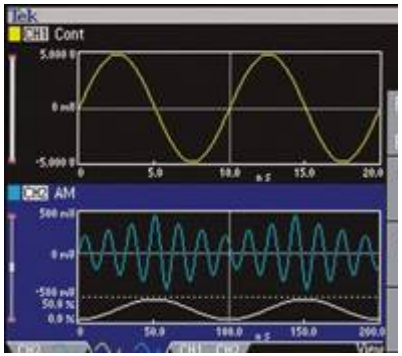
熟练 USB 物理层 验证

- Tektronix USB

测试方法介绍


泰克创新论坛

2009年4月

Tektronix
Innovation Forum

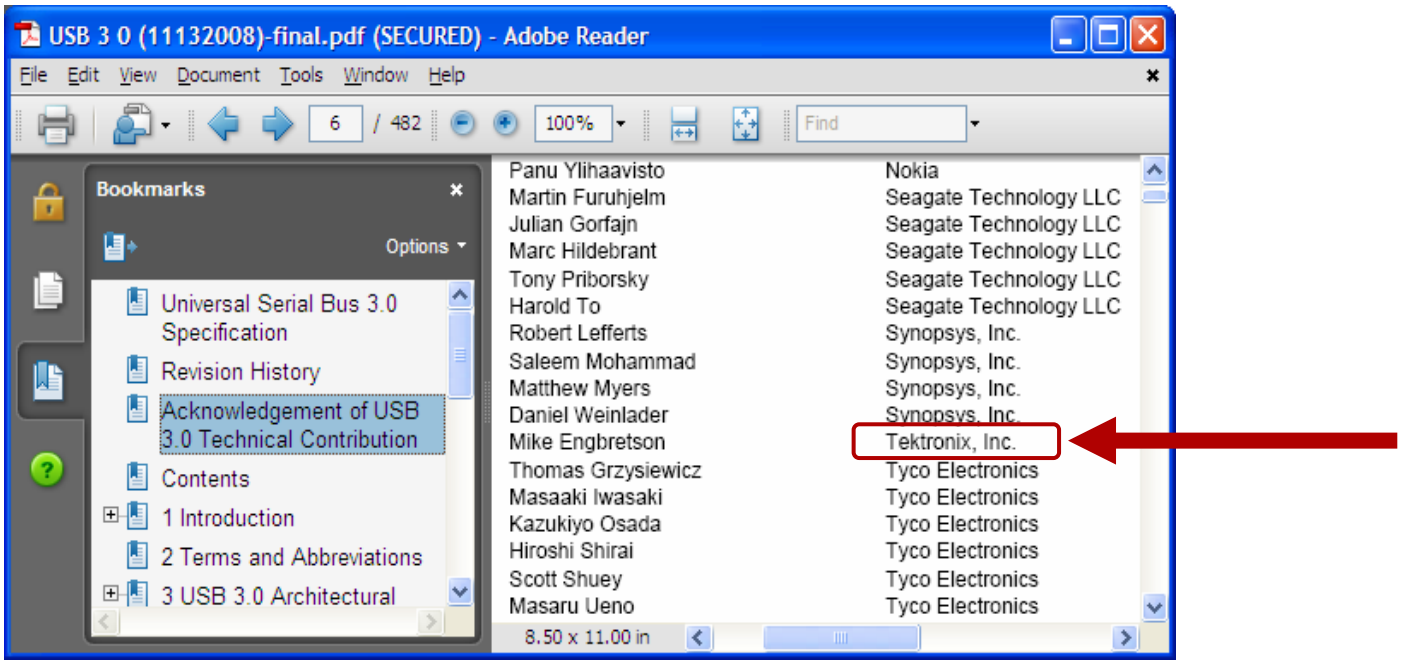
日程

- 简介
- USB 3.0 SuperSpeed
  - USB 3.0出现的愿因?
  - 时间表
  - 线缆
  - 发射端
  - 接收端
  - 协议分析
- USB 2.0
  - 简介
  - 一致性测试
- Wireless USB
  - 概览
  - 一致性验证和调试

Disclaimer: The material and content that describes specific details of the USB 3.0 specification (and SuperSpeed logo) belong to the USB 3.0 Promoters. Tektronix is not speaking or presenting on behalf of the USB 3.0 Promoters.

USB 行业领导地位

- Tektronix 是第一家推出 USB 2.0测试方案的公司
- 唯一对Wimedia USB物理层测试提供 测试步骤方法 (MOI)
- 数百万被Tektronix测试方案认证过的USB设备
- Tektronix 是唯一参与 USB 3.0 规范制定的测试测量仪器公司!



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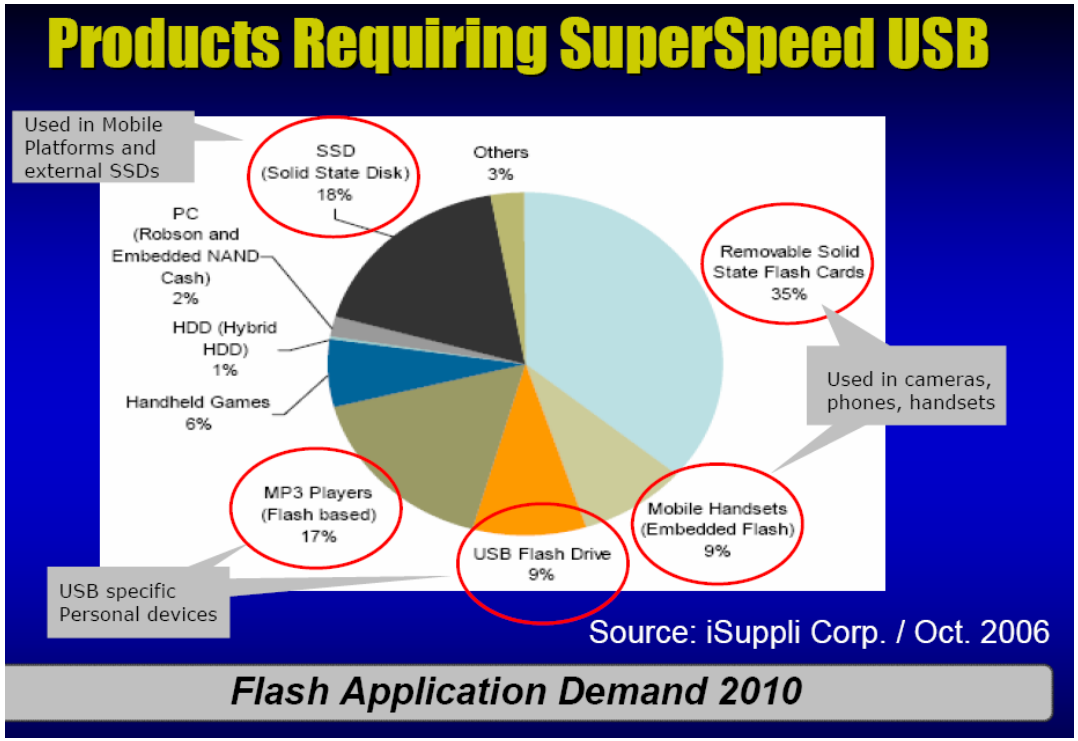
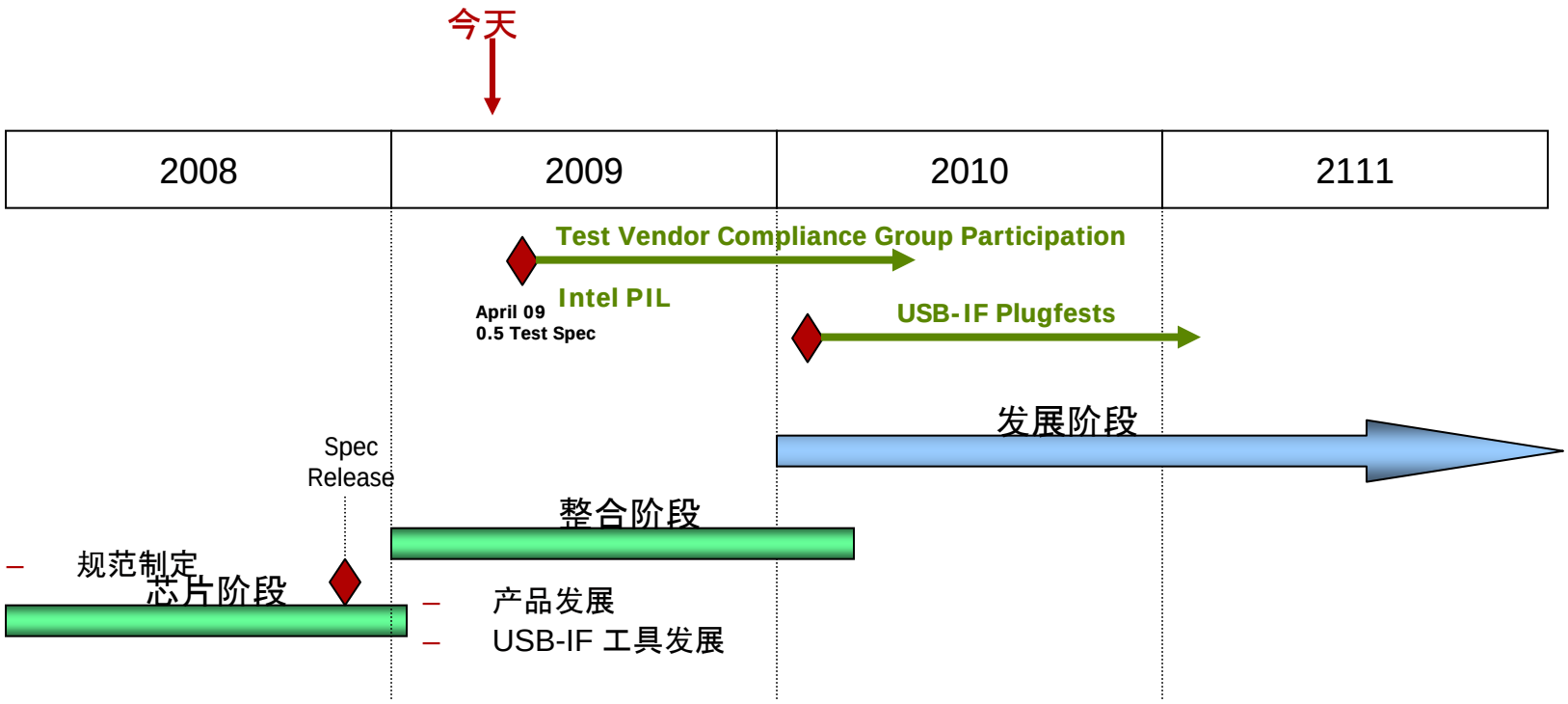
SuperSpeed USB出现的原因?

- USB 2.0 对于大多数产品来说是适合的…
- 新出现的应用将会受益于高性能.
- 大量的数字多媒体文件传输需要更快的性能



Source: USB-IF

USB 3.0 时间表 & Tektronix 参与状况



Tektronix 测试方案 更新

- Chapter 5 – 线缆
- **Chapter 6 – 发射端、接收端、信道**
- Chapter 7 – 协议 (合作伙伴方案)

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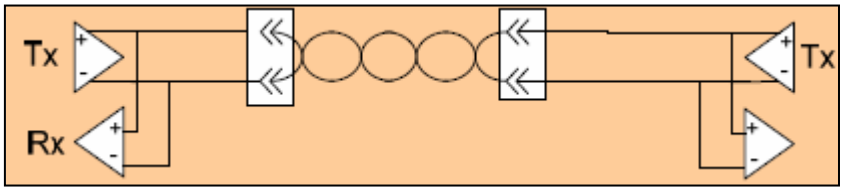
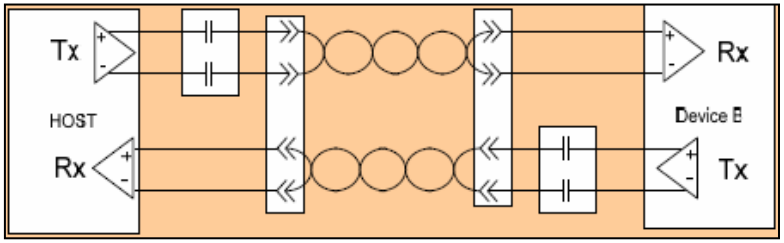
和High Speed USB电气层的不同

- High-Speed
  - 480MT/s
  - 没有SSC
  - 2 个走线做信号传输
    - 发射和接收用同一个走线
    - 1 双向链接
  - DC 耦合总线
  - NRZ 编码

- SuperSpeed
  - 5.0GT/s (10X 速度递增)
  - 有SSC
  - 4 个走线做信号传输
    - 2个发射2个接收
    - 单向链接
  - AC 耦合总线
  - 8b/10b 编码

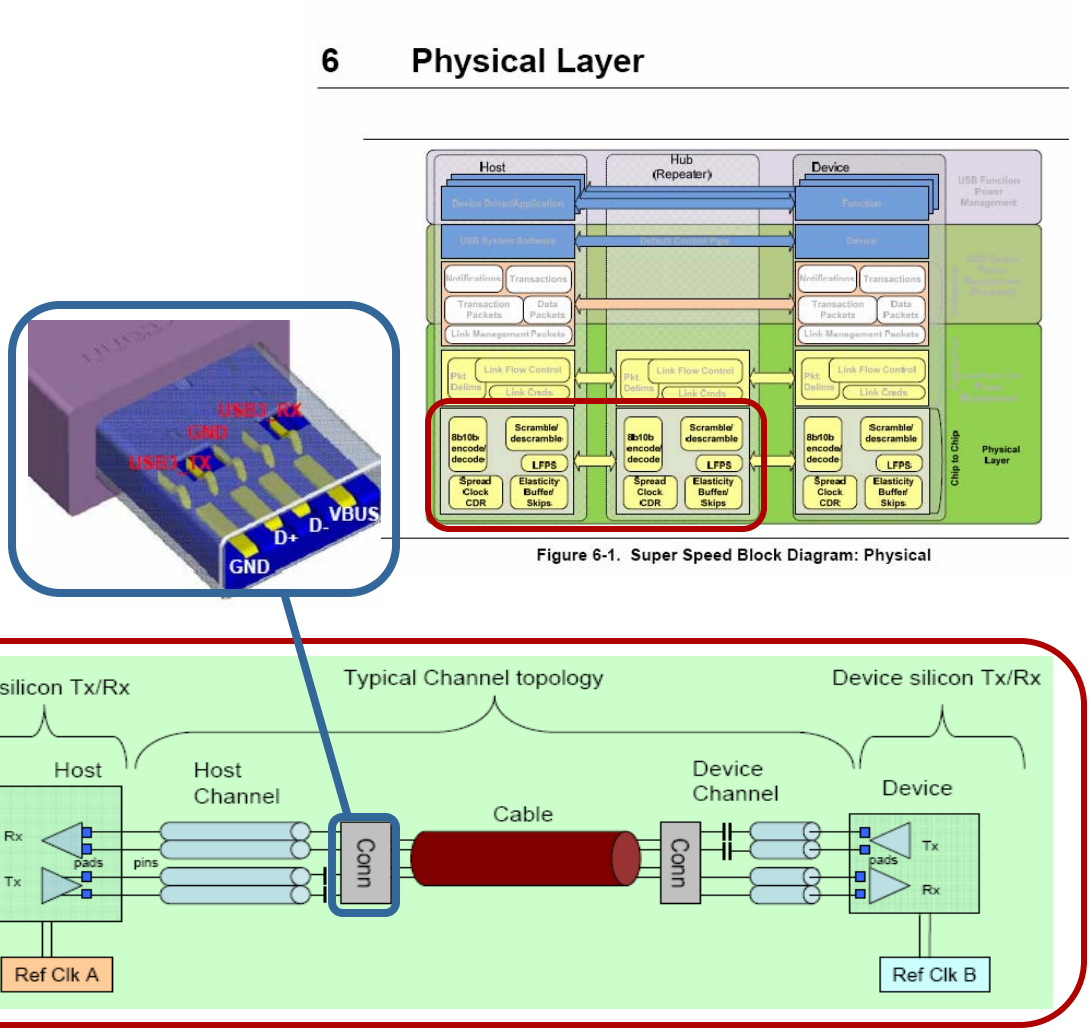




Source: USB-IF

USB 3.0 关键考虑事项

- 需要接收端段测试
  - 抖动容限
  - SSC, 异步参考时钟 会导致协调性问题
- 信道关键考虑事项
  - 需要考虑传输线缆影响
  - 早起设计需要对信道做软件仿真
- 一些新挑战
  - 12英寸长走线
  - 接收端眼图闭合
  - 均衡
    - 发射端去加重
    - 接收端连续时间线性均衡器(CTLE)
- 测试策略
  - 高性价比的工具
  - 灵活的方案



Source: USB 3.0 Rev 1.0 Specification

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标准发射端测试

- 在 TP1点测量
- 需要硬件参考线缆和测试通道
- …或者在 TP1’ 有发射路径通道仿真

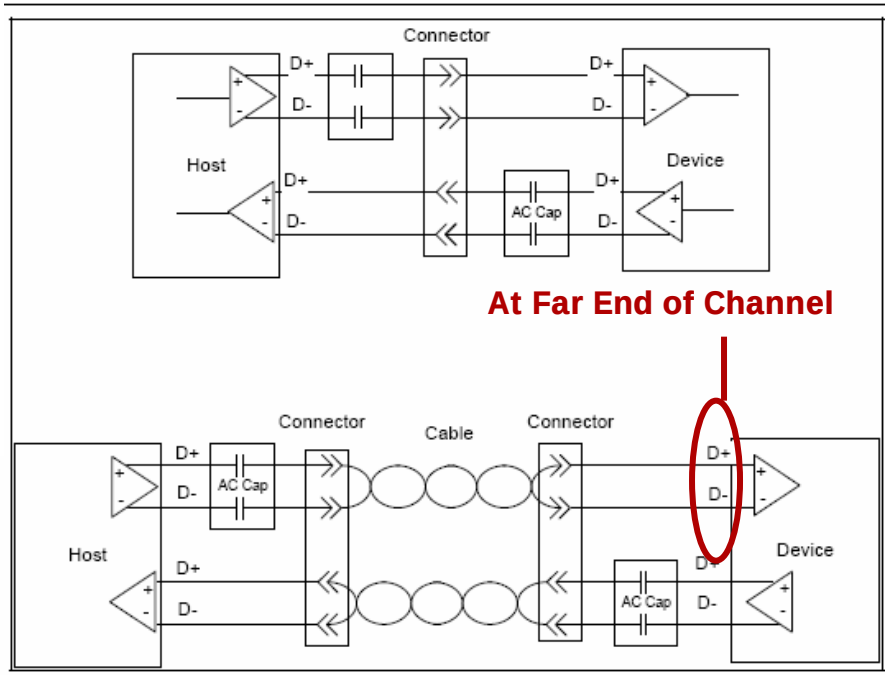


Figure 6-4. Channel Models without Cable (Top) and with Cable (Bottom)

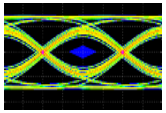
6.7.2 Transmitter Eye

The eye mask is measured using the compliance data pattern CD1 described in Section 6.4.4. Eye Height is measured from 10^{6} UI. Jitter is extrapolated from 10^{6} UI to 10^{-12}.

Table 6-12. Normative Transmitter Eye Mask

Signal Characteristic	Minimal	Nominal	Maximum	Units	Note
Eye Height	100		1200	mV	2
Dj			93	ps	1,2,3
Rj			60	ps	1,2,3
Tj			132	ps	1,2,3

Notes:
1. Measured over 10^{6} UI and extrapolated to 10^{-12} BER
2. Measured after receiver equalization function
3. Measured at end of reference channel and cables at TP1 figure 6-14



CTLE

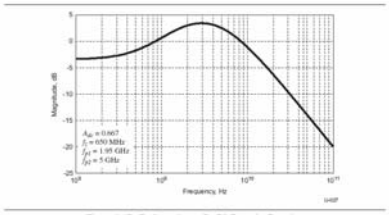


Figure 6-17. Tx Compliance Rx EQ Transfer Function

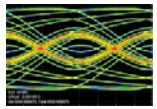


Figure 6-14. Tx Normative Setup with Reference Channel

发射端测量的一些有用信息

- 发射端测量需要通道反嵌

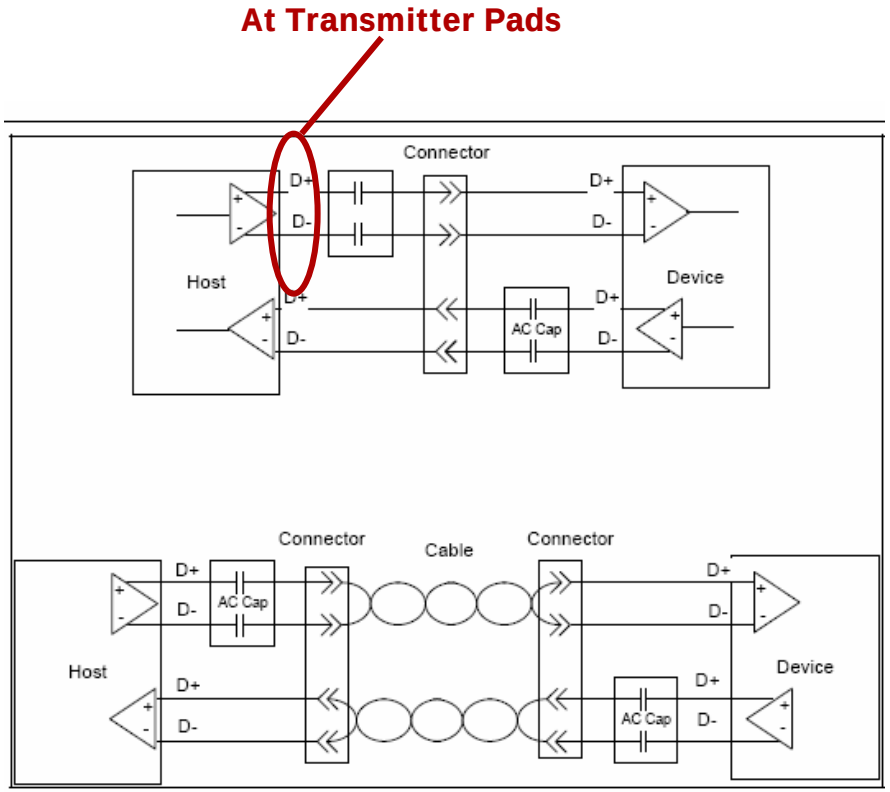


Figure 6-4. Channel Models without Cable (Top) and with Cable (Bottom)

Table 6-10. Transmitter Normative Electrical Parameters

Symbol	Parameter	5.0 GT/s	Units	Comments
UI	Unit Interval	199.94 (min) 200.06 (max)	ps	The specified UI is equivalent to a tolerance of ±300 ppm for each device. Period does not account for SSC induced variations.
$V_{TX-DIFF-PP}$	Differential p-p Tx voltage swing	0.8 (min) 1.2 (max)	V	Nominal is 1 V p-p
$V_{TX-DE-RATIO}$	Tx de-emphasis	3.0 (min) 4.0 (max)	dB	Nominal is 3.5 dB
$R_{TX-DIFF-DC}$	DC differential impedance	72 (min) 120 (max)	Ω	
$V_{TX-RCV-DETECT}$	The amount of voltage change allowed during Receiver Detection	0.6 (max)	V	Detect voltage transition should be an increase in voltage on the pin looking at the detect signal to avoid a high impedance requirement when an "off" receiver's input goes below ground. See Section 1.2.5.6 and Note 9 for details
$C_{AC-COUPLING}$	AC Coupling Capacitor	75 (min) 200 (max)	nF	All Transmitters shall be AC coupled. The AC coupling is required either within the media or within the transmitting component itself.
$T_{CDR\_SLEW\_MAX}$	Max slew rate	10	ms/sec	See the jitter white paper for details on this measurement.

Table 6-11. Transmitter Informative Electrical Parameters at Silicon Pads

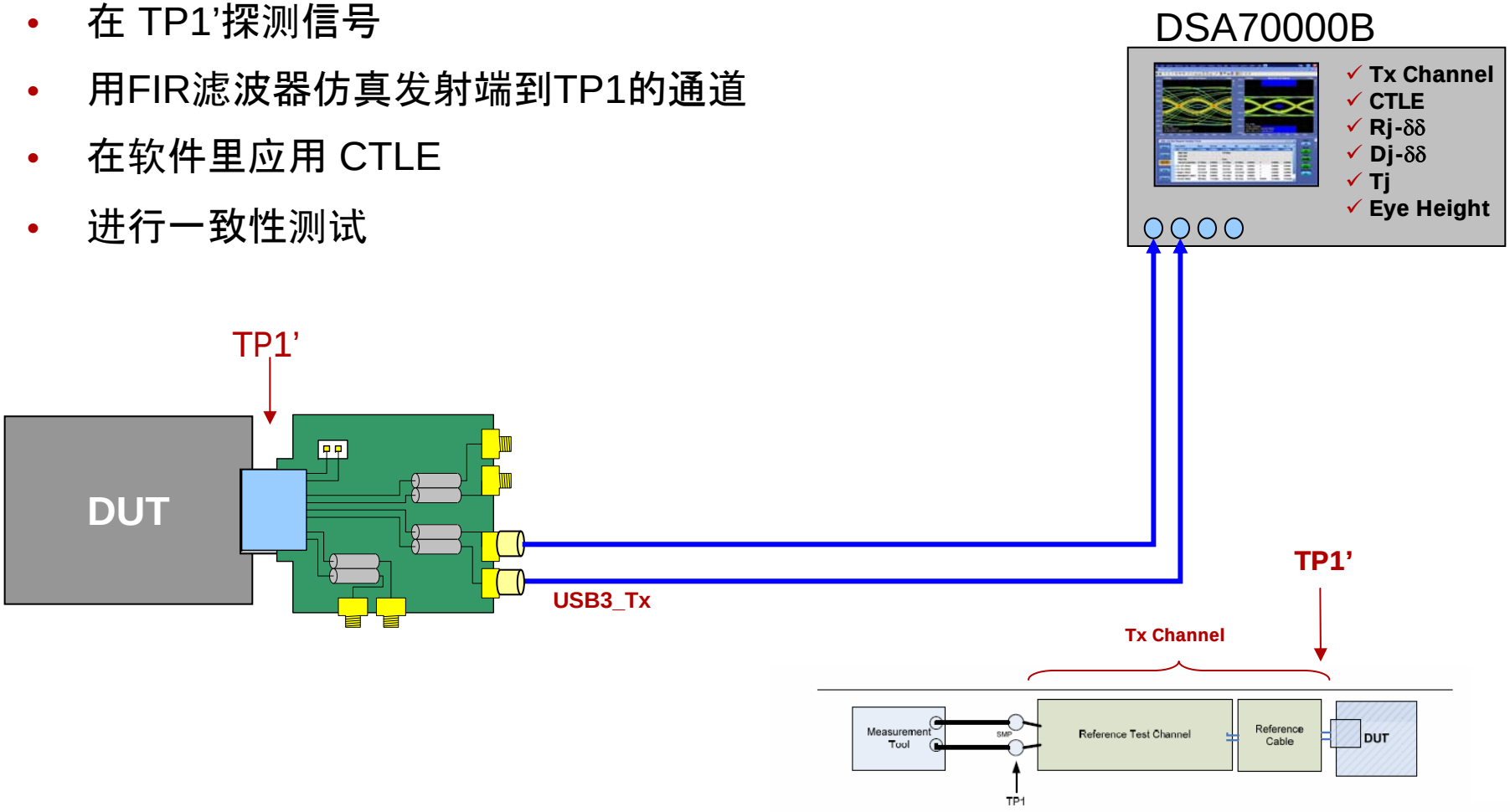
Symbol	Parameter	5.0 GT/s	Units	Normative	Comments
$T_{MIN-PULSE-DJ}$	Deterministic min pulse	0.96	UI		Tx pulse width variation that is deterministic.
$T_{MIN-PULSE-TJ}$	Tx min pulse	0.90	UI		Min Tx pulse at 10^{-12} including Dj and Rj.
T_{TX-EYE}	Transmitter Eye	0.625 (min)	UI		Includes all jitter sources
$T_{TX—DJ-DD}$	Tx deterministic jitter	0.19 (max)	UI		Deterministic jitter only assuming the Dual Dirac distribution
$C_{TX-PARASITIC}$	Tx input capacitance for return loss	1.25 (max)	pf		Parasitic capacitance to ground

Symbol	Parameter	5.0 GT/s	Units	Normative	Comments
R_{TX-DC}	Transmitter DC common mode impedance	18 (min) 30 (max)	Ω		DC impedance limits to guarantee Receiver detect behavior. Measured with respect to AC ground over a voltage of 0-500mV.
$I_{TX-SHORT}$	Transmitter short-circuit current limit	60 (max)	mA		The total current Transmitter can supply when shorted to ground.
$V_{TX-DC-CM}$	Transmitter DC common-mode voltage	0 (min) 2.2 (max)	V		The instantaneous allowed DC common-mode voltages at the connector side of the AC coupling capacitors.
$V_{TX-CM-AC-PP\_ACTIVE}$	Tx AC common mode voltage active	100 mv	mVPP		Max mismatch from D+ D- for both time and amplitude. While signaling.
$V_{TX-CMADJ-ACTIVE-IDLE-DELTA}$	Absolute Common Mode Voltage between U1 and U0	200 (max)	mV		peak
$V_{TX-IDLE-DIFF-AC-pp}$	Electrical Idle Differential Peak – Peak Output Voltage	0 (min) 10 (max)	mV		
$V_{TX-IDLE-DIFF-DC}$	DC Electrical Idle Differential Output Voltage	0 (min) 10 (max)	mV		Voltage must be low pass filtered to remove any AC component. This limits the common mode error when resuming U1 to U0

Source: USB 3.0 Rev 1.0 Specification

Tektronix 发射端 MOI (测量操作方法)

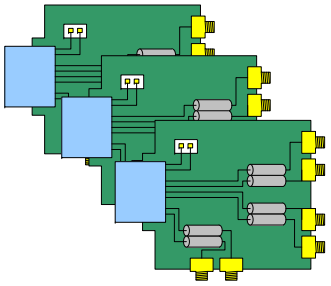
- 测试夹具
  - 探测应该尽量靠近芯片或者链接器
- 在 TP1’探测信号
- 用FIR滤波器仿真发射端到TP1的通道
- 在软件里应用 CTLE
- 进行一致性测试

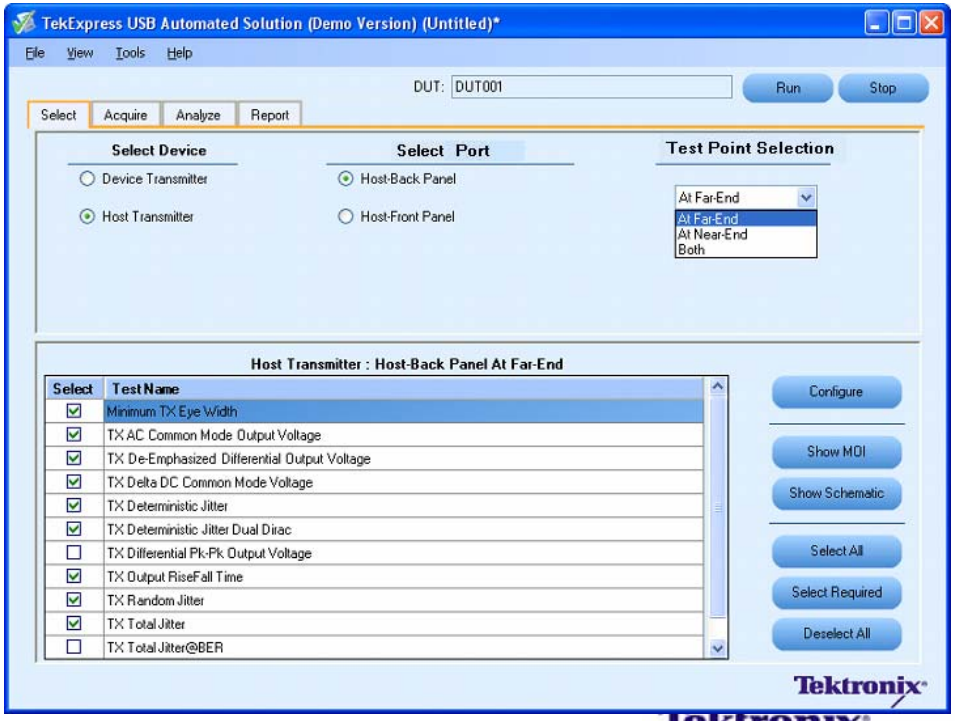


完整的USB 3.0 发射端测试方案

DPO/DSA70000B 系列示波器

- Tektronix Super Speed USB 夹具
- 12.5 GHz 带宽实时示波器 覆盖5次谐波
- 分析软件用来做验证和调试
  - DPOJET 带 USB3选件
- 自动化测试软件用来做特征描述和一致性测试
  - TekExpress 带 USB-TX选件





标准接收端测试

- Receiver processes the BERT 订购的设备 使用 ‘built-in BERT’ 功能
- TP1的损伤
- 需要硬件参考线缆和测试通道
- …或者在 TP1’ 有接收路径通道仿真

6.7.4.1 Loopback BERT

During loopback the receiver processes the BERT ordered sets BRST, BDAT, and BERC. These ordered sets are given in Table 6-14 through Table 6-17. BRST and BDAT are looped back as received. BERC ordered sets are not looped back but are replaced with BCNT ordered sets. Anytime a BRST is received the error count register EC is set to 0 and the scrambling LFSR is set to 0FFFF h. Any number of consecutive BRST ordered sets may be received.

BRST followed by BDAT starts the bit error rate test. BDAT sequence is the output of the scrambler and is equivalent to the logical idle sequence. It consists of scrambled 0 as described in Appendix B. As listed in Appendix B, the first 16 characters of the sequence are reprinted here:

FF	17	C0	14	B2	E7	02	82	72	6E	28	A6	BE	6D	BF	8D

The receiver must compare the received data to the BDAT sequence. Errors increment the error count register (EC) by 1. EC may not rollover but must be held at FFFF h. The LFSR is advanced once for every character except SKPs. The LFSR rolls over after 2^16 symbols. SKPs inserted or deleted as necessary for clock tolerance compensation.

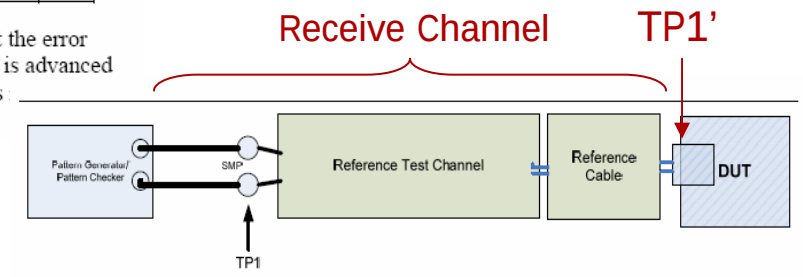


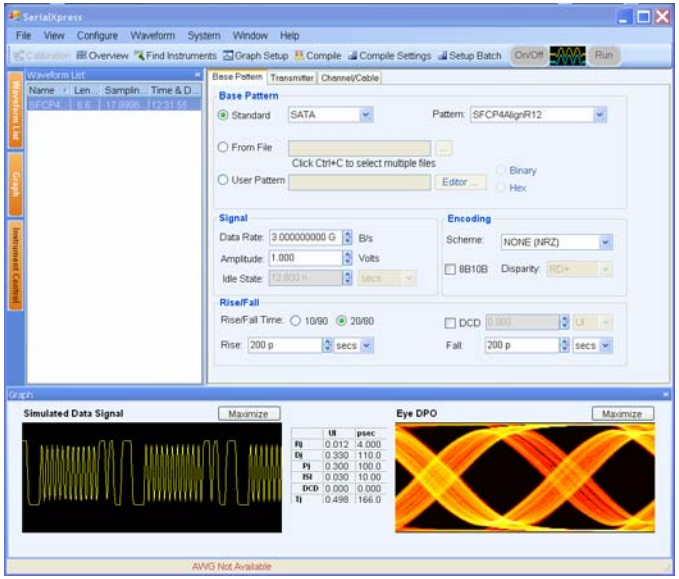
Figure 6-18. Rx Tolerance Setup

Source: USB 3.0 Specification

完整的USB 3.0接收端测试解决方案

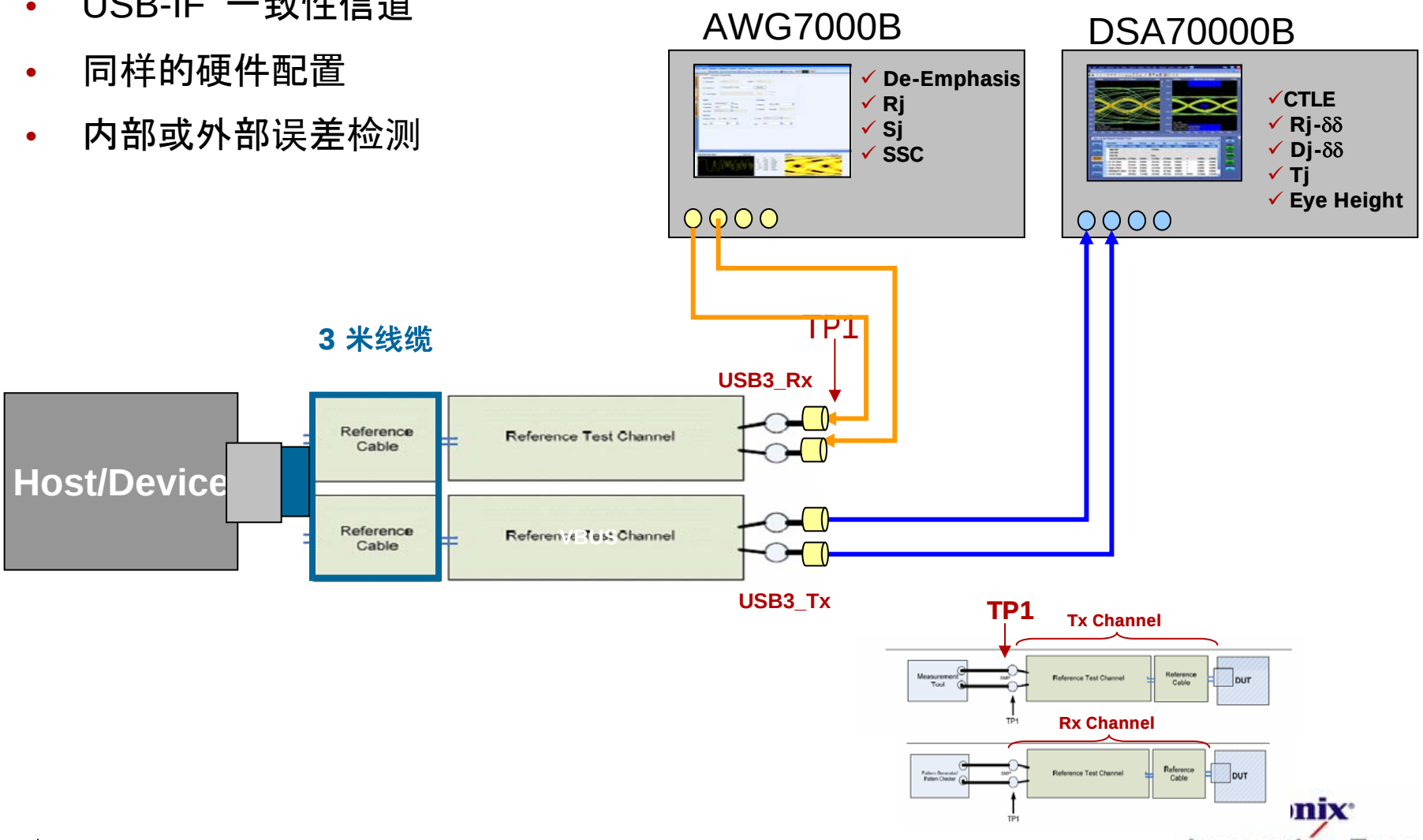
AWG7000 任意波形发生器 with SerialXpress®

- 任意信号间的损伤不需要折衷
- 仿真任意长度的含有ISI抖动的信道
  - 不再需要等待USB一致性仿真通道
- 模拟真实环境的 SSC 状况以 避免系统协调性问题
- 最小化重新连接的时间
- 用一些设置文件来增强接收端测试的可重复性和便携性



Tx/Rx MOI (含硬件信道仿真)

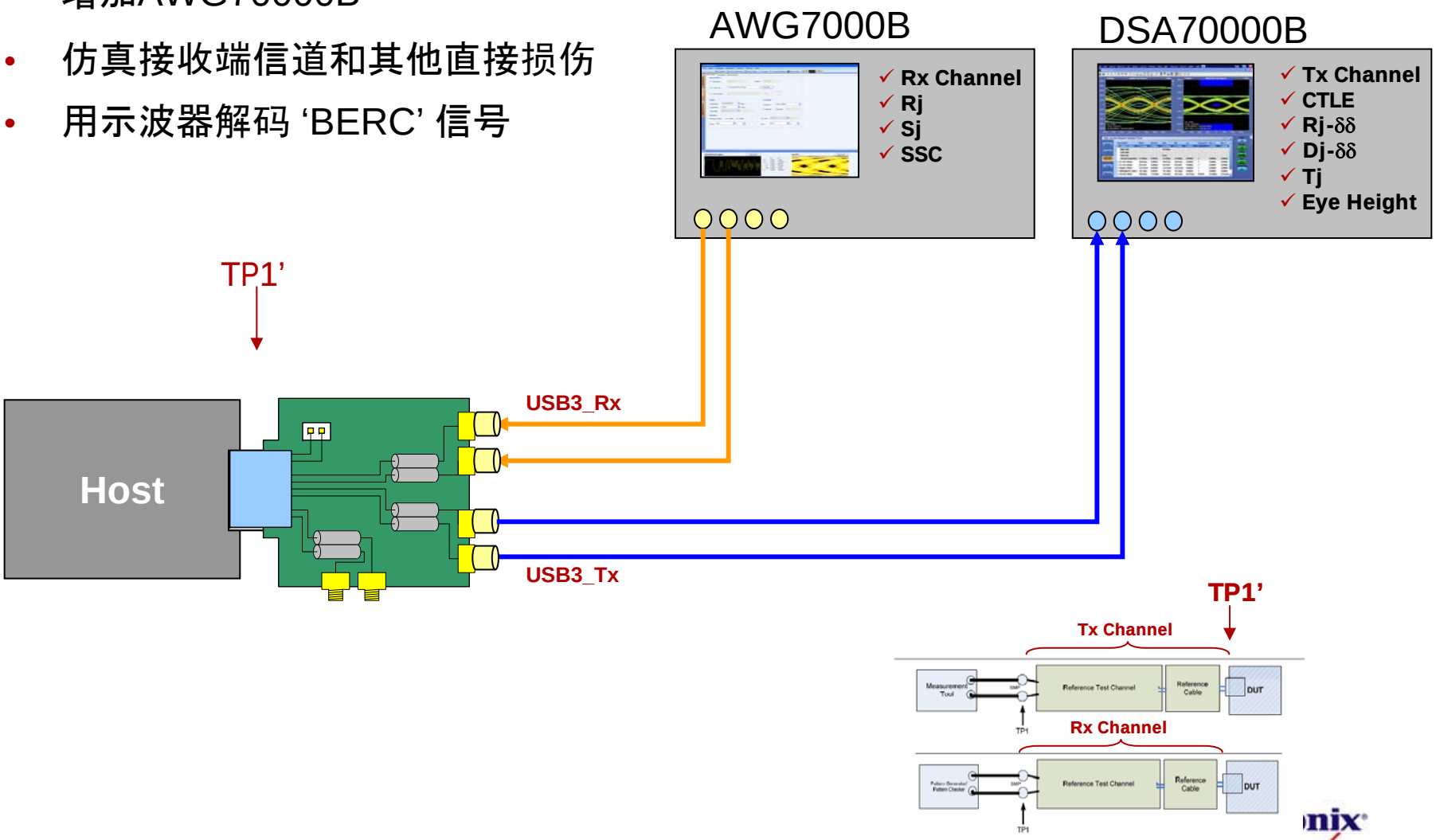
- USB-IF '一致性信道'
- 同样的硬件配置
- 内部或外部误差检测



Tx and Rx MOI (含软件信道仿真)

如果被测设备支持 ‘内部误码’ 计数

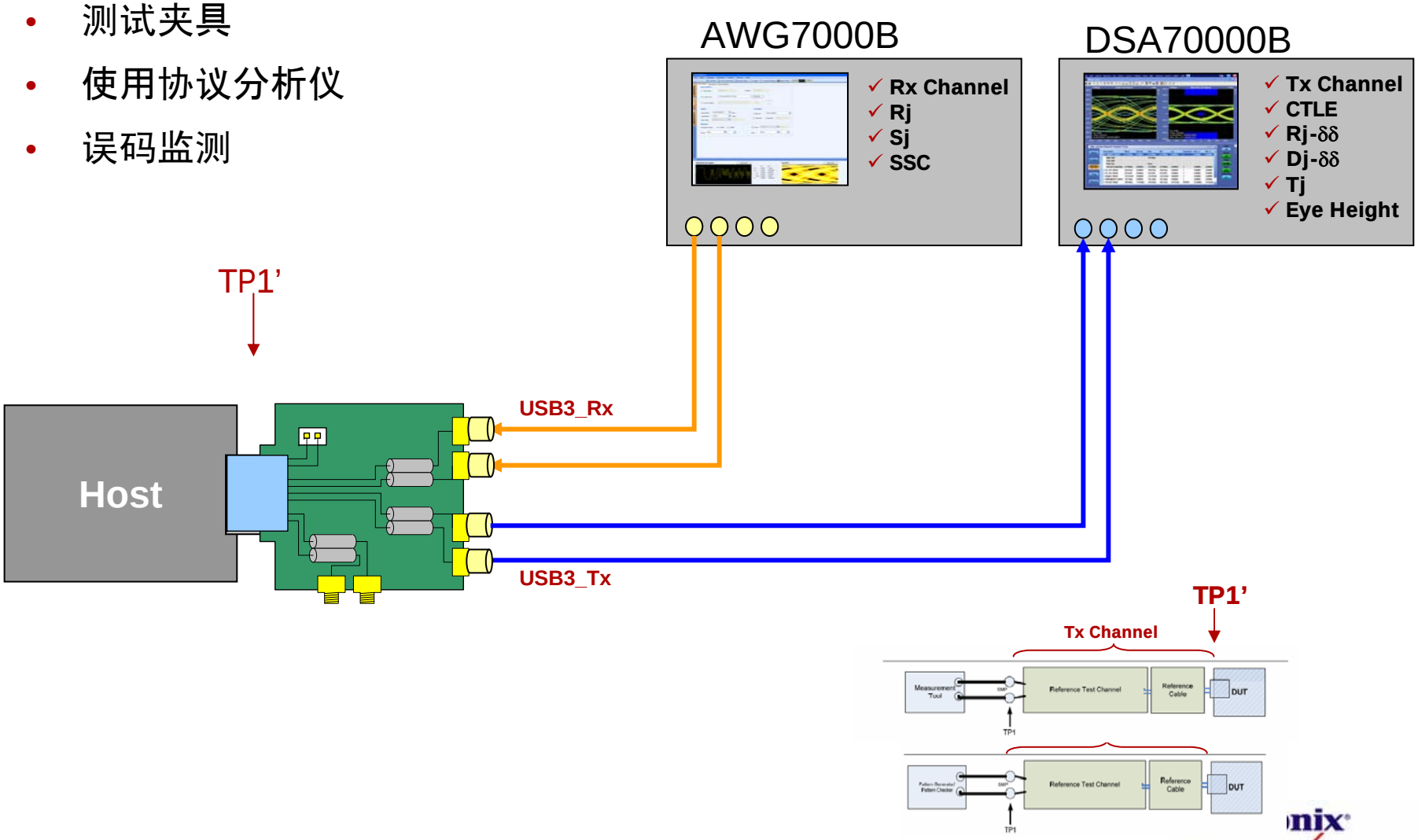
- 增加AWG70000B
- 仿真接收端信道和其他直接损伤
- 用示波器解码 ‘BERC’ 信号



Rx MOI (含软件信道仿真)

如果被测设备只支持外部误码计数

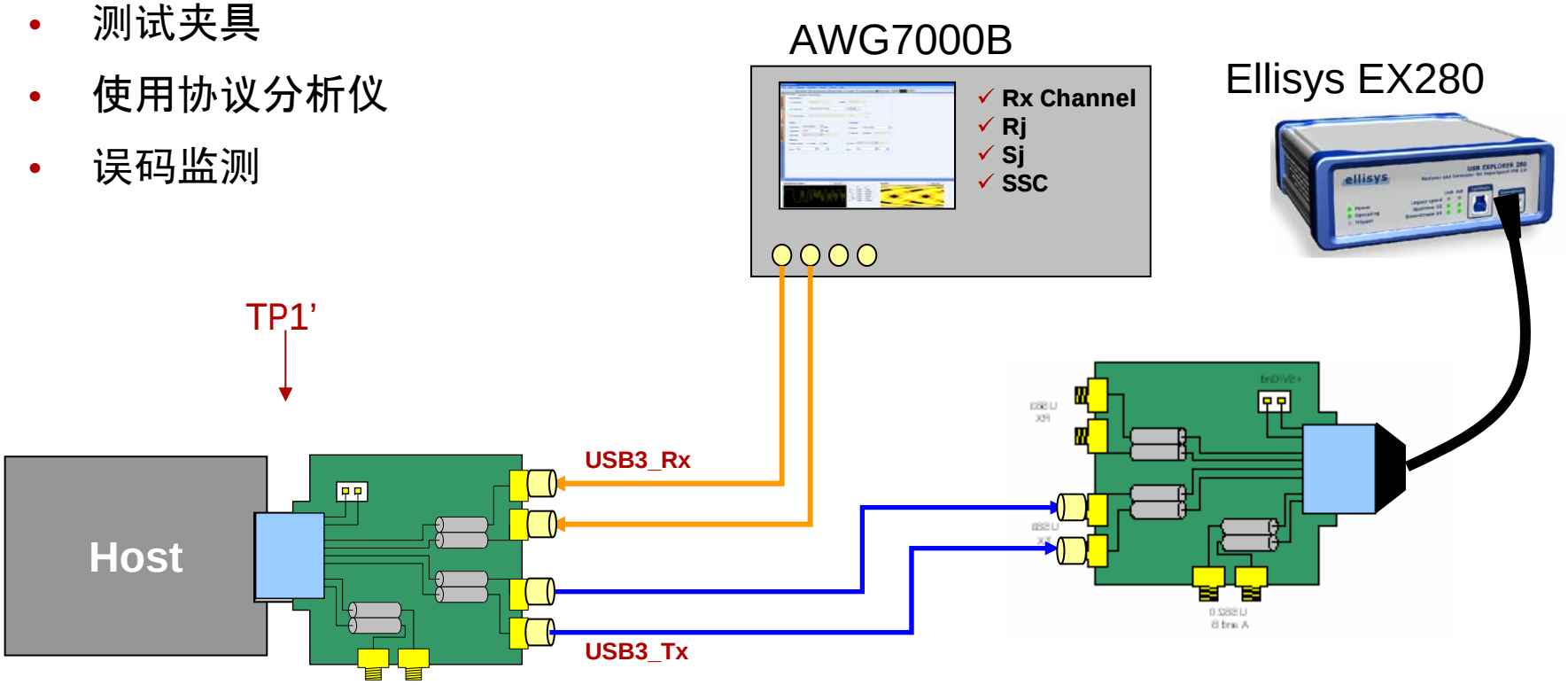
- 测试夹具
- 使用协议分析仪
- 误码监测

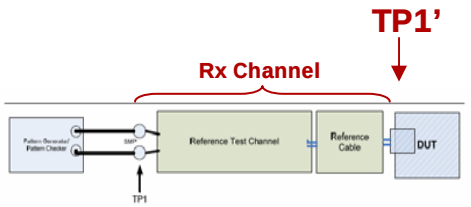


Rx MOI (含软件信道仿真)

如果被测设备只支持外部误码计数

- 测试夹具
- 使用协议分析仪
- 误码监测

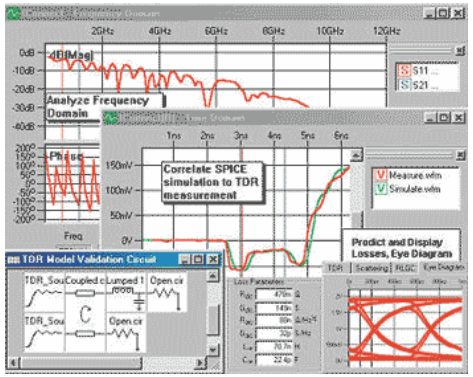




线缆测试

DSA8200 采样示波器含 IConnect® 软件

- 测试夹具
  - A 型插口
  - B 型插口
  - USB2/USB3 做串扰测量的连接器
- 使用采样示波器 & S参数计算软件
- 测量项目:
  - 阻抗
  - Intra-Pair Skew
  - 差分插入损耗
  - 差分回波损耗
  - 差分近端串扰
  - USB3.0 和 USB2.0 间的差分串扰
  - 差模到共模转换



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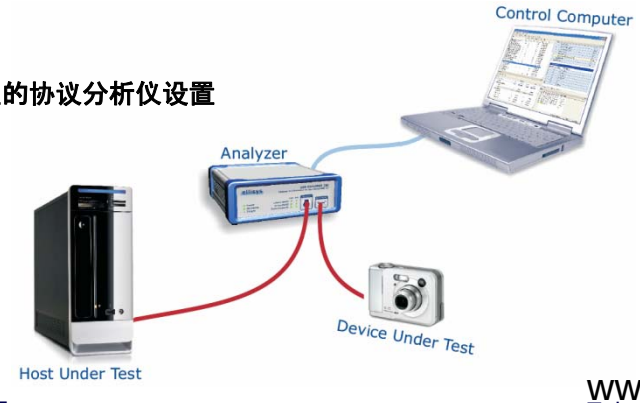
Ellisys EX280 探测器- USB 3.0 分析仪

- 分析仪应用方案
  - USB host & device 监测
  - 性能分析
  - 调试驱动软件
  - 链接状态分析
  - 协议错误检查
- 发生器应用方案
  - USB host & device 仿真
  - 测试错误校正方法
  - 性能负荷试验
  - 一致性验证
  - 链接状态分析

典型的协议分析仪设置

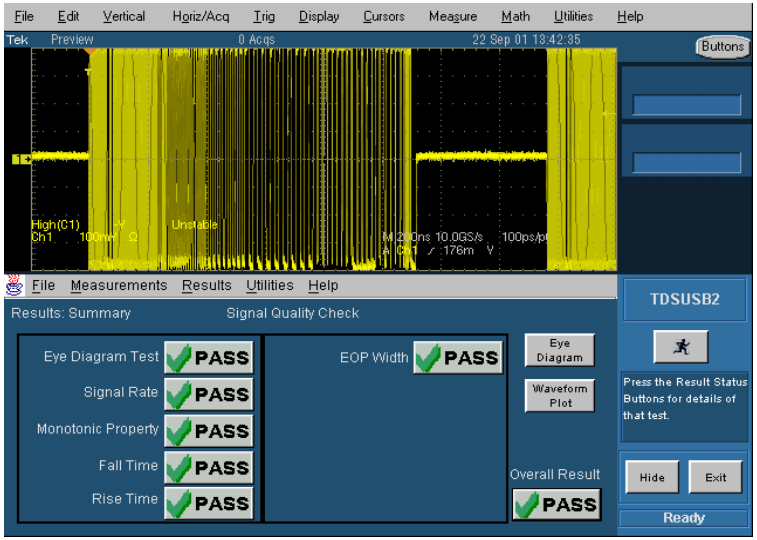


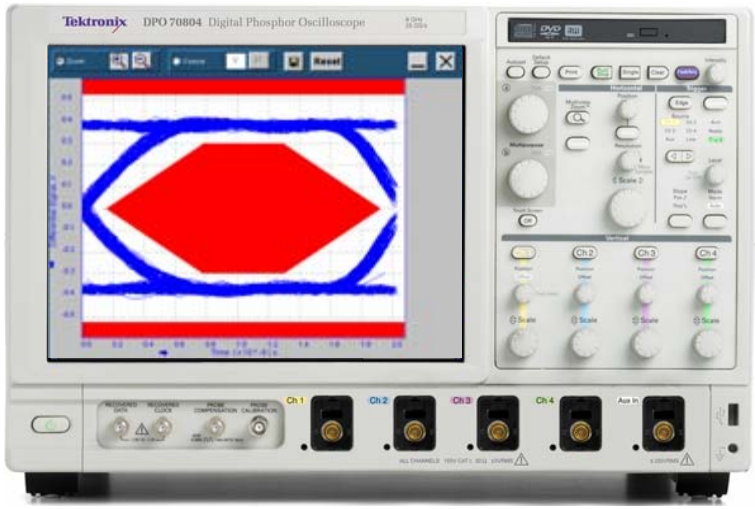
典型的用协议分析仪仿真主机设置

USB 2.0 一致性测试

信号质量

- 眼图
- 信号速率
- 包尾宽度
- 交叉电压范围（用于低速和全速）
- JK 抖动
- KJ 抖动
- 连续抖动
- 单调性测试（用于高速）
- 上升时间和下降时间





时域测量

- Packet Parameters
- Suspend
- Resume
- Reset from High-Speed
- Reset from Suspend

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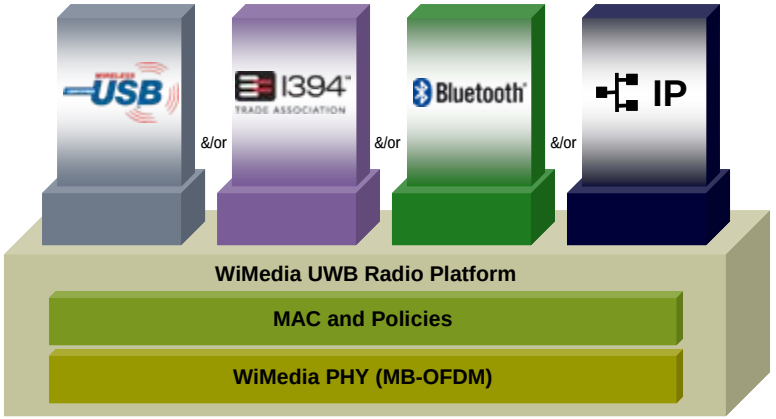
无线 USB

- 无线 USB 应用
  - 传输大量数据的短距离通信
    - 点对点
    - 无线USB主机和外围设备的链接
    - 最高支持127个设备
  - 促使没有执照和现存有执照的射频频谱改变
    - 低功率和调频 信号 最小化干扰
- 挑战
  - 数据吞吐量, 带宽分配
  - 电源管理和安全



PAL: Protocol Adaptation Layer

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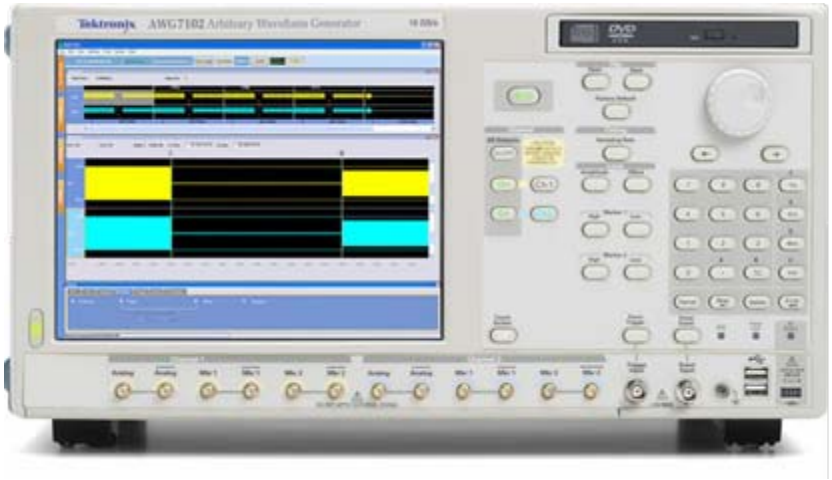
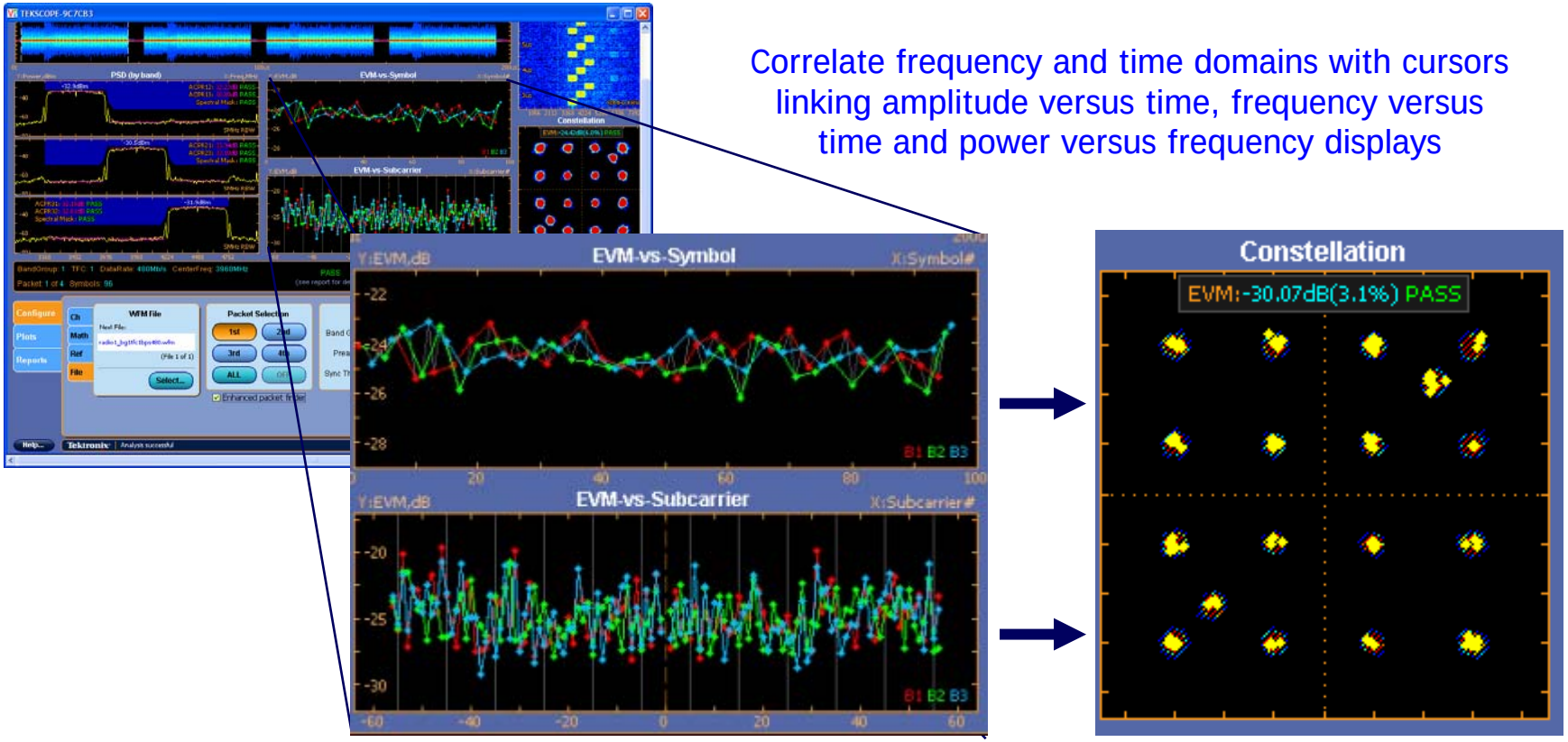
Tektronix 无线USB 调试验证方案

- 设置简单: 从射频波形包头开始自动检测时间频率编码方式 (TFCs) 和数据速率
- 解调, 分析 和记录 每个包的测量结果
- 根据无线USB EVM测试规范画出测量结果
- 只针对工业的 MOI (测试步骤方法) 对于 WiMedia 测试!
  - 无线USB EVM 测试是 WiMedia 物理层测试验证的一部分



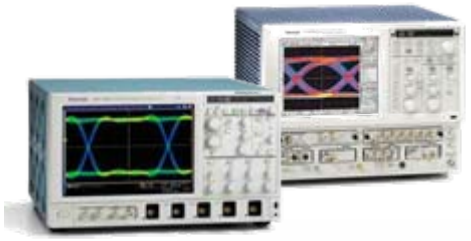
强大的调试分析能力
分析 EVM 时间和频率的错误

- EVM 对 码符：在时域调试码符
- EVM 对 子载频: 在频域调试EVM误差



Tektronix USB 测试方案

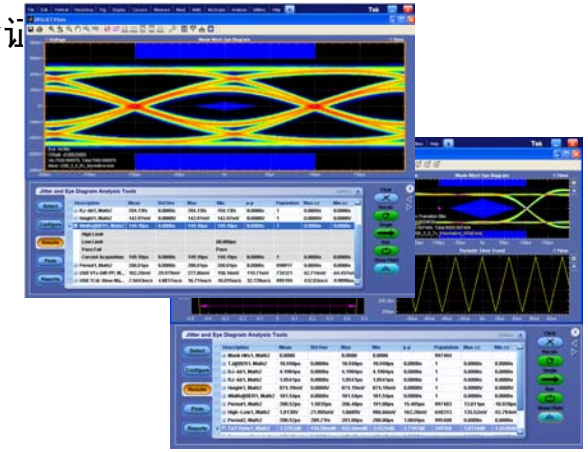
从物理层到协议层完整的测试方案 对USB 2.0, 3.0 and 无线 USB



USB领导地位: Tektronix 积极的参与 USB-IF 一致性组织 并且参与制定 USB 3.0 对反

节约开支: 在一台仪器实现自动化测量方案

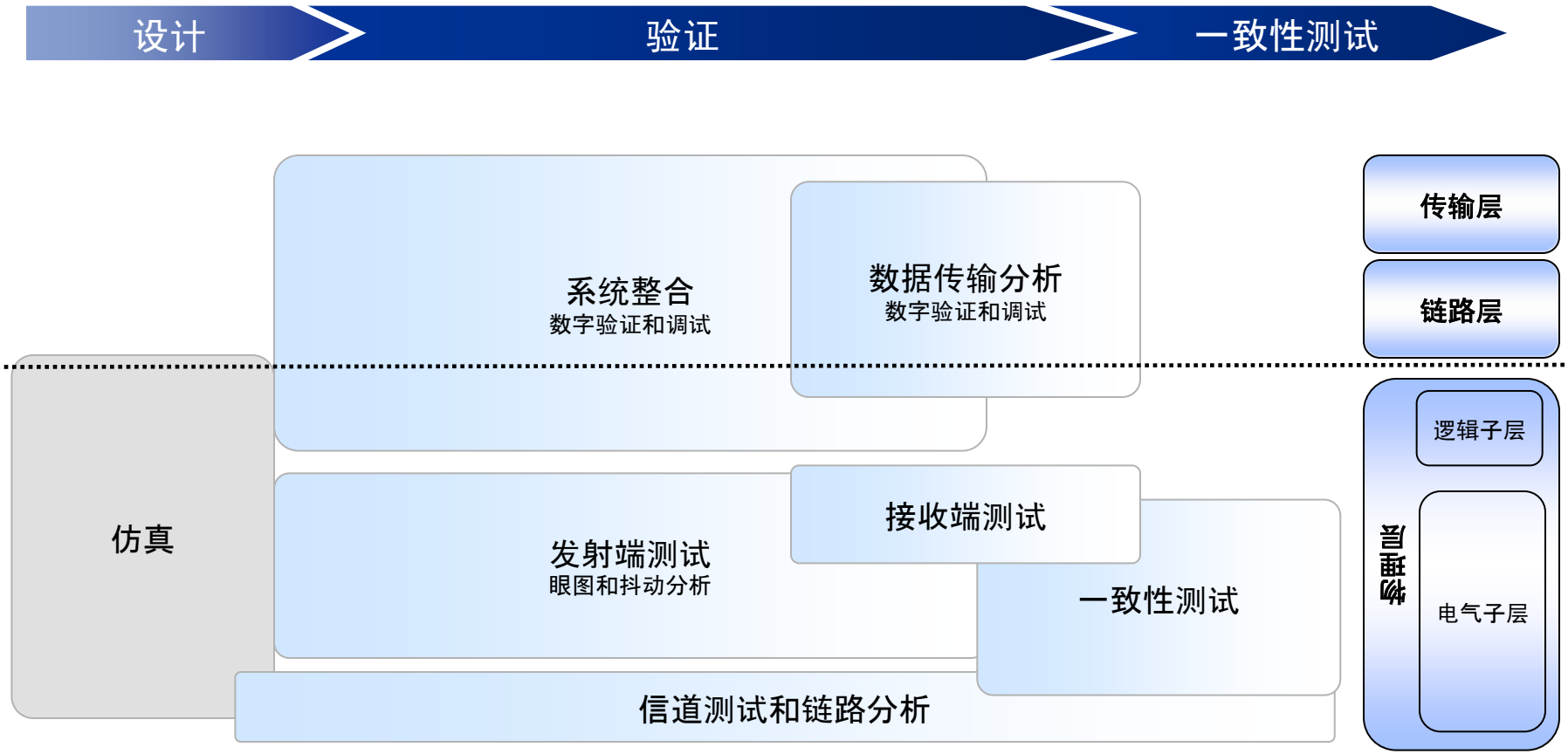
连接简单: 测量连接方法类似于 发射端 对于USB 3.0 设备、主机性能验证

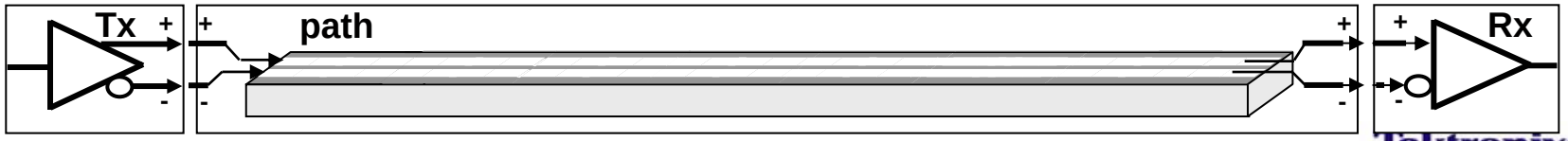


灵活性:用软件信道仿真实现一致性验证, 调试, 描述

Tektronix Innovation Forum

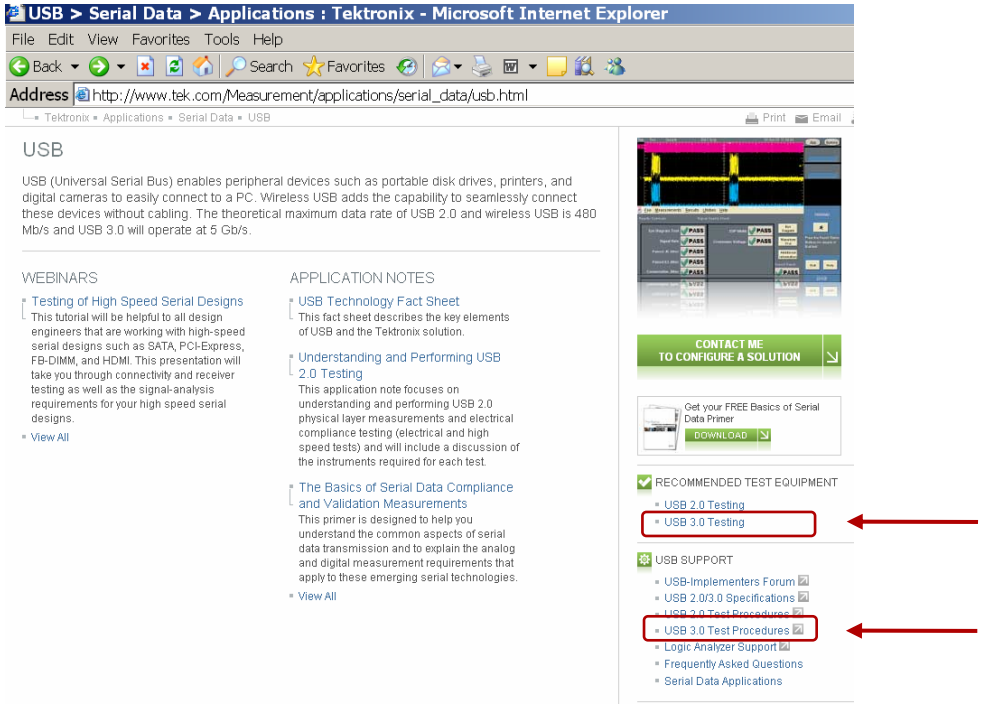
高速串行数据测试挑战


设计
验证
一致性测试
系统整合
数字验证和调试
数据传输分析
数字验证和调试
传输层
链路层
仿真
发射端测试
眼图和抖动分析
接收端测试
一致性测试
信道测试和链路分析
逻辑子层
物理层
电气子层

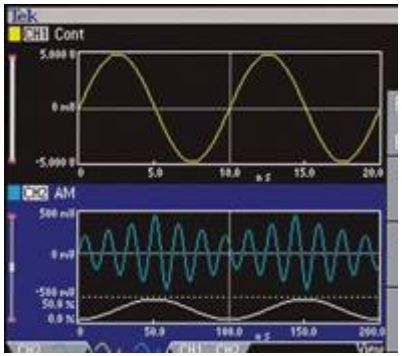

Tx
+
-
+
-
path
+
-
+
-
Rx

资源

- 规范连接
  - Rev 1.0, http://www.usb.org/developers/docs/
- Tektronix USB 电物理层测试工具
  - www.tektronix.com/usb
  - www.tektronix.com/software
- Ellisys 协议分析工具
  - www.ellisys.com



在新数字世界中提供创新动力...



提高性能

通过高速串行技术

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