

高速误码仪,光通讯测试仪,任意波形发 生器和超高带宽示波器技术介绍



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Outline

- 高速误码仪介绍
- 光通信测试仪介绍
- 任意波形发生器介绍
- 超高带宽示波器技术介绍

新数字世界推动因素 – 性能指标日新月异

高速串行技术趋势和影响



PCI
EXPRESS®



HDMI™

DDR3
A JEDEC STANDARD

DisplayPort



GbE

行业/技术/市场趋势

- 接口从低速并行技术转向高速串行技术
- 数据速率继续提高：
3 ⇒ 6 ⇒ 10 ⇒ 12 Gb/s
- 行业标准化，实现即插即用互连
- 消费电子成为更大的推动因素

对测试测量的影响

- 千兆位数据速率需要性能更高的产品
- 行业标准提出了严格的测量和分析要求
- 测试整个系统，包括发射机、接收机和传输路径或电缆
- 要求广泛的产品系列及提高一致性测试的自动化程度
- 测试测量在标准机构中发挥着关键作用

BERTScope系列产品概览



BERTScope

- 主要产品BSA系列
- BERT和示波器的结合，基于BER的分析、测试平台
- 主要应用于高速串行和通信的芯片、系统测试

- 28.6G
- 26G
- 17.5G
- 12.5G
- 8.5G



Clock Recovery

- 配合BERT和示波器使用
- 抖动测量

- 28.6G
- 17.5G
- 12.5G



Bitanalyzer

- 基本的误码仪和示波器
- 最低码速率100K，适合于卫通应用

- 1.5G/1.6G



Pre-Emphasis

- 配合BERTScope码型发生器使用
- 提高输出加重以克服通道损耗

- 12.5G

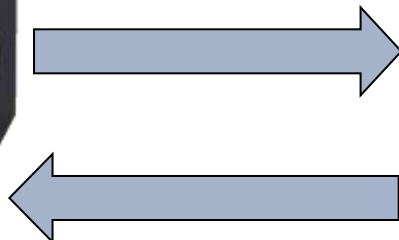
什么是BERTScope?

针对计算机系统和通信串行数据的应用而设计，同时集成误码仪和示波器的仪器。

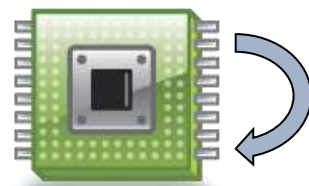
- 1 Pattern Generator产生特定的比特码流，例如. PRBS 码型；信号可以被施加压力




从带压力的Pattern Generator输出

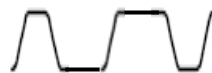


loopback



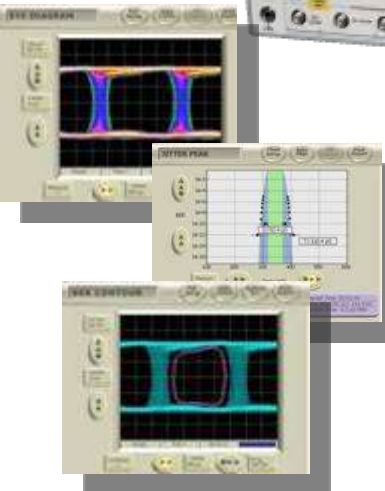
被测芯片/被测系统
有源/无源

到 Error Detector



- 2 比特码流从DUT输出到Error Detector比较以进行BER测量

- 3 进行BER测试，也能像示波器一样进行分析



BERT基本功能

■ 码型发生器(PG)

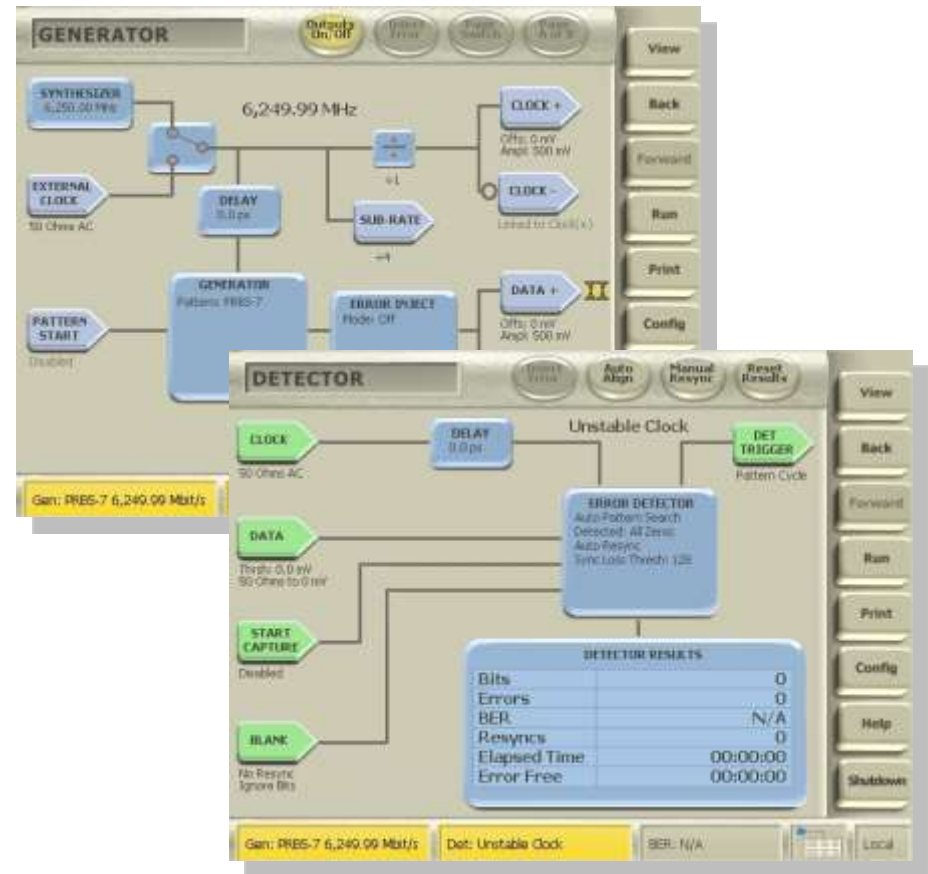
- 业内最高速可加壓码型发生器：**28.6Gbps**
- 业内最深的延迟线，产生幅度更大的抖动

■ 误码检测器(ED)

- 精确高达100fs的延迟线
- 专利的Dual ED构架，快速准确完成
眼图、抖动测量
- 快速比特同步

■ 时钟恢复器(CR)

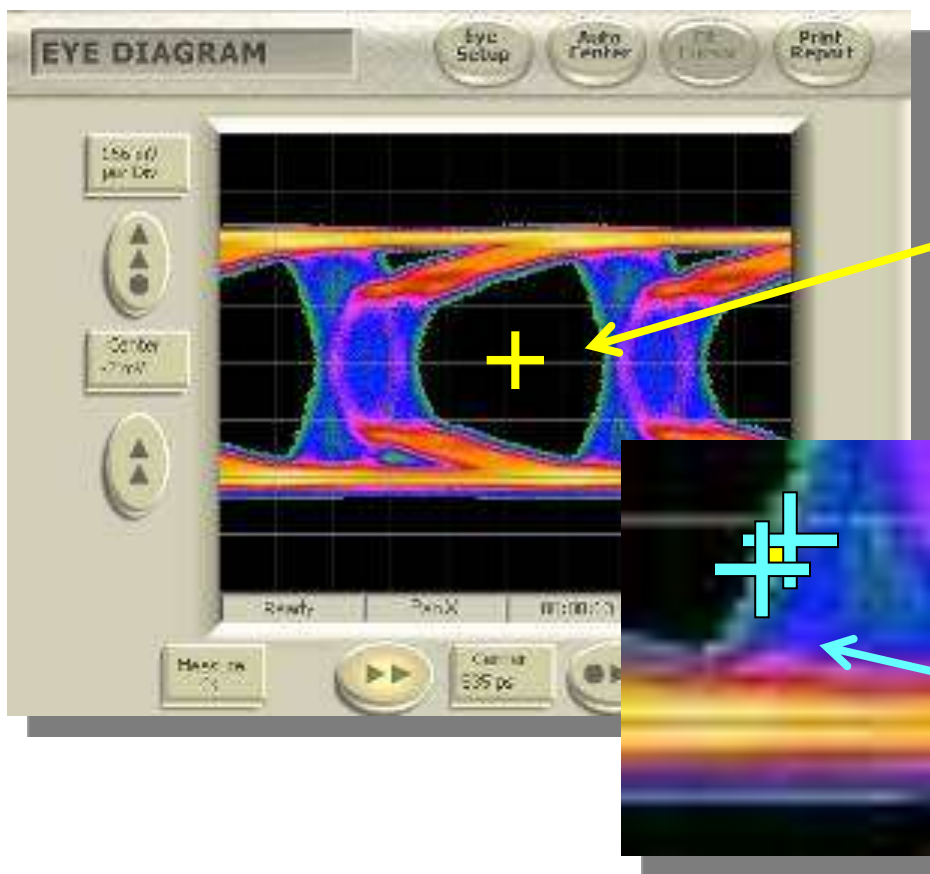
- 业内最高速的仪器级CR: **28.6Gbps**
- 业内参数设置最全的CR: 连续调谐
Loop BW/Peaking
- 外置模块、配置灵活



Beyond the BERT...

使用BERTScope深入分析误码率事件

The BERTScope Eye Diagram



1

用一个比较器，可以比较输入的bit和参考bit之间的差异-> BER 测量

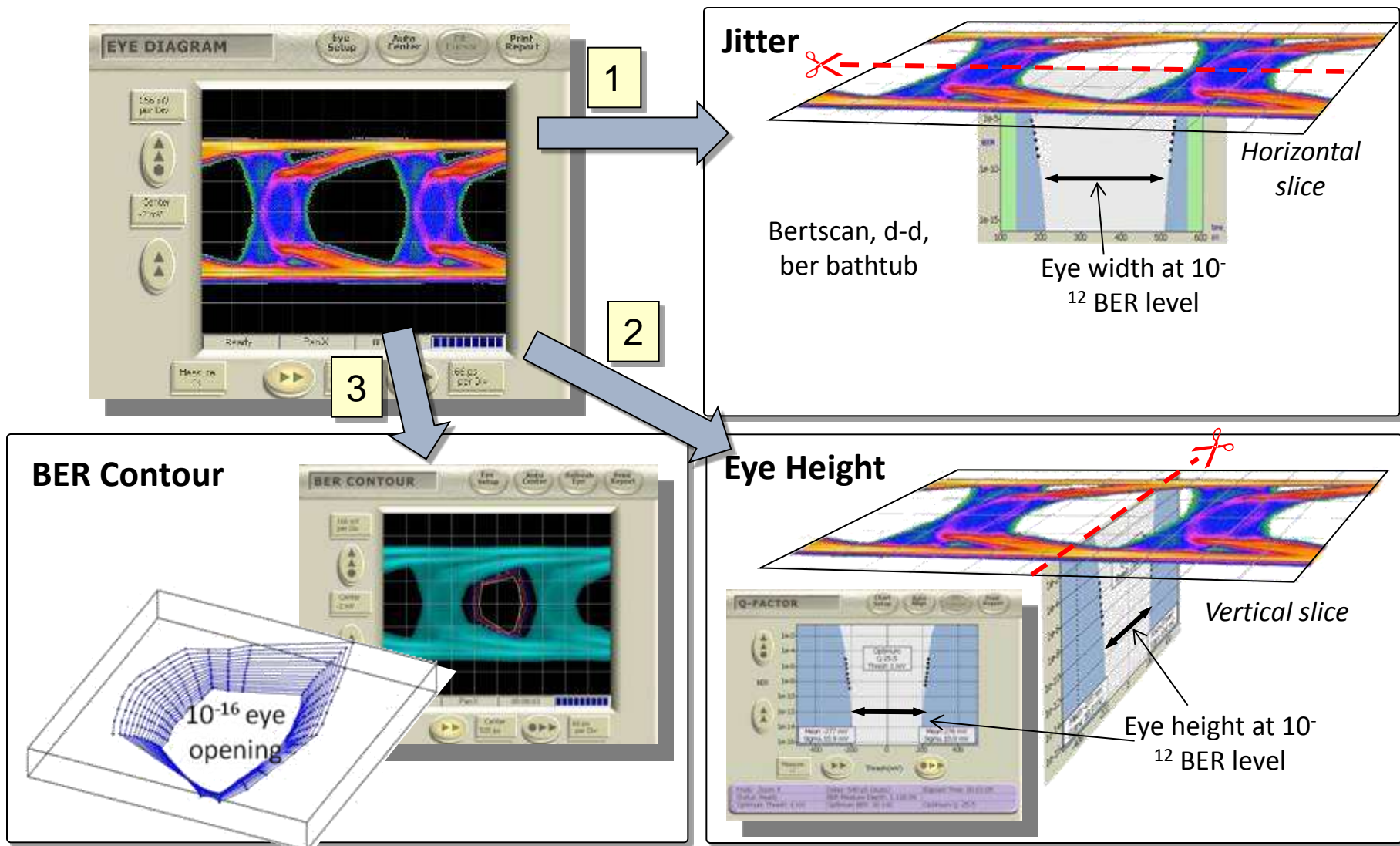
2

用两个比较器，可以测量出有多少bit落在两个比较器之间-> 眼图！

可以区分不同误码率事件，找到外部信号和误码之间的关联

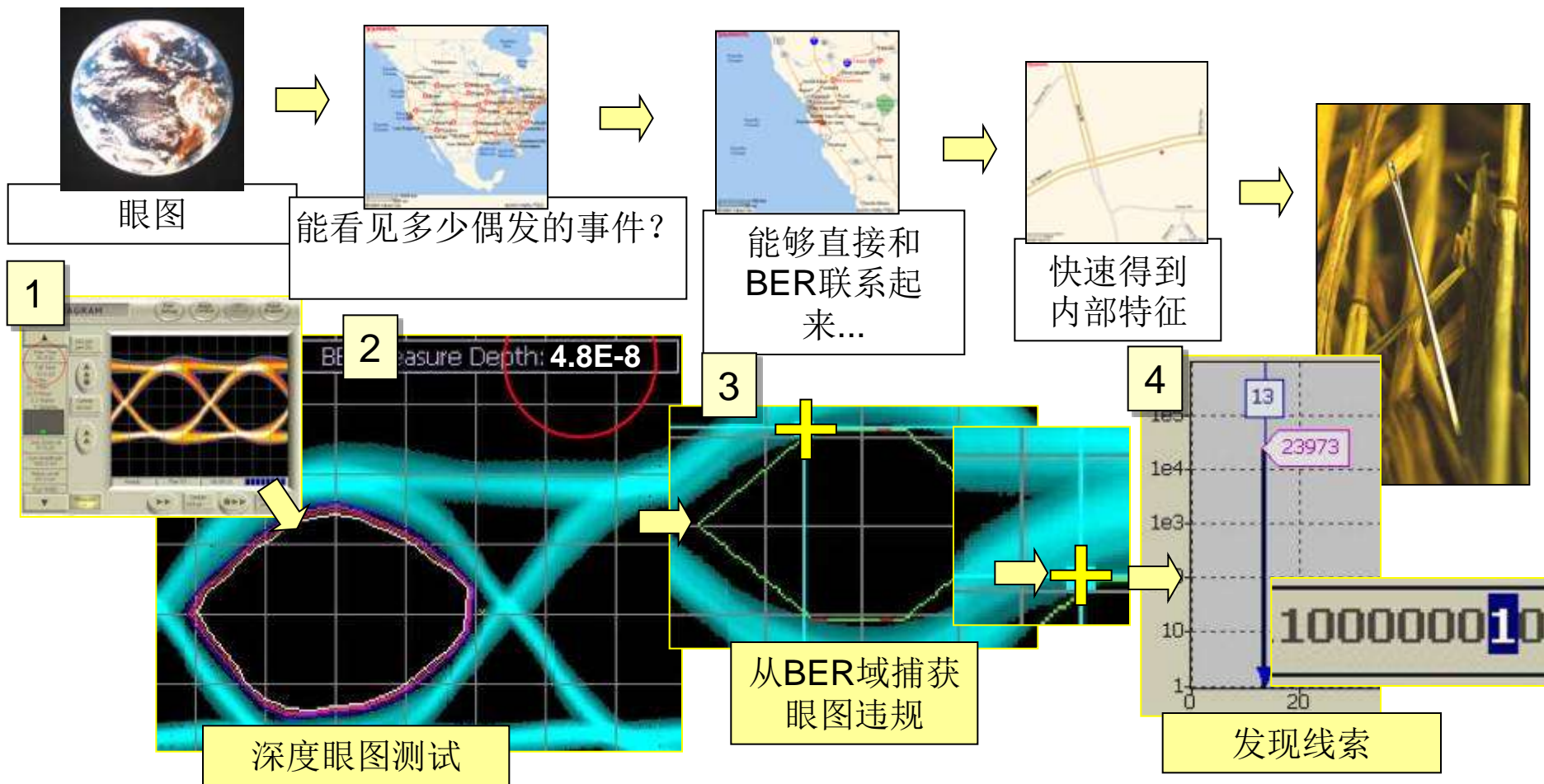
Beyond the BERT...

使用BERTScope深入分析误码率事件



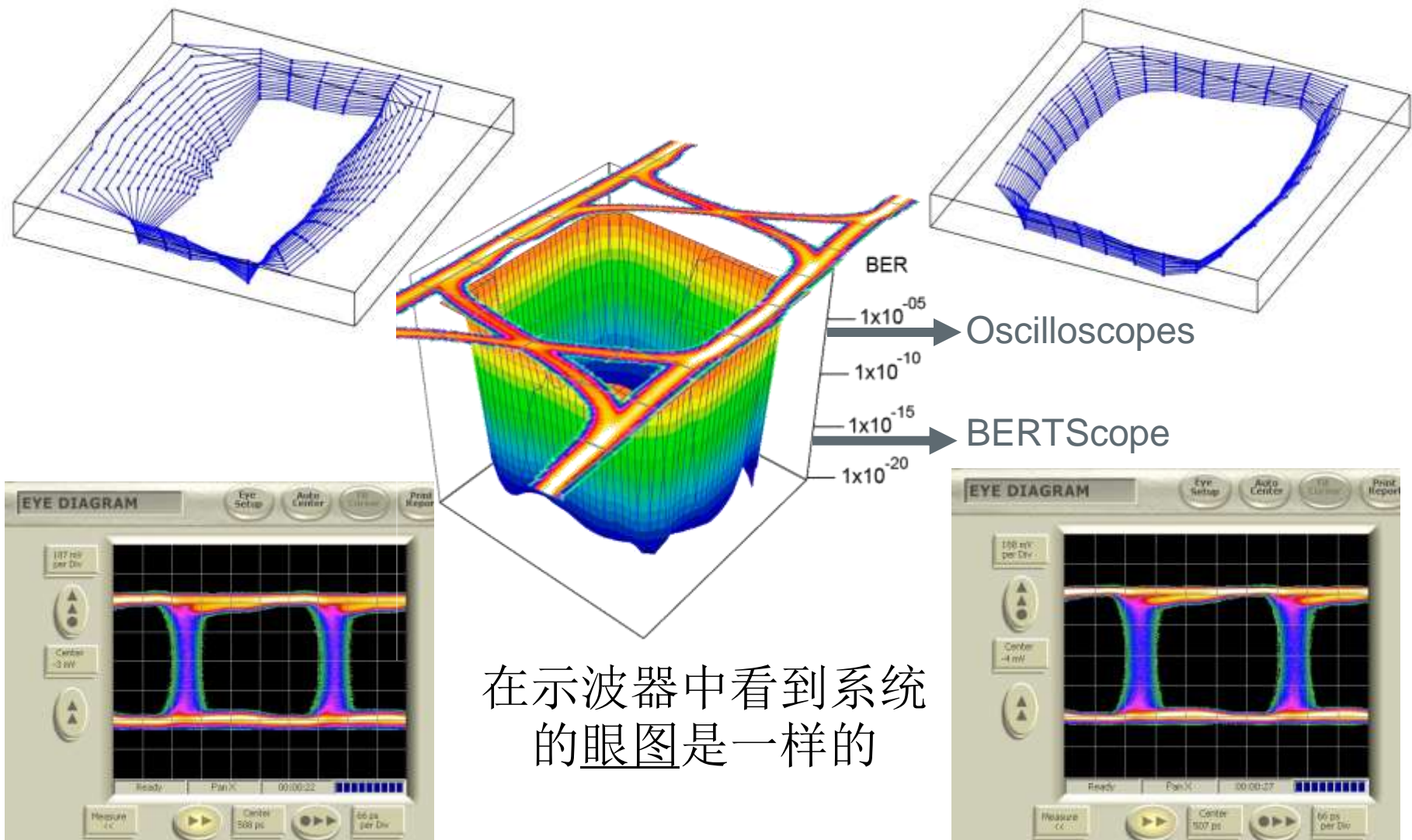
Beyond the BERT...

多种工具联合使用深入信号特征



Beyond the BERT...

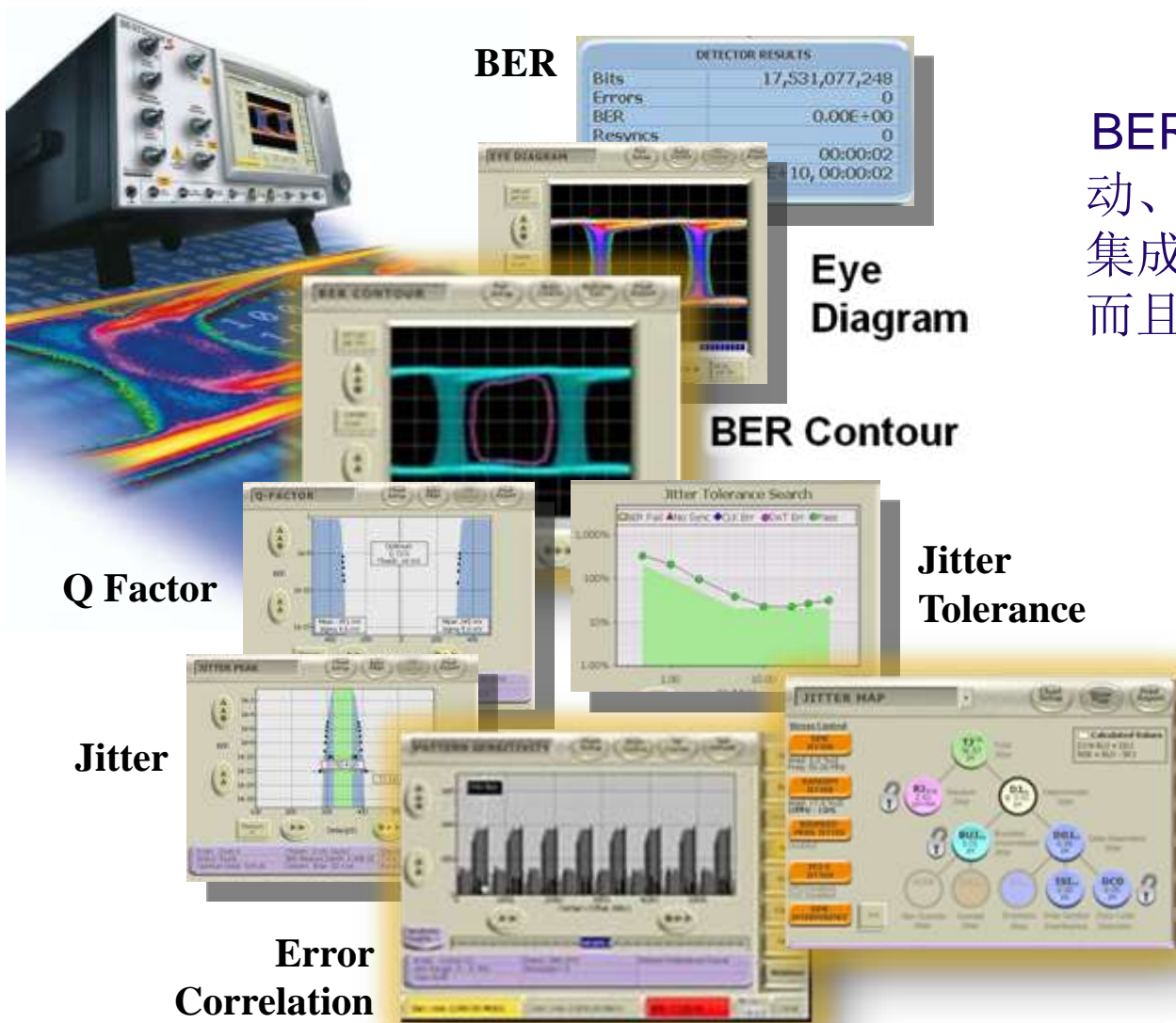
案例: System BER Trend



在示波器中看到系统的
的眼图是一样的

Beyond the BERT...

BERTScope工具集



BER

DETECTOR RESULTS	
Bits	17,531,077,248
Errors	0
BER	0.00E+00
Resyncs	0
	00:00:02
	10,00:00:02

Eye Diagram

BER Contour

Q Factor

Jitter Tolerance

Jitter

Jitter Decomposition

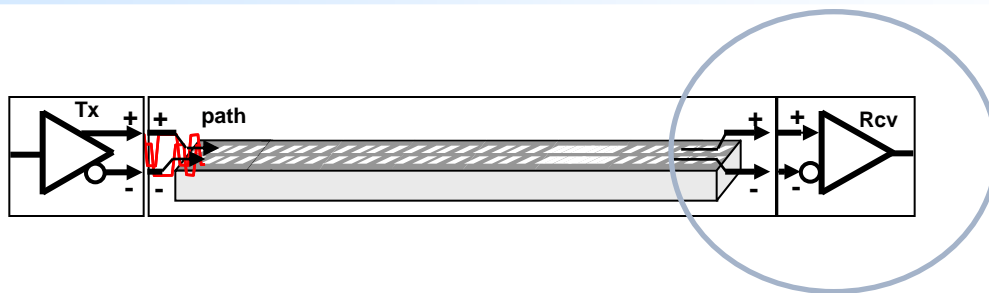
Error Correlation

BERTScope 将眼图、抖动、信号发生和信号损伤集成在一起，简单易用，而且有和误码仪一样的测深度和精度

高速串行系统Rx端容限测试

- 单纯考察Tx端是不足以保证BER
- Rx端复杂的结构: **Equalizer**、**CDR**
- 没有Tx和传输链路时对Rx的压力测试
- 对Rx端施加各种各样的压力和一致性测试信号

- 信号产生
 - 高速串行信号不断增加的数据率
 - 不断增加的信号带宽
- 复现现实世界中的信号
 - 复现传输线效应
 - 产生各种干扰信号: 抖动、噪声和其他干扰, 并精确的知道干扰量的大小



各种高速串行总线对Rx接收端测试的要求

无论是针对设计还是生产制造，规范都定义了明确的Rx端测试需求

所有标准都要求进行Jitter Tolerance一致性测试

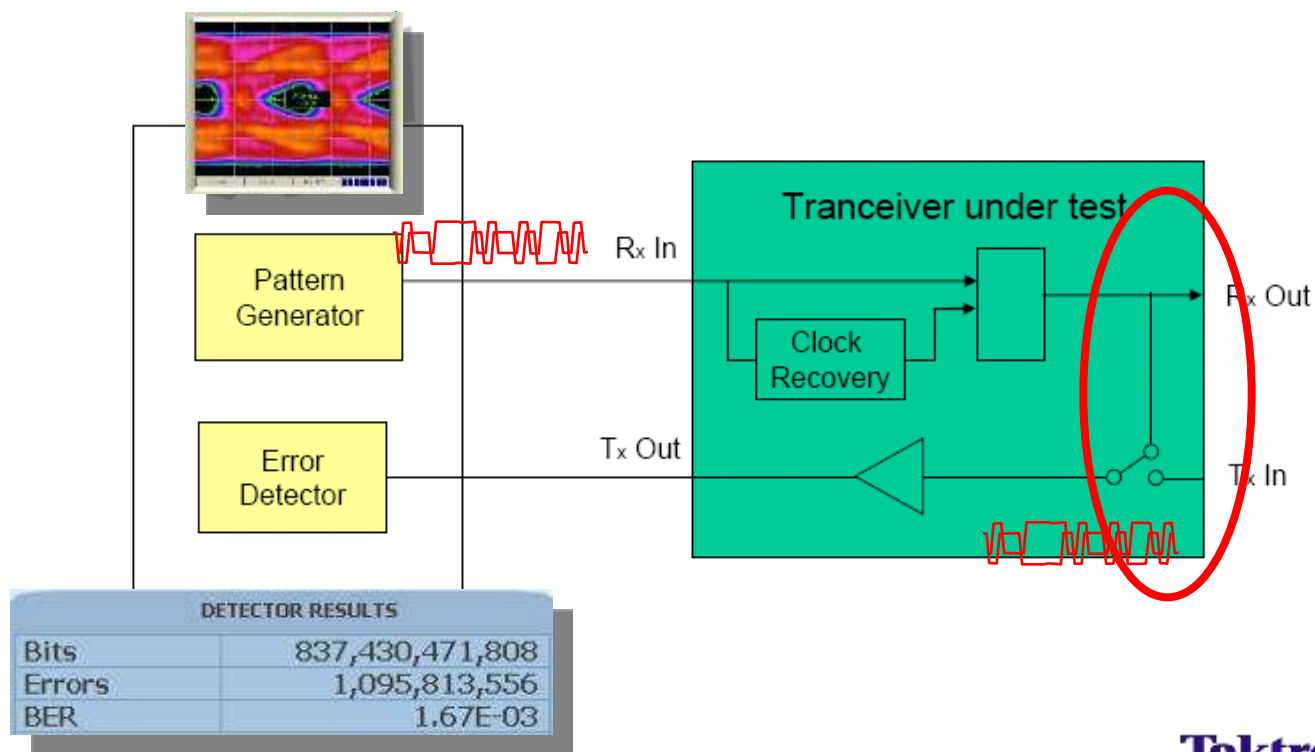
被测设备类型:

- SerDes
- Transceivers
- Multi Media Sink devices
- Rx devices

Standard	Data Rate	Jitter Tolerance	Timing Skew	Amplitude Sensitivity	Emphasis
SATA Gen 3	6 Gb/s		-		-
PCI Express 2.0	5 Gb/s				
PCI Express 3.0	8 Gb/s				
HDMI 1.3	0.75 Gb/s to 3.4 Gb/s				-
FC 4, 8 G	4.25 Gb/s to 8.5 Gb/s				
DisplayPort	2.7 Gb/s 5.4Gb/s				
USB 3.0	5 Gb/s		-		

各种高速串行总线对Rx接收端测试的要求

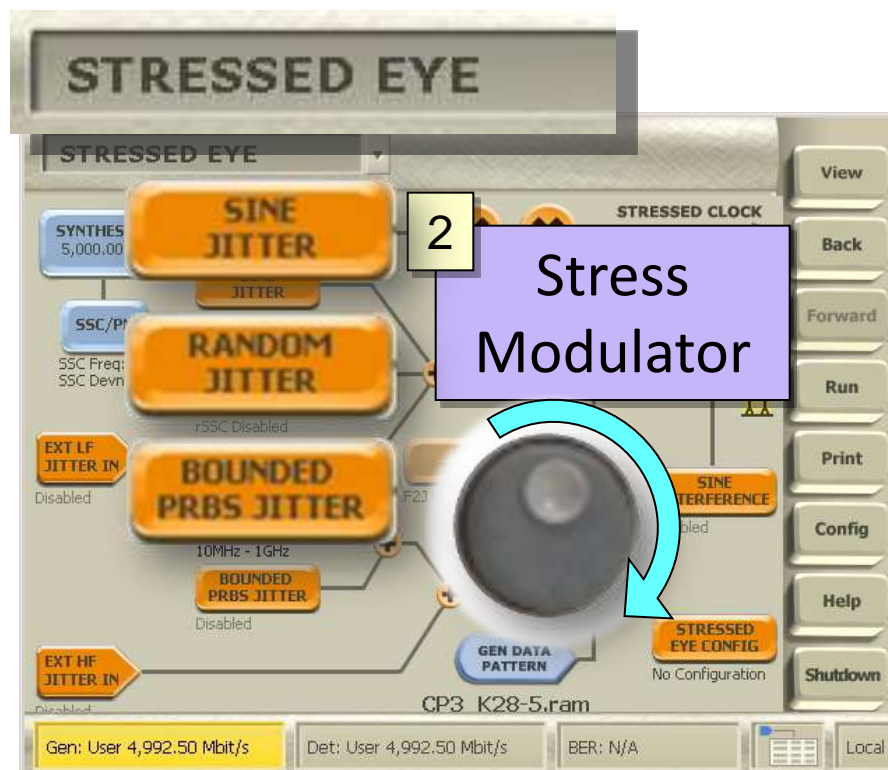
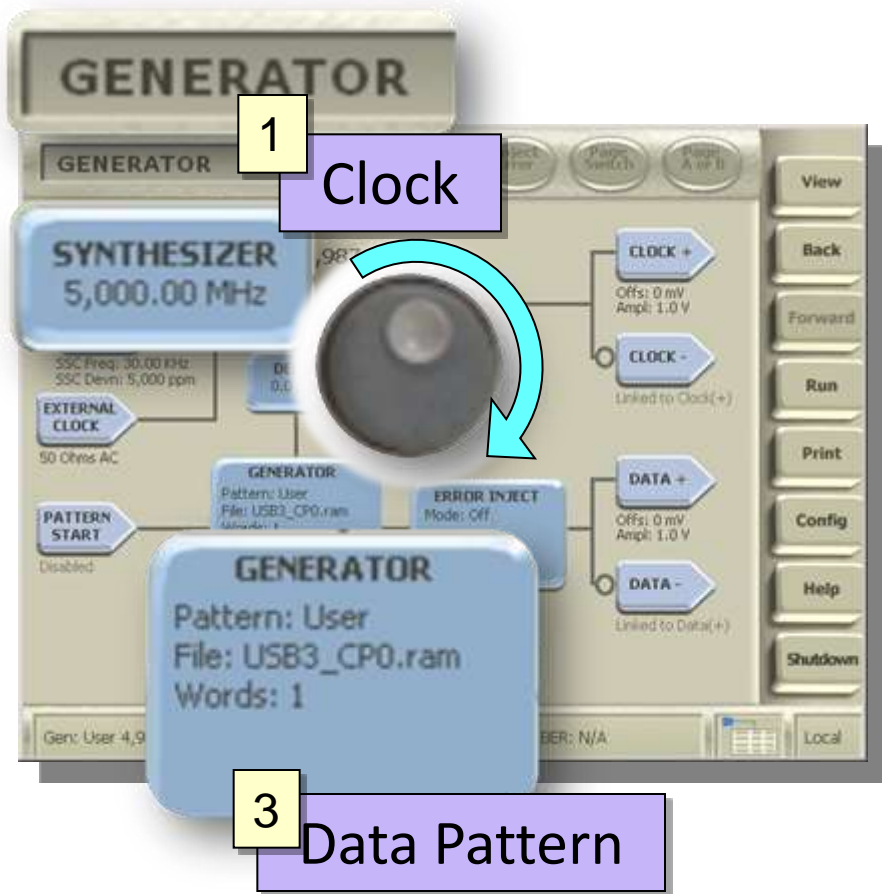
1. 设置DUT进入Loopback模式
2. 产生规范要求的抖动分量，在不同的频点上分别产生相应的抖动量
3. 将stressed信号注入DUT Rx
4. 统计DUT Tx端发出的信号的误码率是否达到要求



Stressed Eye

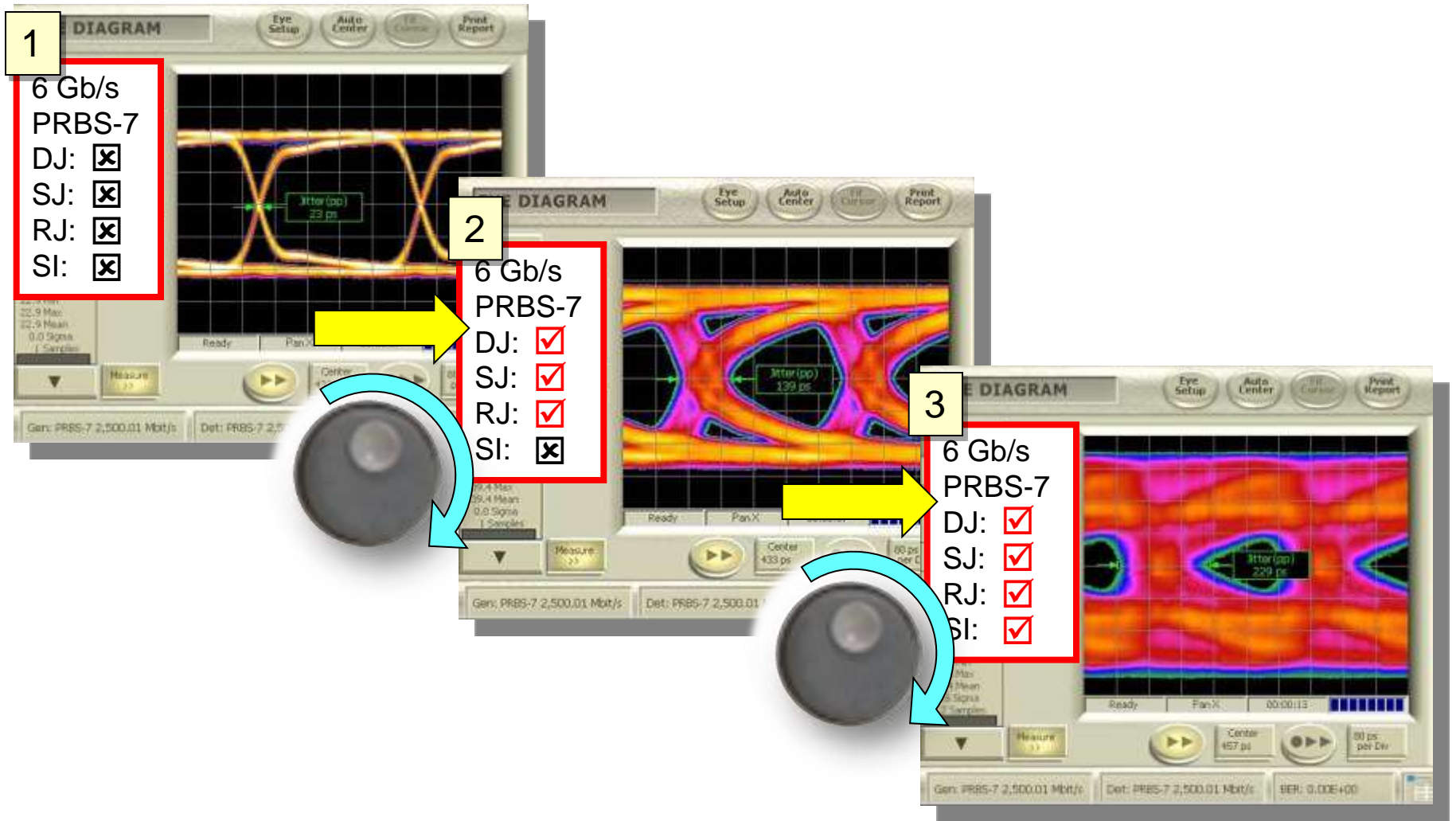
动态改变数据率、压力损伤和码型

- ✓ Sine jitter
- ✓ Random jitter
- ✓ Bounded PRBS jitter
- ✓ SSC
- ✓ Sine Interference



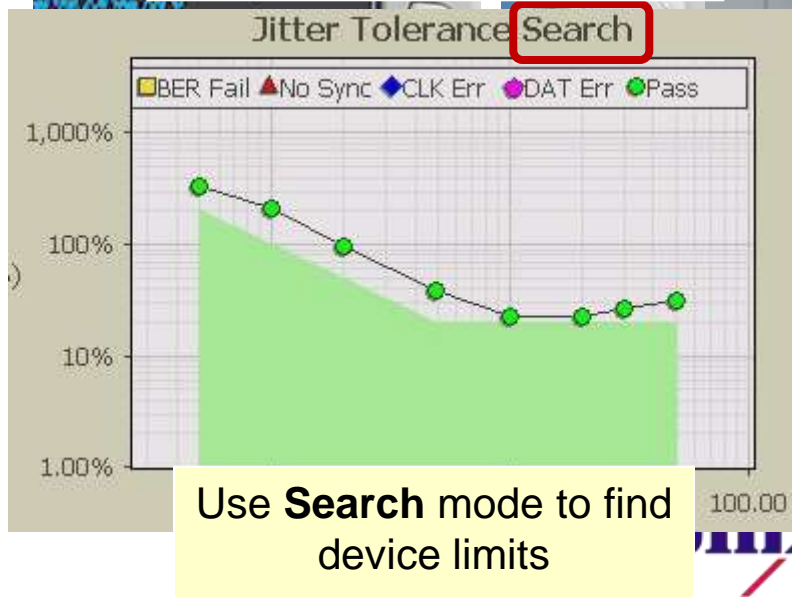
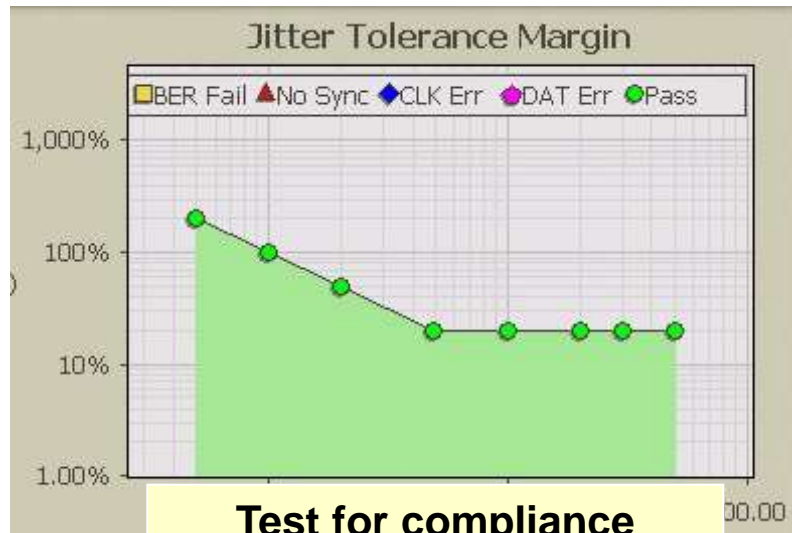
Stressed Eye

案例：SATA3 6Gbps压力信号

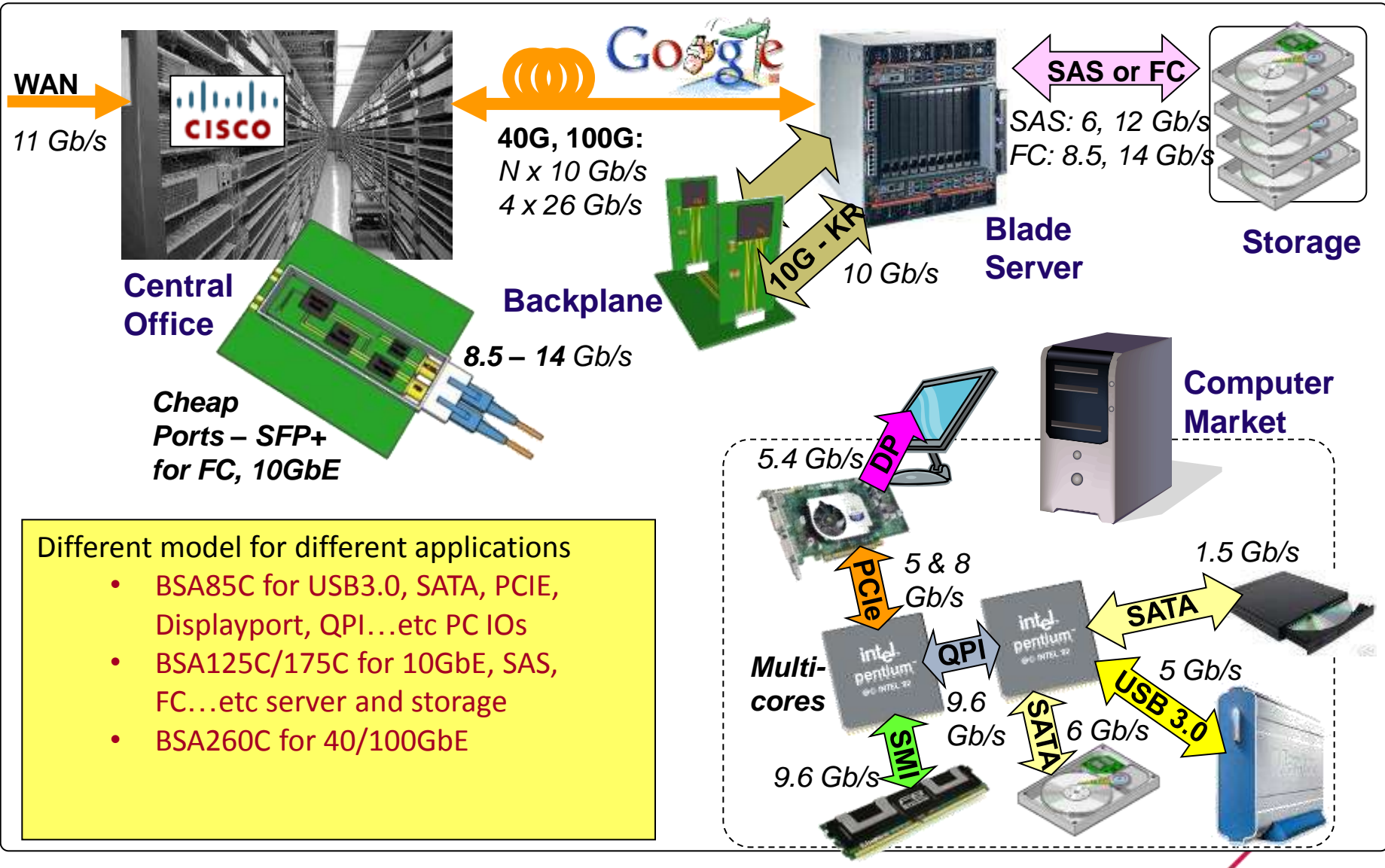


自动化Jitter Tolerance一致性测试方案

- ✓ PCIE
- ✓ SATA
- ✓ USB3
- ✓ Display Port
- ✓ XFP/XFI
- ✓ 10GBase-KR
- ✓ Optical
- ✓ Serial Bus...

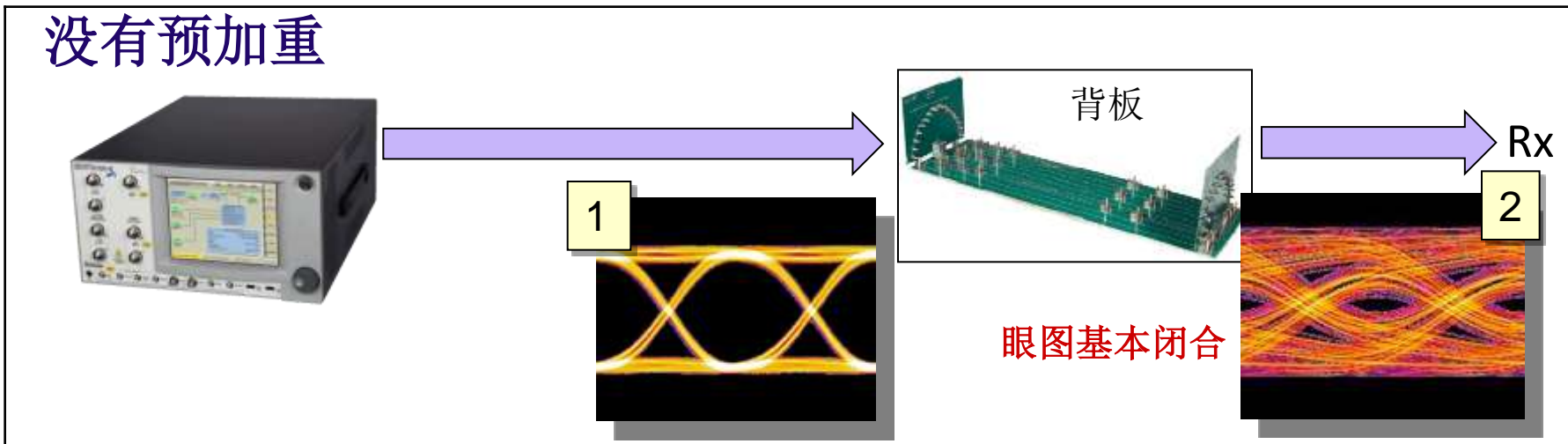


BERTScope 高速串行应用解决方案

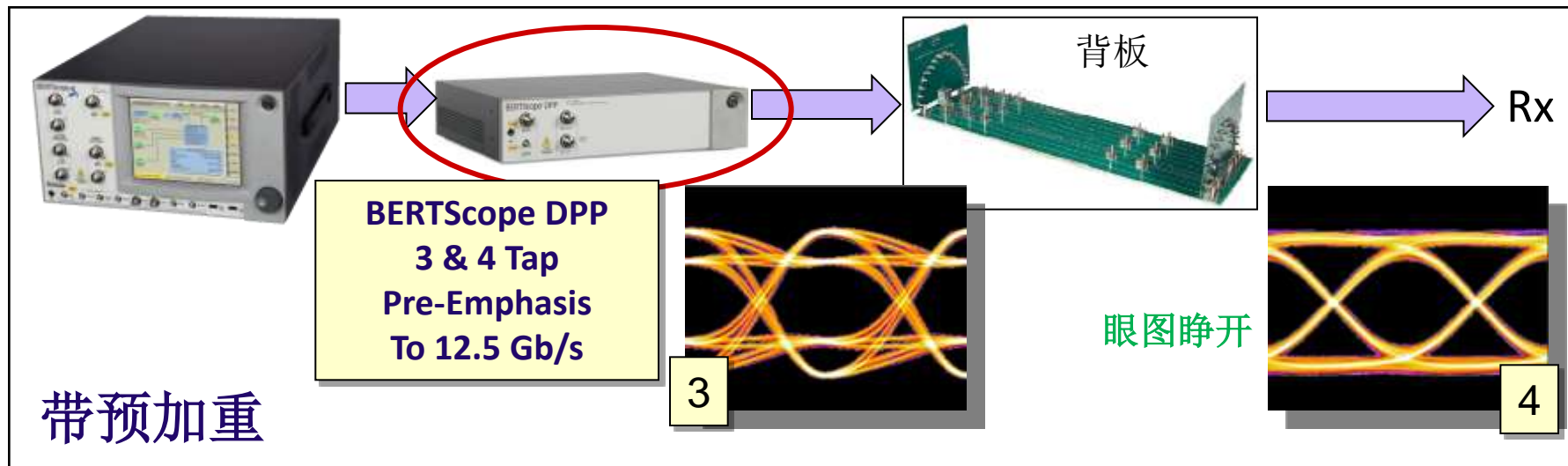


BERTScope DPP预加重处理器

没有预加重



带预加重



与Tektronix现有系统的集成

- 40G/100GE
 - DSA8300+80C10B+82A04
 - BSA26000
 - CR12500
- 无源背板、cable眼图测试
 - DSA8300+80E04
 - BSA12500CPG
 - DPP



BERTScope 误码分析仪产品

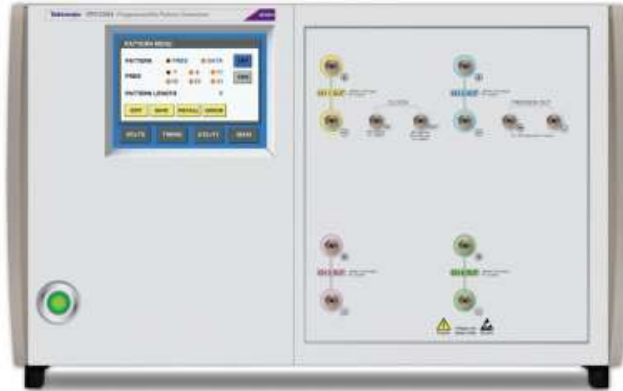
- BERTScope 系列产品为设计和测试工程师提供结合了示波器的直观观察、误码仪的精度性能于一体的、快速的发现、定位被测系统问题的解决方案。



不仅仅是误码率测试...

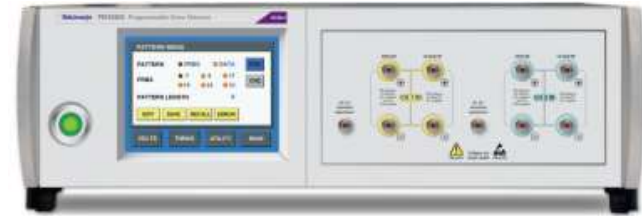
- ✓ 深度样本的信号完整性测量
- ✓ 测试验证和调试的快速切换
- ✓ 快速准确的抖动容限测量
- ✓ 极佳的可用性
- ✓ 丰富灵活的配套产品

High Quality Analog Inputs and Outputs



▶ Pattern Generators

- **12.5G, 30G, 32G, and 40G** Models
- Fast risetime
- Low jitter
- Multi-channel
- NRZ and PAM-4
- Jitter insertion
- Pre-emphasis
- Front panel and remote control

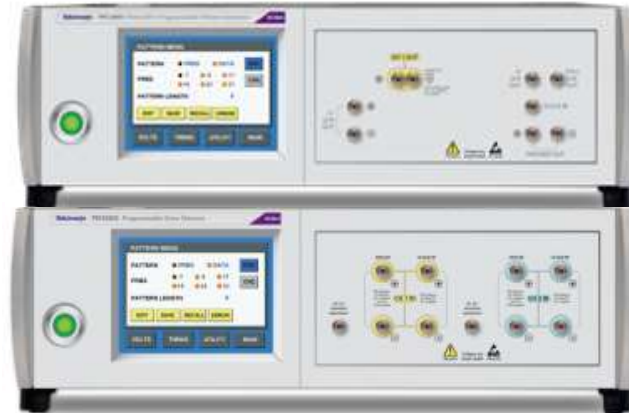


▶ Error Detectors

- **32G and 40G** Models
- High sensitivity
- Wide phase margin
- Multi-channel
- NRZ and PAM-4
- Auto sync and phase align
- Bathtub and contour analysis
- Front panel and remote control

PatternPro Product Portfolio

Typical BERT Configurations



*40G BERT system
with full Rx test
stress capabilities*

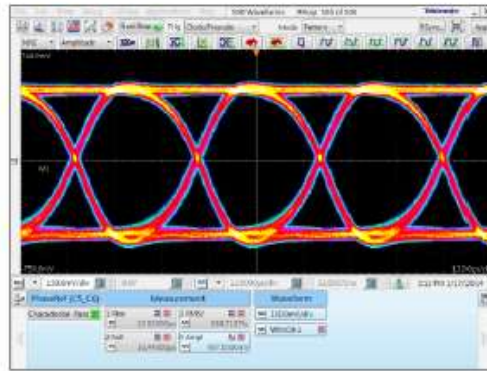


*Full 4 channel 32G
BERT system with
independent data
channels*

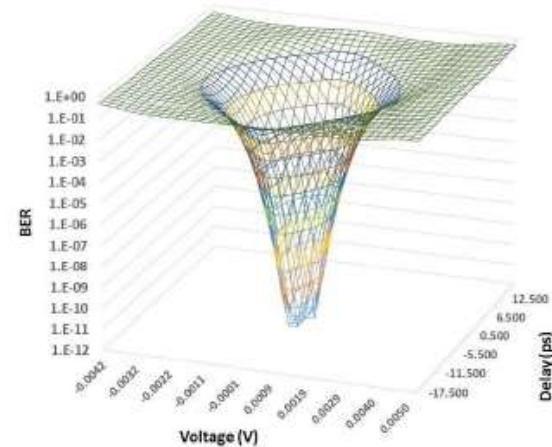
2014 Improvements Result in Industry Best Performance!

Best in Class BERT Performance

Picosecond Pulse Labs, Boulder, CO 80301



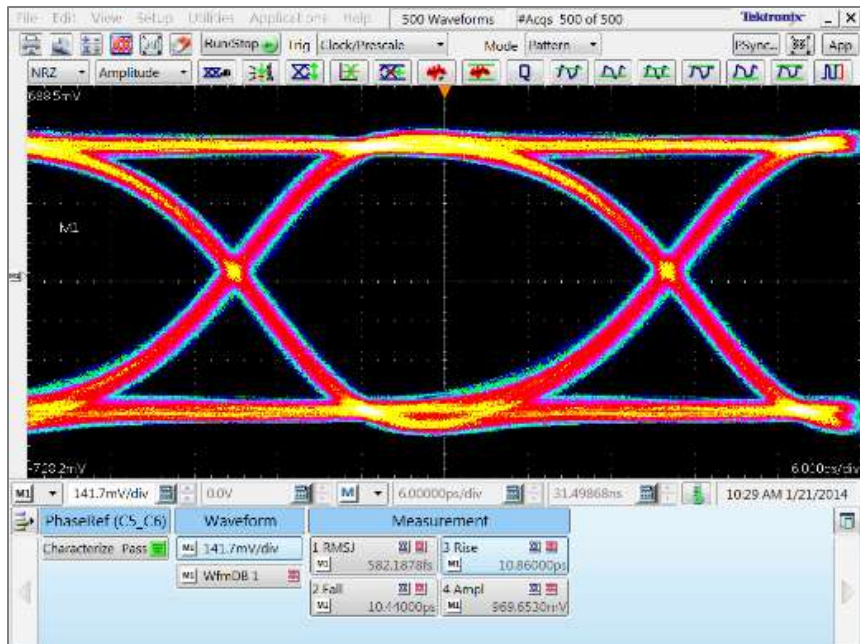
**Lowest Pattern Generator
32 Gb/s Jitter in the Industry with
7.5 ps TJ (1e-12) and 250 fs RJ [1,2]**



**Highest Sensitivity Error Detector in the
Industry with <6 mVpp at 28.1 Gb/s [1,3]**

Picosecond Pulse Labs' **PatternPro™** serial data instruments have recently been improved to provide the **highest performance of any BERT instruments in their class**. Today's high-speed test applications demand the best performance possible and the key performance parameters are pattern generator inherent jitter and error detector sensitivity. This applications brief gives details of the measured jitter and sensitivity for the Model 12072 32 Gb/s pattern generator and the Model 13025 32 Gb/s error detector.

Fast Risetime and Low Jitter 32Gb/s Multi-channel PPG



PPG320X 32Gb/s
OPT-ADJ

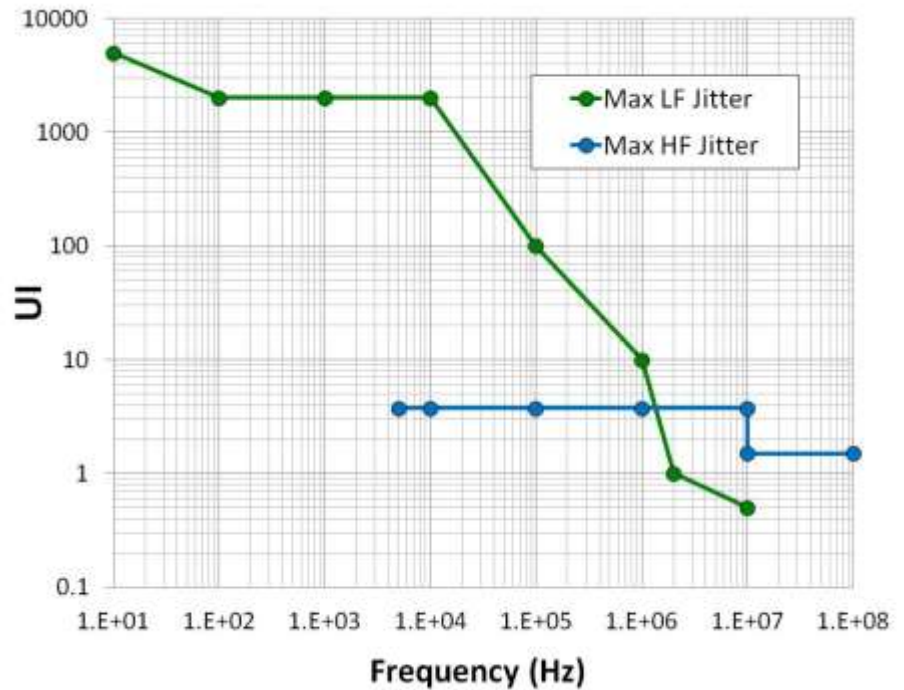
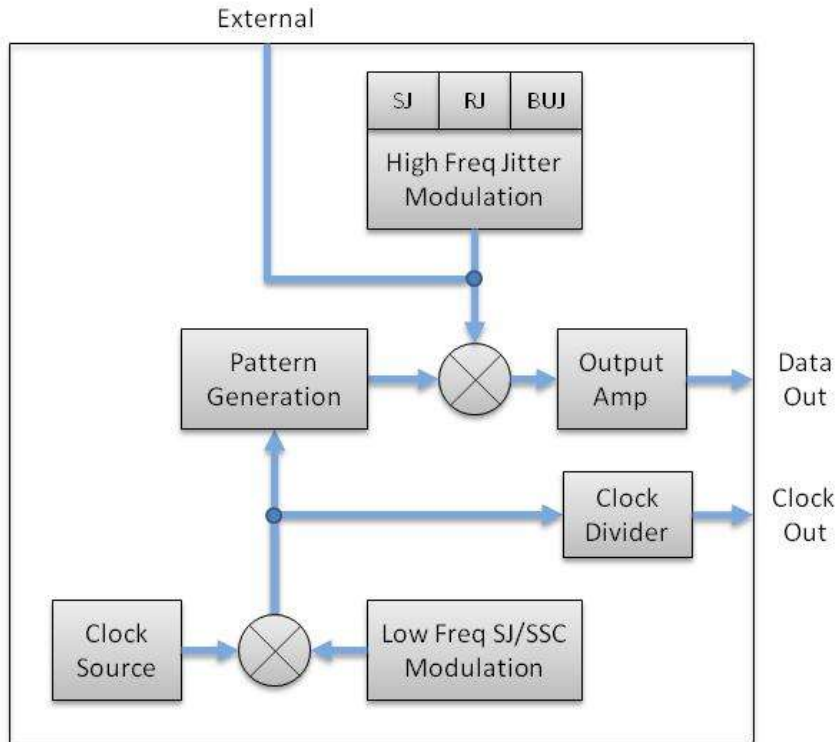
Data Source: MATH1	Data Rate: 32 Gbps	Filter: False
SSC: Off	Pattern: 2047 bits	Channel: False
Phase Reference: 32 GHz	Sample Count: 304.70 k	Equalizer: None

Jitter (Decision Threshold: -11.95 mV)		Noise (Sampling Phase: 0 UI)	
Random Jitter			
RJ (RMS)	= 211.36 fs	Random Noise	
RJ(h) (RMS)	= 211.20 fs	RN (RMS)	= 581.45 uV
RJ(v) (RMS)	= 8.39 fs	RN(v) (RMS)	= 567.11 uV
		RN(h) (RMS)	= 128.35 uV
Deterministic Jitter			
DJ	= 4.94 ps	Deterministic Noise	
DDJ	= 3.20 ps	DN	= 149.69 mV
DCD	= 971.00 fs	DDN	= 149.22 mV
DDPWS	= 2.77 ps	DDN(level 1)	= 124.94 mV
BUJ(d-d)	= 50.00 fs	DDN(level 0)	= 167.15 mV
PJ	= 718.02 fs	BUN(d-d)	= 1.74 mV
PJ(h)	= 717.99 fs	PN	= 633.25 uV
PJ(v)	= 6.79 fs	PN(v)	= 458.95 uV
NPJ(d-d)	= 50.00 fs	PN(h)	= 436.33 uV
		NPN(d-d)	= 1.70 mV
Total Jitter @ BER			
TJ (1E-12)	= 6.76 ps	Total Noise @ BER	
Eye Opening (1E-12)	= 29.49 ps	TN (1E-12)	= 157.72 mV
		Eye Opening (1E-12)	= 821.79 mV
		Eye Amplitude	= 979.51 mV
Dual Dirac			
RJ(d-d)	= 243.96 fs	SSC Modulation	
DJ(d-d)	= 3.32 ps	Magnitude	= 0 ppm
		Frequency	= 0 Hz

**Industry Best 32Gb/s
Jitter Performance!**

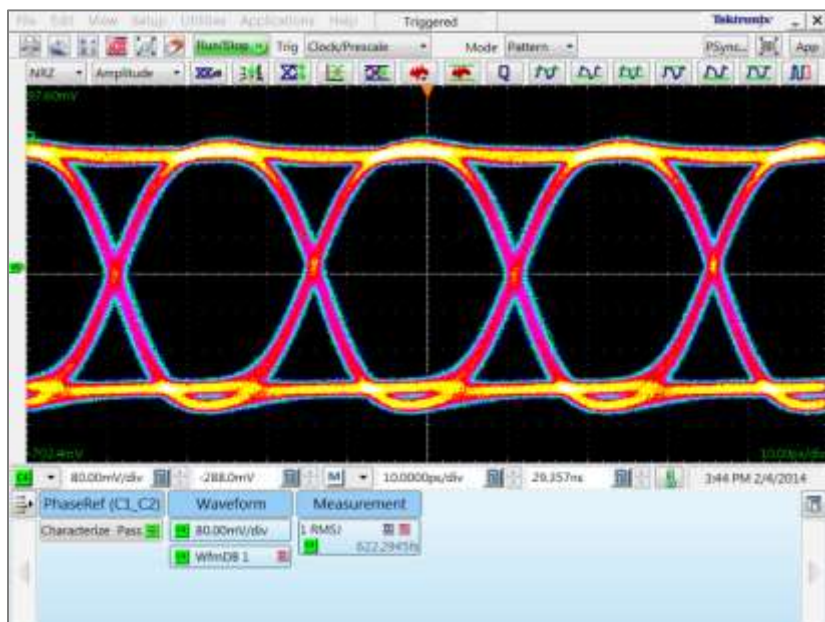
DSA8300
80E11 sampling plug-in
82A04-60G phase reference

Jitter Insertion Architecture and Ranges



OPT-LFJ with OPT-HFJ ranges.
Based on 25Gb/s data rate.

New PPG4001 40Gb/s PG with Built-in Jitter Insertion



PPG4001 40Gb/s

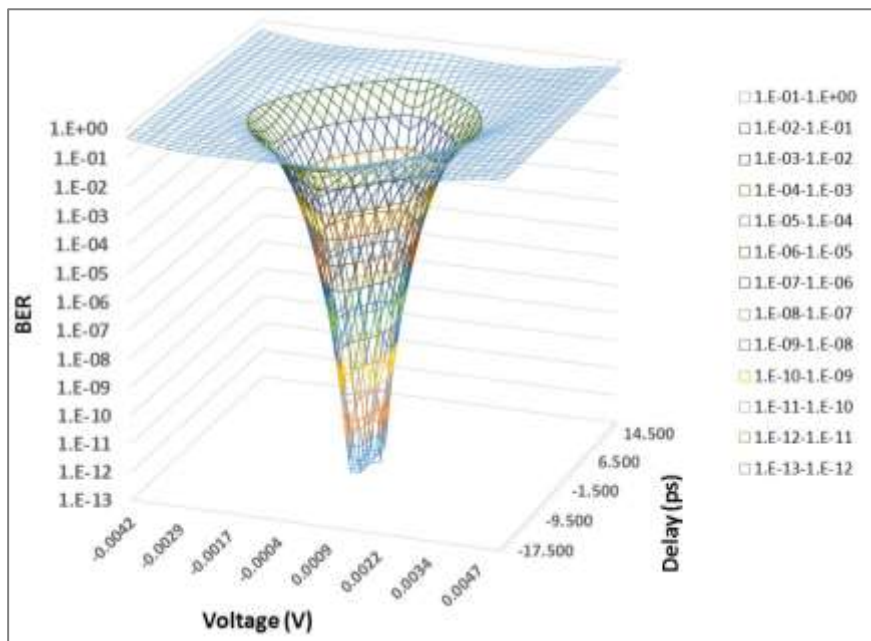


Data Source: CH3	Data Rate: 40 Gbps	Filter: False
SSC: Off	Pattern: 2047 bits	Channel: False
Phase Reference: 20 GHz	Sample Count: 304.70 k	Equalizer: None

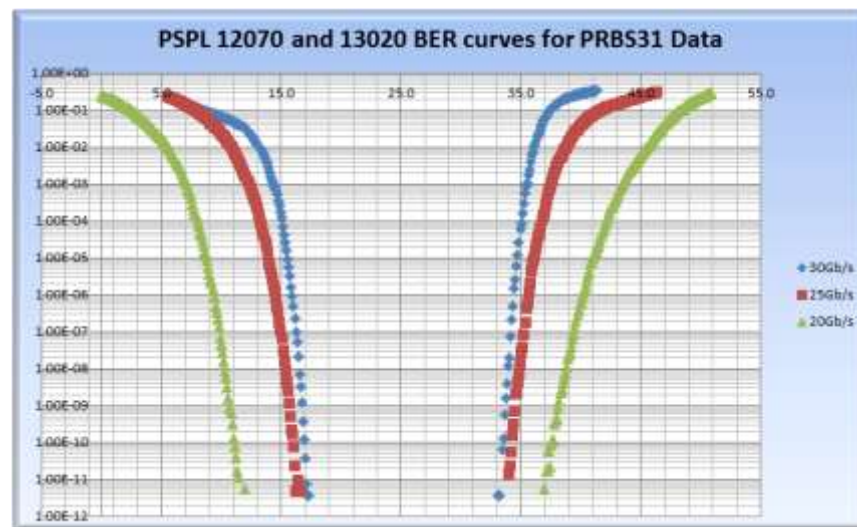
Jitter (Decision Threshold: -306.80 mV)		Noise (Sampling Phase: 0 UI)	
Random Jitter			
RJ (RMS)	= 213.54 fs	RN (RMS)	= 1.82 mV
RJ(h) (RMS)	= 210.77 fs	RN(v) (RMS)	= 1.80 mV
RJ(v) (RMS)	= 34.25 fs	RN(h) (RMS)	= 308.52 uV
Deterministic Jitter			
DJ	= 4.01 ps	DN	= 109.34 mV
DDJ	= 3.18 ps	DDN	= 106.85 mV
DCD	= 548.10 fs	DDN(level 1)	= 90.15 mV
DDPWS	= 2.18 ps	DDN(level 0)	= 122.45 mV
BUJ(d-d)	= 50.00 fs	BUN(d-d)	= 5.28 mV
PJ	= 106.14 fs	PN	= 2.58 mV
PJ(h)	= 94.12 fs	PN(v)	= 2.57 mV
PJ(v)	= 49.06 fs	PN(h)	= 137.76 uV
NPJ(d-d)	= 50.00 fs	NPN(d-d)	= 4.97 mV
Total Jitter @ BER		Total Noise @ BER	
TJ (1E-12)	= 6.50 ps	TN (1E-12)	= 133.66 mV
Eye Opening (1E-12)	= 18.50 ps	Eye Opening (1E-12)	= 422.81 mV
		Eye Amplitude	= 556.46 mV
Dual Dirac		SSC Modulation	
RJ(d-d)	= 251.65 fs	Magnitude	= 0 ppm
DJ(d-d)	= 2.95 ps	Frequency	= 0 Hz

DSA8300
 80E11 sampling plug-in
 82A04-60G phase reference

High Sensitivity Wide Phase Margin 32/40G Multi-channel PED



6mV_{pp} Sensitivity
Industry Best!



Wide Phase Margin

2014 NEW! Integrated 9-tap Pre-emphasis

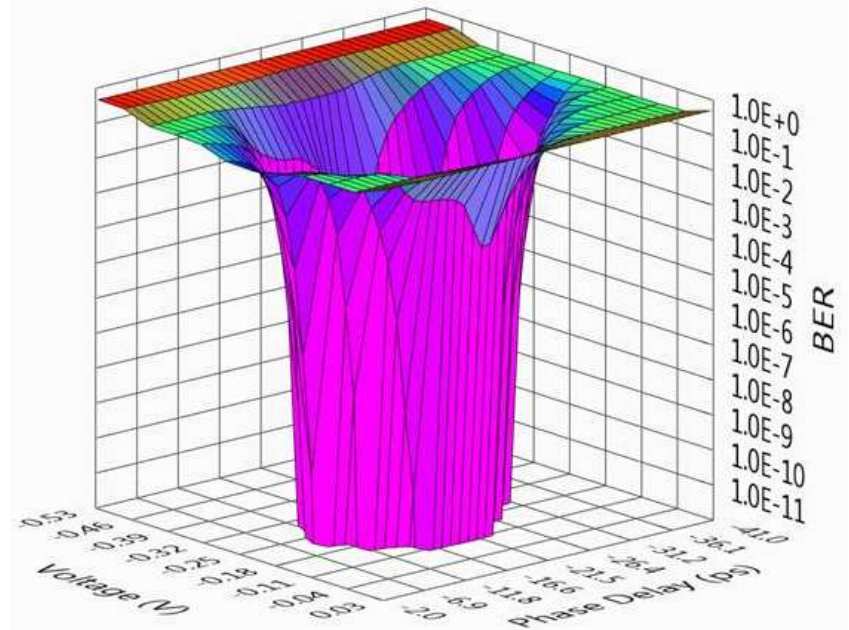


Maintains both standard and pre-emphasized outputs!

- 9 adjustable taps
- Compensate for channel or model channel effects
- Per channel, available on 1, 2, and 4 channel units
- Essentially an integrated version of the LE320
- Programmable via front panel, USB, and PC GUI controls

BERT Control and Analysis Software

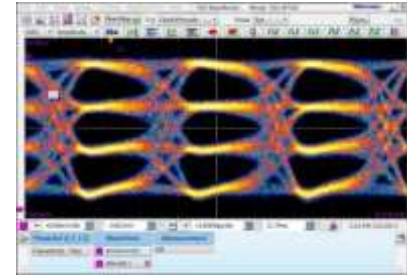
- Free, easy to use PC GUI software console:
 - Free to PatternPro customers
 - Works with PG's and ED's
 - Remote GUI control
 - JTOL and J2/J9
 - Bathtub curves
 - Contour Analysis
 - Low level control
 - Code available
 - Full engineering support



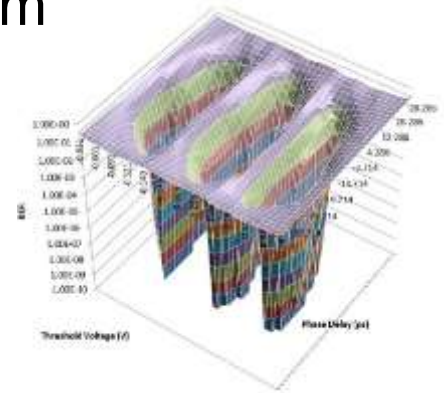
Current and Next Generation Optical and Electrical Testing

- Current and emerging optical standards
 - QPSK - 2x20Gb/s
 - 100G Ethernet LR4/ER4 – 4x25Gb/s
 - DP-QPSK - 4x32Gb/s
 - QAM - 4x32Gb/s with each channel having PAM4
 - Advanced testing with custom AWG waveforms
- Current and emerging electrical standards
 - OIF CEI 4x28Gb/s
 - 100GE 4x25Gb/s cable and backplane links
 - 25Gb/s NRZ and 14 Gb/s PAM4
 - Victim-aggressor cross-talk analysis is a critical design verification tool

32G PAM4 BERT System

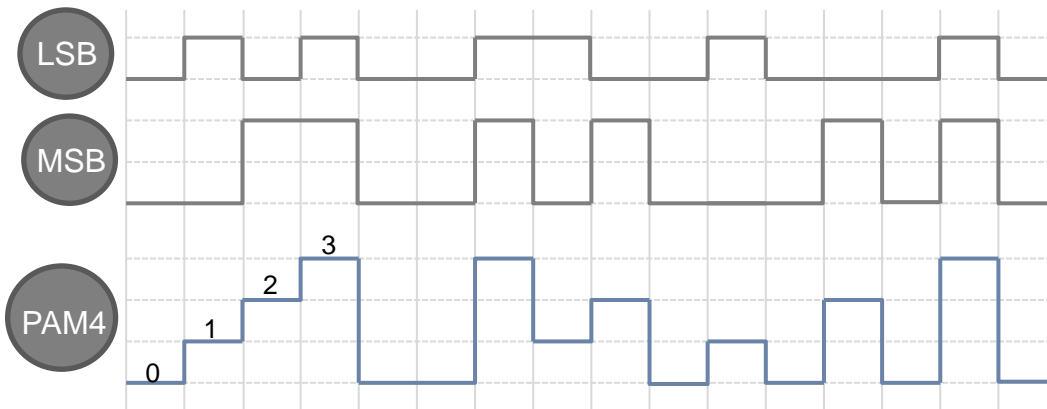


- In 2013 announced the **industry's first** high-speed PAM4 BERT system
- Consists of BERT products bundled into a system
 - Programmable pattern generator
 - Programmable error detector
 - Analysis software
 - Broadband components (power combiners/attenuators)
- PAM4 Signal Generator
 - Phase-aligned channels simplify multi-level signal generation
 - User-programmable data patterns allow test of PAM4 custom data
- PAM4 Analyzer
 - **BER measurements** analyzes every bit of each pattern
 - Contour plots, bathtub curves, total jitter **analysis** via software tools



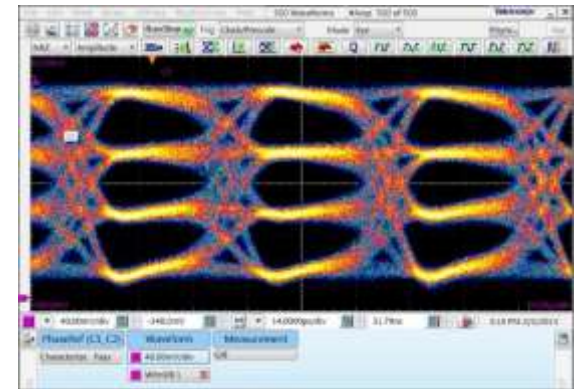
PAM4 Signal Generator

- Use two channel PPG to set up PAM4 signal
 - Use external combiner (eg 5350) to combine two phase-aligned channels
 - See Tech Note for procedure and results
- Program same PRBS with LSB-MSB bit shift or program different user-defined patterns with the same length on PPG channels.

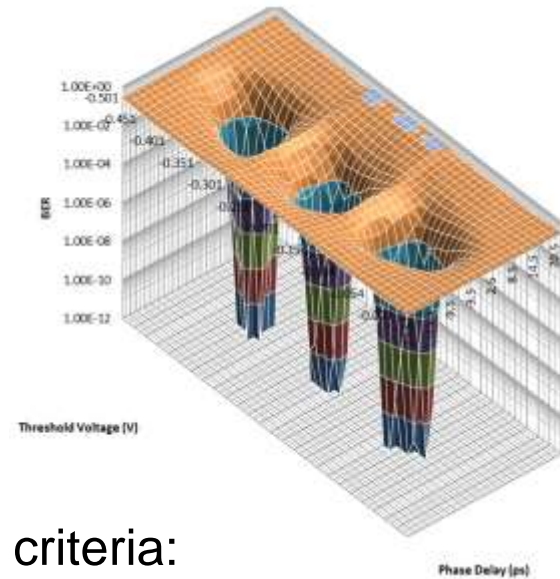
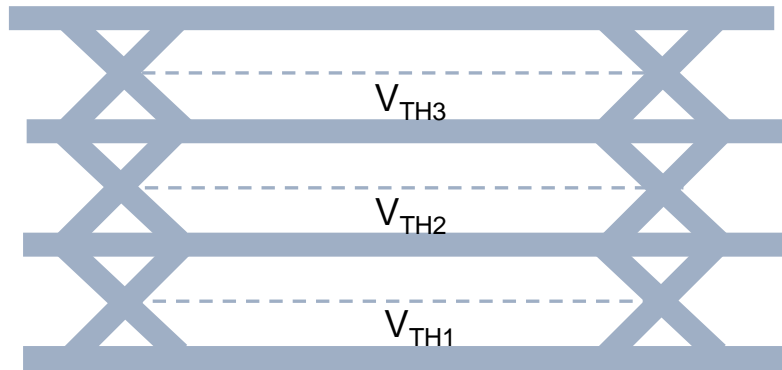


LSB: Ch1 data signal (1V)
MSB: Ch2 data signal (2V)
PAM4: Sum of the two signals

MSB	LSB	PAM4 LEVEL
0	0	0
0	1	1
1	0	2
1	1	3



PAM4 Error Detection and Analysis



- Define three ED patterns using the following criteria:
 - “lower eye” equals ‘OR’ of LSB with MSB
 - “middle eye” equals MSB
 - “upper eye” equals “AND” of LSB with MSB
- Use PSPL ED and software to test all three PAM4 eye diagrams
 - Load pattern for lower, middle, or upper eye
 - Auto align and synchronize to eye.
 - Measure BER, bathtub, or contour data
- PC GUI utility provides automated procedures for these steps

A Full Range of BERT Testers from Tektronix

Summary

Application/Usage	BERTScope	PPG/PED
Single Channel BERT <28.6Gb/s >28.6Gb/s	X	X
Multi-channel BERT/PG/ED		X
Built-in Analysis	X	
Integrated Compliance Testing	X	
Separate PG or ED		X

BERTScope Series



BSA286C
28.6Gb/s, 1-channel
Bit Error Rate Tester

PPG/PED3000 Series



PED3202
32 Gb/s, 2-channel
Error Detector



PPG3204
32 Gb/s, 4-channel
Pattern Generator



BA1600
1.6Gb/s, 1-channel
Bit Error Rate Tester

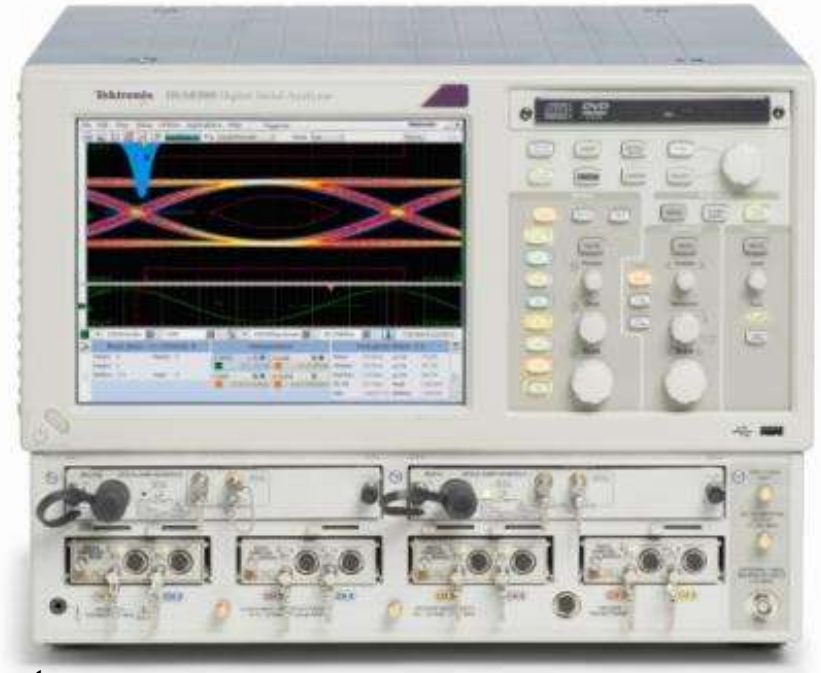


PPG3002
30 Gb/s, 2-channel
Pattern Generator

Introducing the DSA8300 Digital Serial Analyzer


More Performance and Versatility

- Industry's best native jitter noise floor, 425 fs_{RMS} *typical* on up to 8 simultaneously acquired channels
- ≤100 fs_{RMS} jitter noise floor, when equipped with the 82A04B on up to 6 simultaneously acquired channels
- 16,000 point native record length
- 16 bits of vertical resolution
- Optional fully integrated pattern synchronization
- 4X Pattern Sync throughput improvement
- Clock Pre-scalar maximum input frequency 20 GHz *typical*
- 3 GHz Intel Core 2™ Duo CPU
- New user interface look and feel leveraging MS Windows 7 Ultimate Operating System
- XVGA (1024 X 768) 10.4 inch display



DSA8300 Digital Serial Analyzer

DSA8300 Optical Module Portfolio

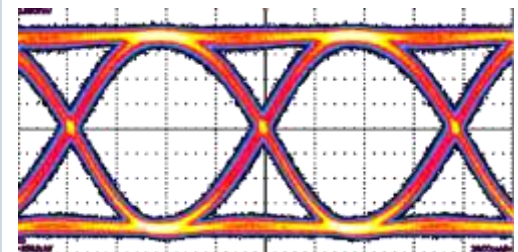
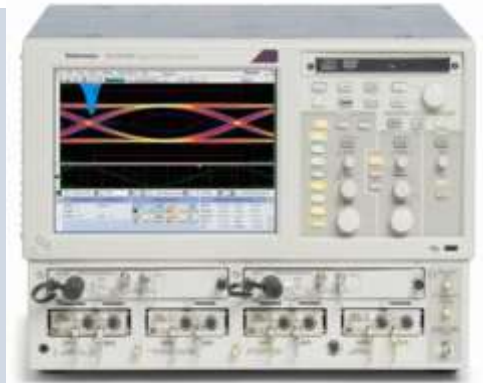
Single and Multi-mode, Broad Wavelength (750 - 1650 nm) Modules	
80C07B	Supports standard rates to 2.7 Gb/s, high sensitivity, optional integrated clock recovery
80C08D	Supports all of the 8/10 Gb/s applications, high sensitivity, optional integrated clock recovery, optional Integrated CR
80C12B	Supports standard rates from 155 Mb/s – 11.3 Gb/s, high sensitivity - data pick-off for external CRU e.g. CR125A
80C14	Supports rates from 8.5 Gb/s – 14.063 Gb/s, high sensitivity – data pick-off for external CRU e.g. CR175A
80C15 	Supports standard rates from 25.73 Gb/s – 28.05 Gb/s (maximum optical bandwidth > 32 GHz)
Single-mode, Long Wavelength (1100 - 1650nm) Modules	
80C11B	Optical bandwidth to 30GHz, supports 10Gbit/s up to 14G+ standards, optional Integrated CR
80C10C	Optical bandwidth to 80GHz, supports all 40 and 100 Gb/s (4 x 25 Gb/s) standards, optional CR trigger pickoff for e.g. CR286A CRU, optional high sensitivity photo-receiver for use with external equipment (e.g. for optical BER testing with BERTScope)

Tektronix 80C15 Optical Sampling Module Highlights

NEW

80C15


- Single-Channel Optical Plug-in Module for DSA8300
- Unfiltered Optical Bandwidth >32 GHz
- 62.5/125 μm Multi-Mode Fiber Input
- Short- and Long-Wavelength Support 780-1650 nm
- 200 kS/s Acquisition Rate
- Jitter Floor <150 fs_{RMS} (with 82A04B)
- Reference Receiver Filters:
 - ✓ 32G FibreChannel (28.05 Gb/s)
 - ✓ OTU4 (27.95 Gb/s)
 - ✓ 100Gbase-LR4/ER4/SR4 (25.78 Gb/s)
 - ✓ 26G EDR Infiniband (25.78 Gb/s)



26 Gb/s

Industry-Leading Optical Portfolio

The 80C15 covers the space between current 80C14 and 80C10C modules

Feature / Specification	80C14	80C15 	80C10C
Input Fiber Type	SMF + MMF 9, 50, 62.5 μm	SMF + MMF 9, 50, 62.5 μm	SMF 9 μm
Wavelength Range	700-1650nm	780nm-1650nm	1290-1620nm
Unfiltered Optical Bandwidth	14 GHz	32+ GHz	80+ GHz
Unfiltered Risetime, typ	31 ps	14 ps	6 ps
Filter Rates	8.5 – 14.06 Gb/s	25.78 – 28.05 Gb/s	25.78 – 44.5 Gb/s
26Gb/s Mask Test Sensitivity AOP @ 1310nm	-16.5 dBm	-9 dBm	-7.5 dBm

80C15 Optical Module

100G Single/Multi-mode Solution



80C15 Optical Module

Performance Specifications	
Single and multi-mode	9, 50, 62.5µm core
Supported wavelengths	700 – 1650 nm
Maximum Optical Bandwidth	>32 GHz
Optical Reference Receivers	25.78 Gb/s – 28.05 Gb/s
Sensitivity	-9 dBm (at 1310 nm)

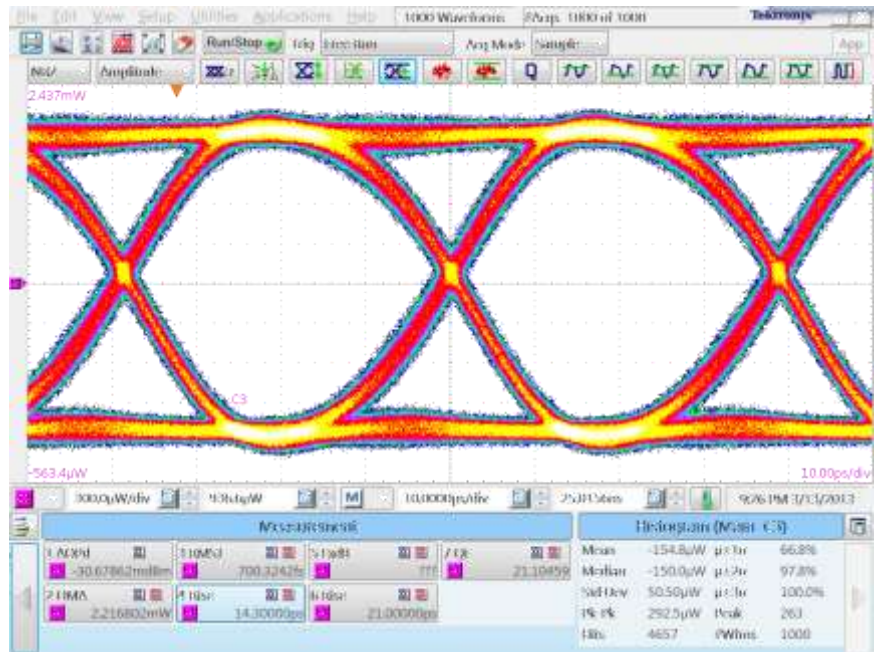
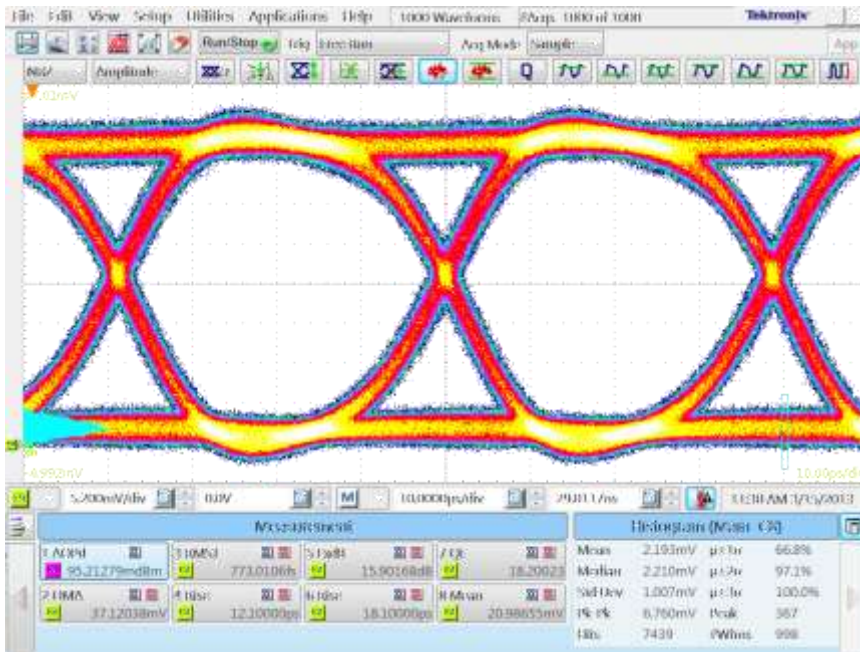
Standards Supported

Standard	Data Rate
26G EDR Infiniband	25.78 Gb/s
100Gbase-LR4/ER4/SR4	4×25.78 Gb/s
OTU-4	4×27.95 Gb/s
32G Fibre Channel	28.05 Gb/s

Unfiltered and Filtered 26Gb/s Eye Comparison

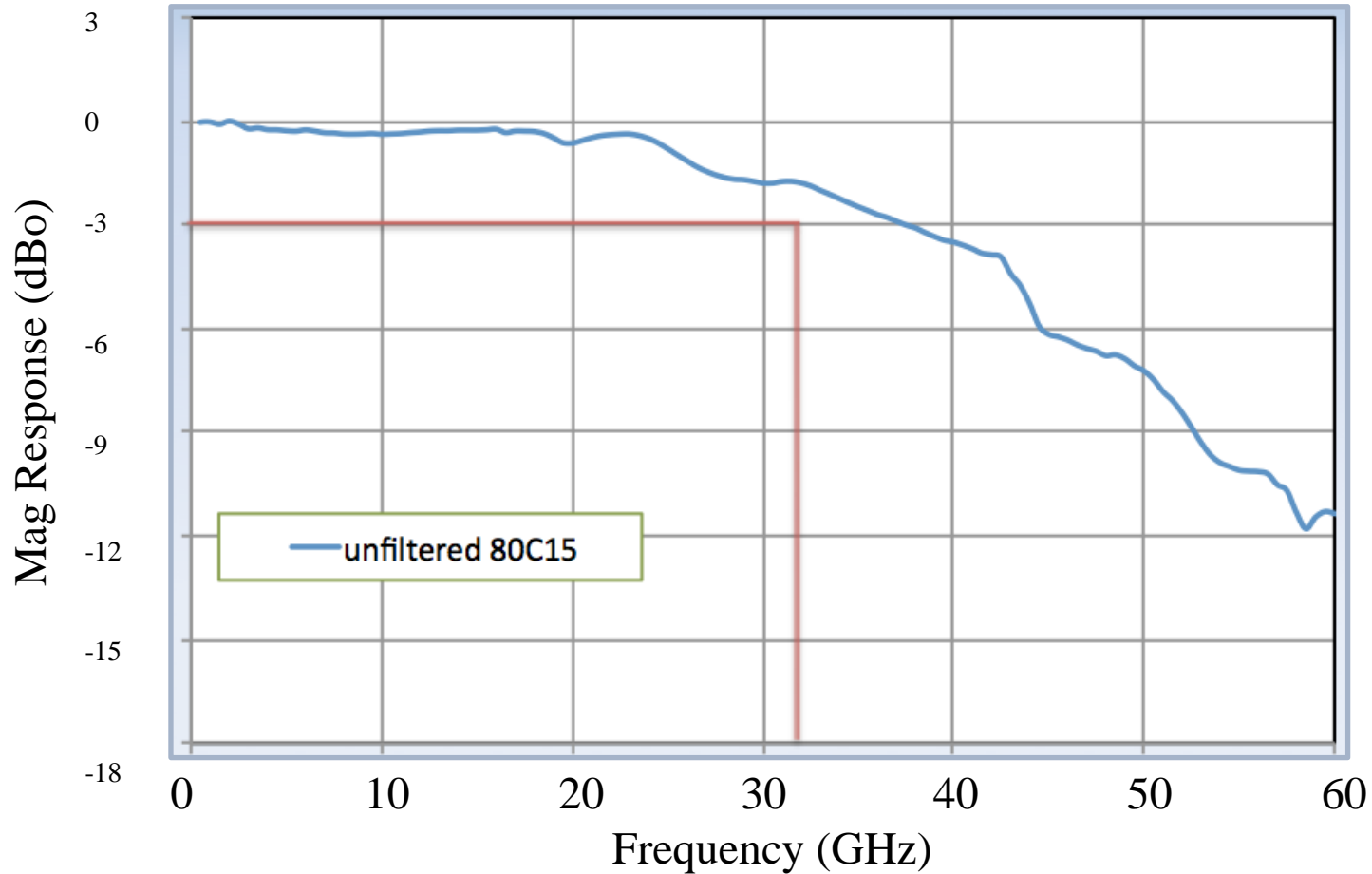
Unfiltered 30+GHz bandwidth

100GBase-R4 filter turned on



Signal source : 1550nm MZM Tx at 0dBm, 25.78125 Gb/s, PRBS31

Unfiltered Optical Bandwidth >32GHz

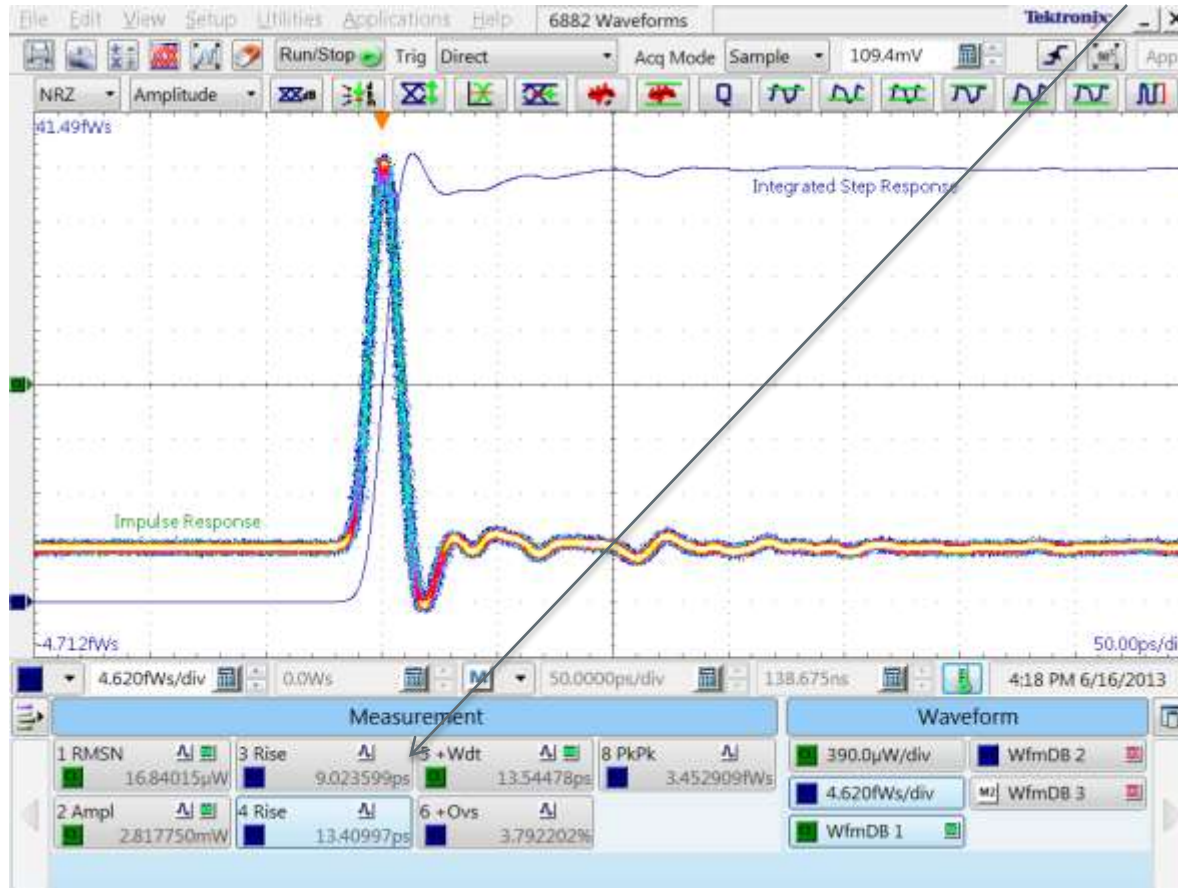
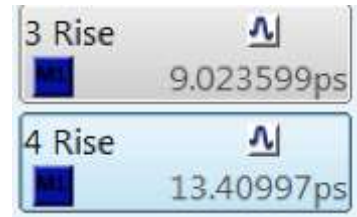


Actual Measured Optical Bandwidth: 37 GHz

80C15 Unfiltered Transient Response

Measured Step Rise Time: 9.0 ps (20-80%)

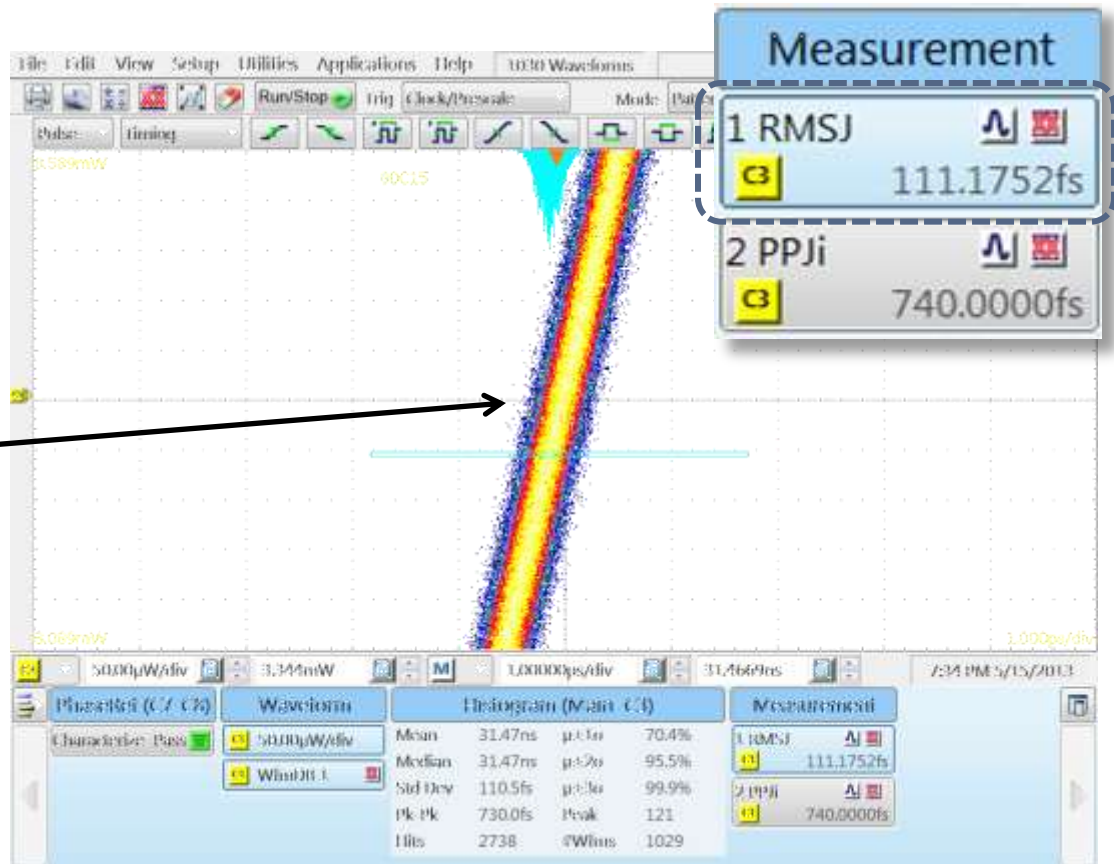
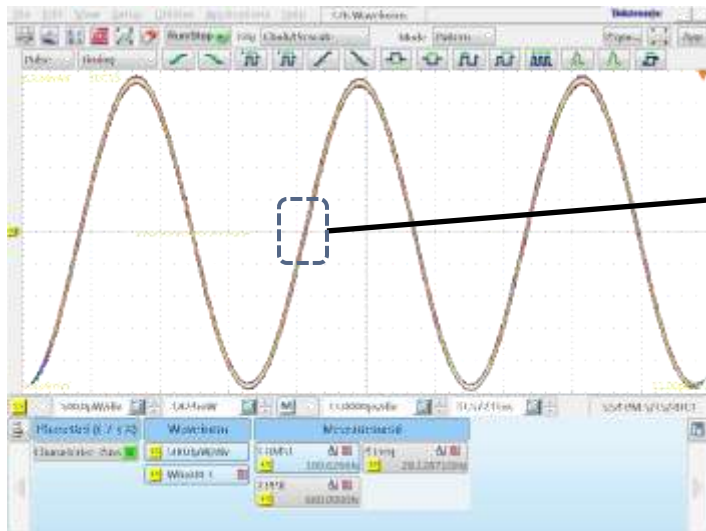
13.4 ps (10-90%)



Impulse source: MLL width FWHM<1ps at 1550nm

80C15 Optical Jitter Floor < 150 fs

New 82A04B PhaseReference module enables ultra-low jitter measurements of optical waveforms with a measured floor of ~110 fs_{RMS}



28GHz optical CLOCK waveform

80C14 Optical Module

16 GFC Single/Multi-mode Solution

80C14 Optical Module

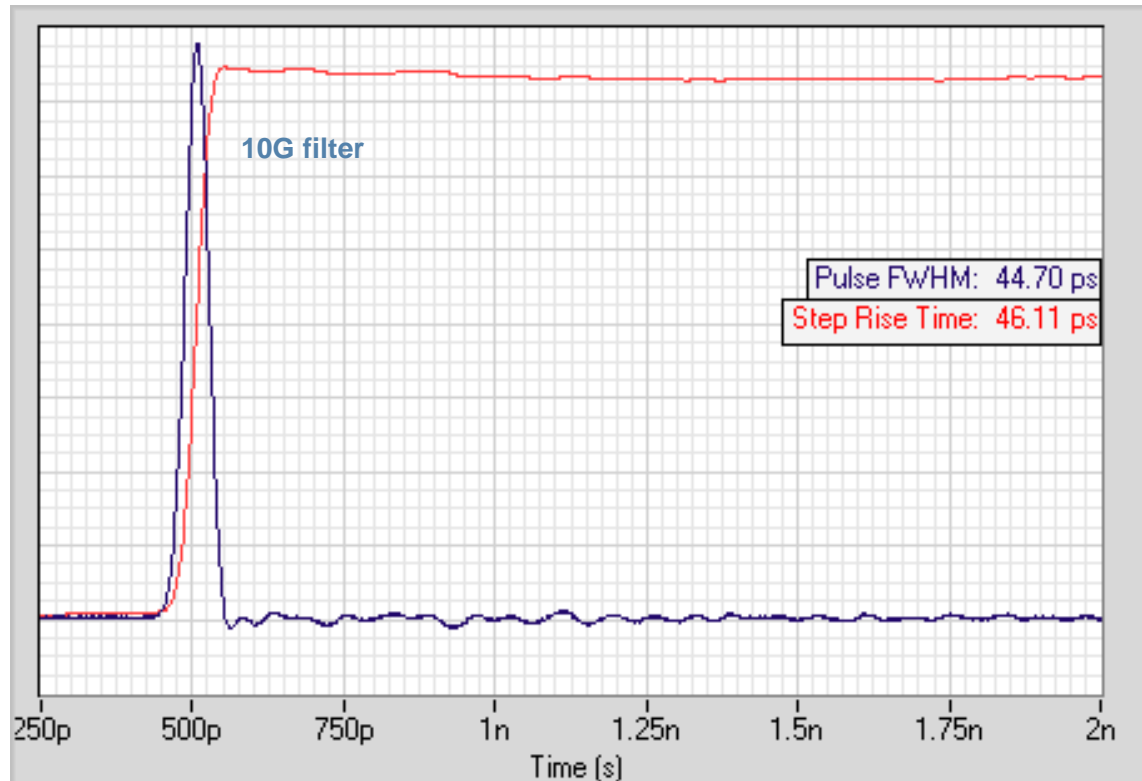
Performance Specifications	
Single and multi-mode	9, 50, 62.5µm core
Supported wavelengths	700 – 1650 nm
Maximum Optical Bandwidth	14 GHz
Optical Reference Receivers	All 10 Gb/s standards + 8 and 16 GFC
Sensitivity	-12 dBm at 850nm (-15 dBm at 1310 nm)
Buffered electrical data pick-off to support external clock recovery instrument	Recommended Tektronix CR175A or CR286A

Standards Supported

Standard	Data Rate
8 GFC (old)	8.500 Gb/s
OC192/STM64	9.953 Gb/s
10GBase-W	9.953 Gb/s
10GBase-R	10.31 Gb/s
40GBase-LR4	9.953 Gb/s
10G EPON	9.953 Gb/s
100GBase-SR10	10.31 Gb/s
10GFC	10.51 Gb/s
G.975 FEC	10.66 Gb/s
G.709 FEC	10.71 Gb/s
10GBE FEC	11.10 Gb/s
10 GFC FEC	11.317Gb/s
12.5 Gb/s FEC	12.50 Gb/s
16 GFC	14.025 Gb/s
Infiniband FDR	14.063 Gb/s

New 80C14 Optical Module Unmatched Signal Fidelity for 16G FibreChannel

Minimal overshoot



80C12B Optical Module

Tributary and 10G Rate, Single/Multi-mode Solution

80C12B

Performance Specifications

- Single and multi-mode (9, 50, 62.5µm core)
- Supported wavelengths (700 – 1650 nm)
- Maximum optical bandwidth – 12 GHz
- Optical Reference Receivers – All 125 Mb/s through 11.3 Gb/s standards
- Buffered electrical data pick-off to support external clock recovery
- Recommended clock recovery, Tektronix CR175A or CR125A

80C12B Module with available ER-Calibrated for accurate repeatable ER measurements

- Accuracy: $\pm 1.2\%$ (-0.76 dB / +0.92 dB at 12dB)
- Repeatability: $\pm 0.6\%$ (-0.39 dB / +0.42 dB at 12 dB)

Three configuration strategies available:

1. Any 4 Trib. rate filters, options F0 through F12
2. All 10 G rates only (8.5 Gb/s to 11.3 Gb/s filters only), Opt. 10G only

3. Select any 3 Tribrate filters, plus 10GP (10G rates)

Filter Opt.	Rate(s) Supported
F0	Unfiltered 12 GHz bandwidth and 8.500 ORR filter
F1	155.52 Mb/s Optical Reference Receiver (ORR) Filter
F2	622 Mb/s ORR Filter
F3	1.0625 Gb/s ORR Filter
F4	1.250 Gb/s ORR Filter
F5	2.125 Gb/s ORR Filter
F6	2.488, 2.500 Gb/s ORR Filter
F7	2.666 Gb/s ORR Filter
F8	3.125, 3.188 Gb/s ORR Filters
F9	4.250 Gb/s ORR Filter
F10	5.000 Gb/s ORR Filter
F11	6.144 Gb/s ORR Filter
F12	7.373 Gb/s ORR Filter
10G	8.500, 9.95, 10.31, 10.51, 10.66, 10.71, 11.1, 11.3 Gb/s ORR Filters plus Unfiltered full bandwidth path (typically 12 GHz)
10GP	8.500, 9.95, 10.31, 10.51, 10.66, 10.71, 11.1, 11.3 Gb/s ORR Filters plus Unfiltered full bandwidth path (typically 12 GHz) – specify 3 additional filter options (F1-F12) to be included.


Key **Electrical** Module Operating Specifications

Item	Selectable Bandwidths	CH.	Risetime (10% - 90%)	RMS Noise	Max. Operating Voltage	Acq. Aberrations
NEW 80E09B ^{1,2}	60 GHz	2	5.8 ps	450 μ V typ. \leq 600 μ V max.	\pm 1.1 V	+6%, -10% for first 400 ps after transition
	40 GHz		8.8 ps	330 μ V typ. \leq 480 μ V max		
	30 GHz		11.7 ps	300 μ V typ. \leq 410 μ V max		
NEW 80E11	70G	2	5ps	70 GHz:950 μ V, \leq 1100 μ V 60 GHz:450 μ V, \leq 600 μ V 40 GHz:330 μ V, \leq 480 μ V	\pm 0.8 V	+6%, -10% or less for the first 400 ps following step transition
NEW 80E07B ^{1,2}	30 GHz	2	11.7 ps	330 μ V typ. 480 μ V max.	\pm 1.1 V	+6%, -10% for first 400 ps after transition
	20 GHz		17.5 ps	300 μ V typ. \leq 410 μ V max		
80E06	70+ GHz	1	5.0 ps	1.8 mV typ. \leq 2.4 mV max	\pm 1.6 V	+6%, -10% for first 400 ps after transition
80E03	20 GHz	2	17.5 ps	600 μ V typ. \leq 1.2 mV max	\pm 1.6 V	+6%, -10% for first 400 ps after transition
80E01	50 GHz	1	7.0 ps	1.8 mV typ. \leq 2.3 mV max	\pm 1.6 V	+6%, -10% for first 400 ps after transition

1. Supports 425 fs RMS native system jitter in DSA8300

2. Supports 100 fs RMS system jitter when DSA8300 is equipped with available 82A04B

Key **TDR** Module Operating Specifications

Item	Selectable Bandwidths	CH.	Incident / Reflected Risetime (10% - 90%)	Acq. Risetime	RMS Noise	Deskew Range
 80E10B ^{1,2}	50 GHz	2	12 ps / 15 ps	5.8 ps	600 μ V typ. \leq 700 μ V max.	\pm 250 ps
	40 GHz			8.8 ps	370 μ V typ. \leq 480 μ V max	
	30 GHz			11.7 ps	300 μ V typ. \leq 410 μ V max	
80E08 ^{1,2}	30 GHz	2	18 ps / 20 ps	11.7 ps	300 μ V typ. 410 μ V max.	\pm 250 ps
	20 GHz			17.5 ps	280 μ V typ. \leq 380 μ V max	
80E04 ^{1,2}	20 GHz	2	17.5 ps	17.5 ps	600 μ V typ. \leq 1.2 mV max	\pm 50 ps

1. Supports 425 fs RMS native system jitter in DSA8300
2. Support 100 fs RMS system jitter when DSA8300 is equipped with available 82A04B

AWG介绍

信号源类型

- 频域和时域信号源
 - RF信号发生器
 - 扫频源
 - 频率综合源
 - 噪声发生器
 - 脉冲发生器
 - 数据、码型发生器
 - 函数发生器
 - 任意函数发生器
 - 任意波形发生器
- 基于DDS的任意波形发生器：高性能、易用的全能信号源

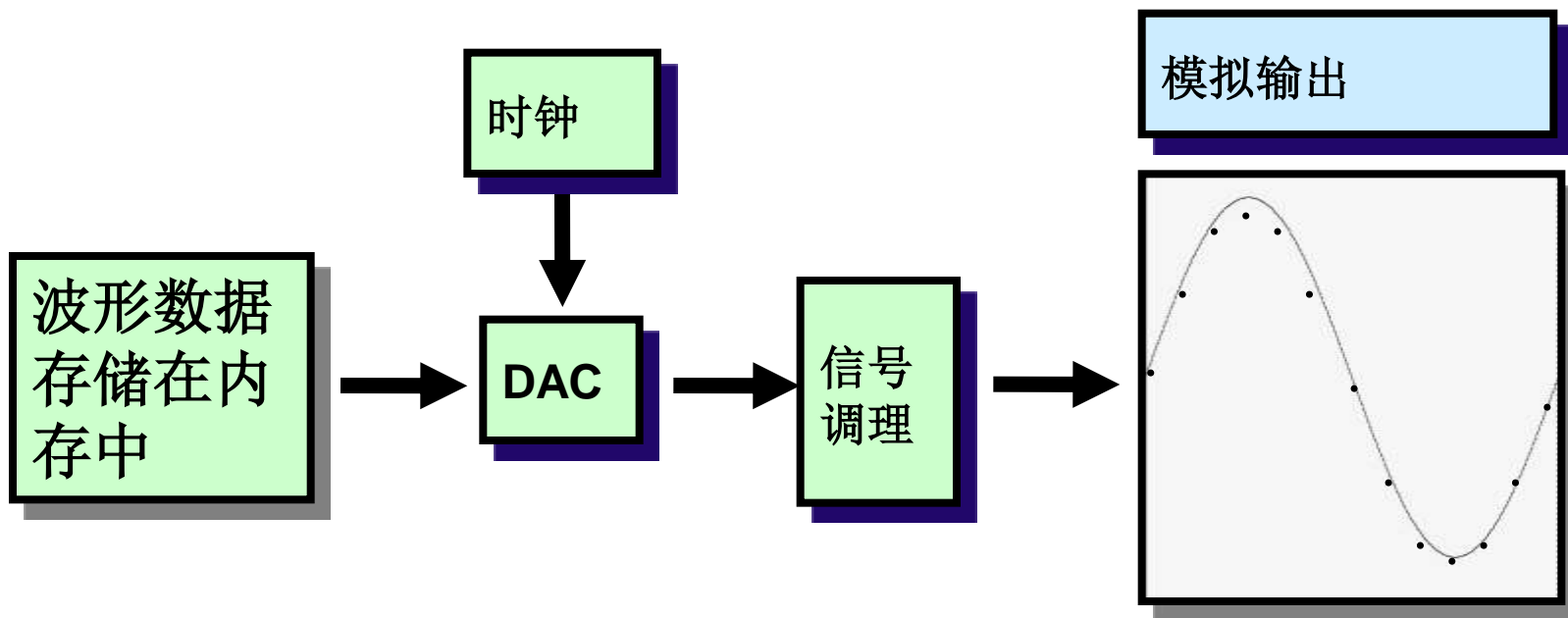
任意波形发生器——一种在未来不可或缺的信号源

- 任意信号发生器的几个用途
 - 产生基带IQ信号
 - 产生中频/射频信号
 - 混合模拟/数字测试
 - 产生多路信号
 - 替代一些传统信号源(如函数信号产生器)
 - 替代一些定制信号源(如特殊脉冲发生器、雷达模拟信号, 低频相位标准等)
- 任意信号发生器能输出“现实世界”各种信号
 - 信号加扰的产生:插入噪声、毛刺、交调等
 - 模拟复杂的信道



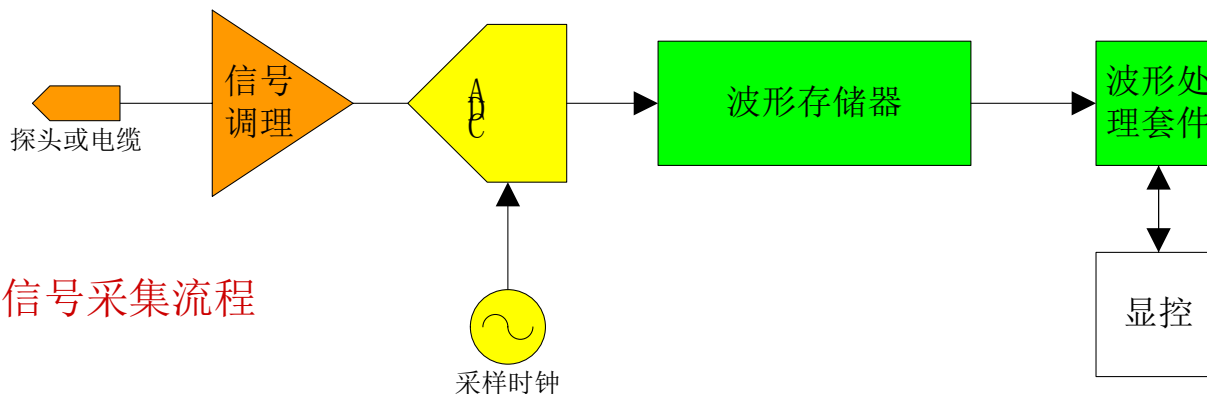
AWG如何生成波形？

- AWG生成波形类似于CD播放器
 - 存储在光盘上数字信息被读出，转换成模拟波形最后通过扬声器输出。

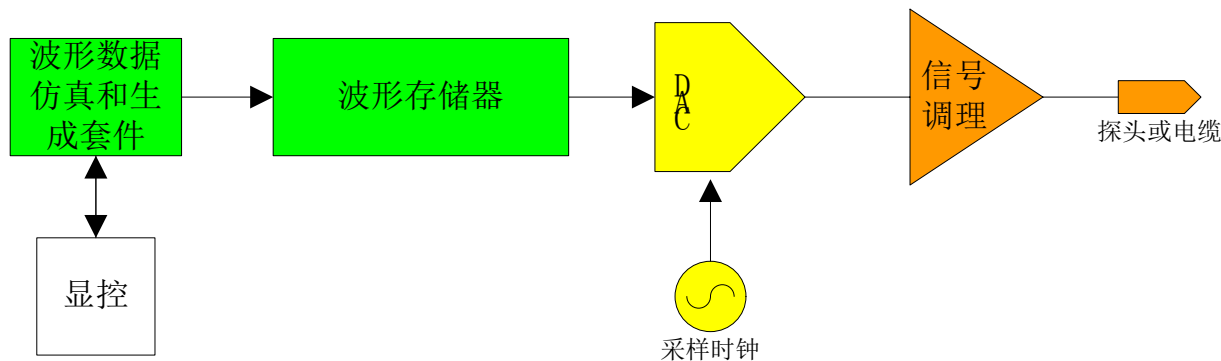


AWG工作原理

- AWG可以被认为是示波器(信号分析仪)的逆过程



示波器信号采集流程



AWG信号生成流程

示波器可以捕获任何其指标范围内的信号

AWG可以产生任何其指标范围内的信号

最新的AWG70000A 任意波形发生器



AWG70001A

通道数量	1
采样率	1.5 KS/s - 50 GS/s
最大输出频率	20.0 GHz
动态范围 (SFDR)	> 80 dBc
DAC分辨率	10位
波形存储器 (每条通道)	2 G样点 (标配) 16 G样点 (选配)





AWG70002A

通道数量	2
采样率	1.5 KS/s - 25 GS/s
最大输出频率	10.0 GHz
动态范围(SFDR)	>80 dBc
DAC分辨率	10位
波形存储器 (每条通道)	2 G样点(标配) 8 G样点(选配)

AWG7000C

AWG7000C	AWG7122C		AWG7082C	
采样率	12 GS (24GS by Interleave)		8 GS	
输出上升时间/带宽 (3dB)	35 ps, 7.5GHz (option 02 /06)		NA	
最高序列长度	16,000			
垂直分辨率	8bit或10bit可选			
波形长度要求	X4 (x8 : 复用模式)	X4		
最高有效射频输出带宽	9.6GHz@24GS/s	4.8GHz@12GS/s	2.4GHz	2.4GHz
最大波形长度	64M点 (AWG7122C复用模式下128M点)			
时延校准范围和精度	±100 ps , 1ps步进			
仪器类型	独立式			

AWG5000C: 基带和通用应用

				
	AWG5014C	AWG5012C	AWG5004C	AWG5002C
Maximum Sample rate	1.2GS	1.2GS	600MS	600MS
Maximum Waveform Length	16M points/ch, 32 M points / ch (option)			
Analog Channels	4	2	4	2
Vertical resolution	14 bit			
Digital (Marker) channels	8 (2/ch)	4 (2/ch)	8 (2/ch)	4 (2/ch)
Digital Data output (Ch1 & Ch2)	NA	28 (option)	NA	28 (option)

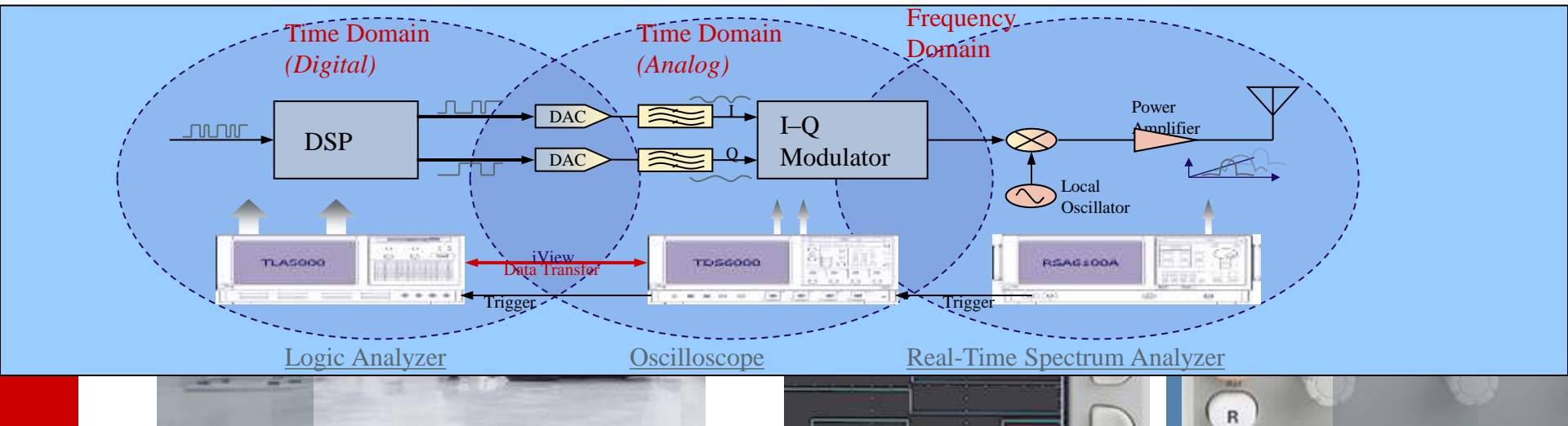
使用AWG产生信号的方法

- 只要能用数学模型表示的信号，只要在AWG的指标范围内，都可以使用AWG来直接生成
- 任何数据生成软件，如Matlab程序、用户自编脚本、泰克提供的专用信号生成工具，甚至写字板等，都可以作为AWG信号数据的来源
- 其它设备采集的数据，如示波器的时域信息、逻辑分析仪的码型或者实时频谱分析仪采集的频域数据均可在AWG上回放
- 内置的高级RF信号生成软件可以直接设置参数生成各种RF信号，方便、快捷

AWG典型应用案例

- 高速串行数据
- 产生用户自定义波形
- 产生任意脉冲信号
- 宽带雷达信号
- 宽带卫星通信信号(数字调制信号)
- 复杂电磁环境信号

应用一：产生高速串行数据信号



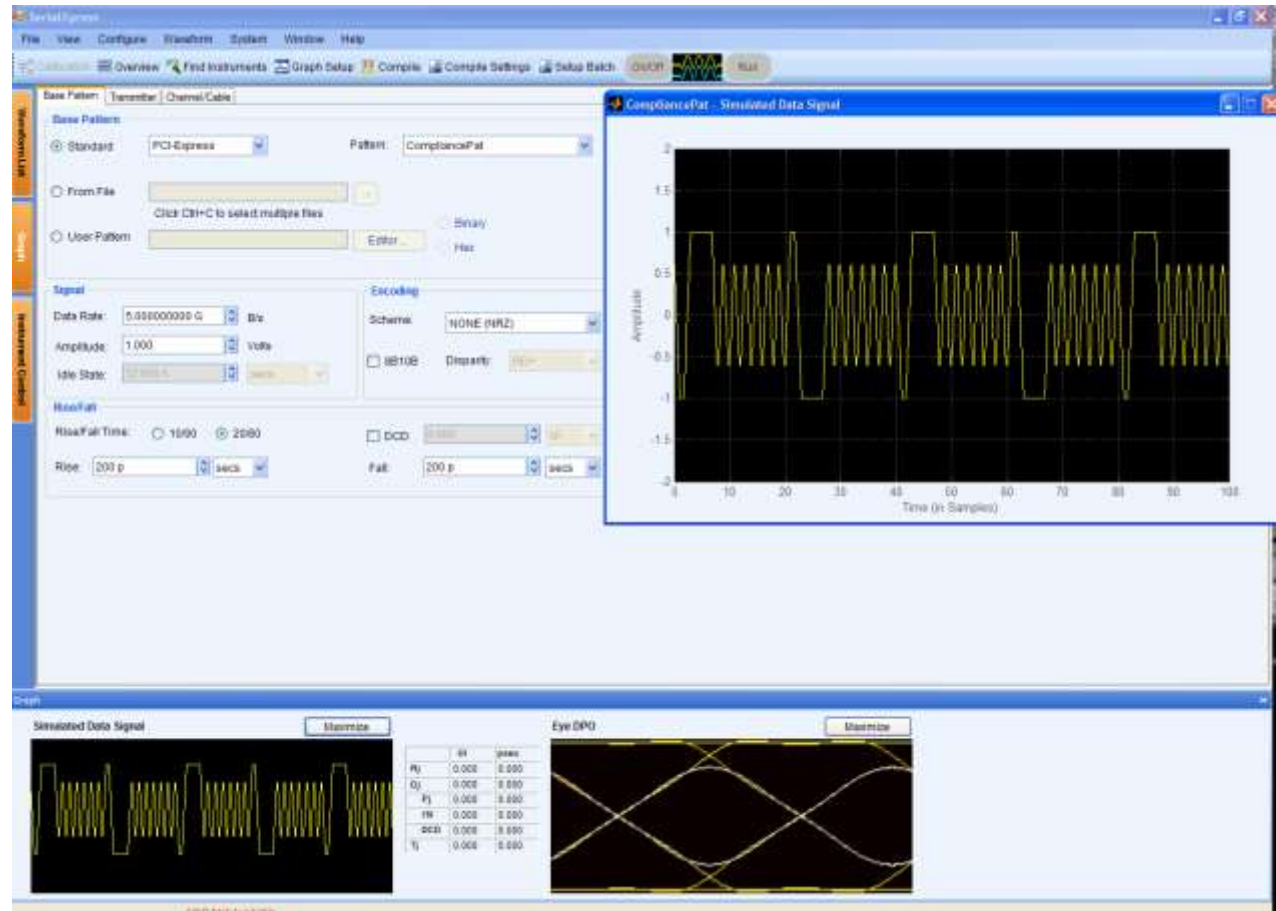
用SerialXpress软件产生高速串行信号

Standard Base Patterns Selections

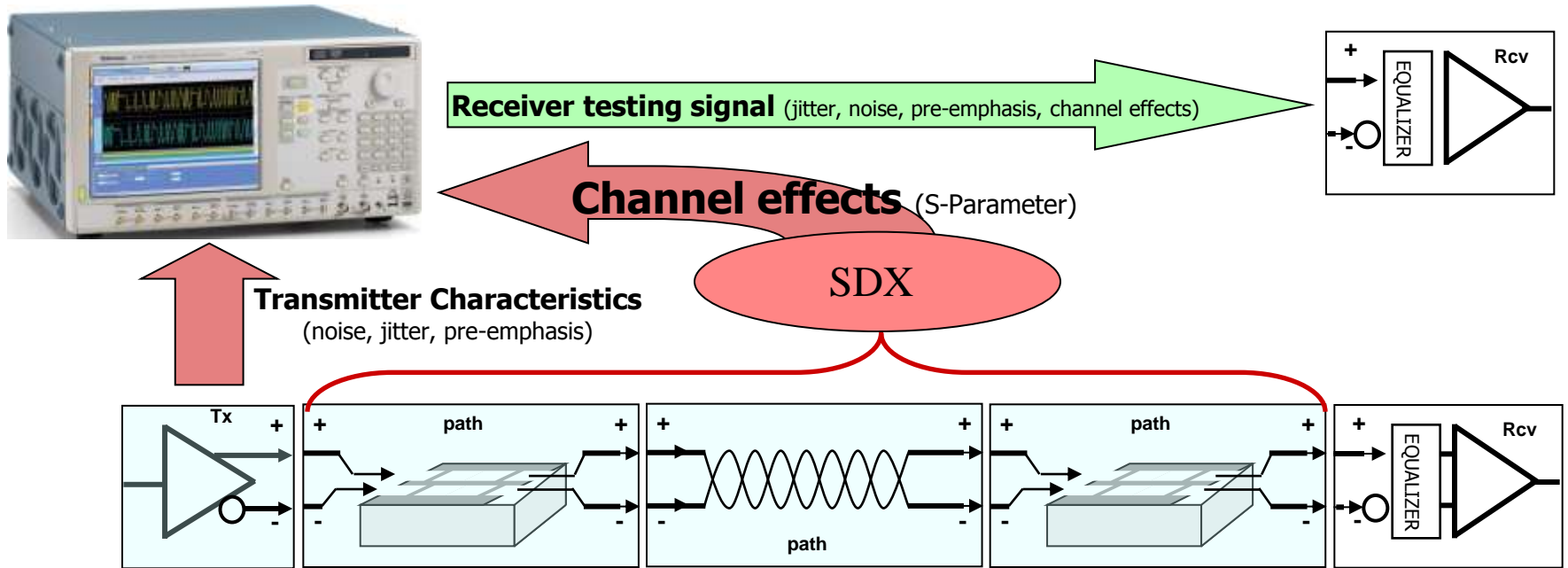
- ▶ SATA
- ▶ SAS
- ▶ HDMI
- ▶ DisplayPort
- ▶ PCIe
- ▶ Fiber Channel

Rise time setting

Graphic simulations of Compiled Data



Direct Synthesis with SerialXpress— Allows for easy, thorough and repeatable receiver testing



Signal Generation (performance)

- ▶ Using Direct Synthesis to “build” analog waveform signals
- ▶ AWG7000 with 24GS/s is the only tool available to build HSSD signal up to 8Gb/s
- ▶ Long memory is required to replicate the complex modulated waveforms

Replication of “Transmitter Characteristics”

(Functionality & Ease of Use)

- ▶ Replicate “real world” transmitter signals including Jitter, noise pre-emphasis, advanced emphasis...
- ▶ Replicate spread spectrum clock modulation

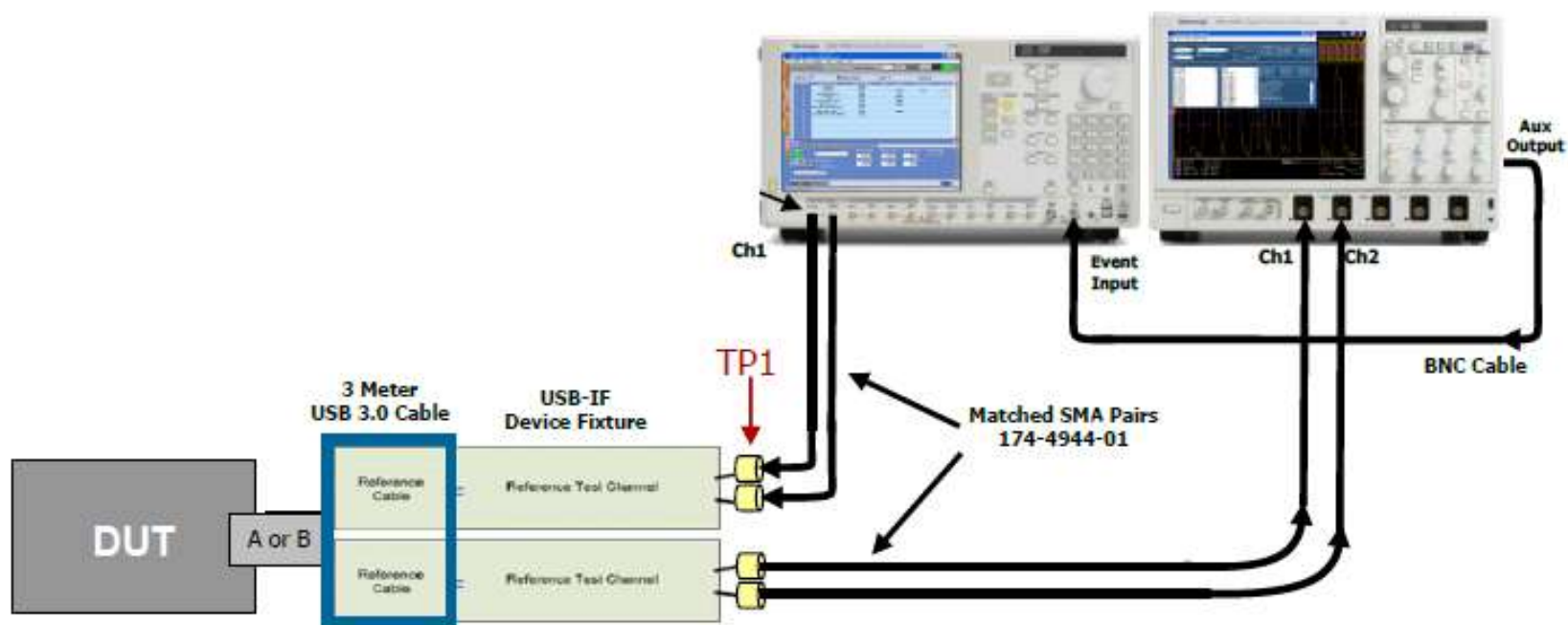
Replication of channel effects

(Functionality & Ease of Use)

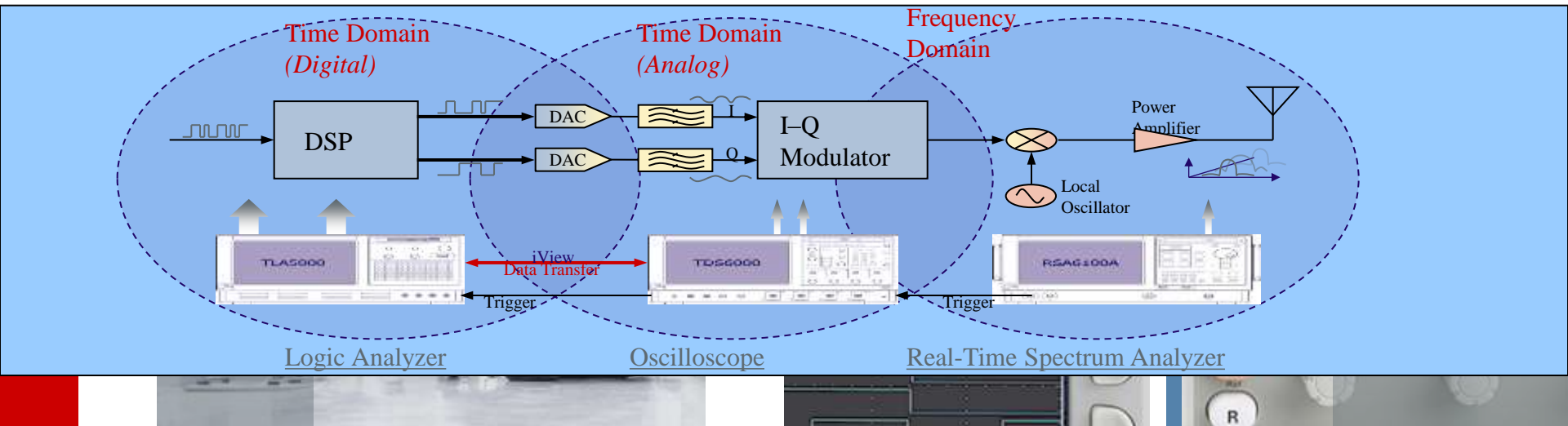
- ▶ Replicate transmission effects and add them to the test signal
- ▶ Import touchstone® S-parameters to automatically replicate channel effects

使用AWG进行 USB 3.0/SATA 3.0/HDMI等抖动容限测试

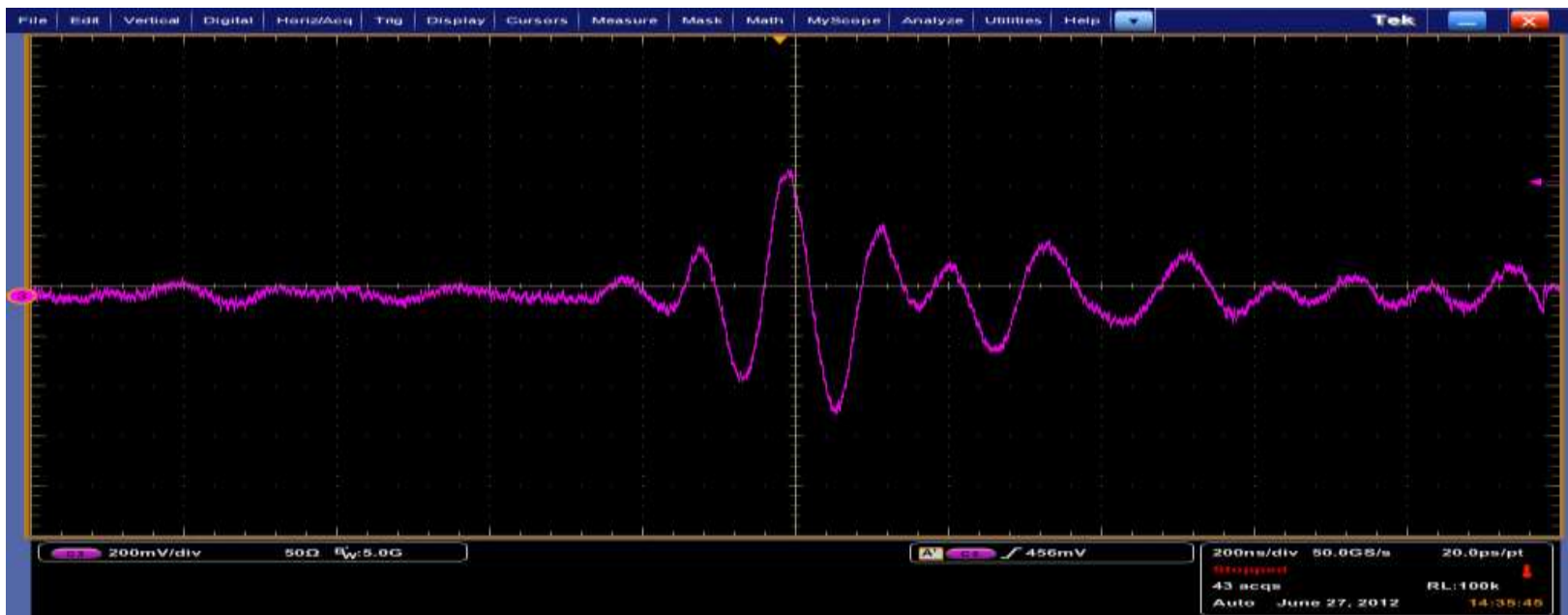
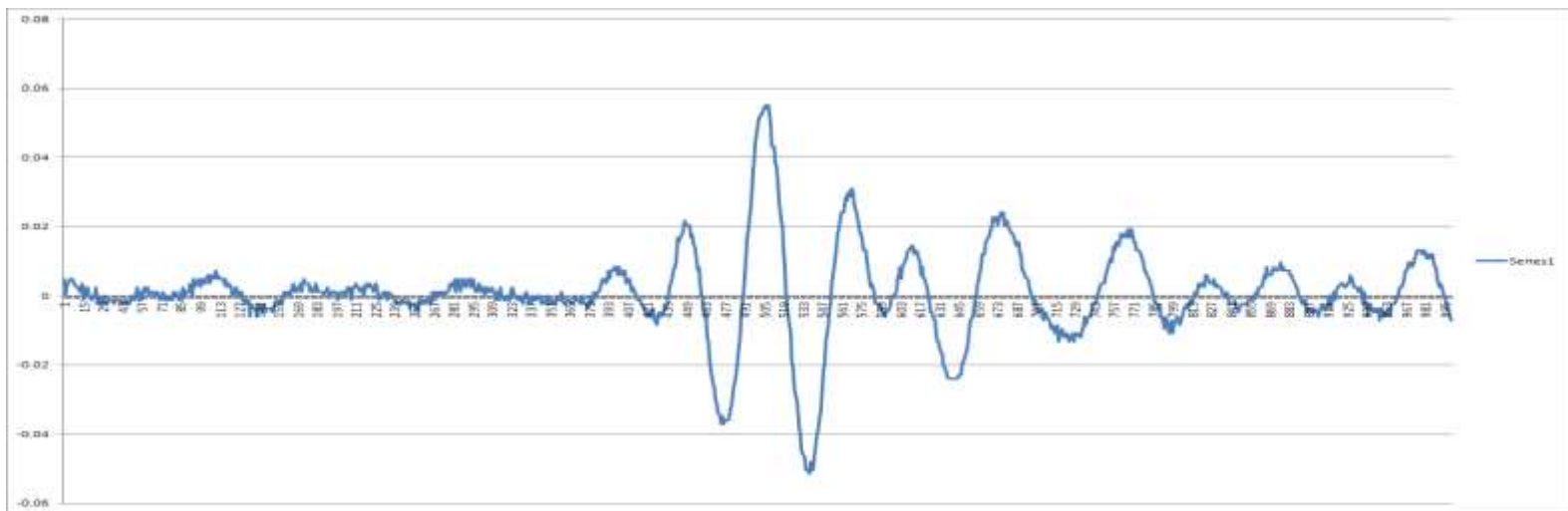
- Only test equipment setup with a common configuration for Receiver and Transmitter Testing
- All Signal Impairments including channel impairments generated by the AWG
- No need for external error detectors
 - Only Oscilloscope based bit or symbol error detection solution (Ellisys Protocol Analyzers also supported)



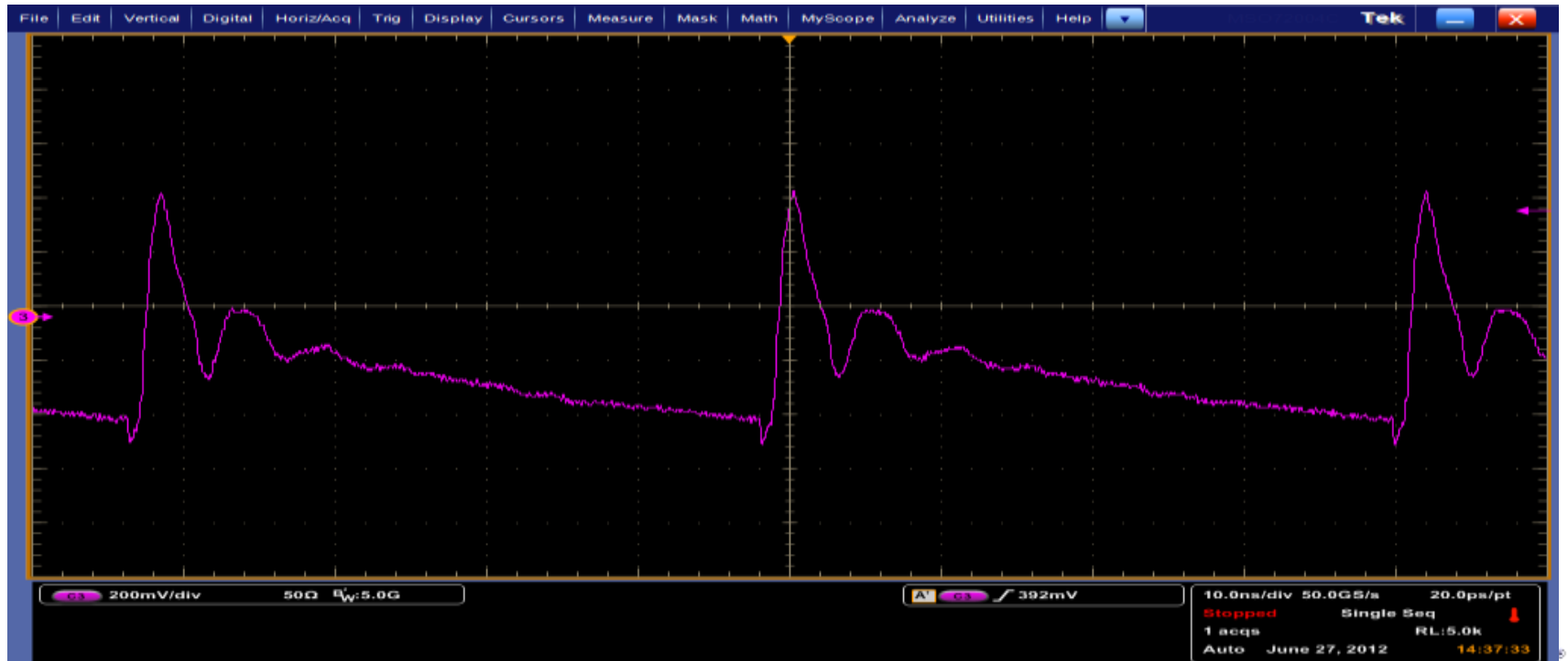
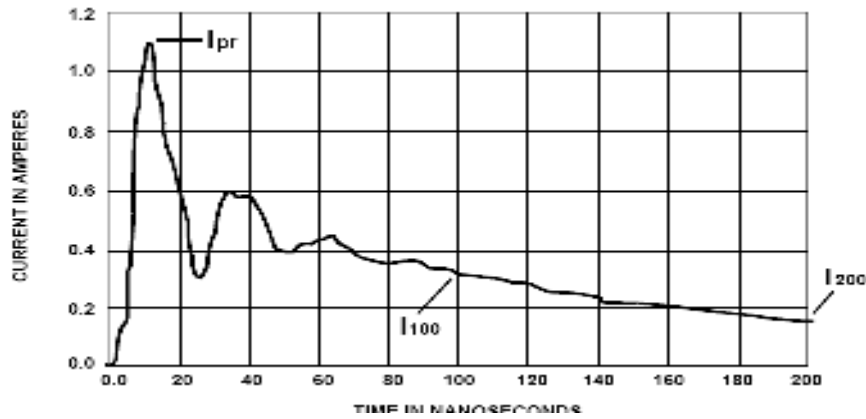
应用二：产生自定义的信号



用户自定义信号产生案例1



用户自定义信号产生案例2

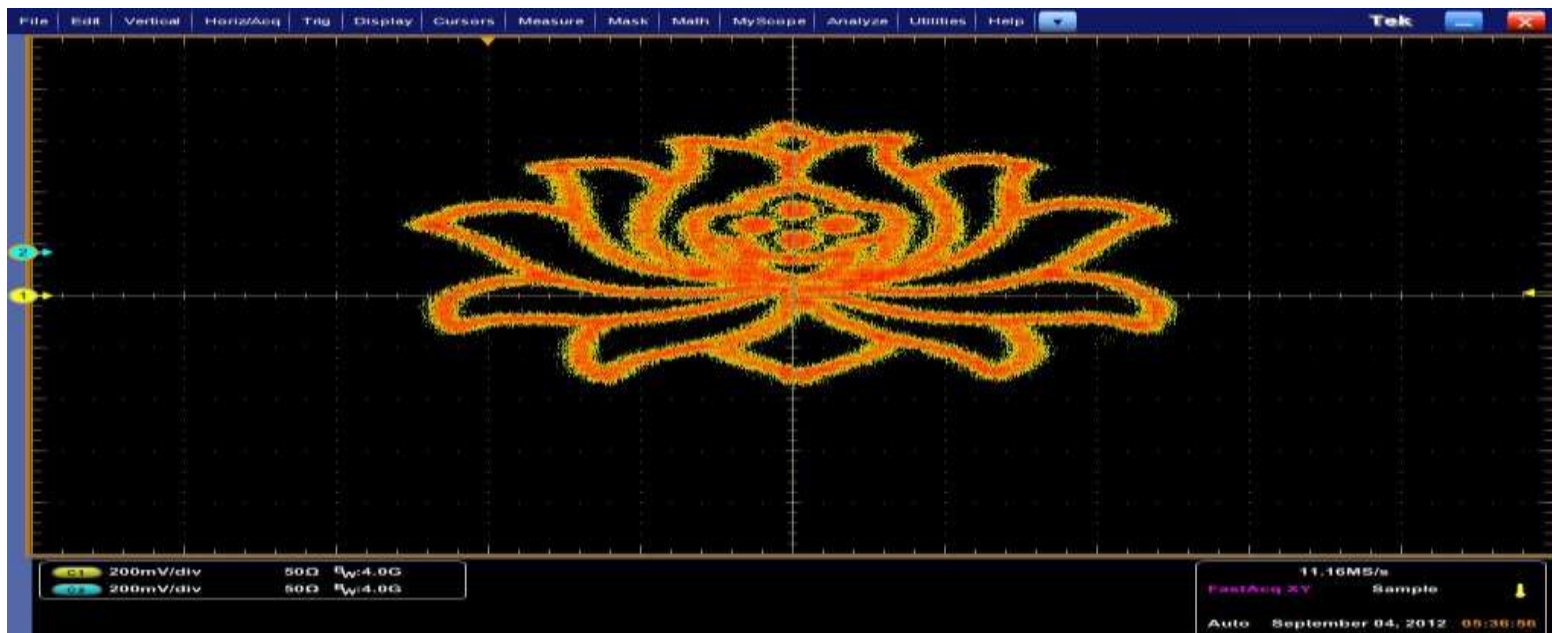
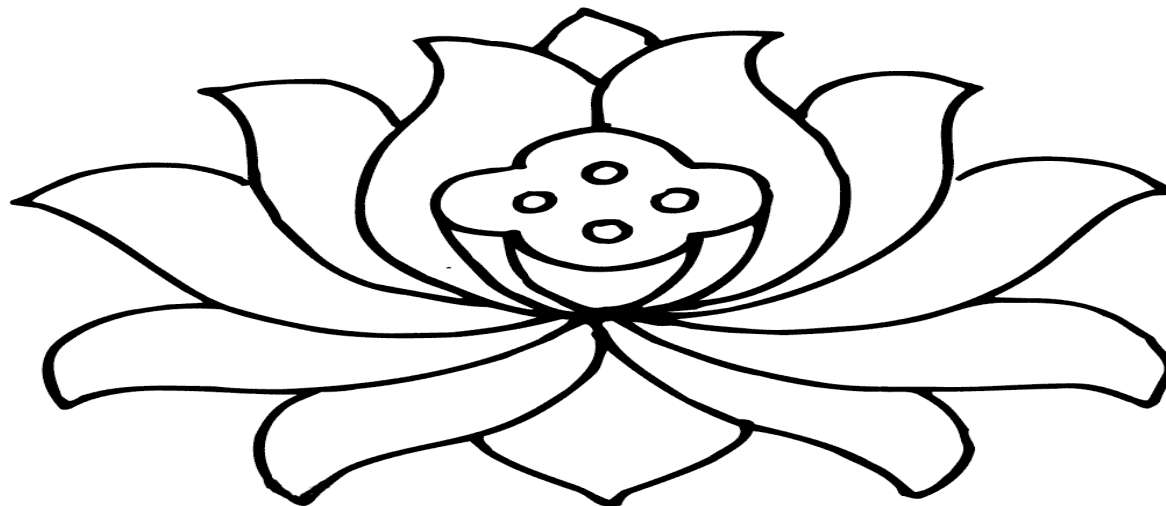


用户自定义信号产生案例3

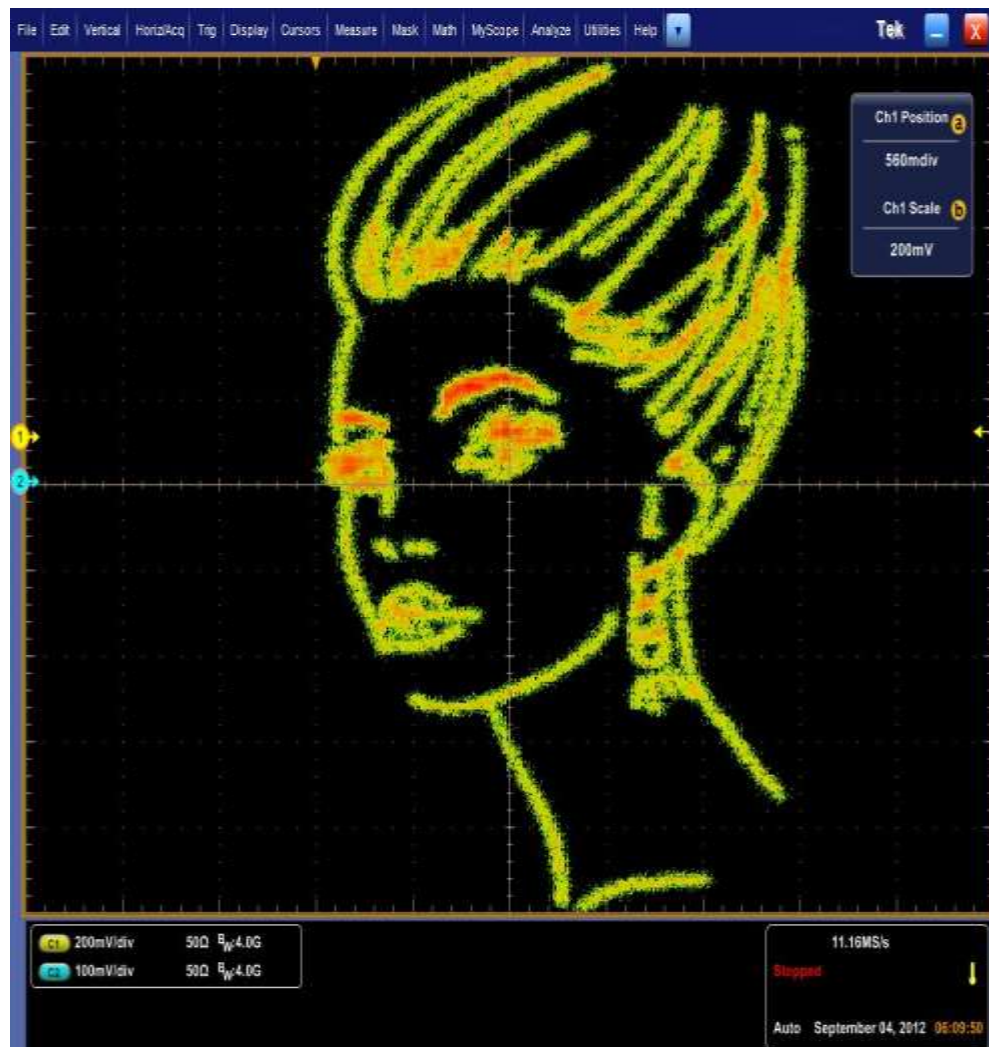
Tektronix



用户自定义信号产生案例4



用户自定义信号产生案例5

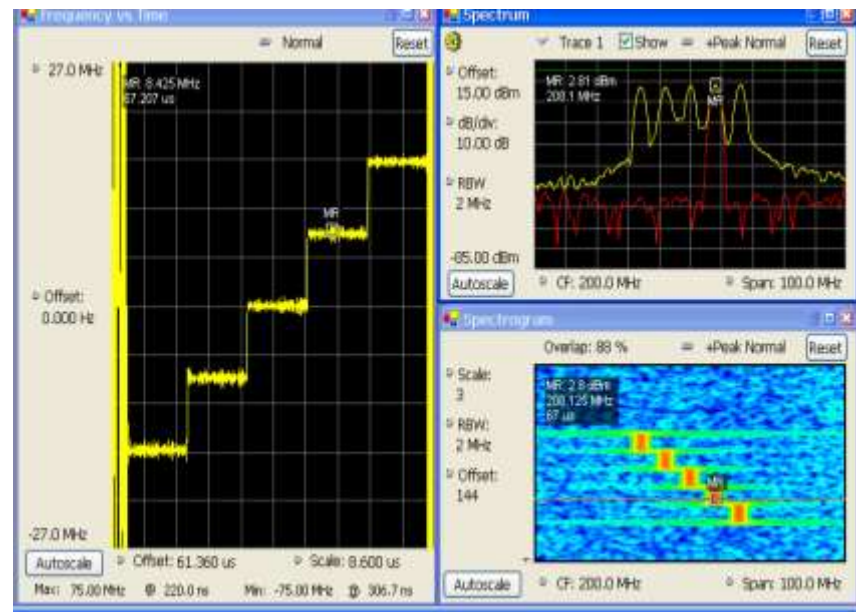


无线通讯系统测试挑战

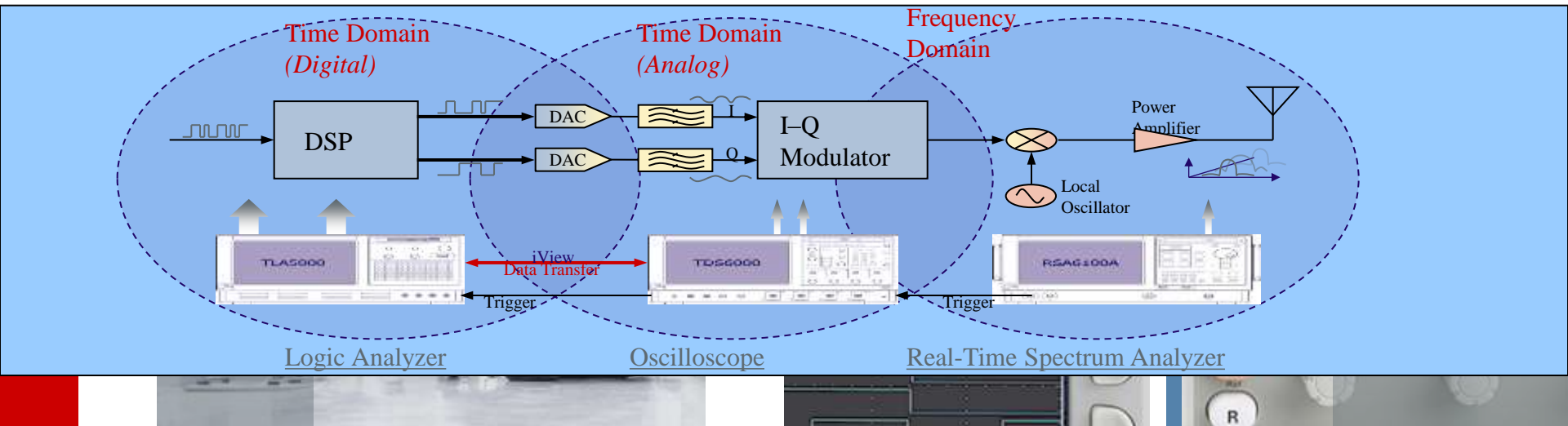
- 雷达
 - 改善雷达系统性能和对故障的发现分析能力
 - 解决超宽带雷达系统测试瓶颈
 - 准确描述、测量复杂的系统特性
- 通信
 - 应对新体制复杂的通信信号的分析能力
 - 复杂电磁环境下信号的识别与侦测
- 卫星通信
 - 增强解决方案质量，提高效率
 - 系统误码性能鉴定
- 无线电监测
 - 解决当前棘手的信号侦查和信号识别挑战
- 复杂电磁环境
 - 复杂电磁环境下信号的仿真、识别与侦测

复杂数字RF测试对测试设备的要求

- 信号源
 - 能够简洁地产生各种需要的激励
 - 能够模拟现实情况
 - 能够识别、增强或者回放已采集的信号
 - 调制带宽足够宽
- 接收机
 - 分析带宽足够宽
 - 合适的动态范围
 - 含有准确时间信息
 - 数据方便采集、存储以及多种分析
 - 频谱监测
- 数据处理
 - 各种时域、逻辑域测试设备
- 其它测试设备
 - 功率测试设备、VNA、天线测试系统



应用三：宽带雷达信号仿真



泰克AWG高级雷达信号仿真平台特点

- 超高带宽（20G），超高采样率（50G）的AWG，可以直接生成超宽带雷达信号（基于DA的信号生成方式）。
- 可以直接产生射频，中频，基带信号
- 基于AWG的高级雷达信号仿真软件
- 方便产生各种复杂的雷达信号
- 与泰克的实时频谱仪，示波器逻辑仪搭成无缝环路
- 对实际回波信号进行二次“改造”：如加“噪声”加“干扰”
- 与各种软件兼容如:Matlab等

业内唯一的高级雷达信号生成信号源+软件RF Express

- 针对新型雷达体制的特点和要求，雷达插件为RFXpress加入了以下功能
 - 建立单个或者多个雷达脉冲组，并由此产生相参或者非相参的脉冲序列
 - 每个脉冲组的所有参数均可独立设置.
 - 可在每个脉冲内和脉冲间独立定义幅度变化和频率变化（hopping）
 - 定义雷达脉冲图案，并且以时频图方式显示，便于观察
 - 简便定义所有脉冲参数，包括起始时间、关断时间、上升时间、下降时间、脉冲宽度、跌落和纹波
 - 定义变化PRI的信号，PRI变化可为步进或者用户自定义规律.
 - 建立用户定义的脉冲顺序，并使用AWG的序列模式，在产生大量脉冲信号的同时优化内存使用
 - 支持多种内调制方式，包括捷变频调频、步进跳频、巴克码、多相位编码。用户可自定义步进跳频，各种编码方式和自定义调制.

RFXpress射频信号仿真和生成平台

- RFXress射频信号仿真和生成软件基本功能
 - 通用射频信号生成能力——各种模拟、数字调制，用户自定义调制信号
 - 背景信号模拟、信道模拟
 - 多个信号在一个信道
 - 跳频
 - Power ramping
 - 非匹配的IQ
 - 失真模拟
 - 多径
 - 其它干扰

脉内的调制

- 支持各种各样的调制

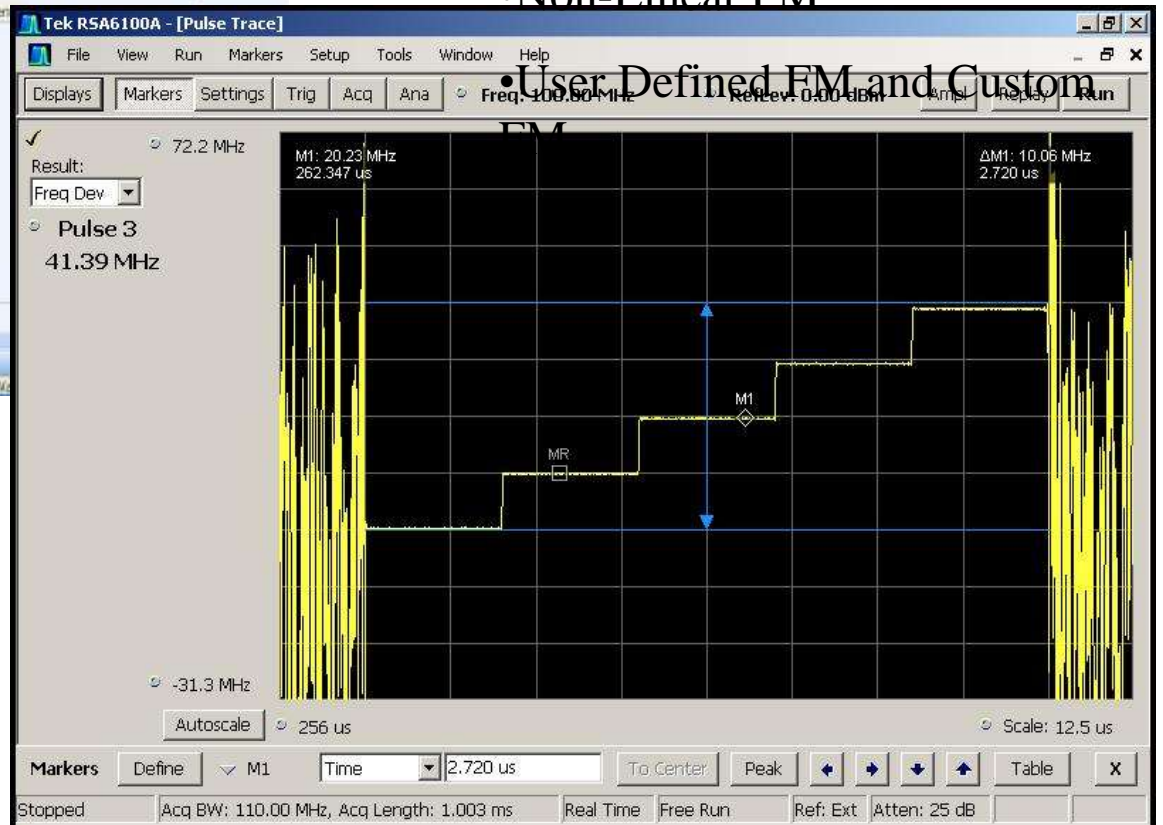
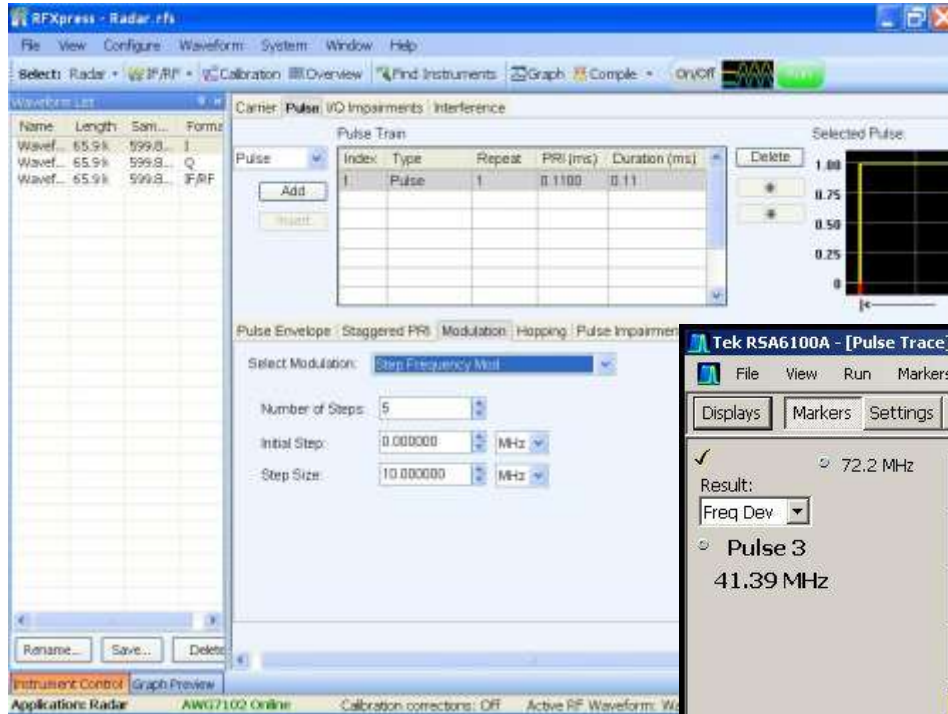
- LFM

- Barker and Poly phase Codes

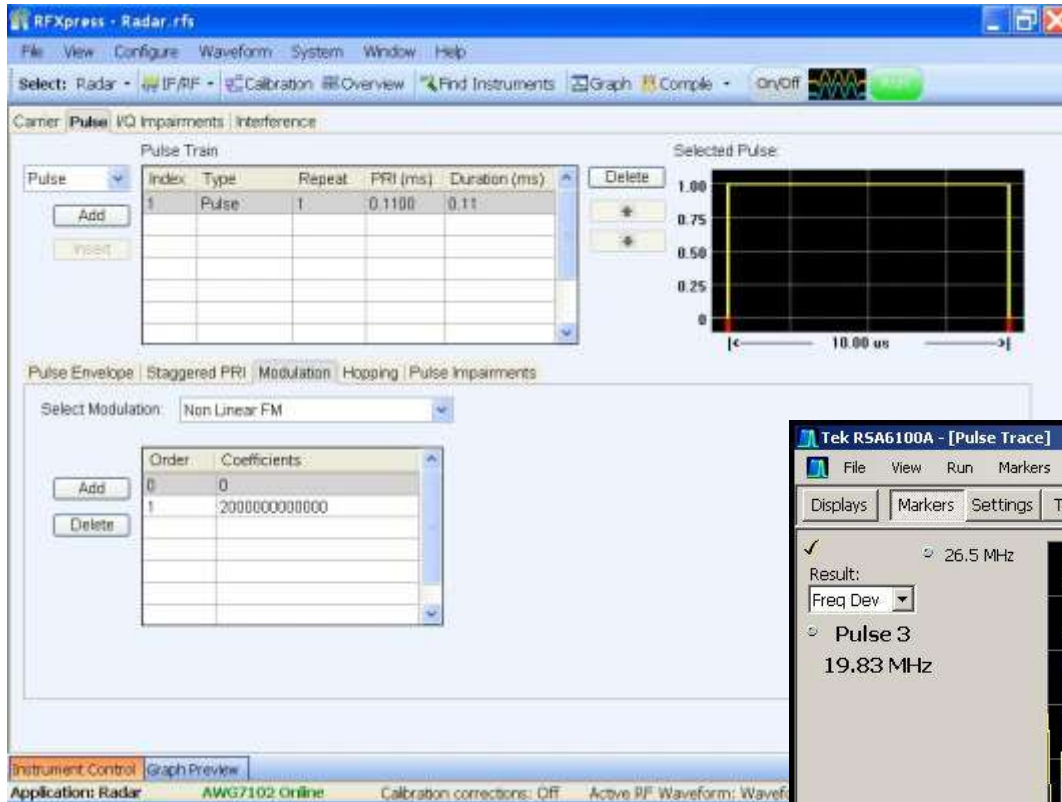
- Step FM

- Non-Linear FM

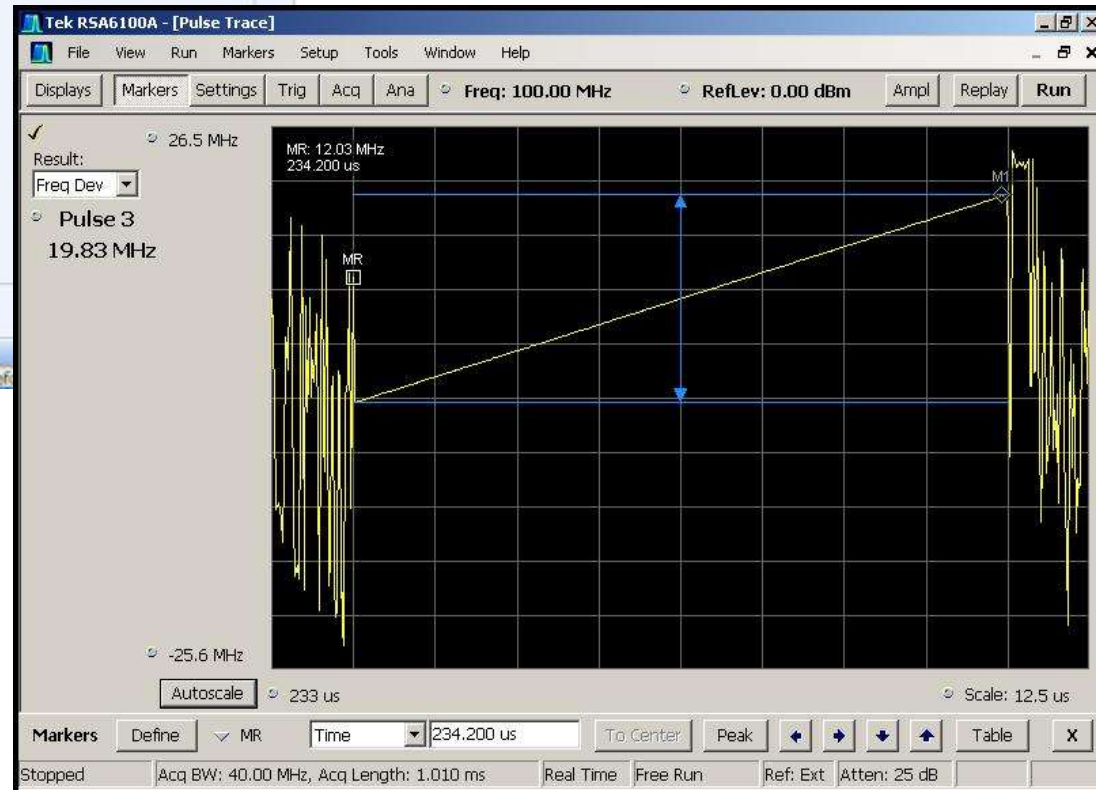
- User Defined FM and Custom



脉内调制举例：线性调频、非线性调频



Non-Linear FM (NLFM) chirp modulation can advantageously shape the PSD such that the autocorrelation function exhibits substantially reduced Sidelobes.



Consequently, no additional filtering is required and maximum SNR performance is preserved.

脉冲间跳频

Hopping

Turn On

Index No:

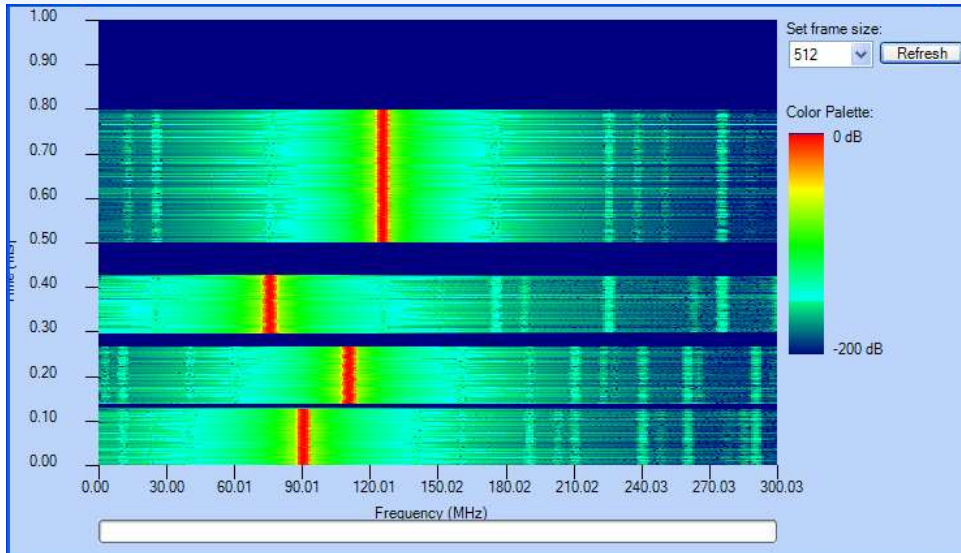
Start Symbol:

End Symbol:

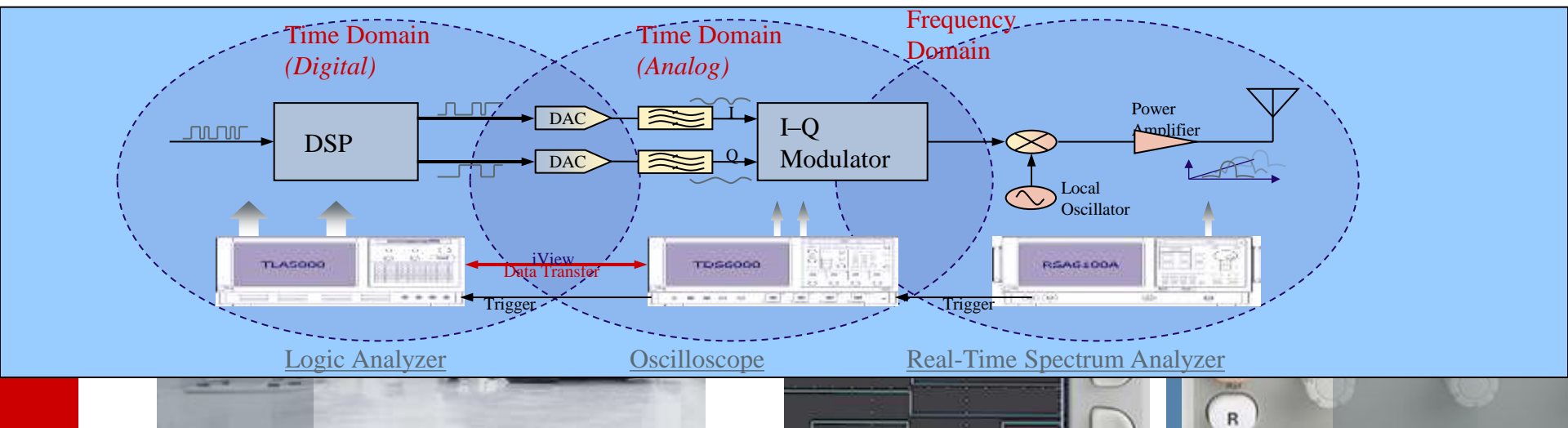
Relative Amplitude: dB

Frequency Offset:

No.	Start Symbol	End Symbol	Relative Amplitude	Frequency Offset
1	0	128	0	-10
2	140	268	0	10
3	300	428	0	-25
4	500	800	0	25



应用四：宽带调制信号仿真



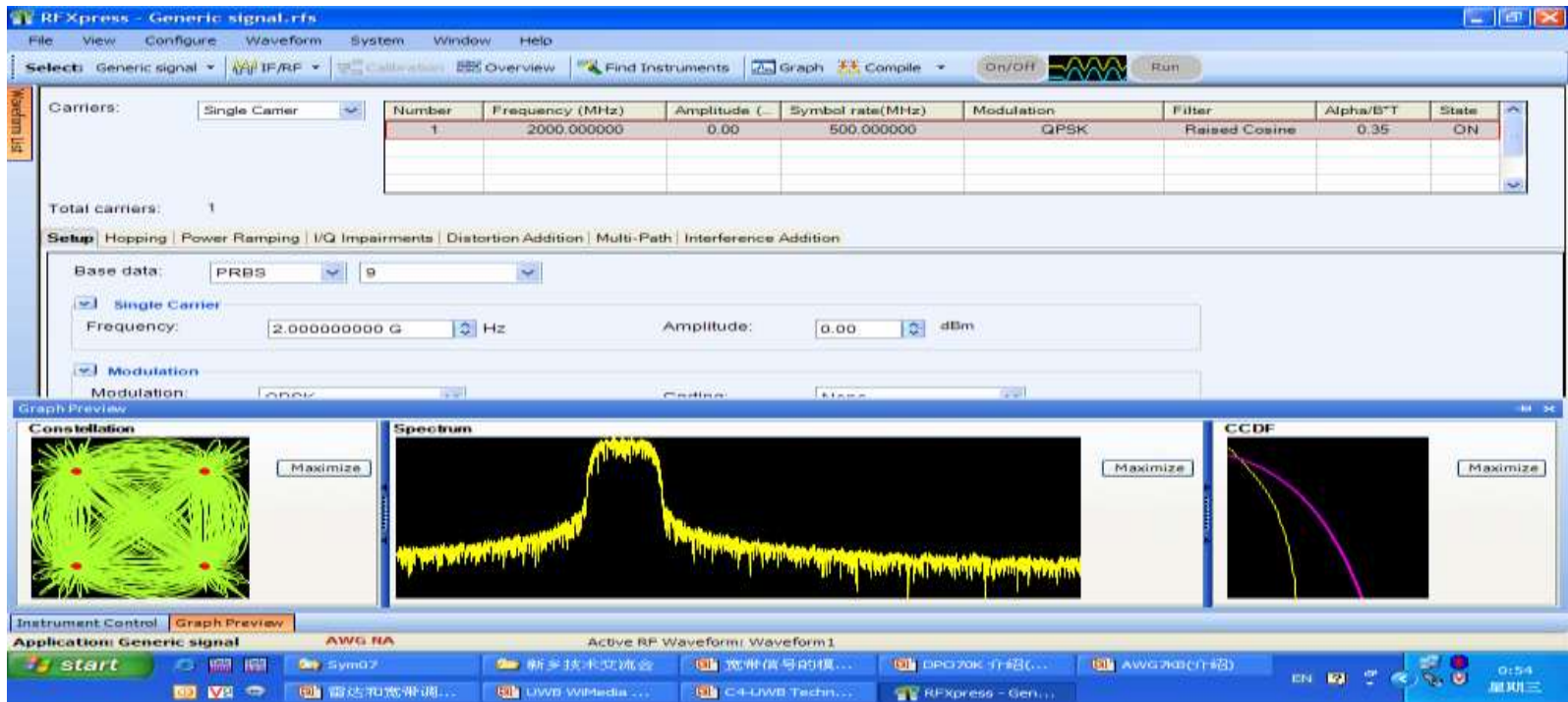
调制信号应用

- 宽带通信
 - 卫星通信-带宽达到800M
 - UWB 通信
 - 扩频通信
- 模拟通用调制(QPSK,QAM)

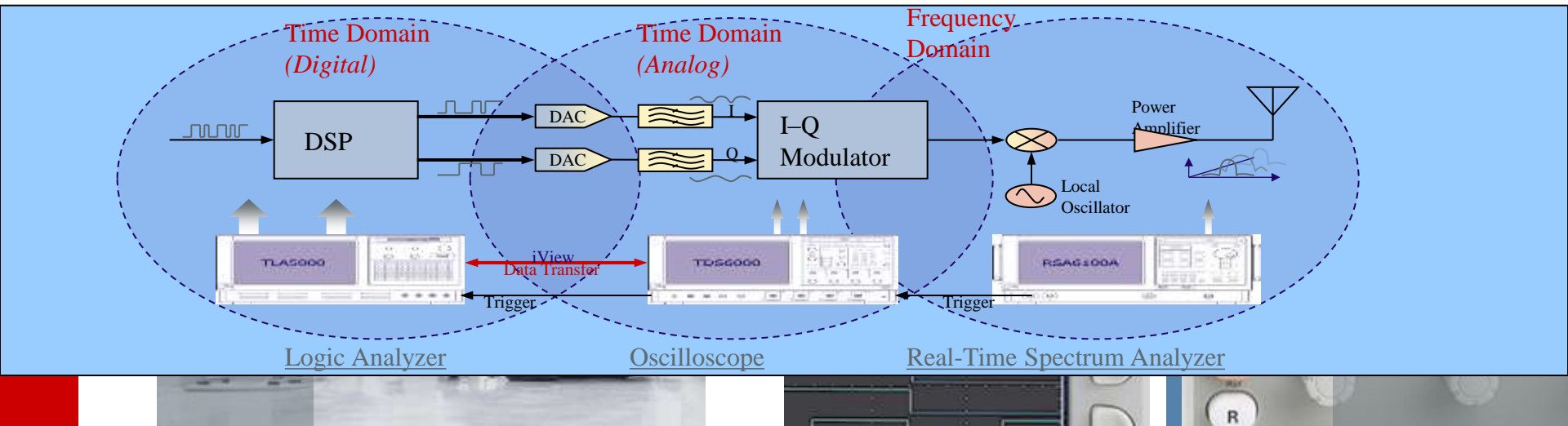


RFXpress软件产生数字调制信号

- 泰克AWG是宽带（超宽带）数字调制信号全球最通用的解决方案
- 泰克提供调制信号生成软件为用户方便产生数字调制信号的基带、中频或者射频信号
- 用户也可以使用Matlab等工具产生任意调制信号



应用五：复杂电磁环境信号仿真



泰克复杂电磁环境的仿真



RFExpress - Environment.rfs

File View Configure Waveform System Window Help

Select: Environment - IF/RF - Calibration - Overview - Find Instruments - Graph - Compile - On/Off

Waveform List

- Generic Signal
- UWB
- Radar(1)
- OFDM
- WiFi
- WIMAX
- GSM(1)
- CDMA(1)
- W-CDMA
- DVB-T
- User Defined
- Noise

Carrier Magnitude Peak: 0.000 dBm

Radar 1 Turn On

Carrier Frequency: 1.000000000 G Hz

Power: 0.00 dB

Start Time: 0 p s

Duration: 11.000000 μ s

Periodically Extend

Configure...

CDMA 1 Turn On

Carrier Frequency: 900.000000 M Hz

Power: 0.00 dB

Start Time: 0 p s

Duration: 26.667040000 m s

Periodically Extend

Configure...

GSM 1 Turn On

Carrier Frequency: 955.000000 M Hz

Power: 0.00 dB

Start Time: 0 p s

Duration: 4.615360000 m s

Periodically Extend

Configure...

GSM Configure

ARFCN: 100

Frequency band: P-GSM_900

Transmit device: Base

Radio format: GSM

Timeslot burst type: GSM

Modulation: EDGE, EGPRS2A, EGPRS2B

Timeslot timing mode: 157 symbols*2 timeslots, 156 symbols*6 timeslots

Timeslot configuration: All timeslots

OK Cancel

Instrument Control Graph Preview

Application: Environment AWG NA Active RF Waveform: Waveform1

复杂信号的参数的设置

The screenshot displays a software interface for configuring a complex signal. The main window shows a 'GSM-1' signal configuration with a 'Turn On' checkbox checked. The carrier frequency is set to 100 M Hz, power to 0 dB, and start time to 0 s. A 'GSM Configure' dialog box is open, showing 'ARFCN' set to 100.

The 'Generic Signal 1 Configure' dialog box is also open, showing a table of carriers and various configuration options.

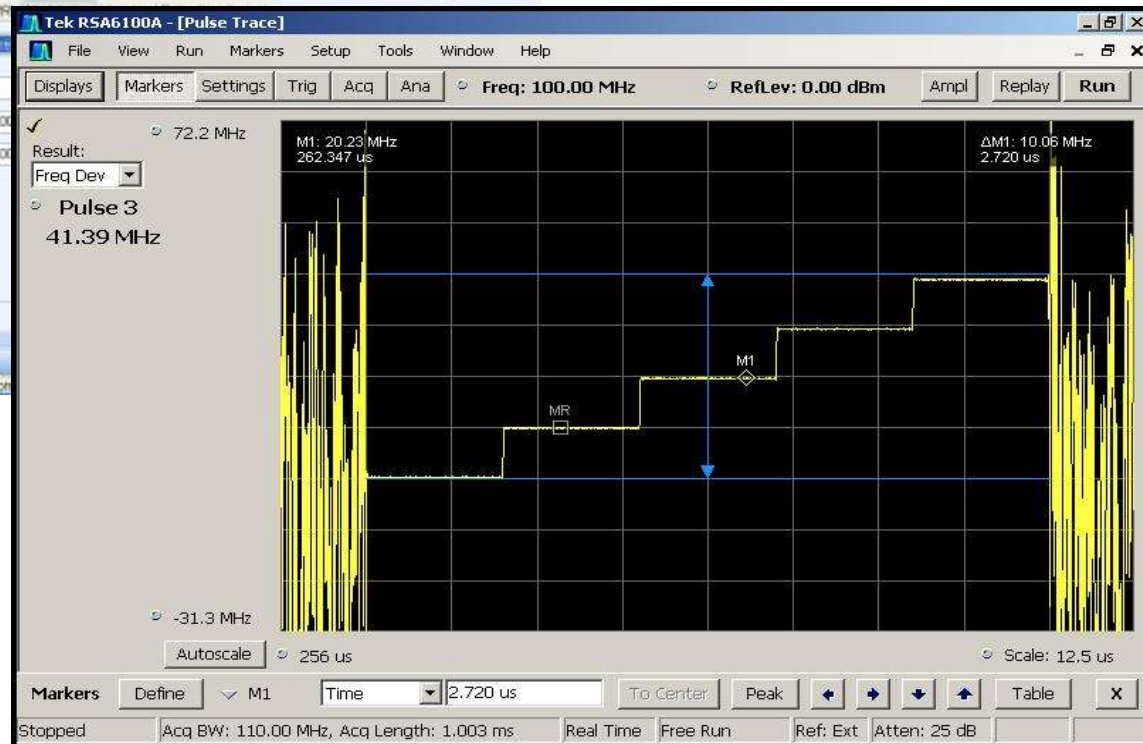
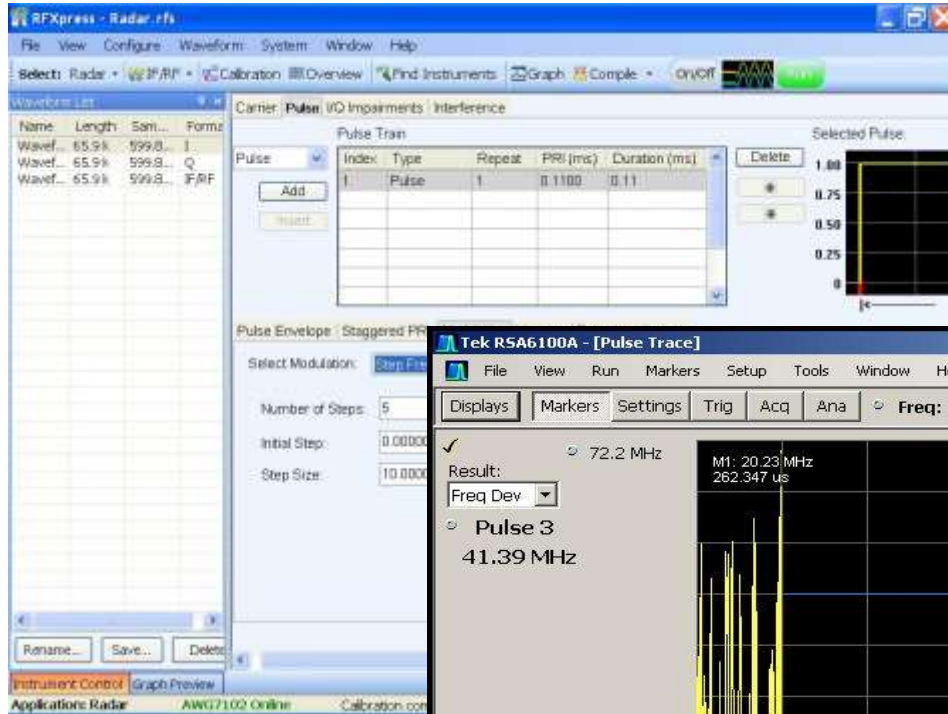
Number	Frequency (MHz)	Amplitude (..)	Symbol rate(MHz)	Modulation	Filter
3	125.000000	0.00	1.000000	QPSK	Rais
4	75.000000	0.00	1.000000	QPSK	Rais
5	125.000000	0.00	1.000000	QPSK	Rais

The 'Generic Signal 1' control panel shows the signal is turned on, with a carrier frequency of 100.000000 M Hz, power of 0.00 dB, and a duration of 1.000000000 m s. A 'Configure...' button is visible.

各种体制雷达信号生成

- 支持各种各样的调制

- LFM
- Barker and Poly phase Codes
- Step FM
- Non-Linear FM
- User Defined FM and Custom FM



AWG70k 利用RFXpress软件宽带快速跳频信号

Hopping Turn On

Index No: 0

Start Symbol: 0

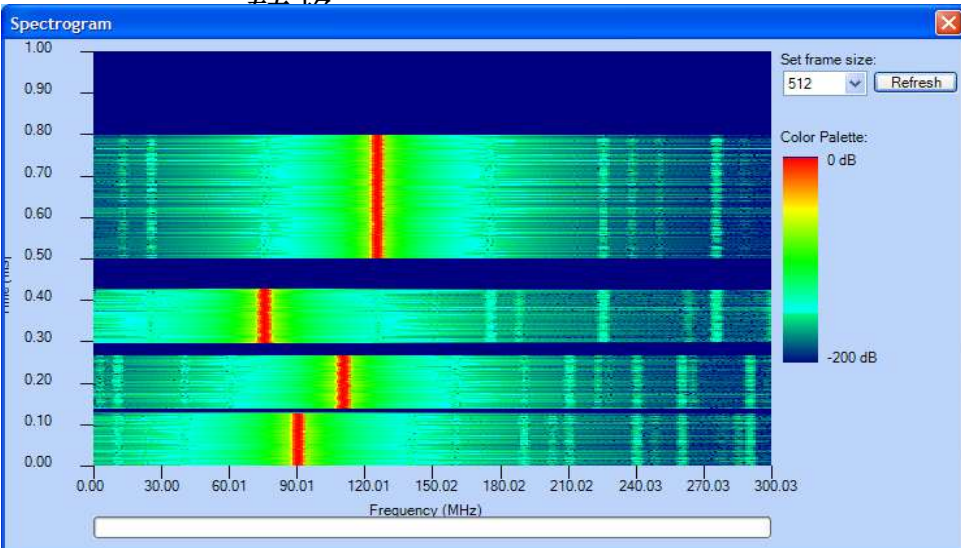
End Symbol: 0

Relative Amplitude: 0.00 dB

Frequency Offset: 0

No.	Start Symbol	End Symbol	Relative Amplitude	Frequency Offset
1	0	128	0	-10
2	140	268	0	10
3	300	428	0	-25
4	500	800	0	25

截图



泰克AWG70K+RFXpress多载波信号生成

The screenshot displays the RFXpress software interface for configuring a multi-carrier signal. The main window is titled "RFXpress - 30carriers.rfs".

Carriers Configuration Table:

Number	Frequency (MHz)	Amplitude (dBm)	Symbol rate (MHz)	Modulation	Filter	Alpha/BT	State
2	6855.100000	-48.65	-	No Mod	-	-	ON
3	6854.900000	-21.22	-	No Mod	-	-	ON
4	6859.400000	-42.48	-	No Mod	-	-	ON
5	6861.200000	-36.42	-	No Mod	-	-	ON

Configuration Parameters:

- Base data: PRBS, 0
- Selected Carrier: Frequency: 6.851200000 GHz
- Modulation: No Mod
- Filter/Window: Filter: Raised Cosine, Alpha/BT: 0.00, Convolution length: 21 symbols

Spectrum Analyzer View:

The spectrum analyzer shows a signal centered at 1.0000 GHz with a span of 200.0 MHz. The plot displays a series of discrete spectral lines. A table below the plot provides marker data:

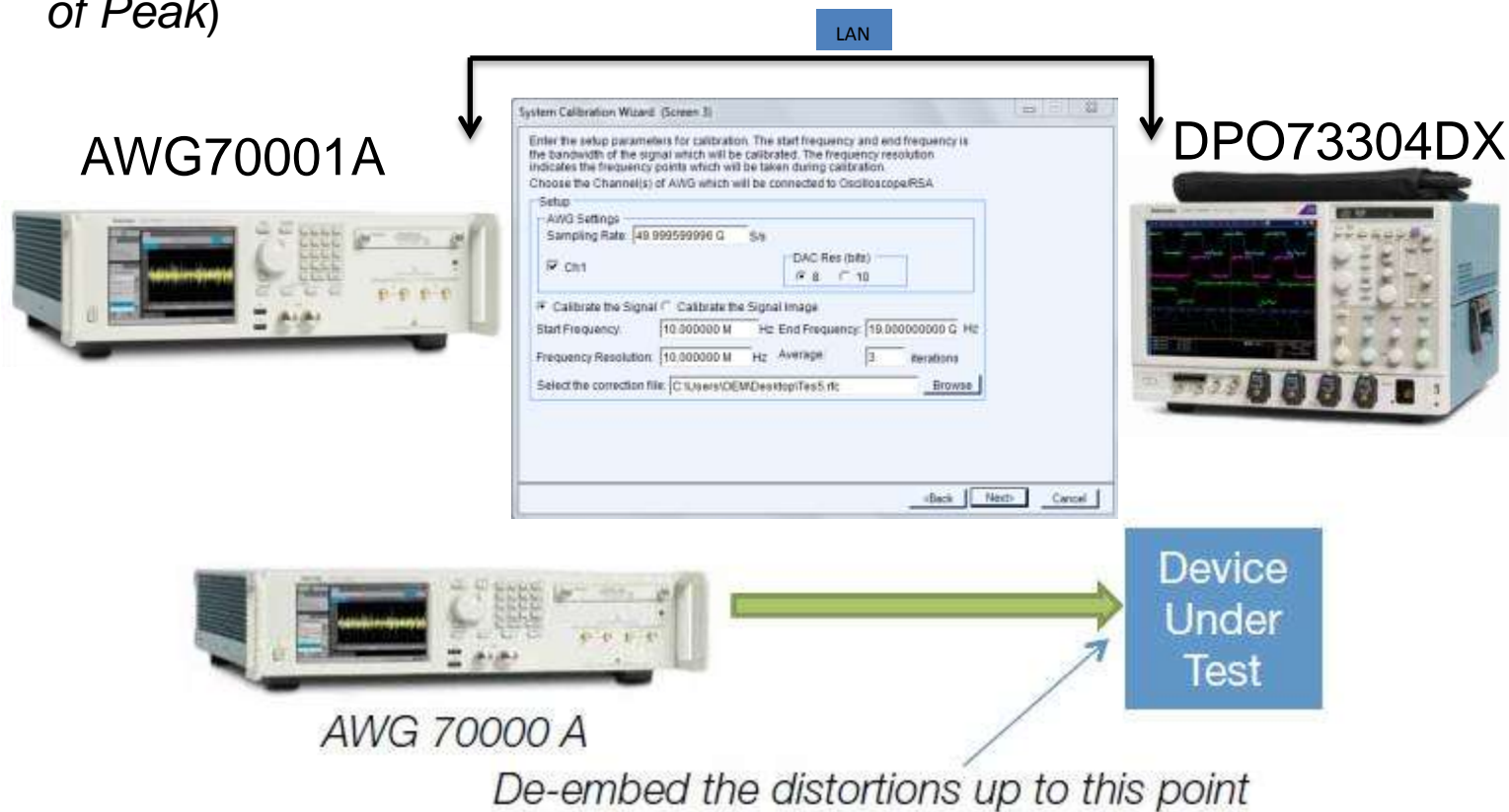
Marker	Frequency	Δ Frequency	Time	Δ Time	Amplitude	Δ Amplitude	Phase	Δ Phase	Spectrum	Δ Spectrum
M0	1.025 GHz	-	-	-	-	-	-	-	-40.05 dBm	-
M1	1.04 GHz	5.940	-	-	-	-	-	-	-40.0 dBm	0.03 dB
M2	1.045 GHz	10 MHz	-	-	-	-	-	-	-40.3 dBm	-0.26 dB

The interface also includes a Windows taskbar at the bottom showing the time as 10:33 AM on 4/15/2014.



Pre-compensation Calibration in RFXpress for Improved Performance in Test System

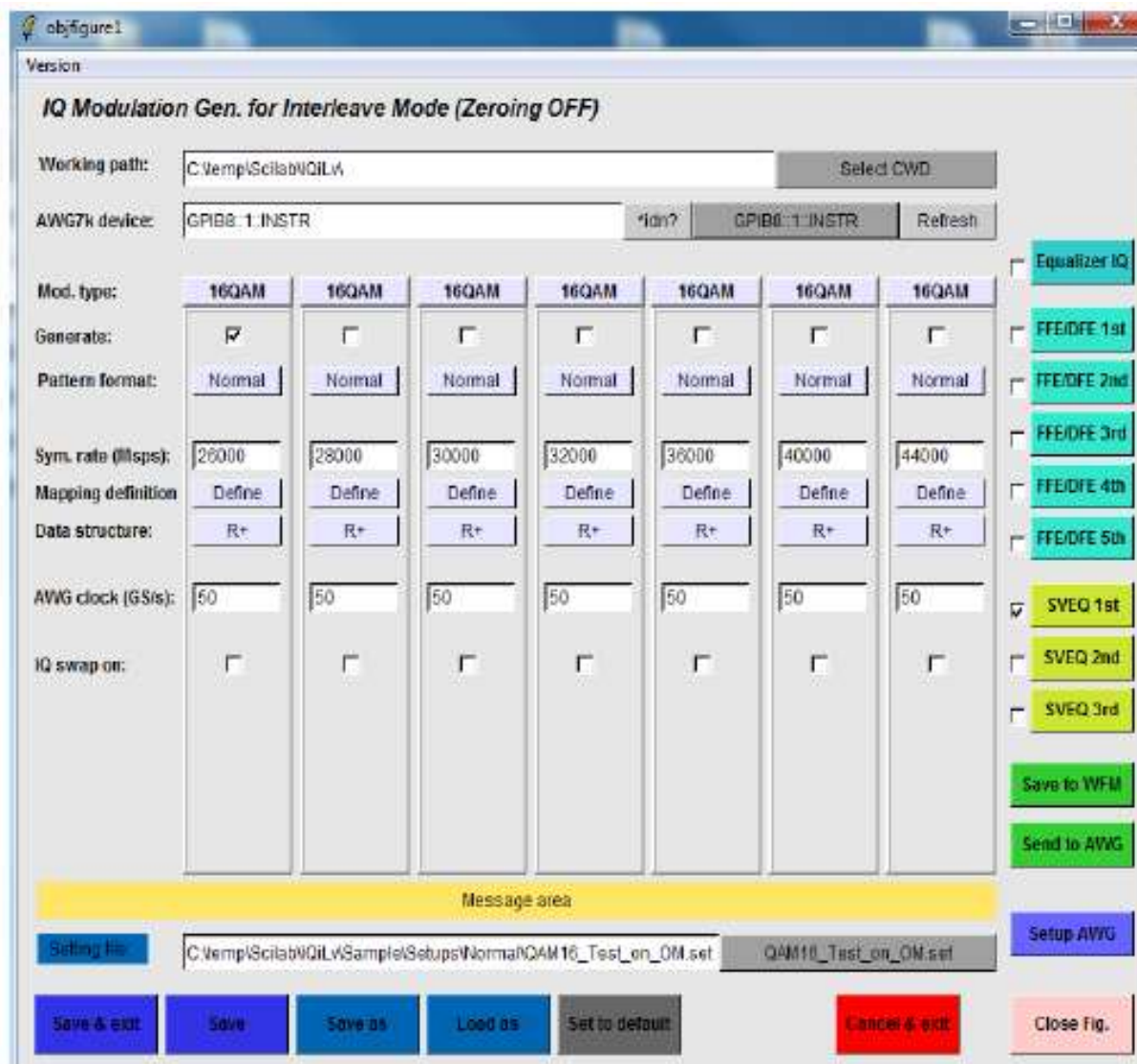
- Calibration is performed using RFXpress from Tektronix
- SignalVu Analysis SW running on DPO73304DX is used to measure the electrical EVM (*note – optical EVM will be lower because RMS is used instead of Peak*)



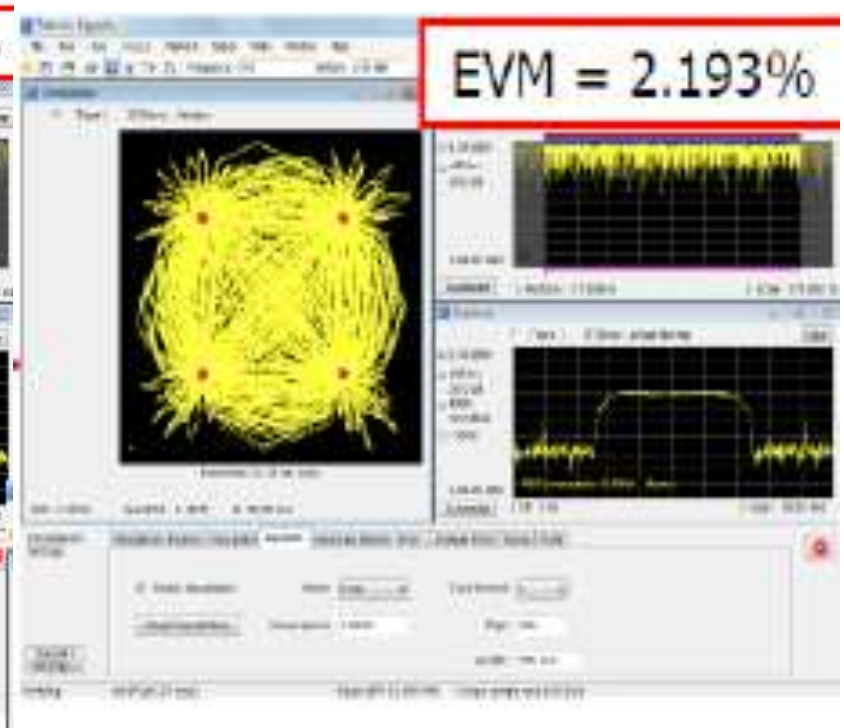
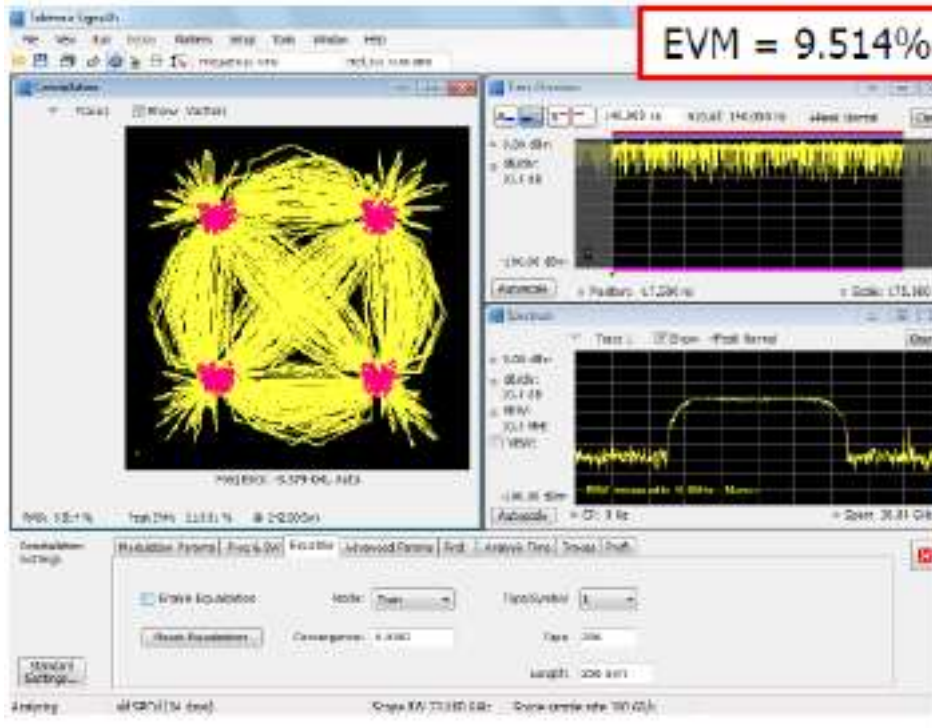
CW: 6GHz, BW:4GHz 雷达线性调频校准前后对比



高波特率复杂调制信号的产生

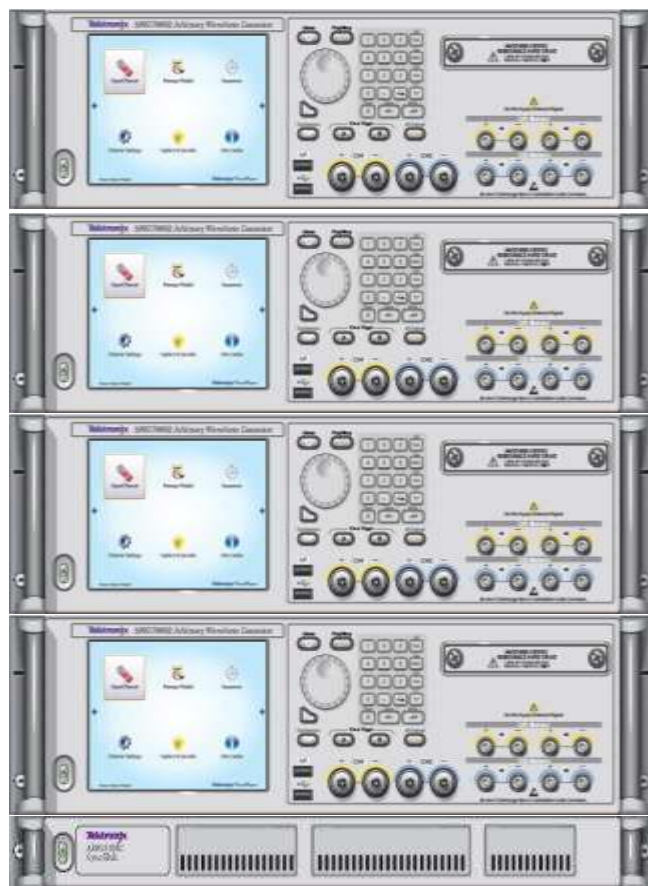


25Gbaud QPSK 校准前后对比



多通道信号产生解决方案

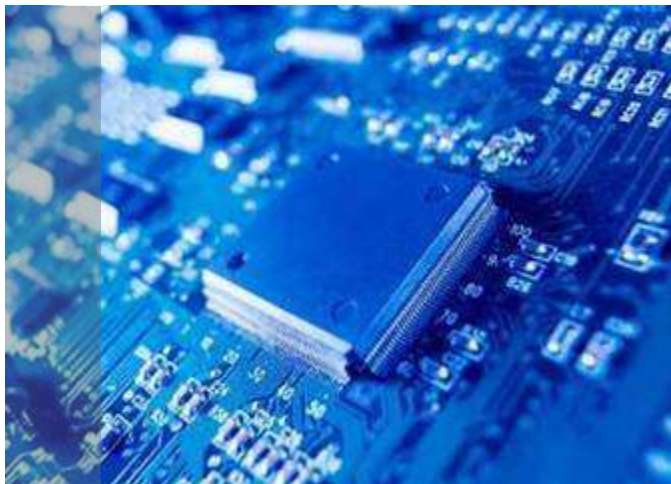
- 泰克的多通道信号产生系统基于泰克的AWG7000C/70002A系列任意波形发生器，利用数字码型发生器作为外同步输出和多通道同步时钟，将多个AWG同步信号进行实时输出。



Happy Customer with 8 sync'd units



Tektronix 70GHz ATI Real Time Oscilloscope



Asynchronous Time Interleaving Technology

Path to 70GHz Real Time Bandwidth

- Patent-pending signal acquisition architecture
- Unique method for digitizing full spectrum that maintains signal path symmetry
- Preserves signal-to-noise ratio for higher signal fidelity
- Lab testing validates 70GHz bandwidth and future extensions

Tektronix

Tektronix Real-Time Oscilloscopes to Achieve 70 GHz Performance

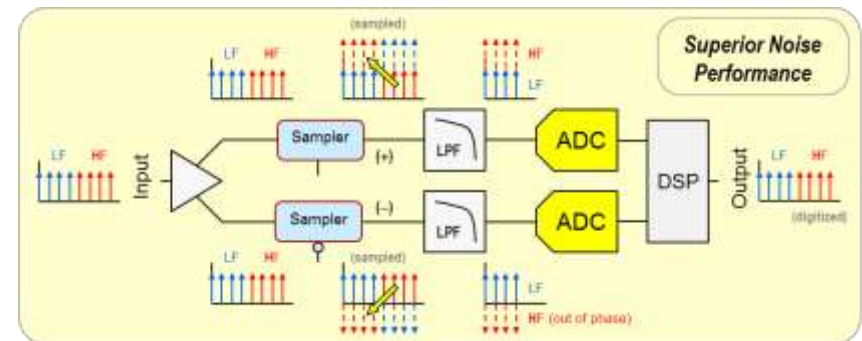
Next Generation Oscilloscopes to Incorporate Breakthrough Low-Noise Architecture for High Speed, High Precision Test Applications

BEAVERTON, Ore., March 10, 2013 – Tektronix, Inc., the world's leading manufacturer of oscilloscopes, today announced that lab testing has shown that its next generation performance oscilloscopes – due for availability in 2014 – will deliver real-time bandwidth of 70 GHz, with significant upside potential. The new oscilloscope platform will deliver the performance and signal fidelity needed for applications such as 400 Gbps and 1 Tbps optical communications and fourth generation serial data communications. Tektronix also announced an investment program that will give customers a cost-effective migration path to the new platform.

The extraordinary gain in bandwidth performance, with improved signal fidelity, is due in part to the development by Tektronix engineers of a patent pending signal processing architecture called Asynchronous Time Interleaving. The new real-time oscilloscope platform will also include a number of other enhancements and refinements to improve overall performance and measurement precision.

"With these latest innovations, Tektronix is continuing to push the envelope on what can be achieved in high-fidelity, high-speed data acquisition systems," said Kevin Ilicisin, chief technology officer, Tektronix. "The development of the industry's first production-ready Asynchronous Time Interleaving architecture is a significant breakthrough that will improve signal-to-noise ratio beyond the frequency interleaving approach used by competing oscilloscope vendors."

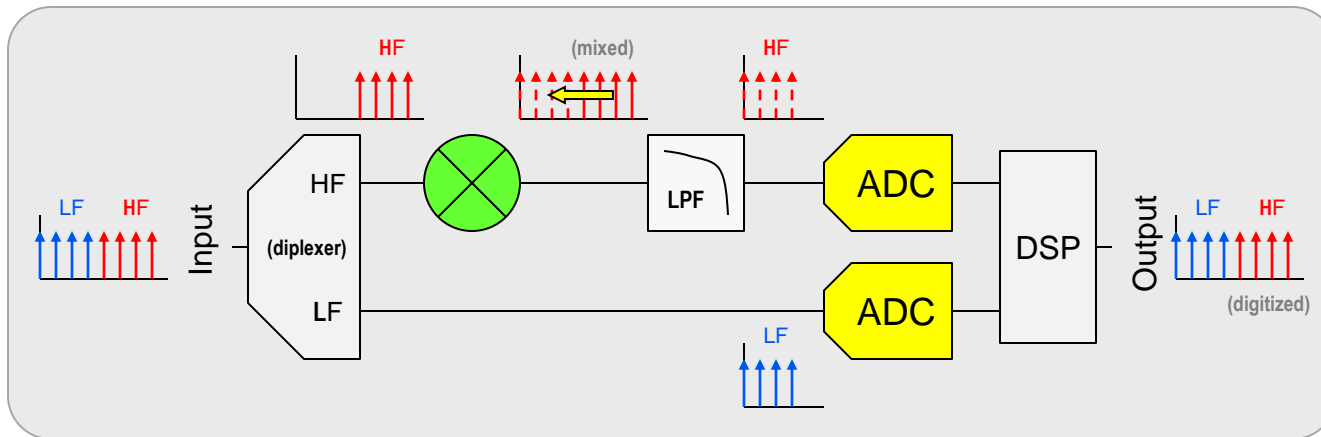
Tektronix ATI Technology



Traditional Frequency Interleaving

- Lecroy “Digital Bandwidth Interleaving” - DBI
- Agilent “RealEdge”

Traditional Frequency Interleaving

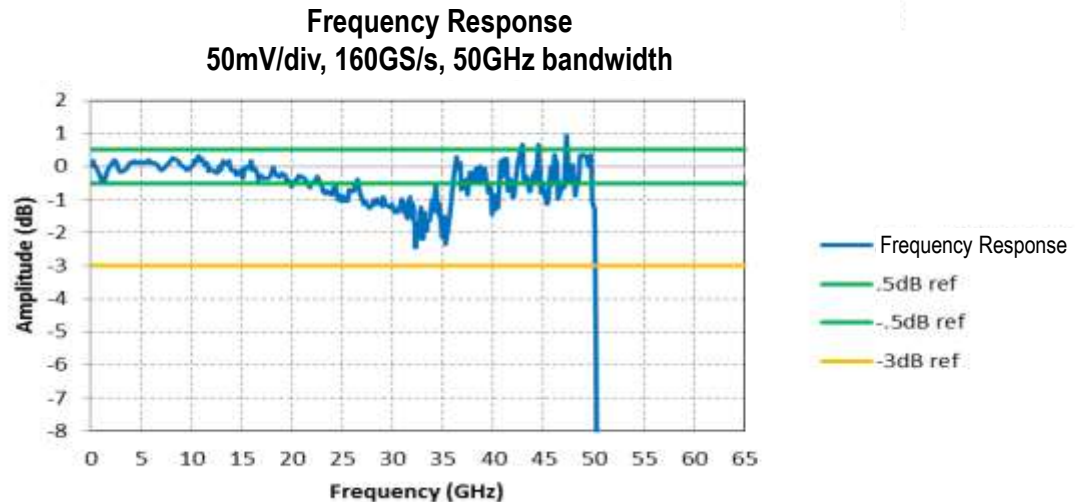


- Each ADC sees **half** spectrum
- **Signal reconstruction involves *summation*** → no improvement in SNR

Frequency-Interleaved Channels

- “Stitching” via DSP is complicated. Due to path differences, compensation must occur adding to complexity
- Recovery of the exact center of spectrum, the lower- and higher-band overlap, is problematic

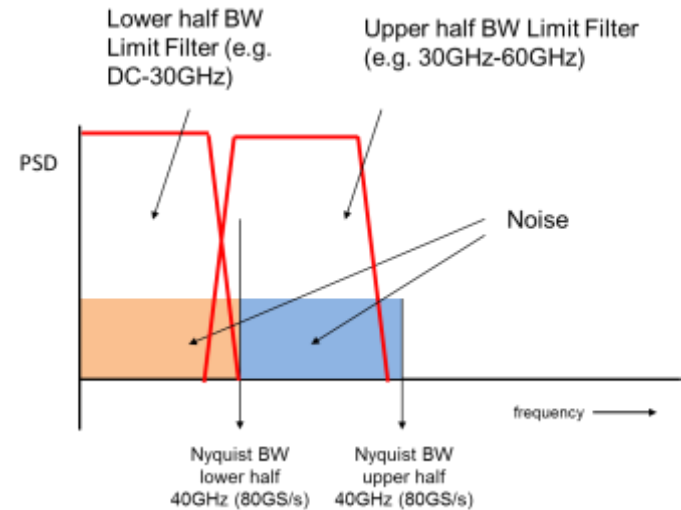
Traditional frequency interleaving suffers a bandwidth dip. This mid-band dip is greater than 2dB low, which means that measurements made in this region will be reported as 20% or more lower than the real signal amplitude.



Data from Agilent DSAX95004Q

Frequency-Interleaved Channels

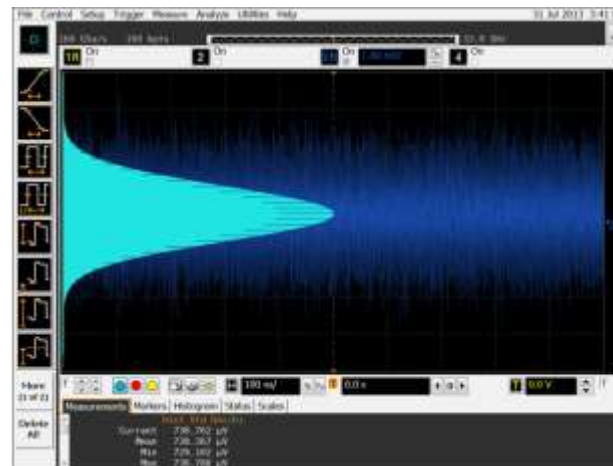
- Each ADC acquires half of the entire frequency span so there is no opportunity for noise reduction when going from Time- to Frequency-Interleaving.
- In reality, a noise increase is seen when using Frequency-Interleaving as shown below.



BW set to 33 GHz using standard acquisition shows 554uV RMS noise



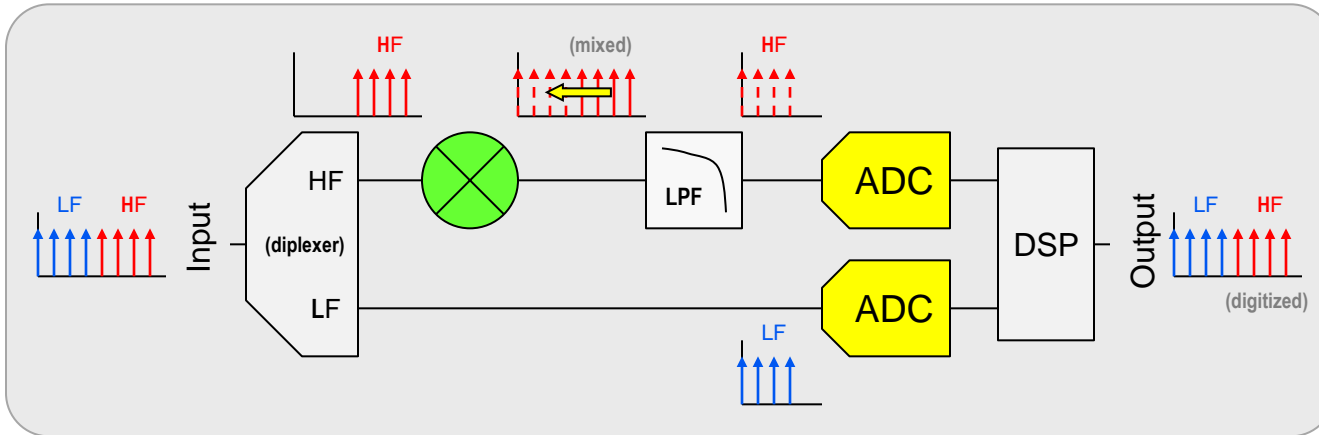
Frequency-interleaved acquisition and BW set to 33 GHz shows 731uV RMS noise – a 32% increase



Data from Agilent DSAX95004Q

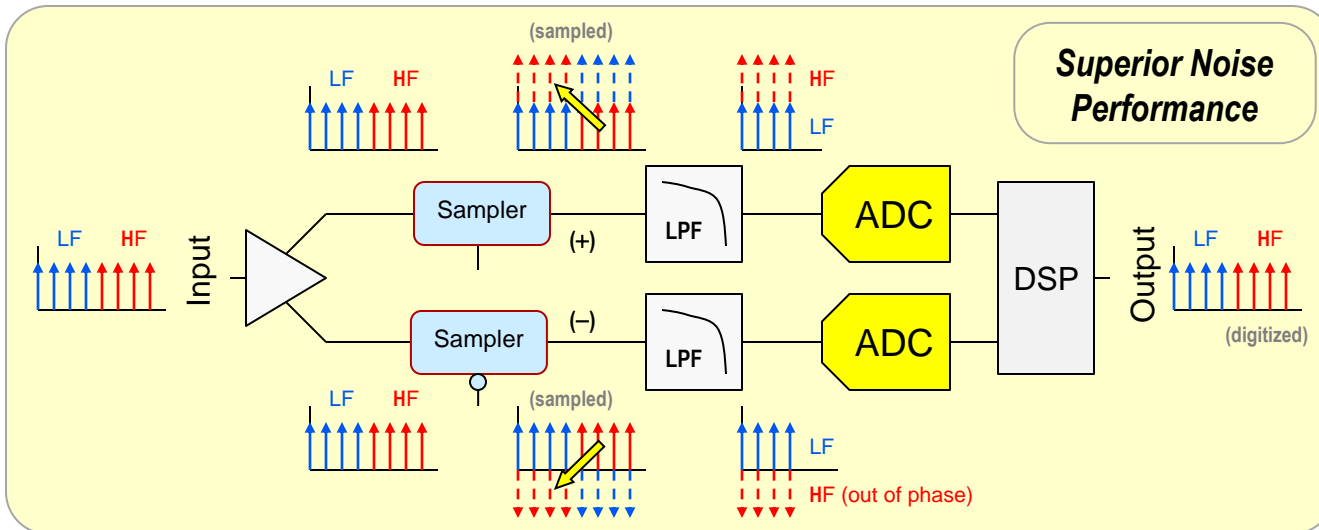
Asynchronous Time Interleave (ATI)

Traditional Frequency Interleaving



- Each ADC sees half spectrum
- Signal reconstruction involves *summation* → no improvement in SNR

Tektronix Architectural Innovation



- ✓ Improved SNR
 - Each ADC sees full spectrum
 - Signal reconstruction involves *averaging* → improves SNR
- ✓ Signal-path symmetry
- ✓ Patented architecture

Thank you !