

# Tektronix Innovation Forum

Enabling Innovation in the Digital Age



泰克最新通信测试解决方案

**Tektronix**<sup>®</sup>

# Agenda

## ■ 光通信

- 从**155M到40G/100G**——光接口物理层测试
- 相干光通信——复杂光调制技术
- **Optical-OFDM**技术

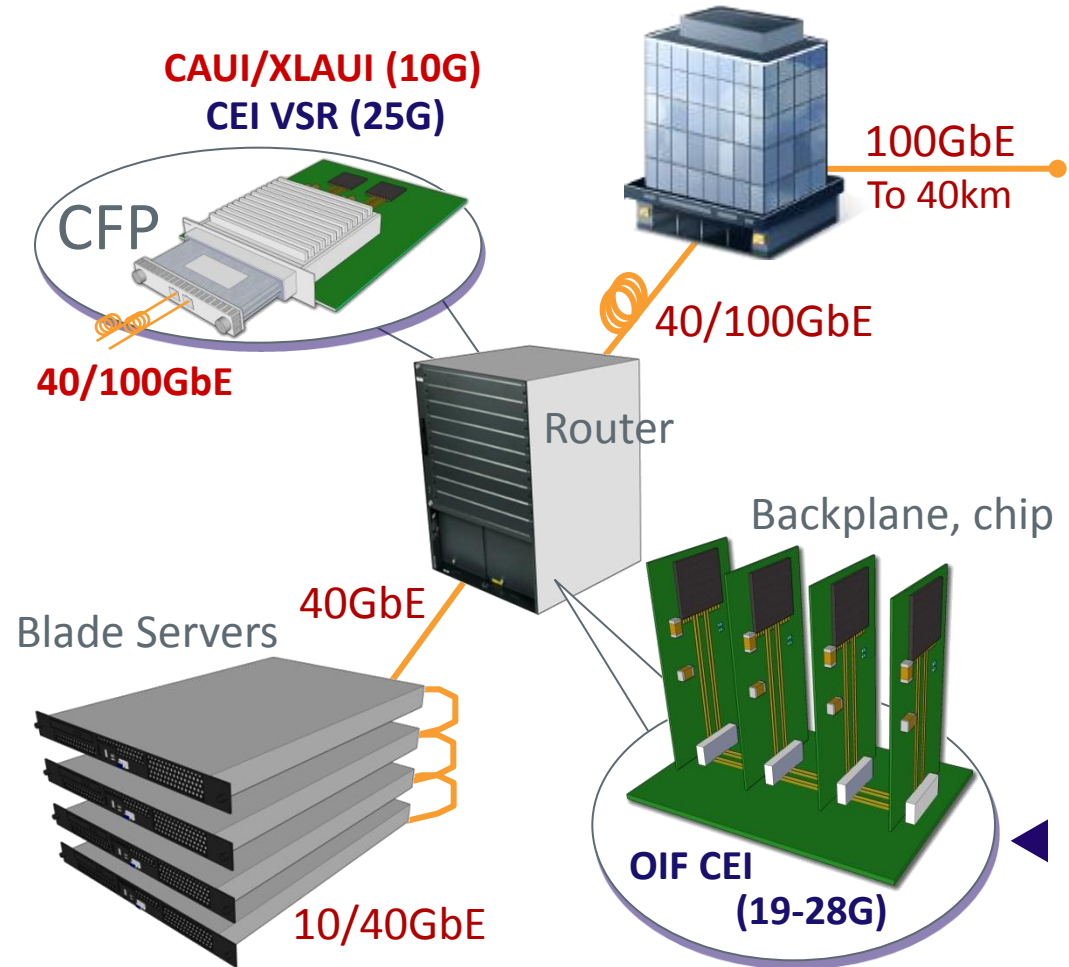
## ■ 无线通信

- 民用
- 卫星

■

# Standards Overview

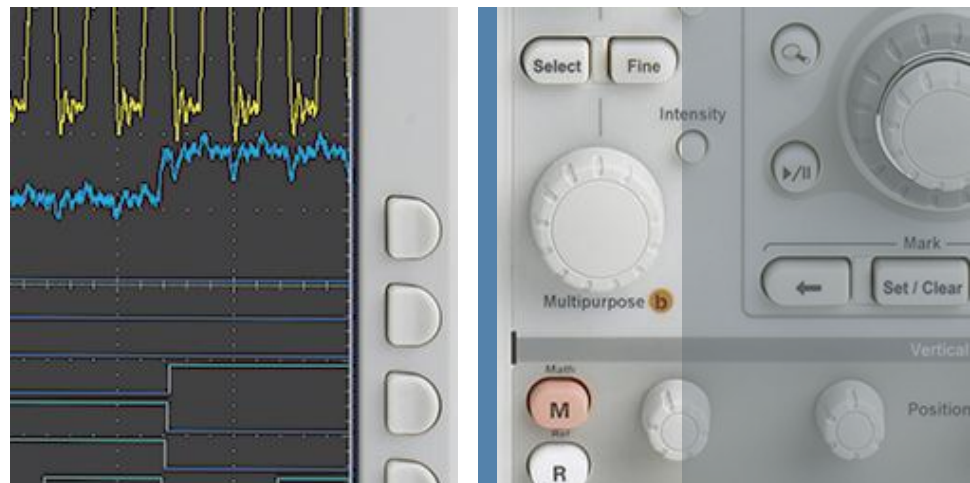
- 10, 100, 1000, 10GBase-T
- 10GBase-SR,LR,ER,SW, LW,EW, LRM, KR, KX4, CX4
- 40GBase-SR4, LR4, LR, SR10, ER4, CR4, KR4
- 100GBase-SR10, LR4, ER4, CR10
- OC768 / STM256 / OTU3
- IEEE, OIF, ITU-T
- CEI, OUT, 802.3ap, 802.3i, 802.3u, 802.3ab, 802.3an, 802.3ae, 802.3aq, 802.3ak, 802.3at
- XAUI, CAUI, XLAUI, CPPI, XLPPI



# 光接口主要标准

- Fiber Channel 光接口速率：
  - Fiber Channel 1: 速率1.063Gbps
  - Fiber Channel 2: 速率2.125Gbps
  - Fiber Channel 4: 速率4.250Gbps
  - Fiber Channel 10G: 速率10.52Gbps
  - Fiber Channel 16G: 速率14.025Gbps
- 以太网光接口速率：
  - 100Base-FX: 速率125Mbps
  - 1000Base-SX/LX: 速率1250Mbps
  - 10GBase-R/W: 速率10.3125/9.953Mbps
  - 802.3ba :40G-base SR/LR ,100G-base SR10.
- SDH光接口速率：
  - 155Mbps、622Mbps、2.488Gbps、9.953Gbps……

# 从155M到40/100G——光信号物理层测试

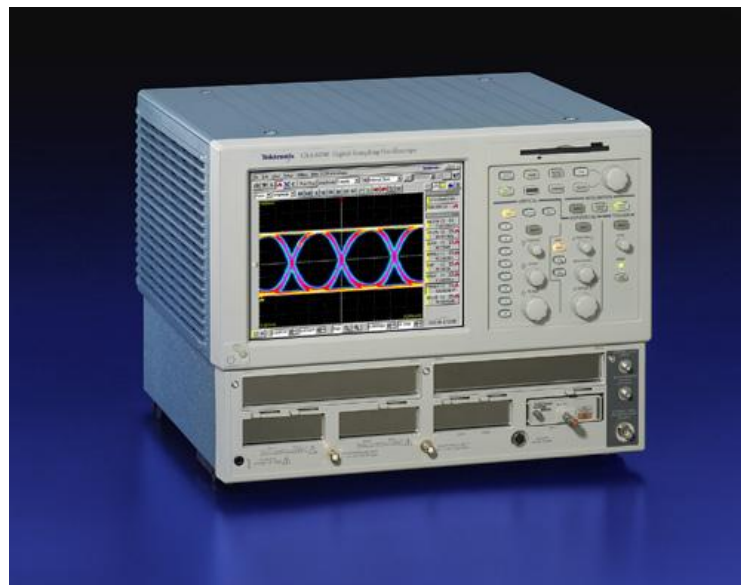




# 使用Tektronix DSA8300能完成什么测试？

## ■ 核心测试

- 眼图测试
- 抖动测试
- 幅度域
  - 平均光功率 (AOP)
  - 消光比 (ER)
  - 光调制幅度 (OMA)



# 泰克2.5G/10G/25G/40G/100G的测试方案-模块概览

## 155 Mb/s to 12+ Gb/s Optical Test

### ■80C07B

2.5 GHz BroadWavelength Multirate 155 Mb/s to 2.5 Gb/s Optical Module

### ■80C12 B

Up to 10GHzBroadWavelengthMultirate 1 Gb/s to 10 Gb/s Optical Module

### ■80C08D

10 GHz Broad Wavelength Multirate 10 Gb/s Optical Module

### ■80C11

30 GHz Long Wavelength Multirate 10 Gb/s Optical Module

### ■80C14

30 GHz Long Wavelength Multirate 10 Gb/s Optical Module

### ■80C15

30 GHz Long Wavelength Multirate 30 Gb/s Optical Module

## 40 Gb/s and 100 Gb/s Optical Test

### ■80C10C

Multirate Datacom and Telecom 40 Gb/s and 100 Gb/s

# 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: ±1.2% (–0.76 dB /+0.92 dB at 12dB)
    - Repeatability: ±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 Trib rate filters, plus 10GP (10G rates)

Filter Opt.	Rate(s) Supported
F0	Unfiltered 12 GHz bandwidth
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.



# 80C14 Optical Module

## 16 GFC Single/Multi-mode Solution



### 80C14 Optical Module

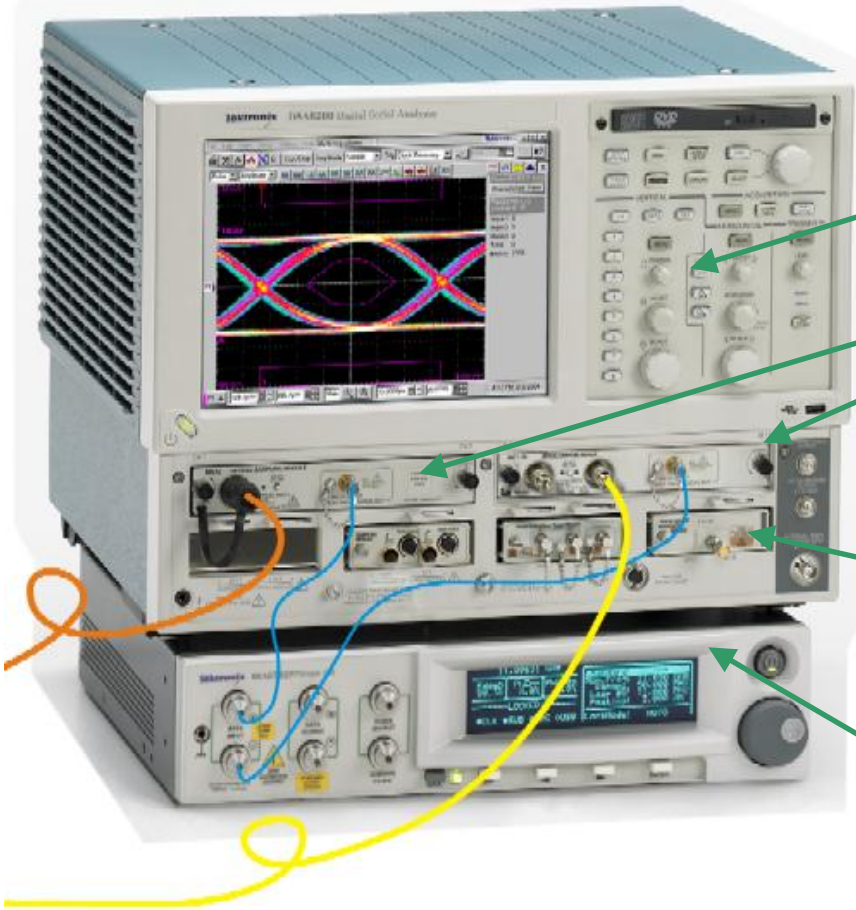
### Standards Supported

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

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

# 25, 28, and 40 Gb/s Capable Test Equipment: Optical Test for 40/100 GbE

- ✓ 100GBASE-ER4/LR4
- ✓ 100GBASE-SR10
- ✓ 40GBASE-SR4
- ✓ 40GBASE-LR4
- ✓ 40GBASE-KR4
- ✓ CAUI



- Single DSA mainframe capable of handling all bit-rates of the standard.
- Industry's first 40GB/sec Optical Module
- Support for Jitter Types in new IEEE Standard Update
- 80SJNB – Industry's more complete Jitter and Noise Analysis for signaling above 10Gb/sec

## Digital Sampling Oscilloscope:

- Tektronix DSA8200

## Optical Modules:

- 10, 25, 28 and 40 Gb/s signaling

## Recommended above 10 Gb/s:

- 82A04 Phase Reference module for high accuracy/low jitter

## Clock Recovery

- Tek 80A07/ BERTScope CRHS28000A up to 28.6 Gb/s

# BERTScope BSA、CR和DPP系列

新

迅速放心地识别数字码流中的误码



## BERTScope® BSA系列

BERT的信心，示波器的洞察力

- 以新的方式测量串行数据系统的信号完整性
- 填补眼图分析与BER码型生成之间的空白
- 简便地隔离有问题的码和码型顺序，然后使用高级误码分析功能进行分析



## BERTScope®时钟恢复CR系列/数字预加重处理器DPP系列

多功能精密时钟恢复和分析

- 测量和显示从100 kHz到12 MHz的PLL频响
- 当前市场上最高的抖动测试环路带宽
- 增加可控数量的预加重，调节信号，用于误码率分析仪

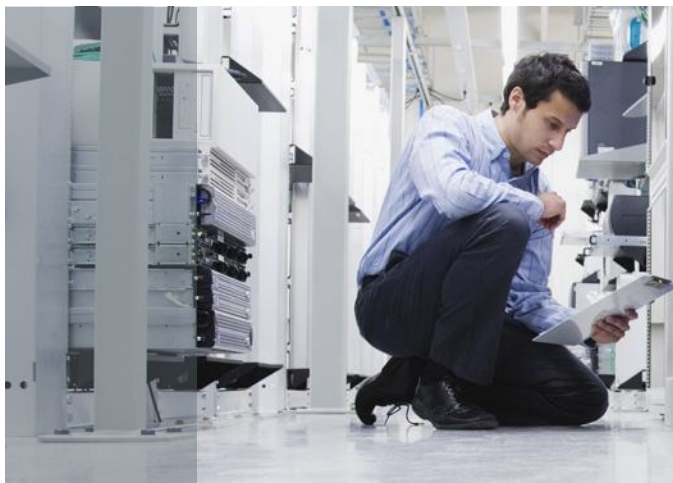


## BERTScope® BA系列

为自定义串行系统误码测试和FEC设计提供测试指导

- 100Kbps-1.6Gbps速率码型产生和误码测试支持
- 内置眼图和抖动分析
- 内置FEC模拟器

# 相干光通信——复杂光调制技术



# 相干光通信优点及应用

- 系统性能好，可以提取信号幅度、相位、偏振全部信息，并通过数字信号处理消除各种传输损伤
- 具有多种调制方式 -除了可以对光进行幅度调制外，还可以使用PSK、DPSK、QPSK、QAM，OFDM等多种调制格式。
- 灵敏度高，中继距离长 -相干接收机比普通接收机提高灵敏度约20dB
  
- 相干光通信在长距离、高速率通信方面具有很大的优势，成为未来光通信的主要手段。
- 光传输
- 空间光通信
- 光接入系统

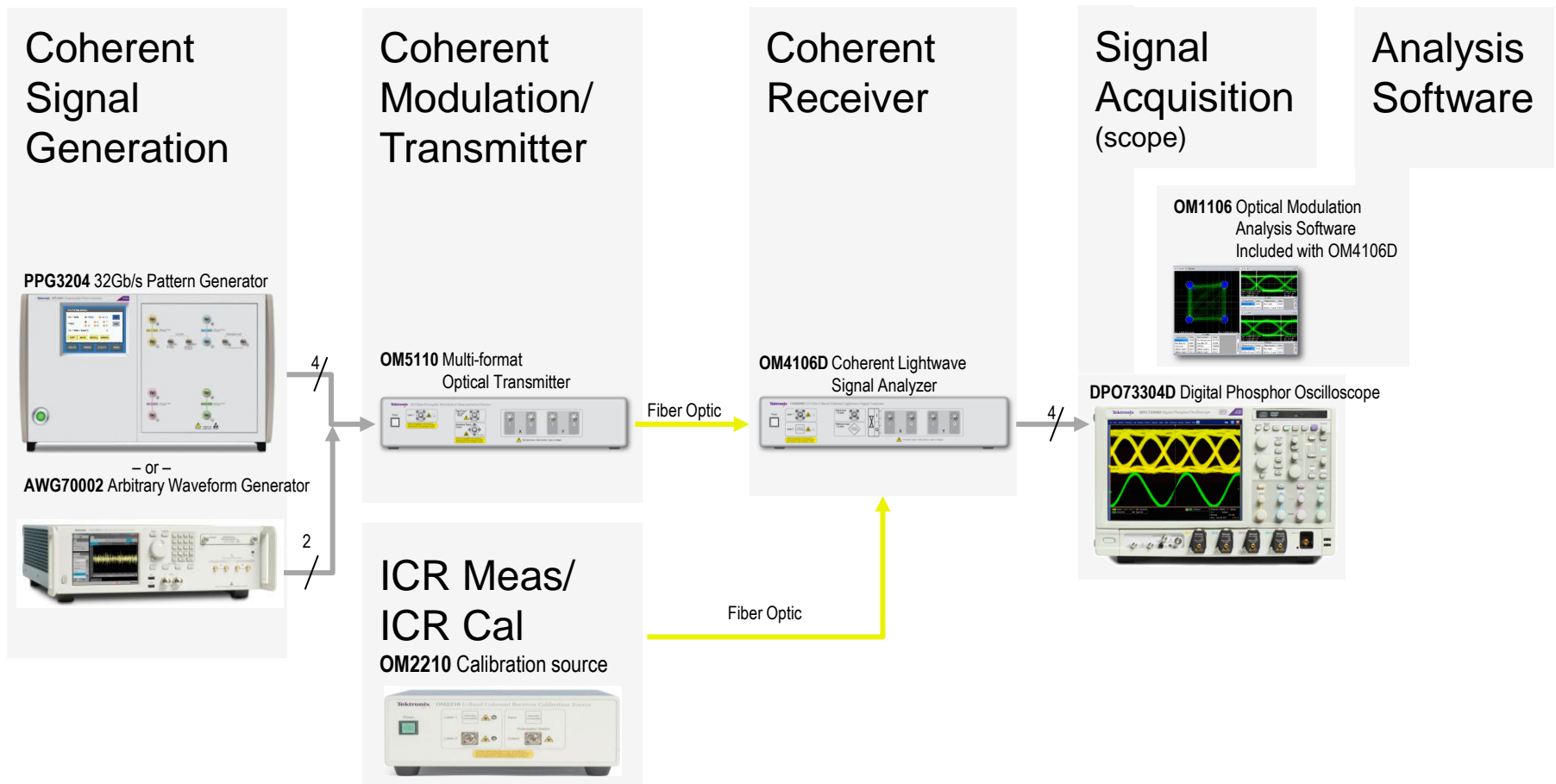






# Coherent Optical System

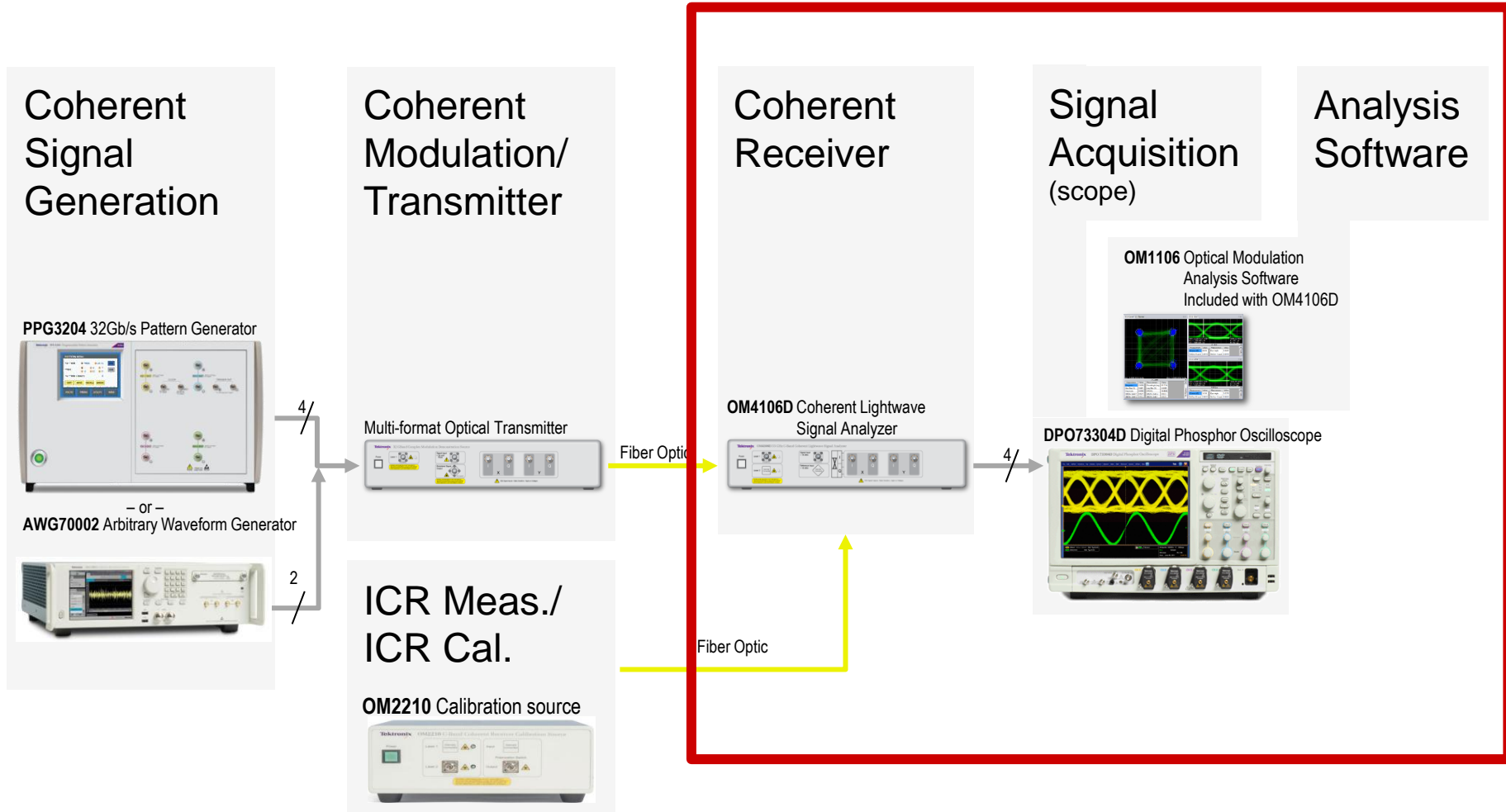
Tektronix offers complete end-to-end testing of coherent modulation formats.



CONFIDENTIAL

# Coherent Optical System

Tektronix offers complete end-to-end testing of coherent modulation formats.

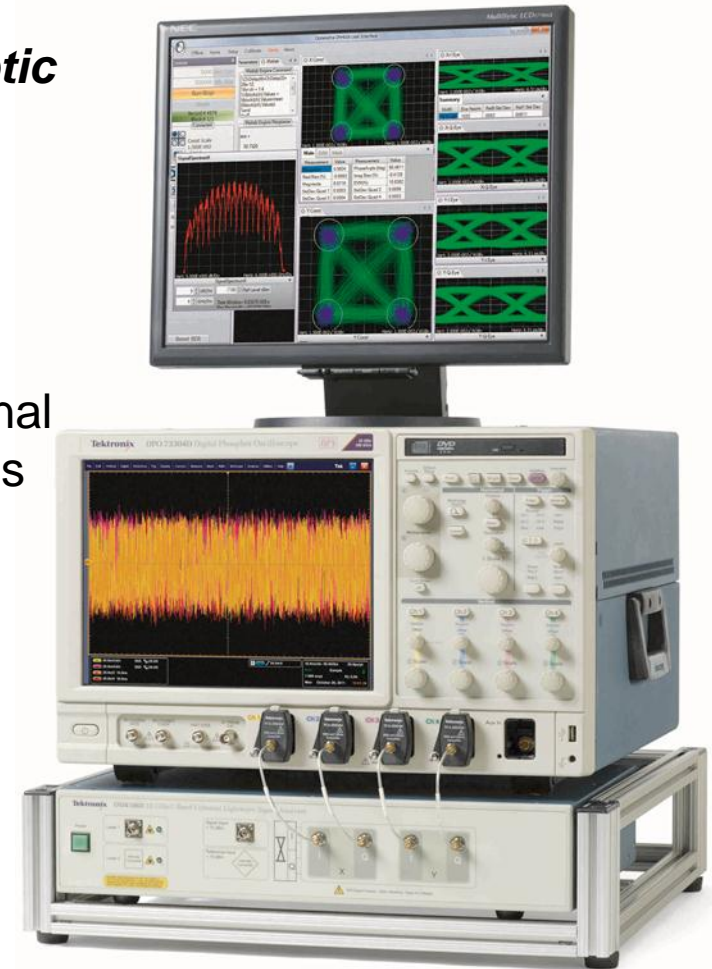


CONFIDENTIAL

# OM4106D 33 GHz Coherent Lightwave Signal Analyzer for >100Gb/s Analysis

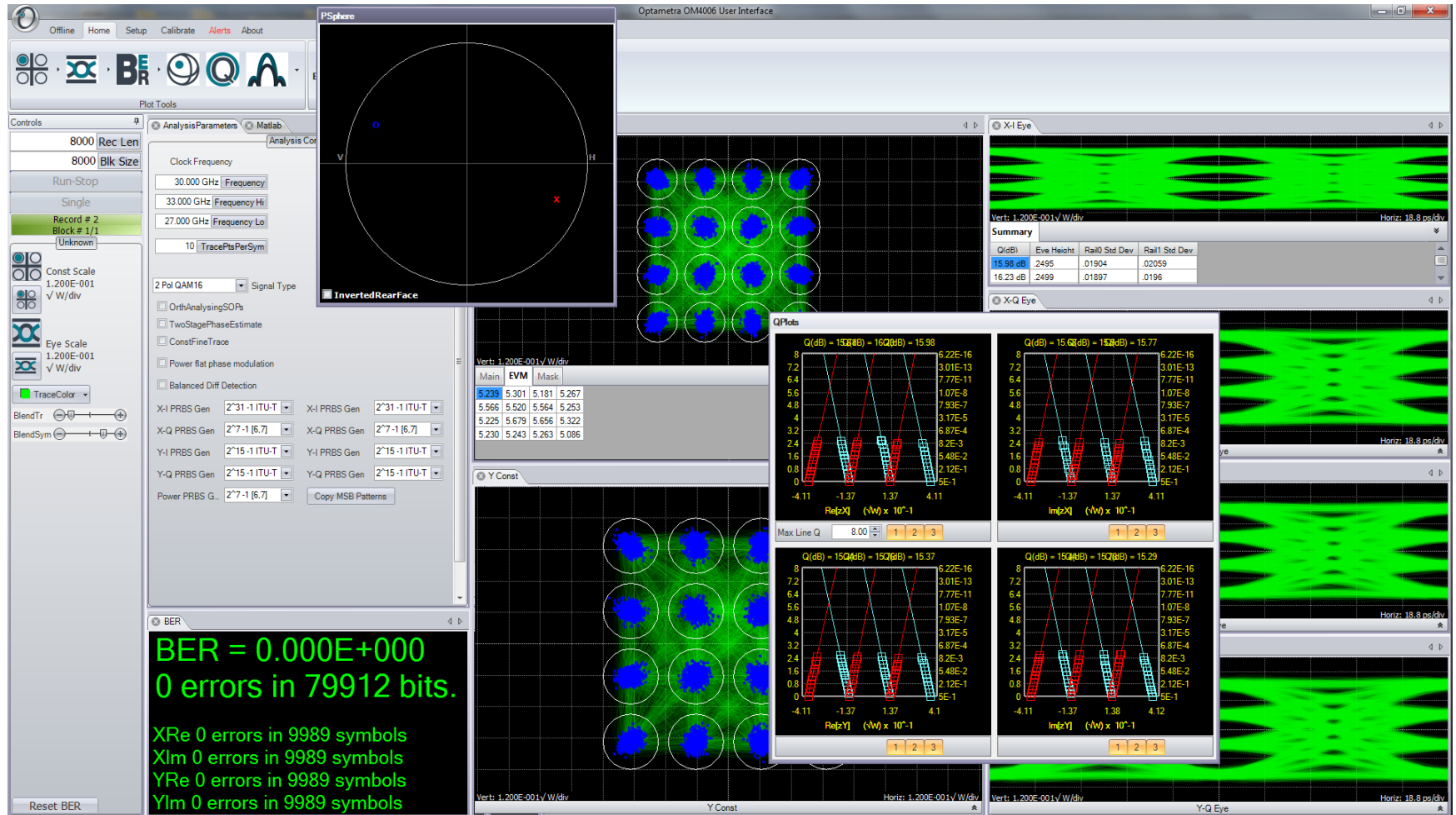
***Complete and open solutions to complex measurement challenges in long-haul fiber-optic communications***

- Advanced dual-polarization in-phase and quadrature receiver with integrated signal and reference tunable laser sources
- Open-architecture MATLAB-based computational engine offers powerful phase-recovery analyses with polarization, bit-error rates, and record/playback
- Intuitive graphical user interface controls frequently-used instrument functions:
  - Laser control
  - Modulation schemes
  - PRBS or user-generated data
- Accessories available to easily verify optical calibration

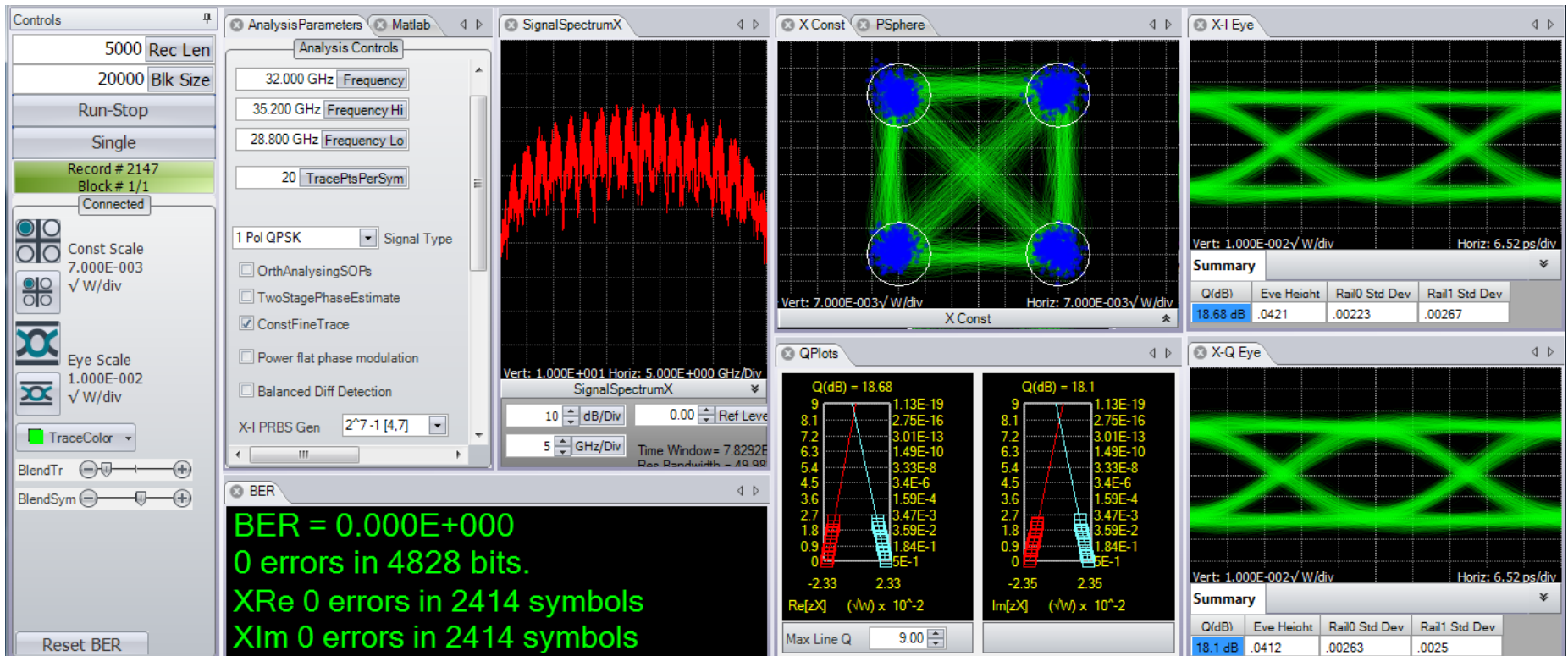


# Customize Analysis Software for Optical Customer

## Measurements Available for QAM Signals

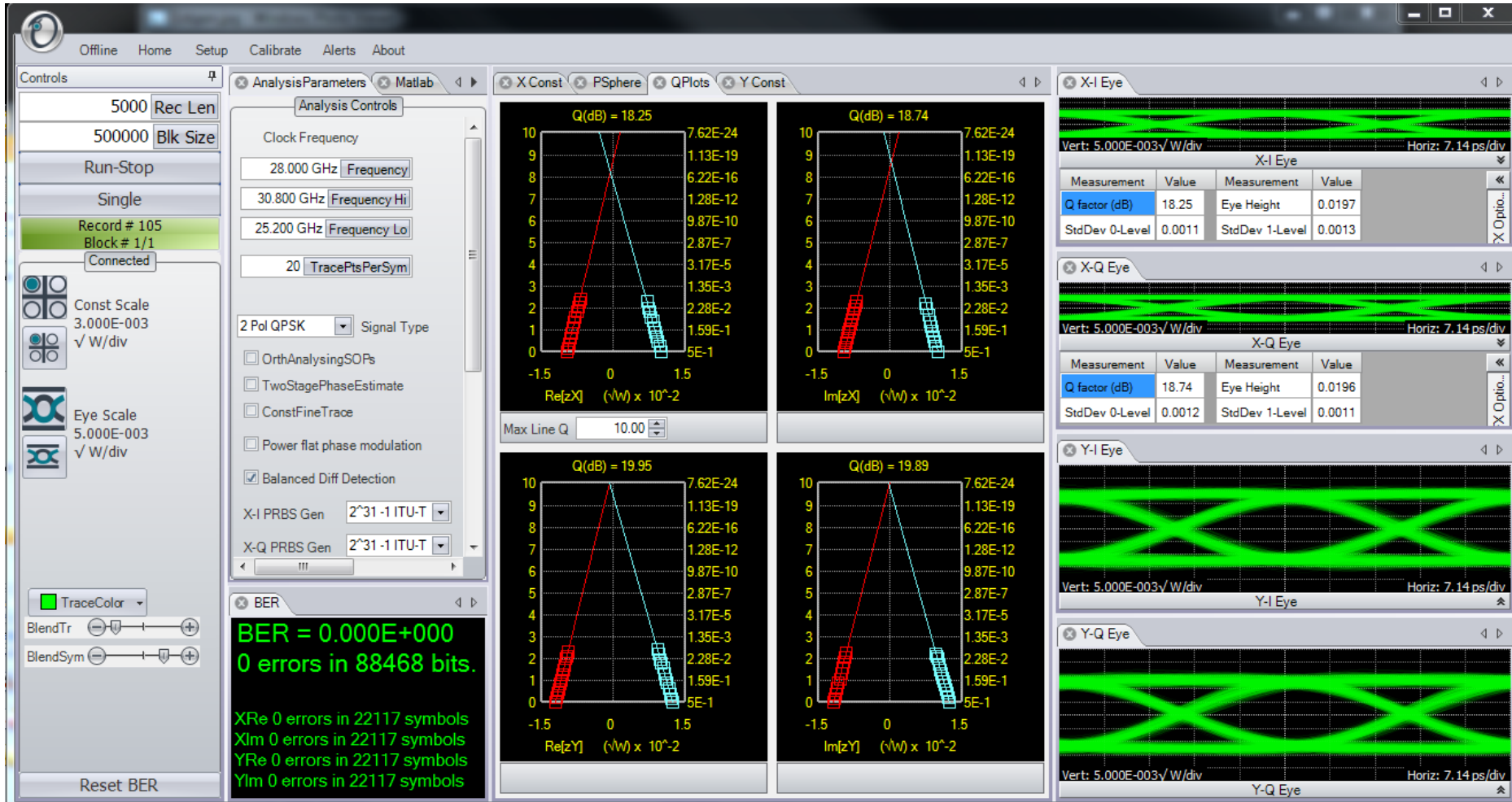


# 32 Gbaud Optical Signal digitized with the DSA73304D in 50Gs/s mode (~23 GHz BW)



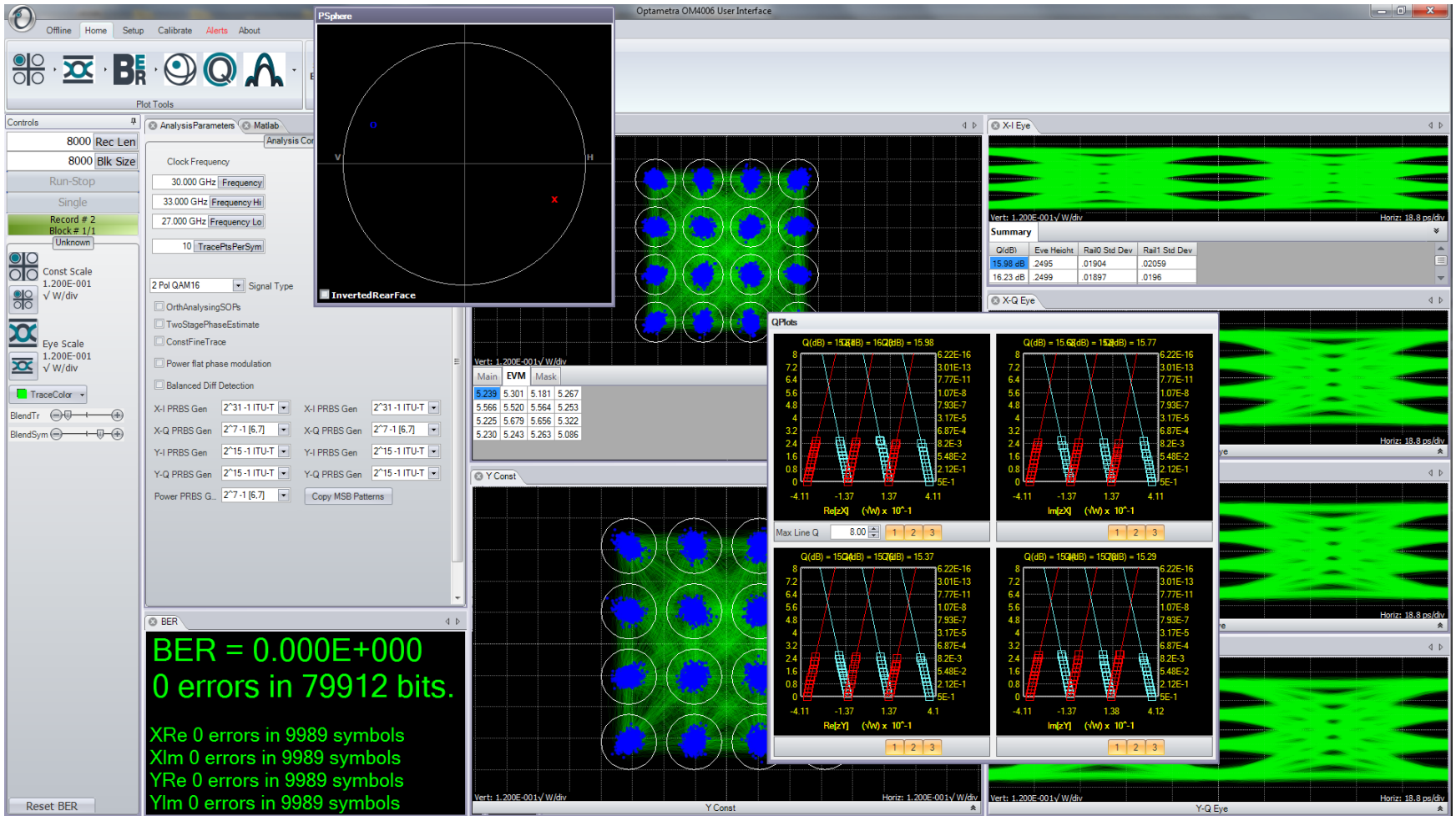


# Measurements available for QPSK signals

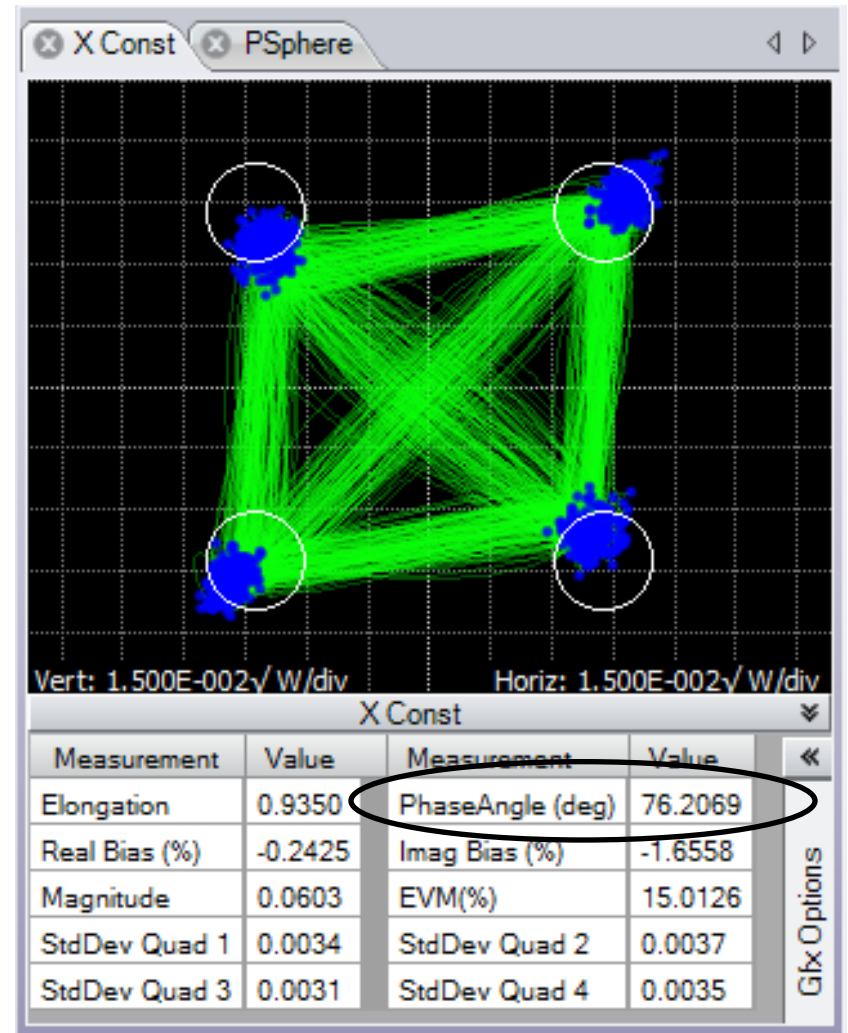
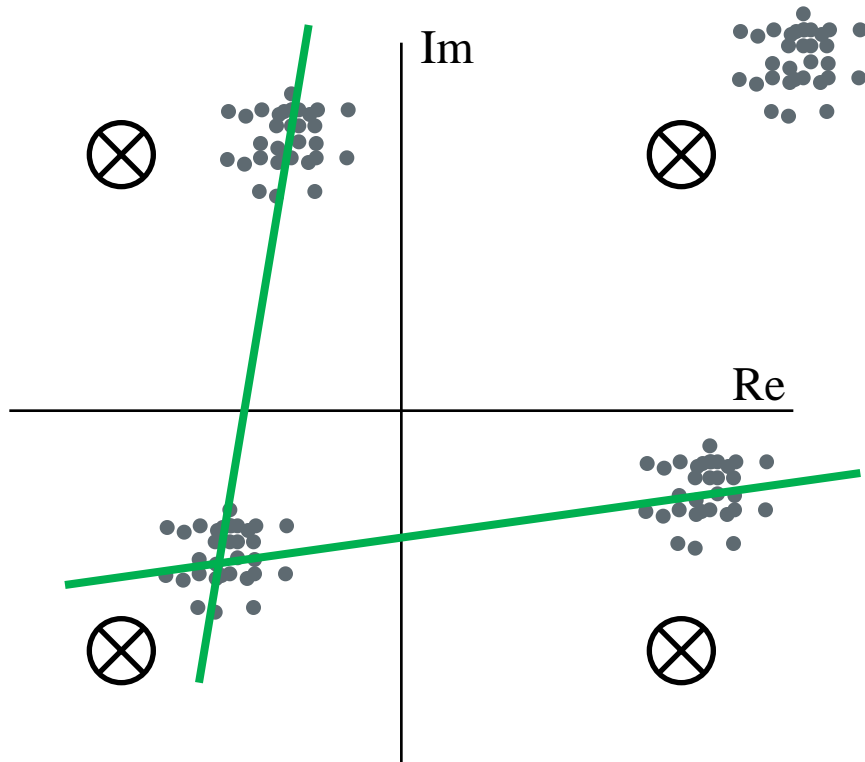




# Measurements available for QAM signals



# Measuring TX constellation imperfections: Phase Angle



# 400G Multi-Carrier Superchannels

## OFC Equipment Configuration



**OM2012 CC**  
4 lasers sources were used. One output went directly to the transmitter, OM5110 #1. The other three were optically combined and sent to the other transmitter, OM5110 #2.



**OM5110 Multi-format Optical Transmitter #1**  
Two of these were used at OFC as a means of testing out different designs. However, all 4 lasers could have been combined into a single transmitter instead.

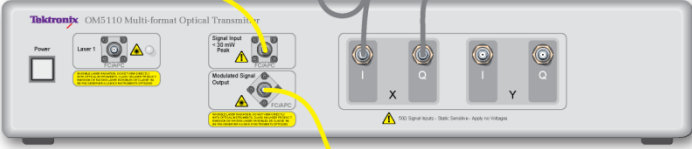


**AWG70001A**  
The AWG was programmed to generate 16QAM at 26GBaud.



The data output of the AWG was split; with one side (the 'T' side) delayed with a longer cable length to prevent I and Q from being synchronous.

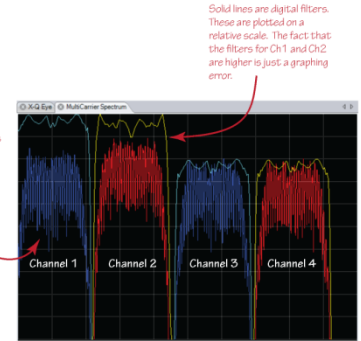
**OM5110 Multi-format Optical Transmitter #2**  
To keep the setup simpler, each transmitter was used in a single-pole mode. With more splitters from the AWG, the system could have been setup as dual polarization which would have created an 800G system!



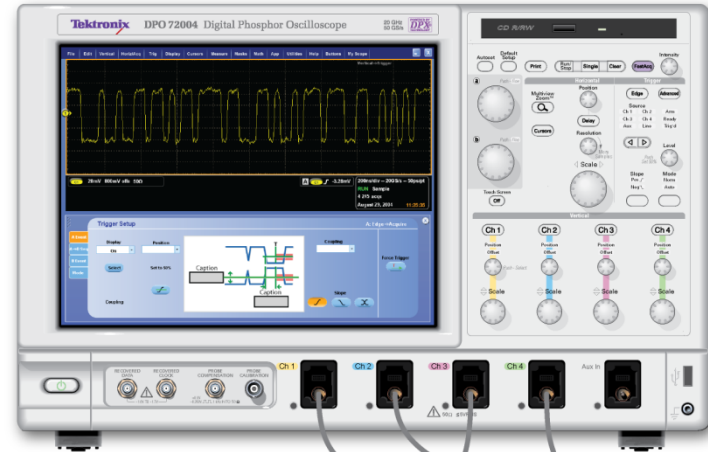
**Superchannel Carrier Channel Table**  
At the right are the frequencies to which the 4 lasers were tuned. Effectively, this is a 35.5GHz grid. These numbers are arbitrary. By the end of the show we had made this grid smaller by a couple of GHz, but using the same digital channel filters, to see good of a job the filters were doing.

Channel	Frequency (THz)	Preferred (GHz)	Include in span
1	193.9700	193.9700	<input checked="" type="checkbox"/>
2	194.0005	194.0005	<input checked="" type="checkbox"/>
3	194.0410	194.0410	<input checked="" type="checkbox"/>
4	194.0785	194.0785	<input checked="" type="checkbox"/>

The blue and red lines are the channels after digital filtering. Multiple digital filters are available, including custom user-specified filters.

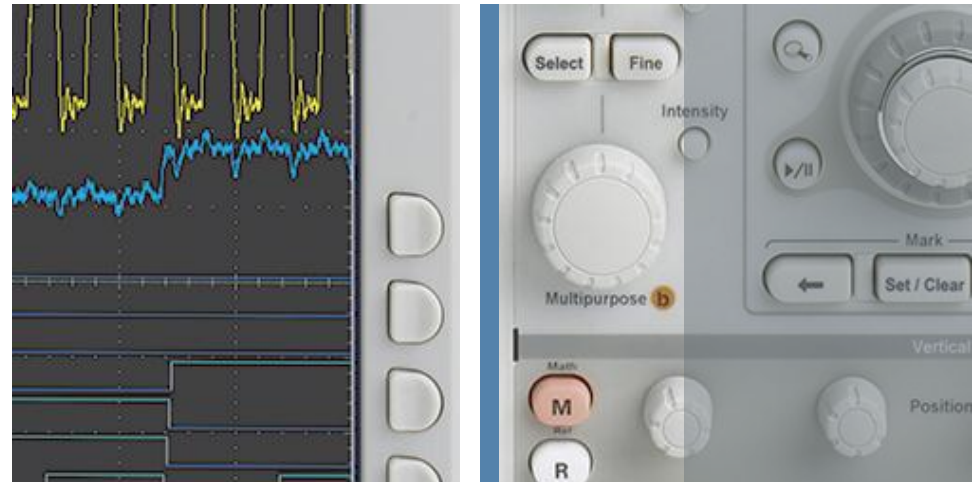


Solid lines are digital filters. These are plotted on a relative scale. The fact that the filters for Ch1 and Ch2 are higher is just a graphing error.



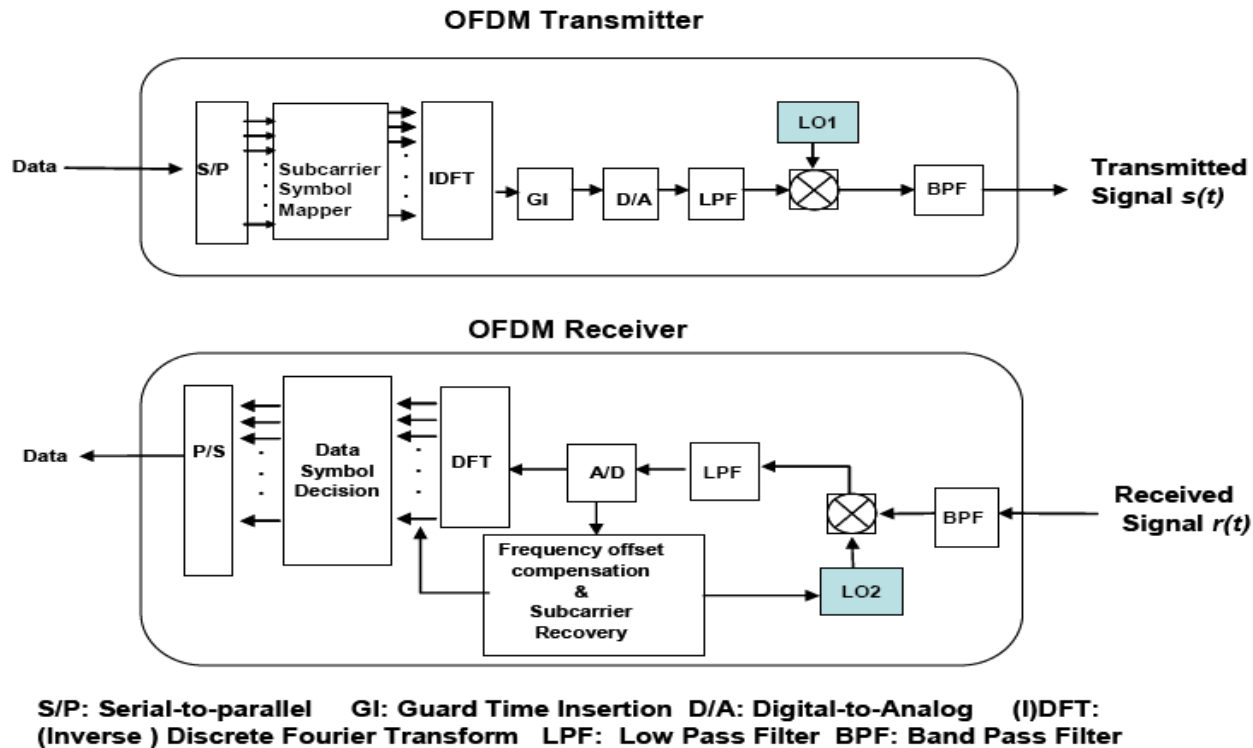
**OM4106D and DPO73304D**  
These were standard production units with nothing special. However, on the OUI laptop (not shown) we had the latest software that supports multi-carrier analysis.

# Optical-OFDM调制技术



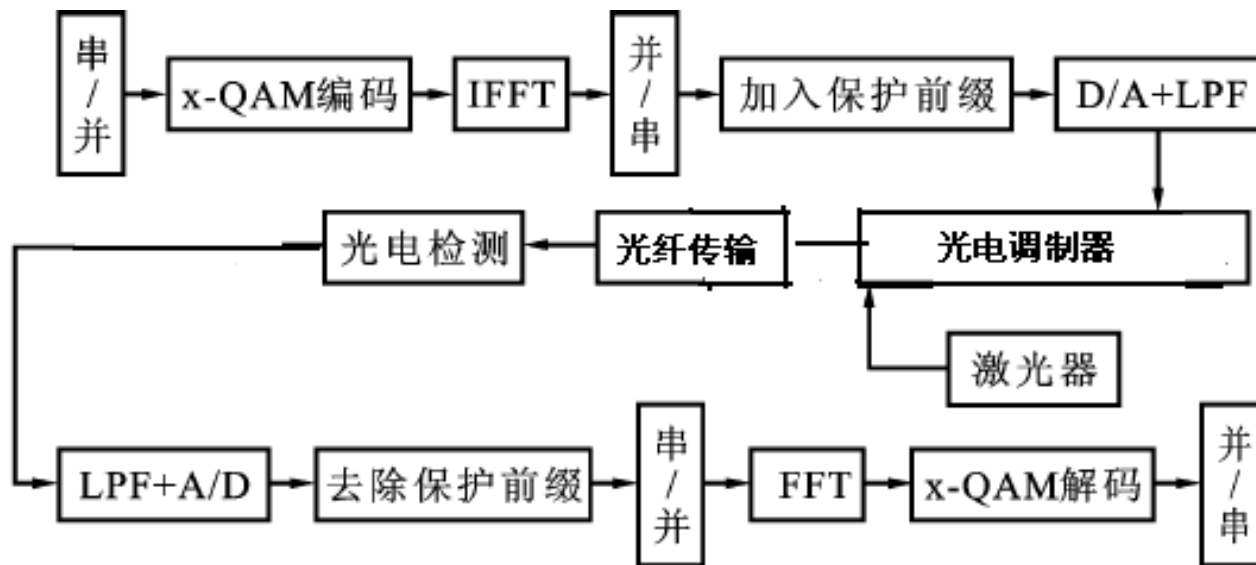
# OFDM基本原理

- 正交频分复用OFDM (Orthogonal Frequency Division Multiplex)是一种多载波调制方式,通过减小和消除码间串扰的影响来克服信道的频率选择性衰落。它的基本原理是将信号分割为N个子信号,然后用N个子信号分别调制N个相互正交的子载波。由于子载波的频谱相互重叠,因而可以得到较高的频谱效率。近几年OFDM在无线通信领域得到了广泛的应用。



# Optical OFDM基本原理

- 一个典型的O-OFDM系统可以分成OFDM基带信号发射机、电/光变换、光纤链路、光/电检测和OFDM基带接收机5部分。



O-OFDM 传输系统原理结构图

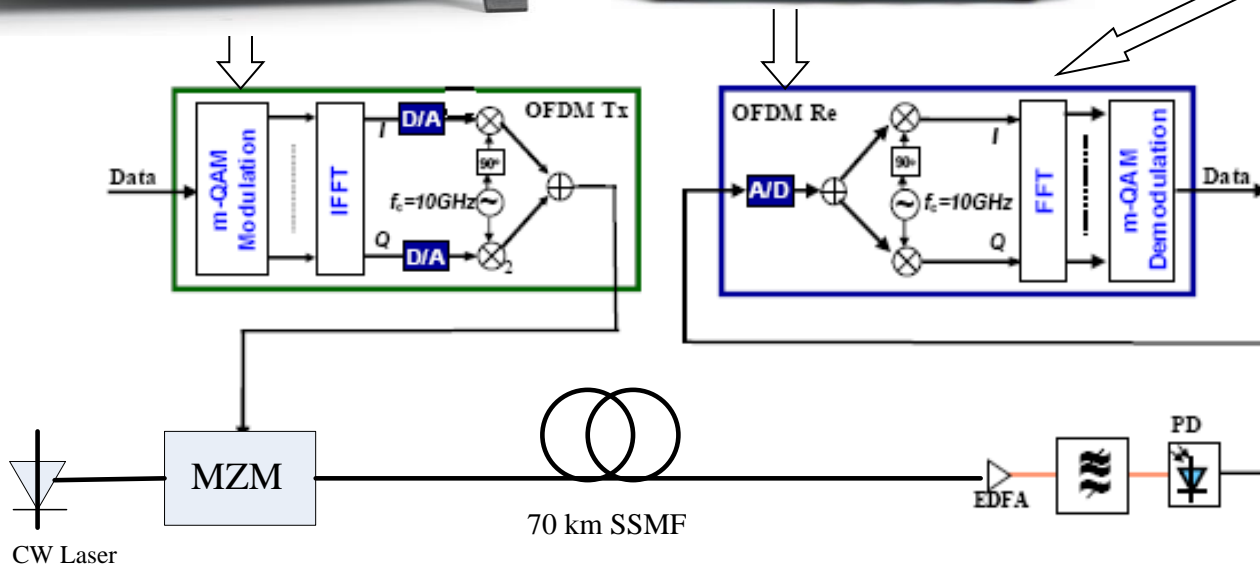
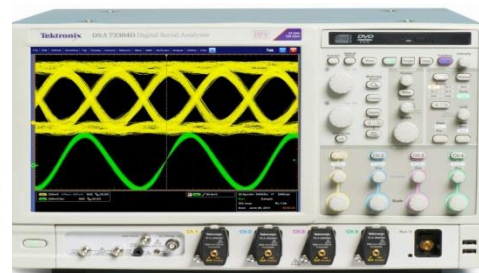


# 泰克光OFDM通信系统测试解决方案

## 光OFDM通信系统测试系统构建

生成宽带OFDM电信号

验证和分析宽带OFDM电信号



# 产品技术数据



## AWG70001A

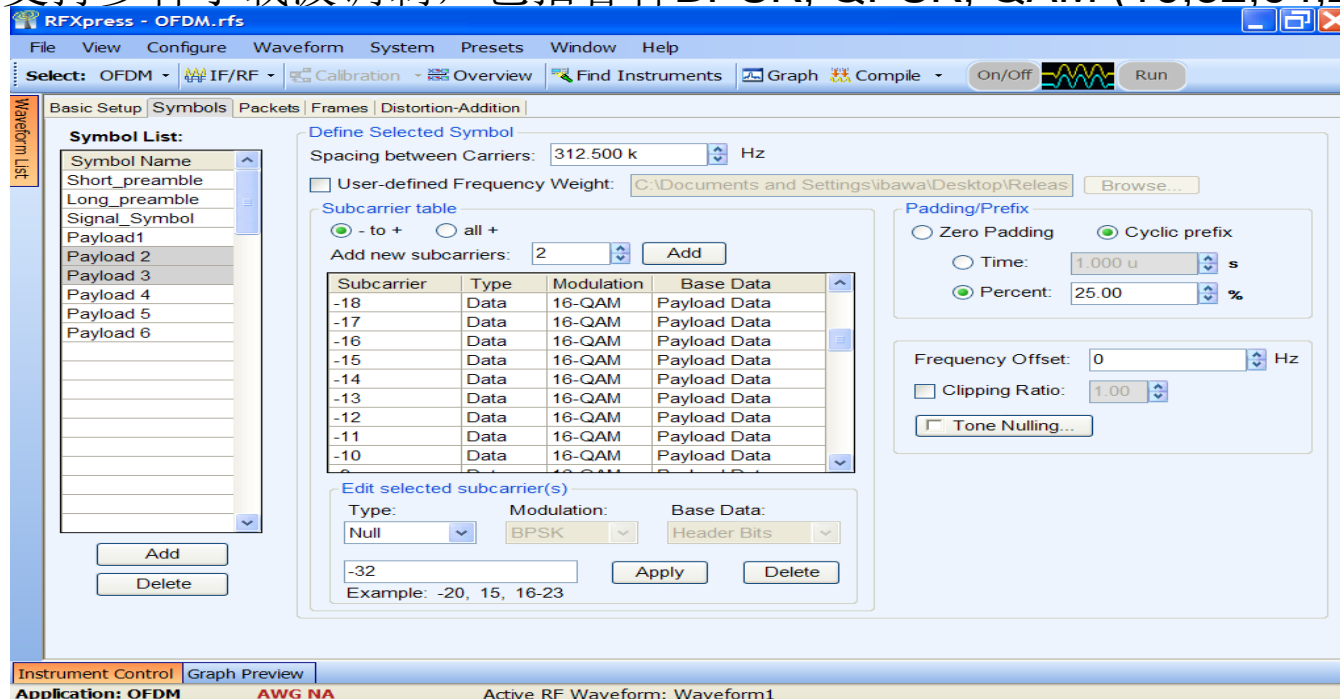
通道数量	1
采样率	1.5 KS/s - 50 GS/s
最大输出频率	20.0 GHz
动态范围 (SFDR)	> -80 dBc
DAC分辨率	10位
波形存储器 (每条通道)	2 G样点 (标配) 16 G样点 (选配)

## 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)

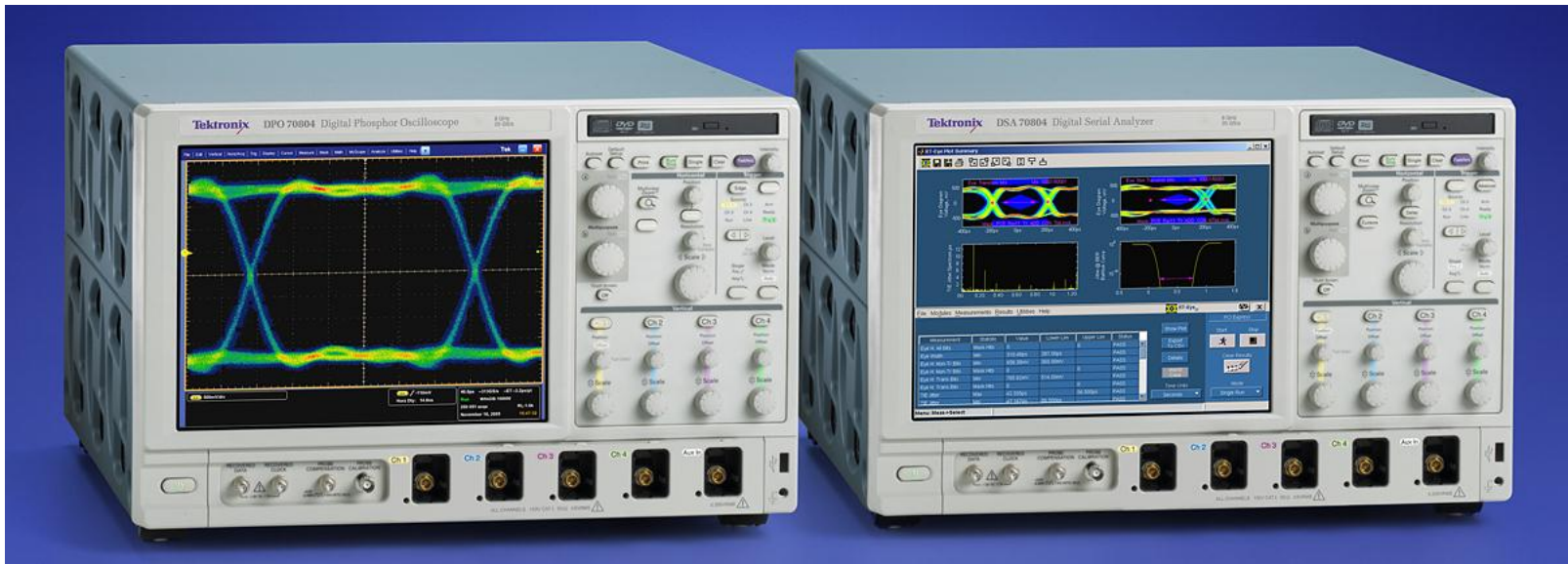
# 业内唯一的OFDM信号生成信号源AWG7122C+软件RFXpress

- RFXpress——基带、中频和射频信号生成软件
  - 可以设置OFDM的所有参数
  - 设置用户自己定义的数据-符号-数据包-数据帧
  - 支持RS(Reed-Solomon)编码、卷积和加扰
  - 可以在信号加入诸如相位噪声、多径或量化损伤
  - 支持多种子载波调制，包括各种BPSK, QPSK, QAM (16,32,64,256) and



# Tektronix 相干光通信信号采集、验证和分析解决方案-硬件平台

- 新超高性能数字荧光示波器：  
**DPO73304D**



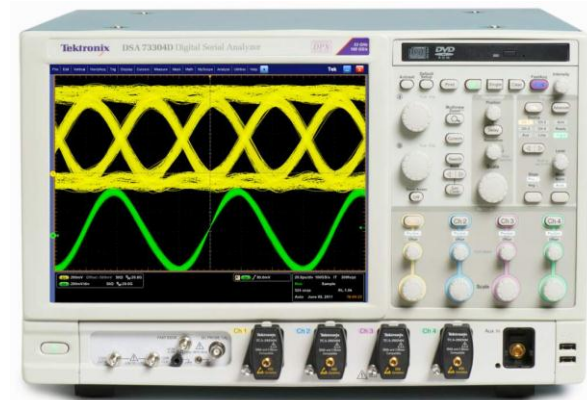
性能毫无折中的第三代数字示波器

# DPO/DSA7000D Series

## Key Specifications

Analog BW	Sample Rate	Rise time
<b>33 GHz</b>	<b>100GS/s</b>	<b>9 ps</b>

- 10 TS/sec Equivalent Time Sample Rate
  - 50x nearest competitor
- Input sensitivity at 62.5mV full scale
- Low internal jitter
  - Jitter Noise Floor: <250fs
- Record length for long time trend / jitter evaluations
  - 250MS on 4 channels
- Waveform acquisition rate of >300,000 wfms/sec



Notes: Typical rise time is measured at 20%/80%  
Specifications subject to change

# 泰克光OFDM通信系统完整的系统测试方案

## 一、超宽带信号源AWG—业内唯一能产生宽带OFDM信号的信号源

- 超高带宽（20G），超高采样率（50GS/s）
- 可以直接产生射频，中频，基带信号
- 基于AWG的高级OFDM信号仿真软件RFXpress，方便产生各种复杂的OFDM信号
- 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
- 与泰克的宽带示波器搭成无缝环路

## 二、宽带示波器

- 带宽33GHz
- 采样率达到100GS/s
- DPOJET软件最专业的抖动眼图测试软件
- SignalVu OFDM分析软件
- 与各种软件兼容如:Matlab等

## 三、BERTScope误码分析仪

- 高达26Gbps码速率
- 专利的Dual ED构架，快速准确完成眼图、抖动测量



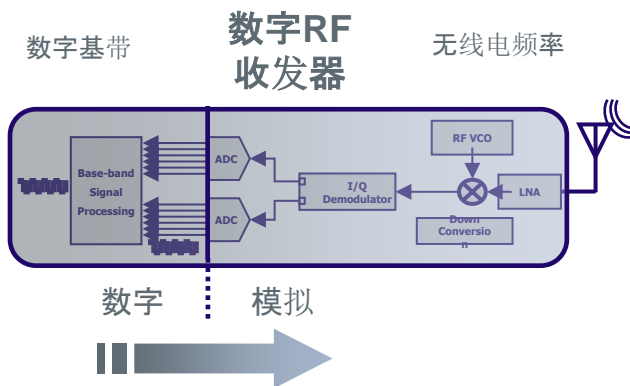
# 无线通信

- 无线通信

-

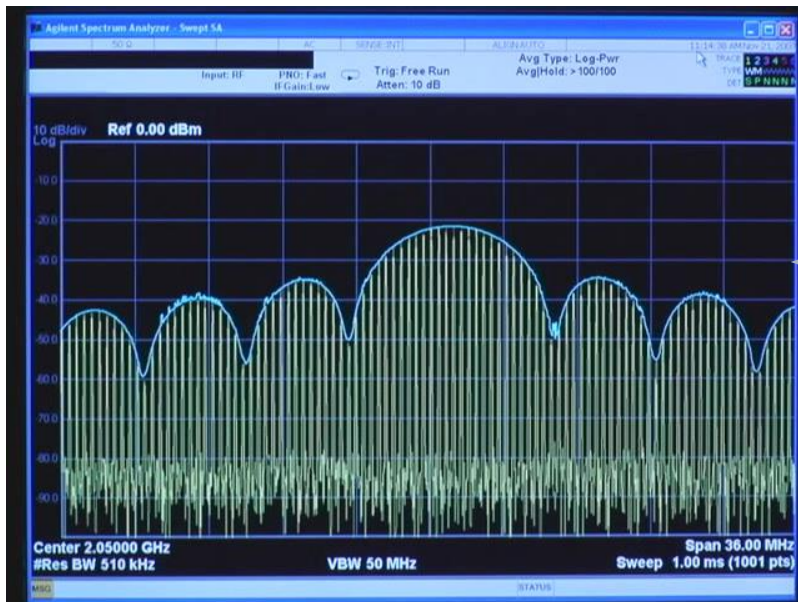
# 客户面临的挑战: 无线电通信设计

- 经济形势要求降低成本并提高效率
  - 开发时间不断缩短
  - 资本支出和开发成本的压力不断加大
- 新兴技术需要新的测试解决方案
  - 带宽提高
  - 复杂调制、SDR和频率捷变已成为标准
  - JTRS



# 传统测量手段难以发现故障和未知的信号特性

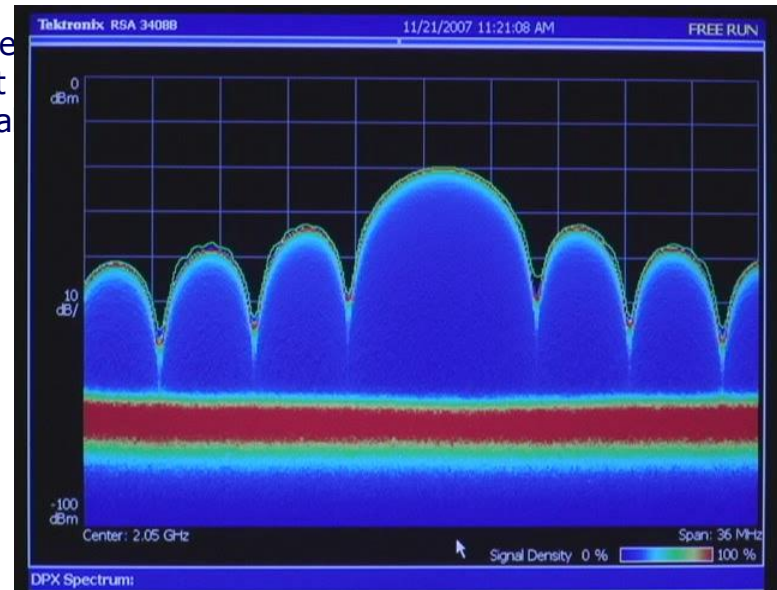
Swept Spectrum Analyzer



Same Test Signal

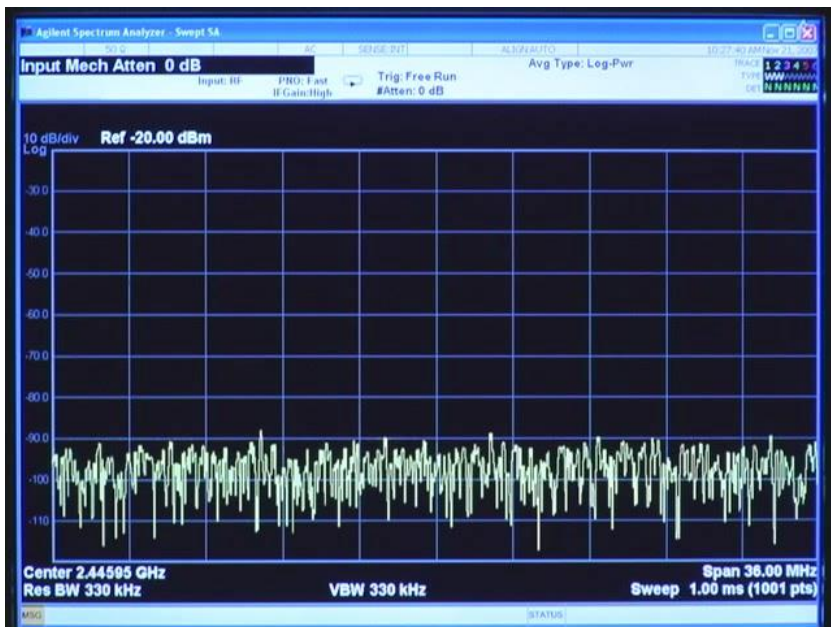
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RSA6100A with DPX™ Spectral



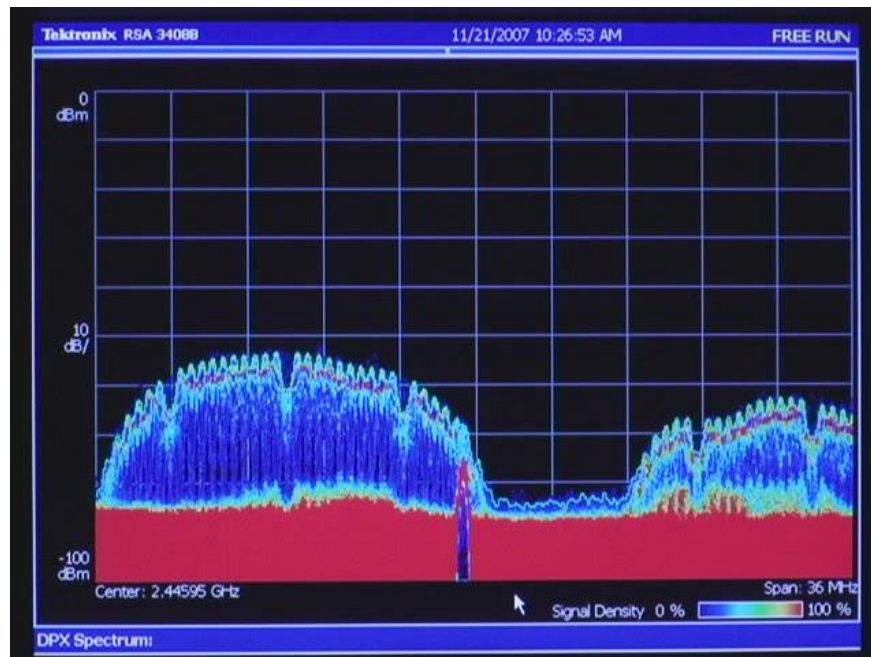
Low Level Signal

# 通信信号的同频出现



## 挑战

- ▶ 监测非法信号
- ▶ 发现干扰源
- ▶ 识别, 分类



## 传统方案

- ▶ 低的监测概览
- ▶ 低的POI 截获概率
- ▶ 分析功能有限

## 泰克优势

- ▶ DPX: 100%发现信号
- ▶ FMT: 精确定位故障
- ▶ Analyze: 超强分析功能

# 泰克实时频谱分析仪最佳实时功能

## ■ 发现

- 新的零SPAN DPX每秒可进行50,000次幅度、频率或相位随时间变化分析
- 每秒292,000次频谱测量
- 最小信号持续时间: 5.8 usec
- 业内唯一可在整个频率范围内进行实时RF分析的扫频DPX

## ■ 触发

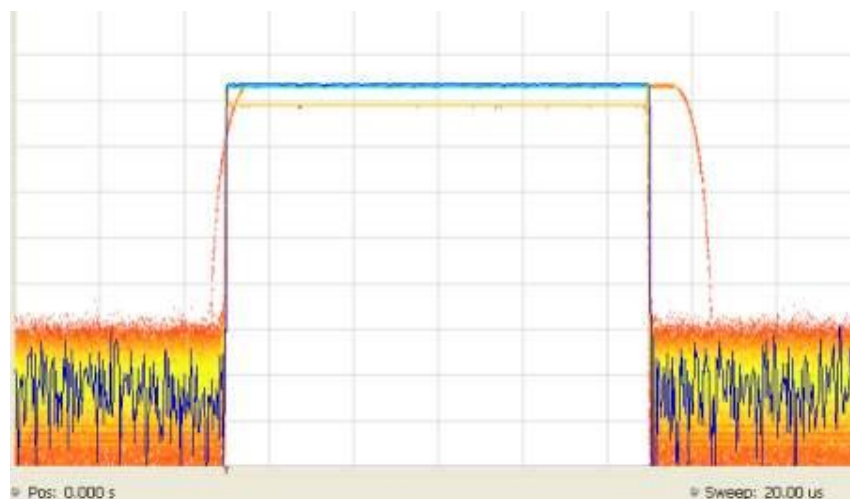
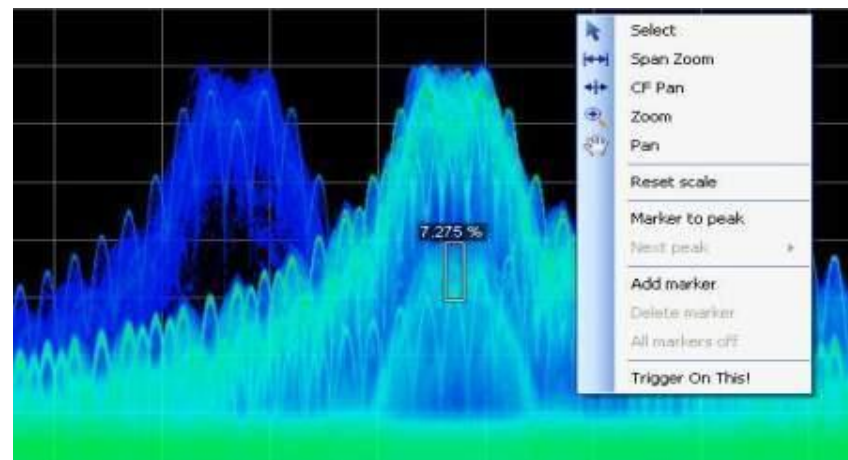
- 具有突破意义的DPX Density密度触发可捕获信号中隐藏的信号
- 频率模板、矮脉冲、时间限定和频率触发捕获每一次变化的信号

## ■ 捕获

- 捕获整个带宽范围内(85 MHz)持续7秒的信号

## ■ 分析

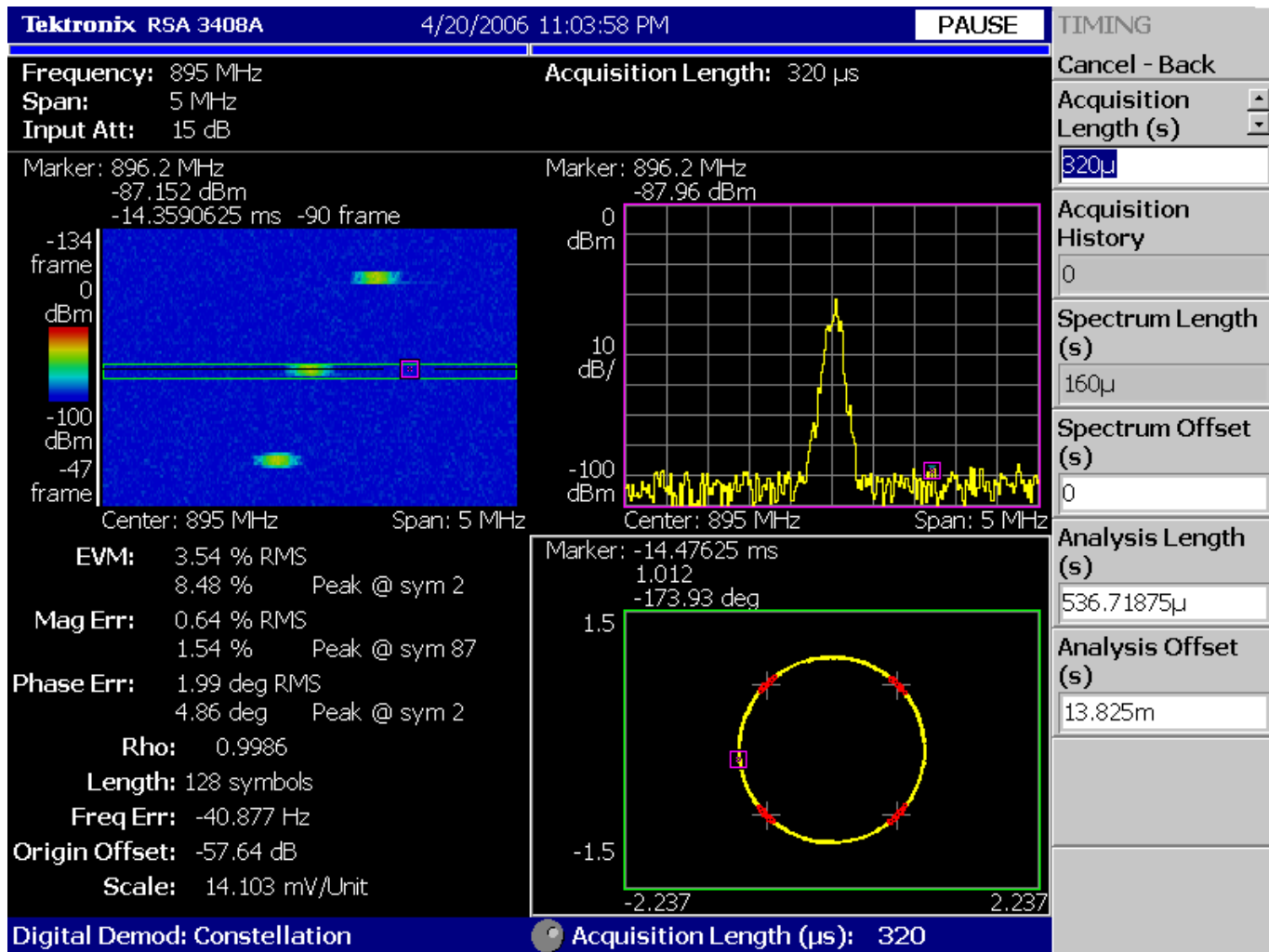
- 频谱、幅度、频率、相位实时信号分析





# 对跳频信号进行解调分析

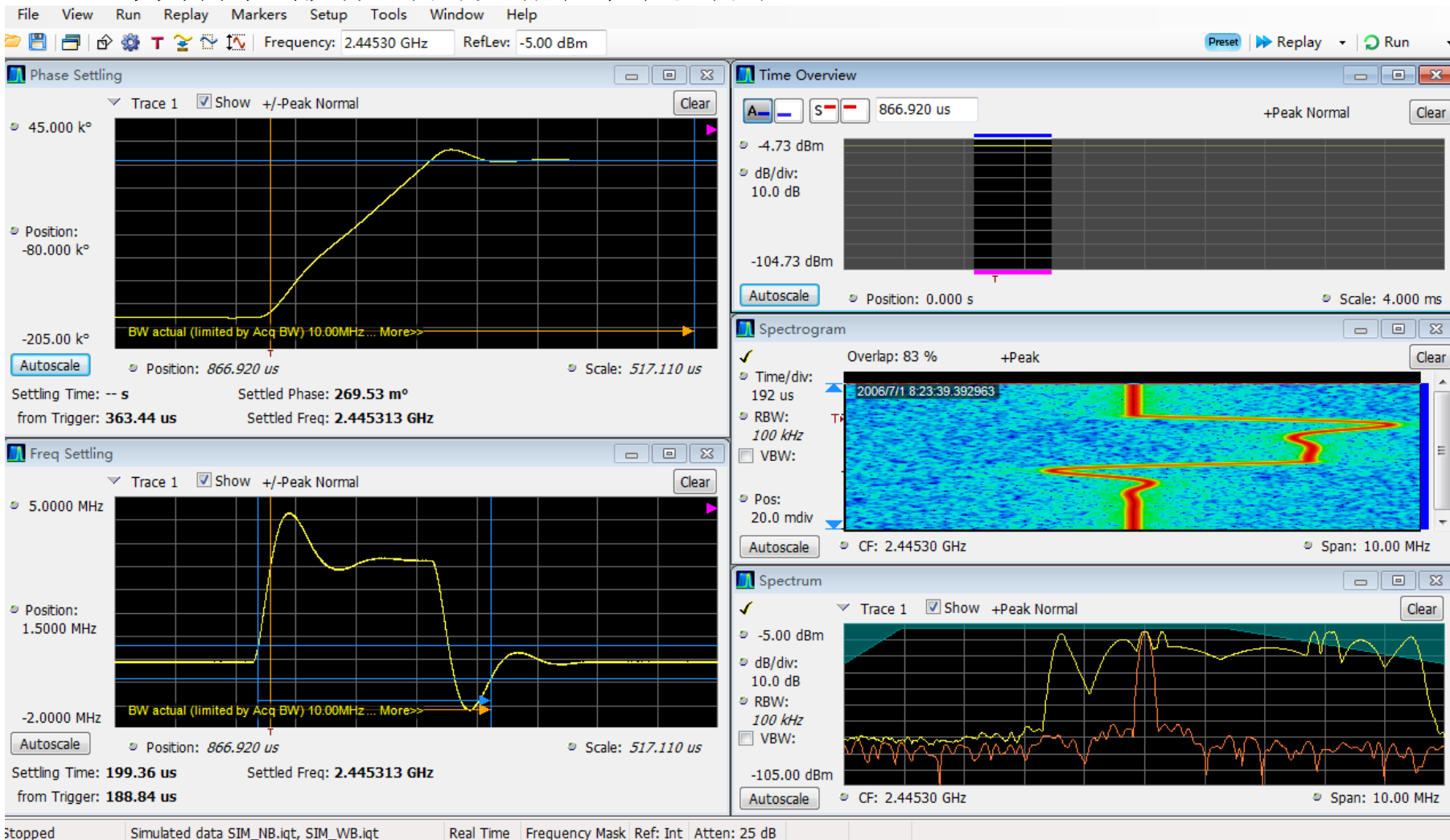
“指哪打哪”  
和  
“打哪指哪”



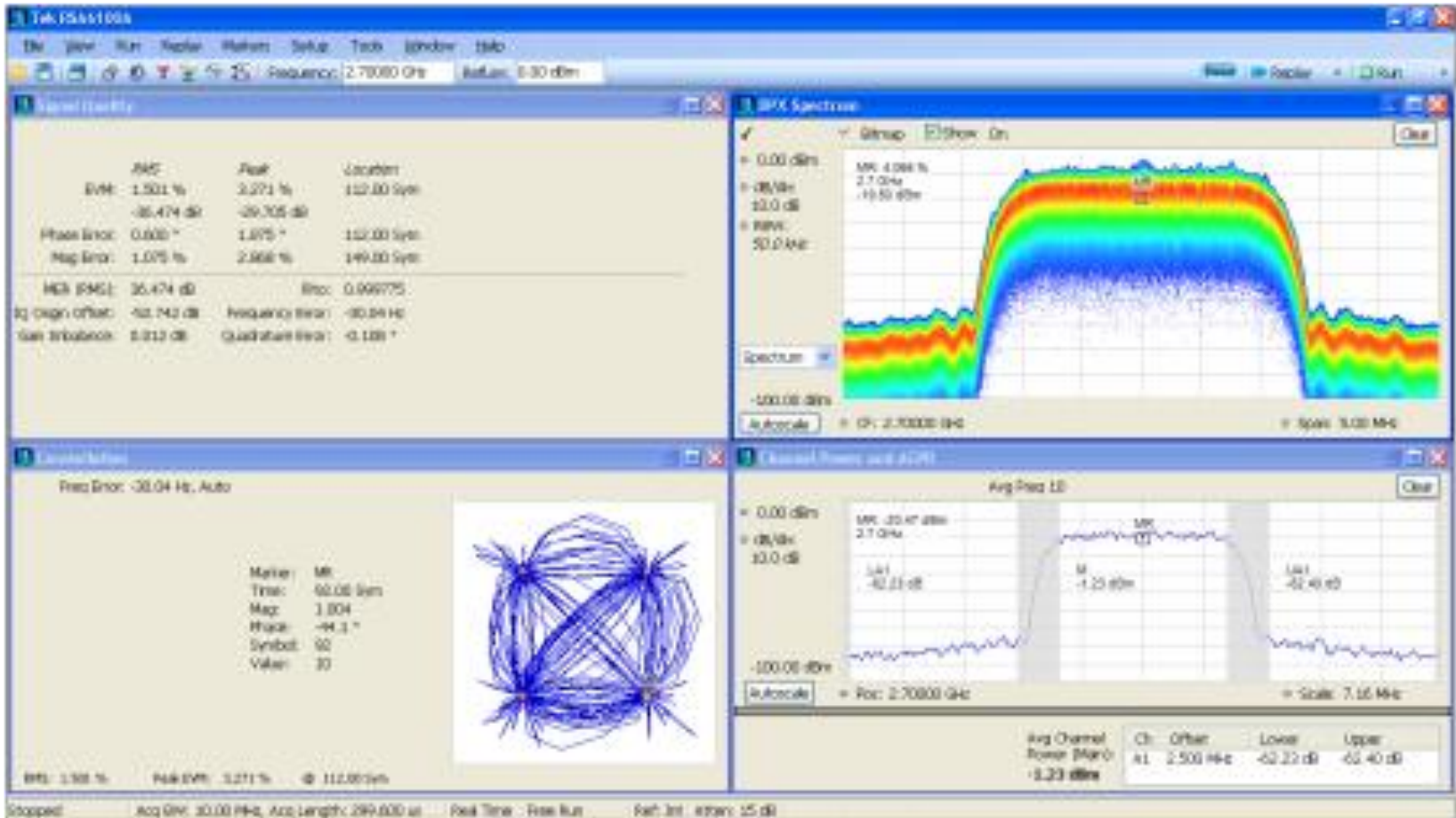


# 时间关联多域分析 – 跳频信号换频时间的测量

## ■ 自动测试换频时间及相位稳定时间

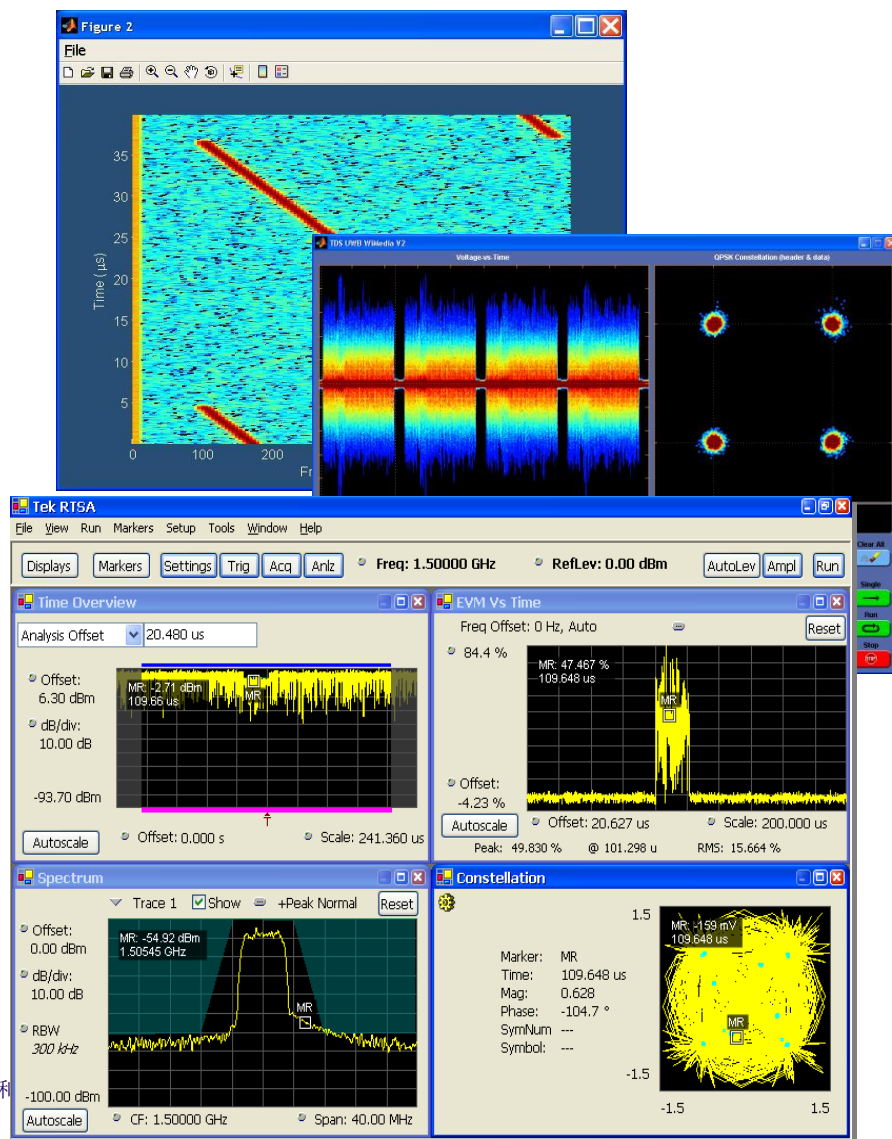


# 对宽带通信信号的分析功能



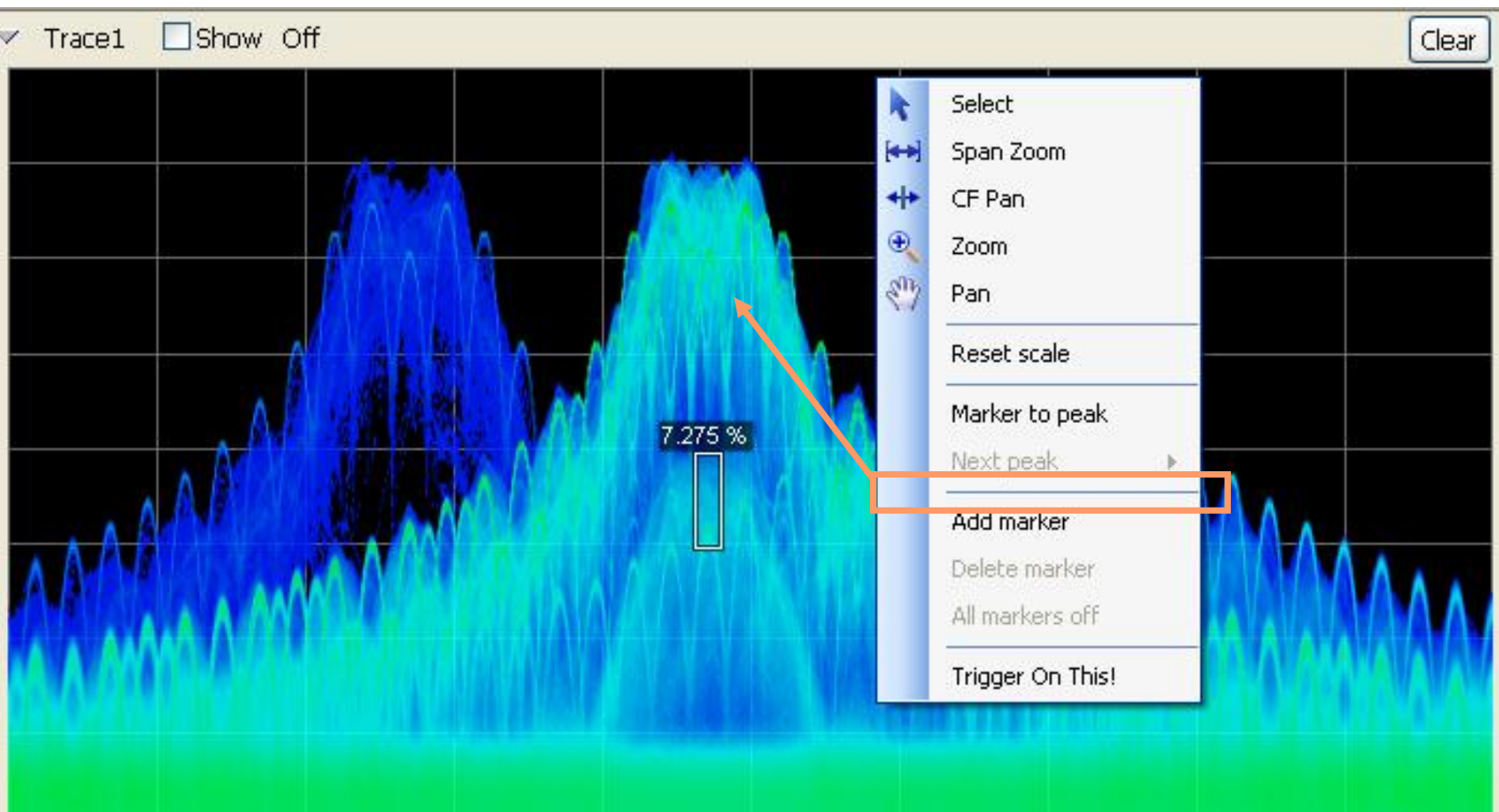
# 示波器作为宽带、超宽带信号采集和分析工具

- 165M以上的调制信号，如何分析？
  - 频谱仪是窄带接收机
  - VSA、RTSA动态范围高，但是110M以上的调制信号无法分析
  - 专用接收机
- 示波器——最通用的宽带接收机
  - 泰克示波器，可以提供最高达33GHz带宽，可直接采集分析射频信号
  - 配合各种分析软件，对调制参数进行测量





# 创新的频谱概率密度统计

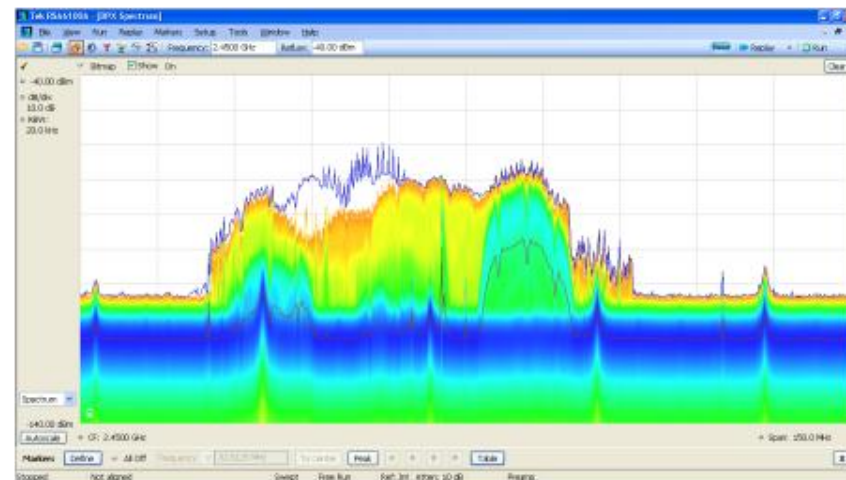




# 应用： 民用无线通信与EMI诊断



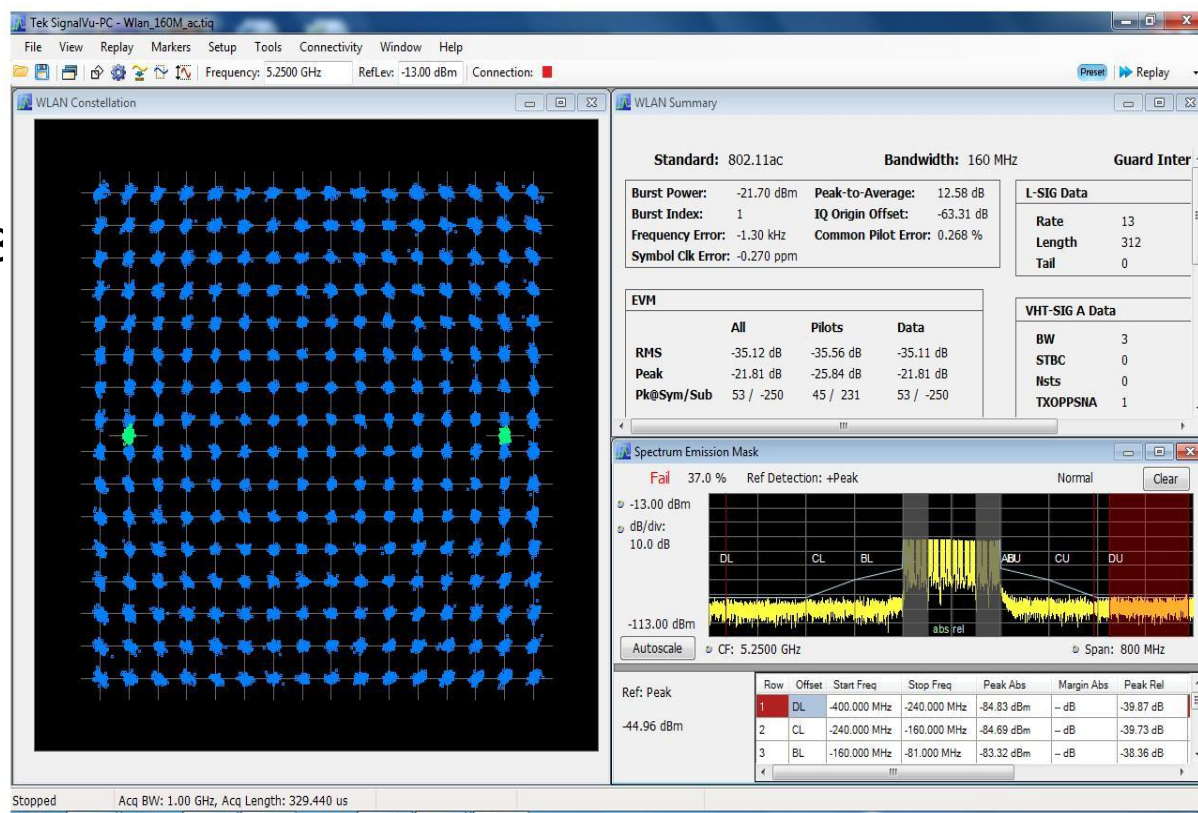
- 以合理的成本实现新设计
  - 165 MHz采集带宽中端分析仪
    - 支持蓝牙、WLAN、其它非许可频谱和专有系统
- 缩短集成和故障排除时间
  - 发现其他分析仪无法识别的问题
  - 区分RF与数字问题
  - DPX
- 支持EMI故障排除提高互操作性和安全性
  - 发现瞬态EMI
  - 优异的低频性能与DPX实时RF显示相结合





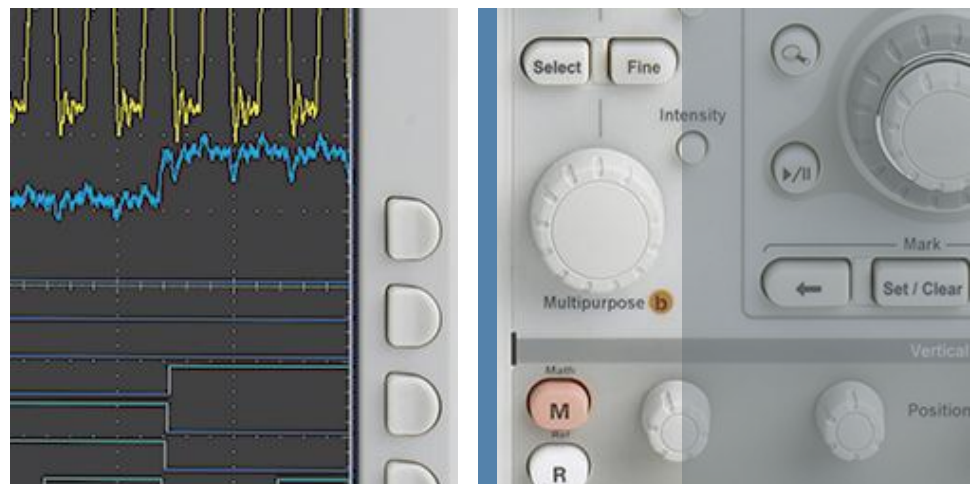
# 应用： 无线通信标准信号测试

- 支持802.11a/b/g/j
- 支持802.11p
- 支持802.11n
- 支持802.11ac
- 短距离无线通信（RFID,ZIGBEE,WLAN E



# 泰克RFID测试方案

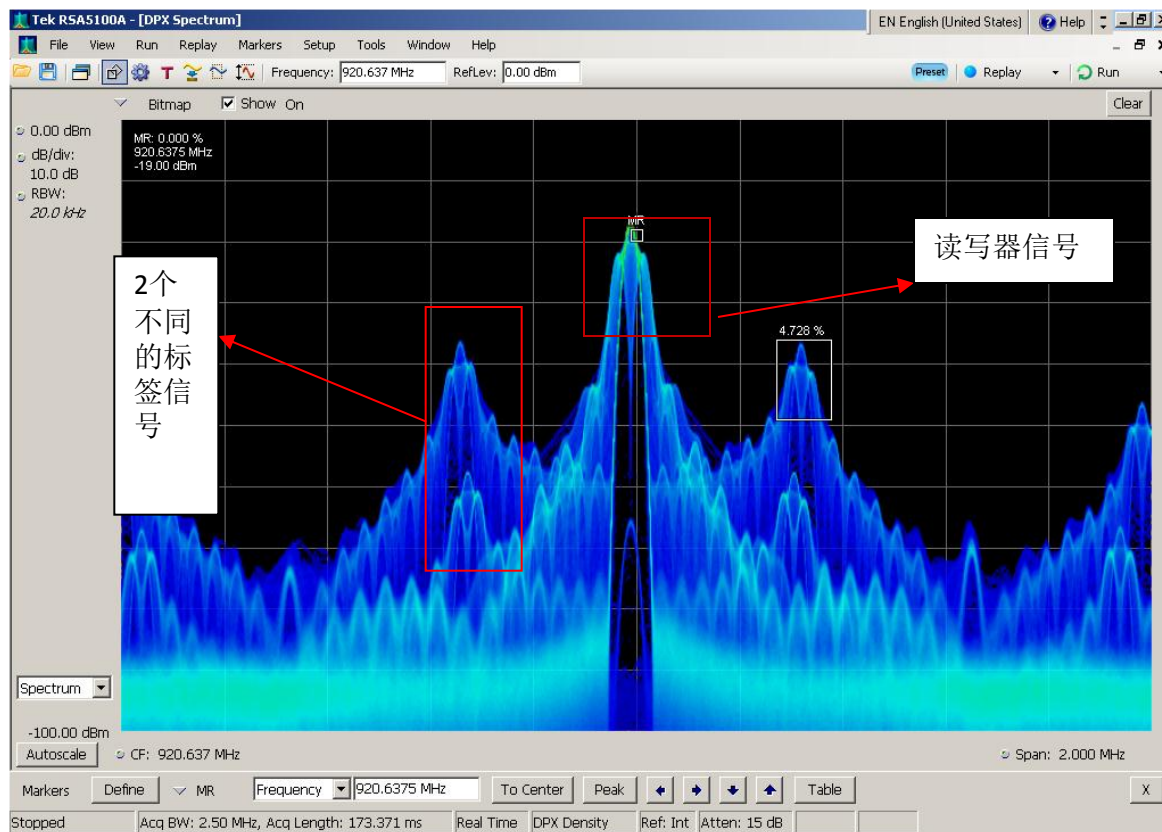
满足研发级和认证级别测试



**Tektronix**<sup>®</sup>

# 实时观测和实时捕获RFID信号

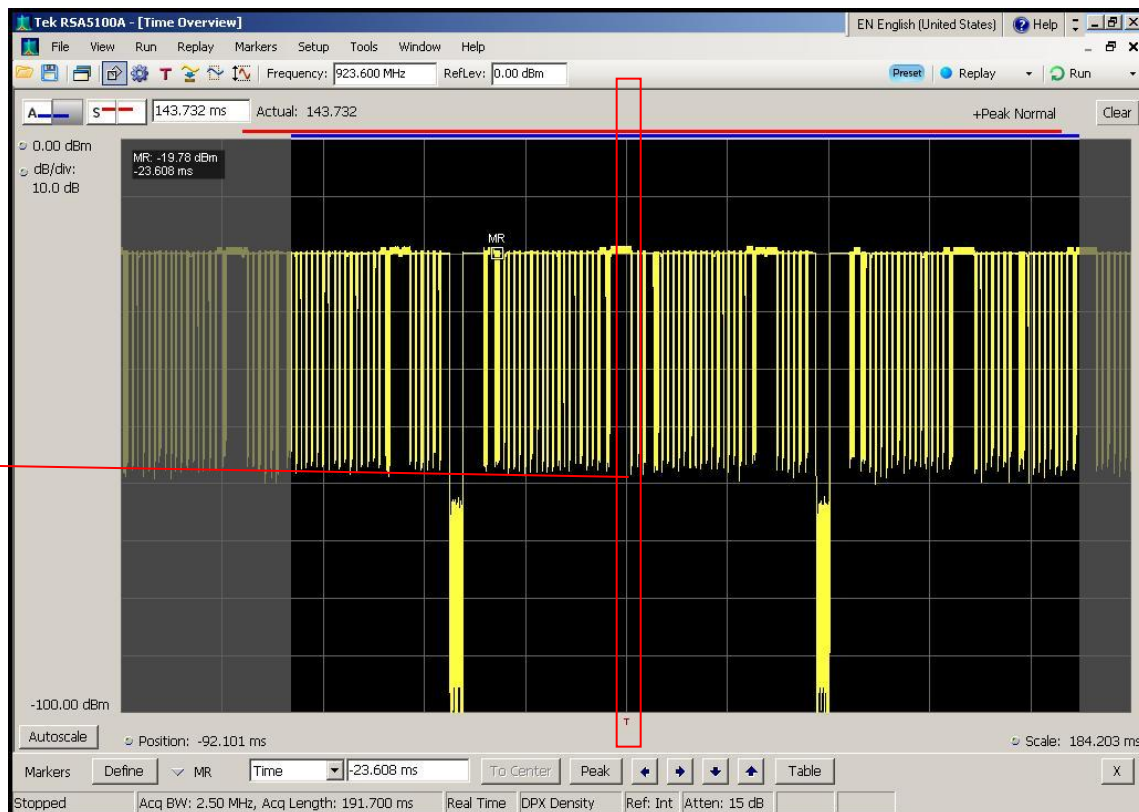
- DPX技术实时观测RFID信号行为
- 观测同频的多标签信号
- 实时捕获标签信号或者读写器信号
- 概率密度触发捕获标签信号



# 捕获的RFID信号时域显示

- 时域上精确显示捕获时的标签信号 (T)
- 时间概览窗，概览全部交互过程

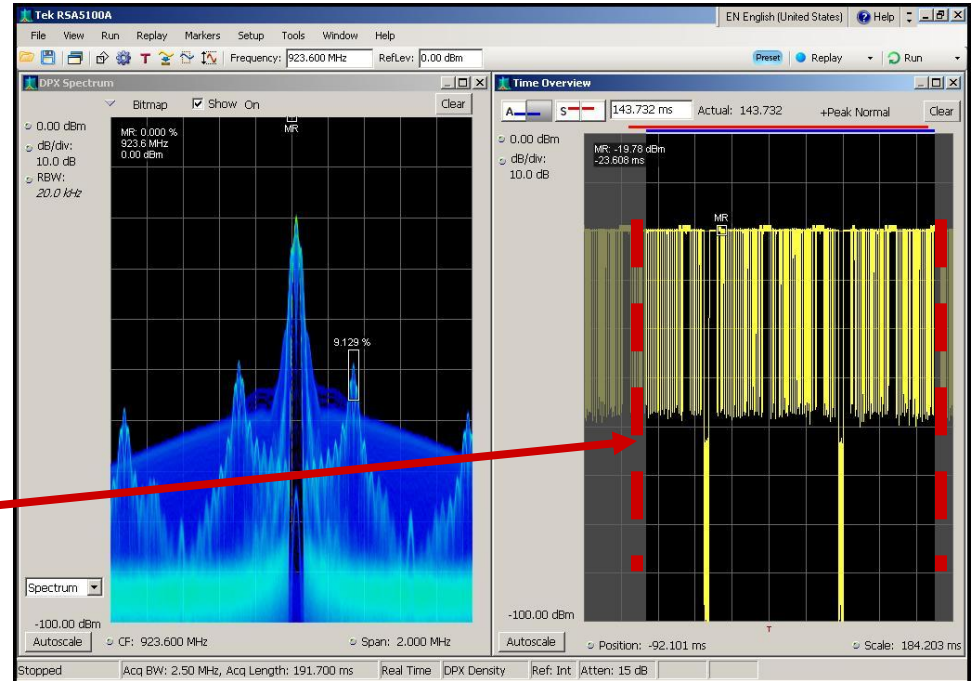
触发的标签信号精确的时刻



# 时间相关，多域分析

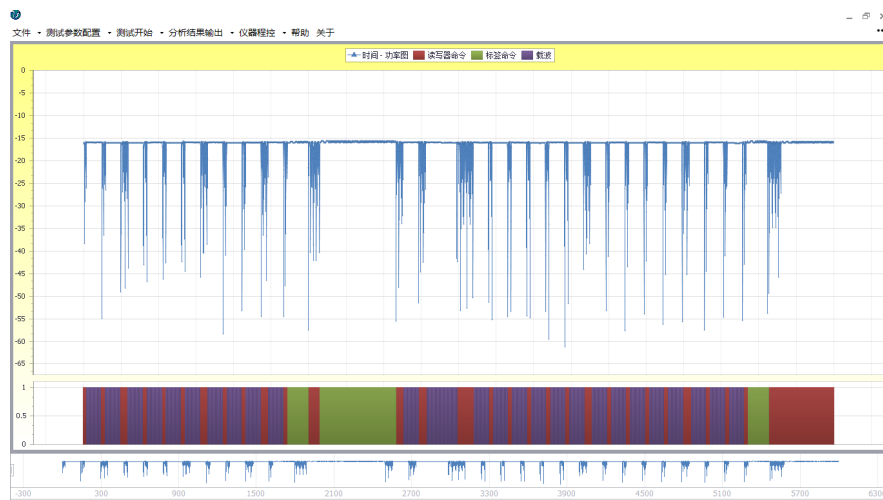
- 时间概览图任意选取想要分析的时间段
  - 各域光标联动
- 码域，时域，频域各个测量域中的光标以时间为参考量，实现关联，同步分析

可任意调节的时间分析窗



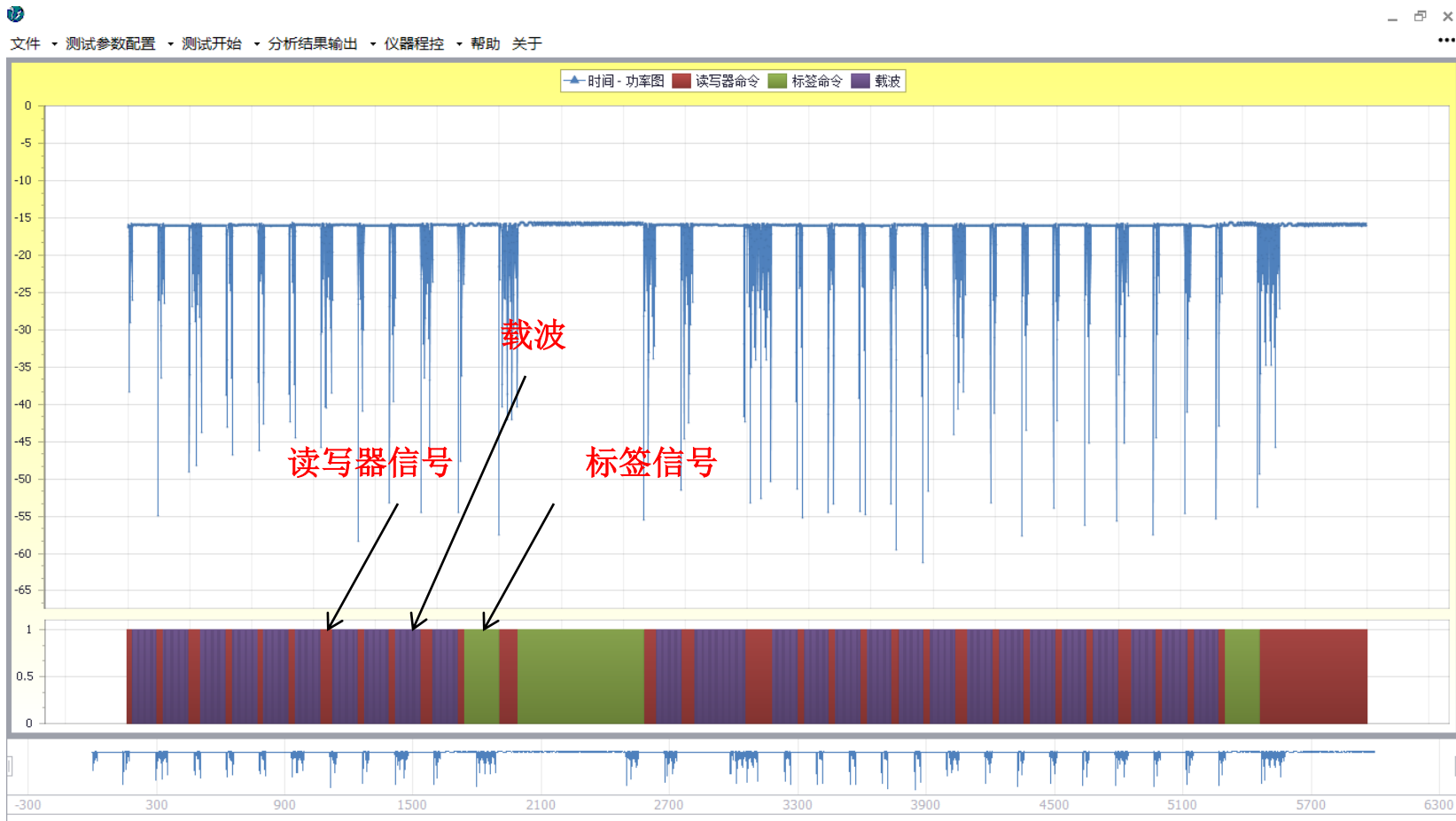
# 系统特点介绍

- 18000-6读写器、标签测试
- 标准符合性和射频一致性
- 协议过程化分析
- 防碰撞测试
- 自动识别编码方式
- 多窗口结果显示
- 过程回放协议联动
- 自动协议解析功能





# 命令时序图-命令状态一目了然



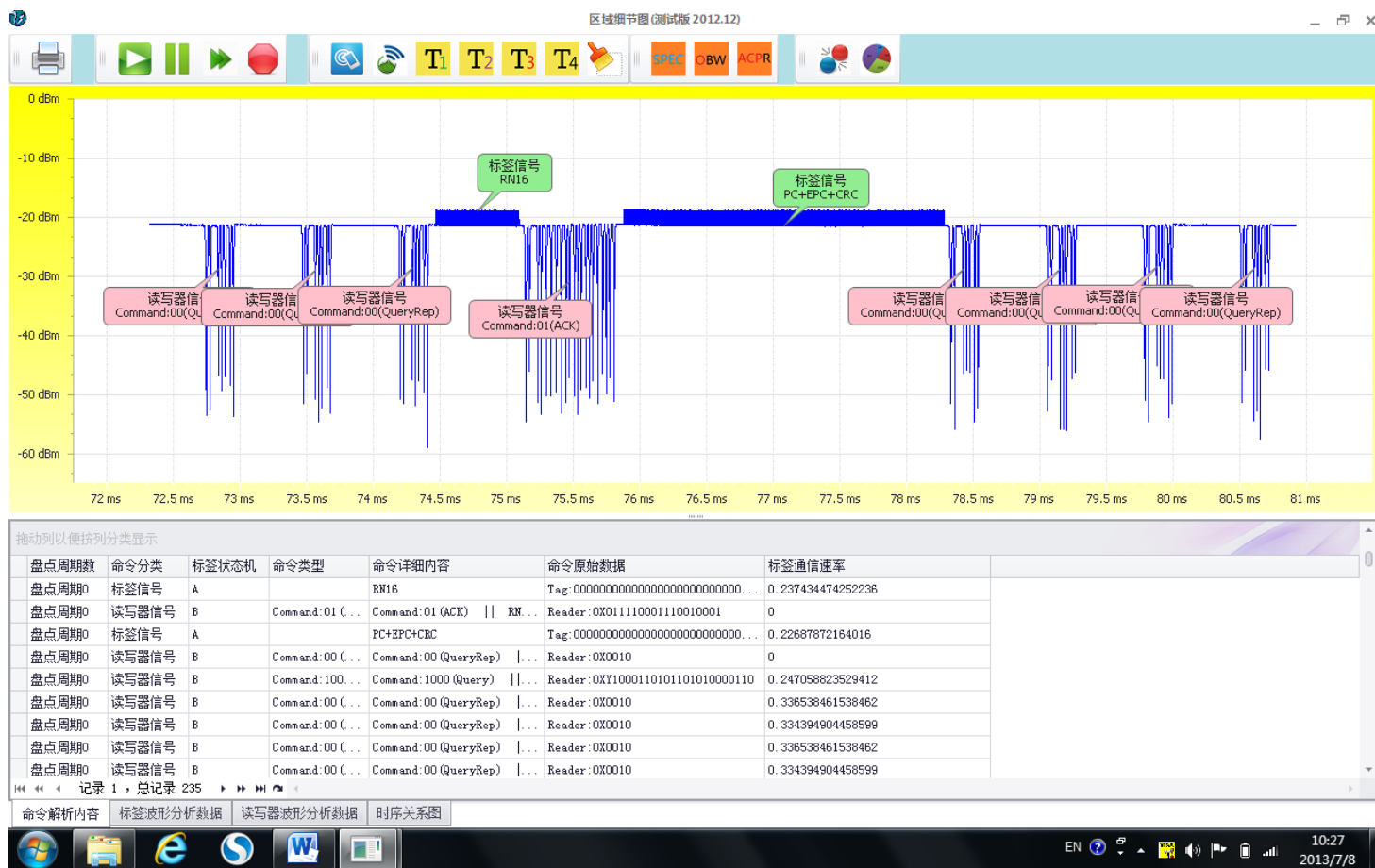
波形细节图

命令时序图

时间概览图, 可变时间窗

# 协议过程化分析

- 读写器命令和协议解析时间联动
- 过程回放
- 命令逐条解析



# 协议一致性测试

- 命令解析
- 标签波形分析数据
- 读写器波形分析数据
- 时序关系分析数据

拖动列以便按列分类显示

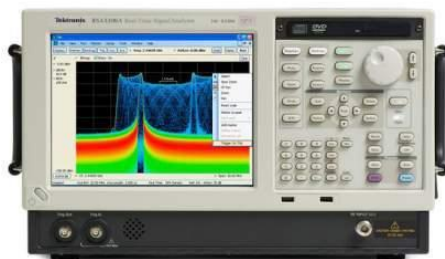
盘点周期数	命令分类	命令类型	T1	T2	T1+T3	T4
盘点周add期0	读写器信号	QueryRep	--	--	522.200000000004	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周期0	标签信号	RN16	66.2000000000044	--	--	--
盘点周期0	标签信号	PC+EPC+CRC	70.8000000000029	--	--	--
盘点周add期0	读写器信号	QueryRep	--	--	522.599999999999	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.399999999994	--
盘点周add期0	读写器信号	QueryRep	--	--	522.399999999994	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.399999999994	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.399999999994	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.399999999994	--
盘点周add期0	读写器信号	QueryRep	--	--	522.400000000001	--
盘点周add期0	读写器信号	QueryRep	--	--	522.599999999999	--

记录 3, 总记录 211

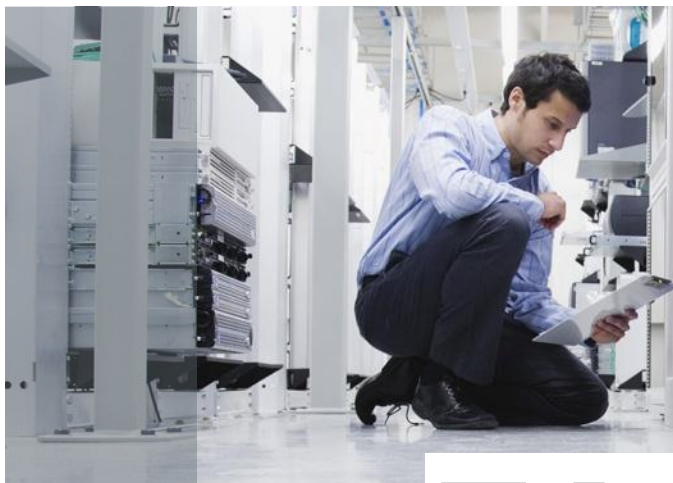
命令解析内容 标签波形分析数据 读写器波形分析数据 时序关系图

# 总结

- 看的更真——DPX, Zero Span DPX, 频率对时间, 相位对时间DPX
- 抓的更准——密度触发, 频率沿触发 矮脉冲触发, 频率模板触发
- 存的更多——内存扩展到4G, 可以一次存贮7.2秒 (85M BW)
- 价钱更低——中端频谱仪、矢量信号分析仪的价格, 高端的性能(85M BW, 高性能的指标, 可以取代传统频谱仪和矢量信号分析仪)
- 适用于
  - 嵌入式RF
  - 频谱管理
  - 无线电通信设计
  - 雷达
  - 短距离无线通信 (RFID, ZIGBEE, WLAN BLUETOOTH)
  - WIMAX



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