear
Ns=2^11-1; % Scrambler length
Nc=70; % Canceller length

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

% 1000BASE-T1 2D-PAM3 assignment
tm4=ones(Ns,1);
map=[-1 -1;-1 0;0 -1;1 -1;0 1;-1 1;1 1;1 0];
scr3=[mod(circshift(scr,1) + circshift(scr,5),2),mod(circshift(scr,1) + circshift(scr,4),2),scr];
data = 4*scr3(:,3)+ 2*scr3(:,2)+scr3(:,1);
    for n=1:length(data)
        tm4([2*n-1,2*n]) =map(data(n)+1,:);
    end
Ns=2*Ns;

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

% Read captured data file, 40us long, 7.5GSample/sec, high resolution capture
fid=fopen('RawData.bin','r');
tx = fread(fid,inf,'double');
fclose(fid);

% LPF 375MHz,
[A,B]=butter(2,1/10,'low'); tx=filter(A,B,tx);
```

Example Matlab script for post processing

```
% HPF 12MHz
tx = filter([1,-1],[1,-exp(-2*pi/625)],tx);

% Select six periods, 10x oversampling, a row vector
tx=tx((1:6*Ns*10)+2e3)'; % removes HPF transient

% Disturber removal and integration (average) of six periods
TX=fft(tx); tx=ifft(TX(1:6:end));

% Level normalization to 1V
tx=tx/(max(tx)-min(tx))*2;

% Compute distortion for 10 clock phases
for n=1:10
txl=tx(n:10:end);

% Align data and test pattern
temp=xcorr(txl,tm4);
index=find(abs(temp)==max(abs(temp)));
X=circshift(X0, [0, mod(index(1)+Nc-10,Ns)]);

% Compute coefficients that minimize squared error
coef=txl/X;

% Linear canceller
err=txl-coef*X;

% Peak distortion
dist(n) = max(abs(err));
end

% Print distortion in mV (normalized) for 10 sampling phases
format bank
peakDistortion_mV = 1000*dist'
```


Distortion limit

- Peak TX distortion is determined by capturing the differential signal as shown in the set up at an arbitrary phase and processing a block of consecutive samples with the given MATLAB code or equivalent.
- The MATLAB code removes the disturbing signal from the measured data and computes the peak distortion. The code assumes the disturber signal and the data acquisition clock are frequency locked to the DUT transmit clock.
- Peak distortion values measured at minimum 10 different equally spaced phases of a single symbol period should be less than **10 mV**. Notice that distortion level is normalized to a peak signal level of 1V.

Conclusion

- It is proposed that the signal pattern shown in page 4 is adopted for 1000BASE-T1, test mode 4.
- It is proposed that the transmit distortion test as shown in page 5 is adopted for 1000BASE-T1.
- It is proposed that peak distortion limit of **10mV** (with peak signal level normalized to 1V) is considered when the measured data is processed with the example Matlab code or equivalent.