

# XGbT –10GBASE-T 自动测量方案



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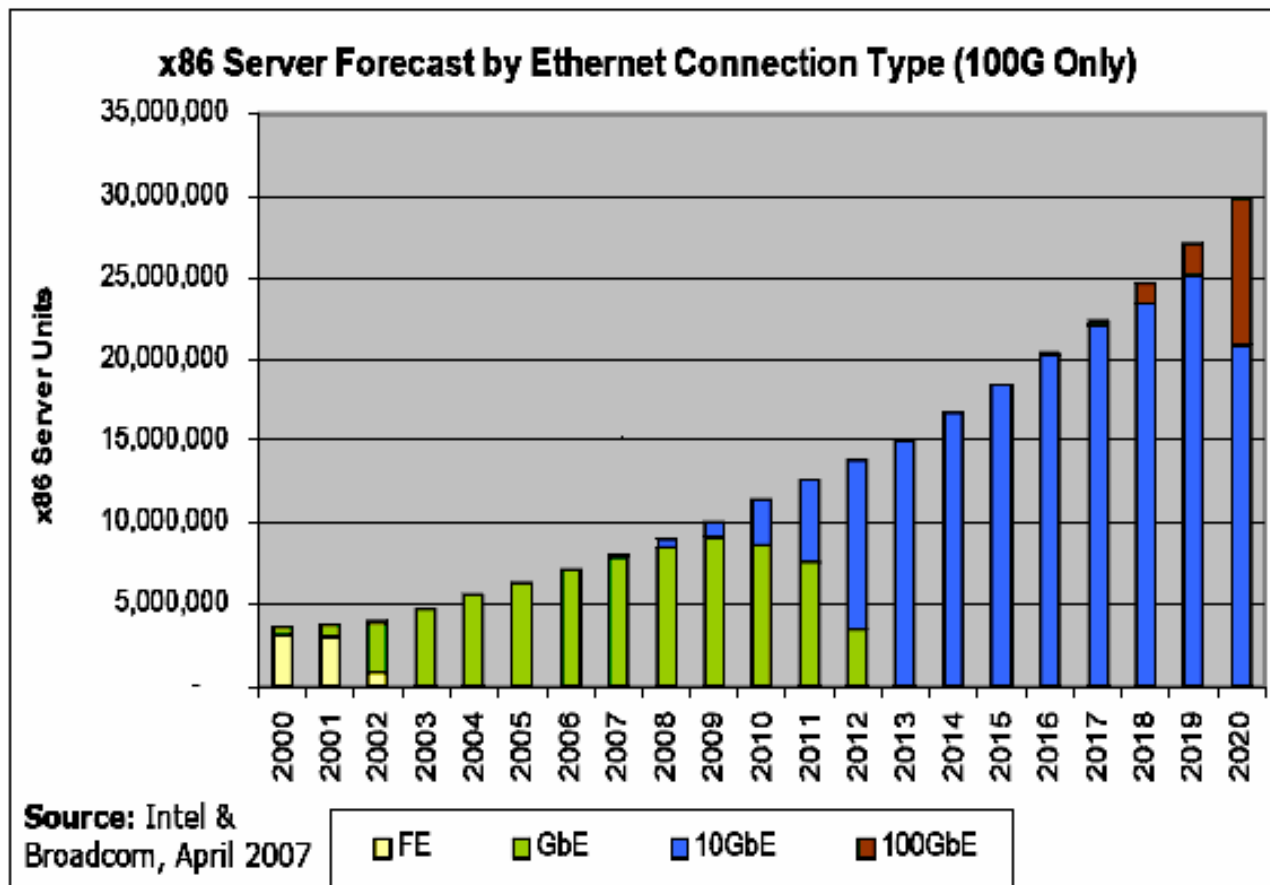
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# 议程

- 10GBASE-T 总揽
- 与1000BASE-T的对比
- XGbT – 10GBASE-T 自动测量方案
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- 相关资源

# 以太网市场趋势图



Base Server Connection:

10 year transition

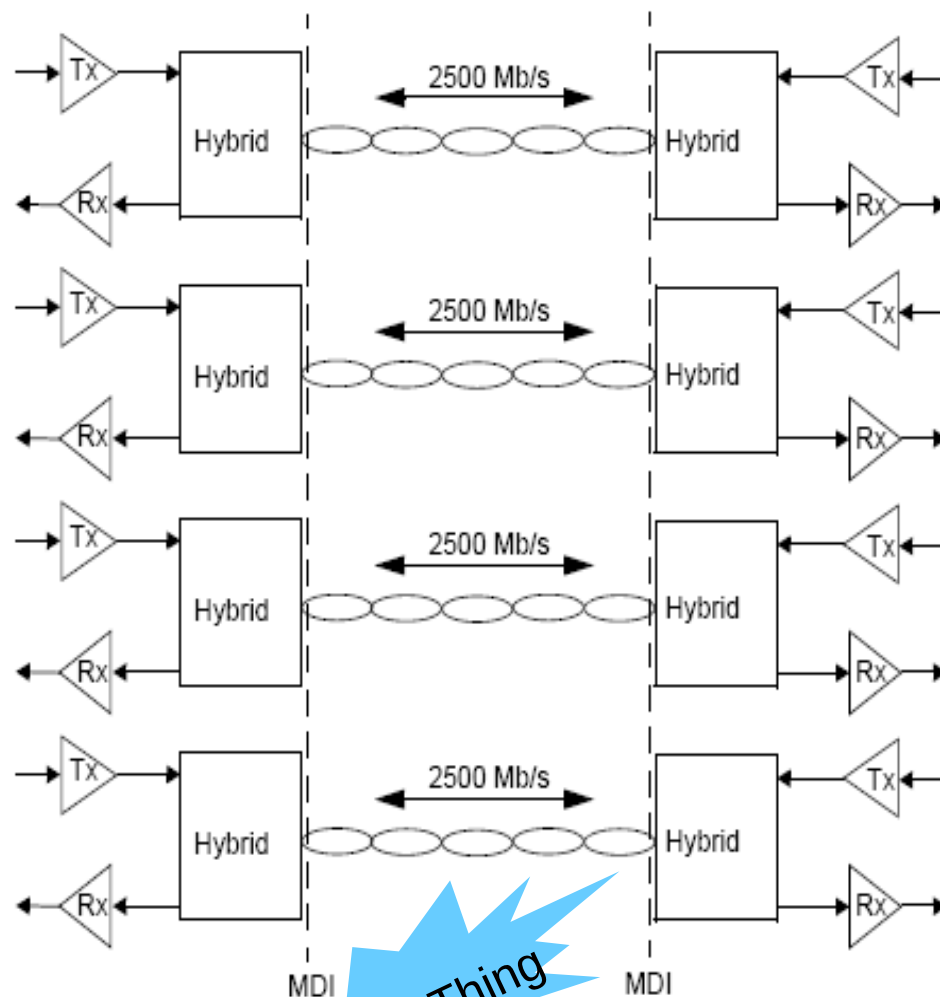
GbE

10 year transition

10GbE

# 10GBASE-T - 总揽

- 10GBASE-T 提供10Gbit/second 数据传输率。通过4对屏蔽/非屏蔽双绞线 (A, B, C, D) 进行传输，每对2.5Gbps。最远传输距离100m。
- 基于16级PAM编码，调制速率为800M symbols/s。每个Symbol包含3.125bit的数据信息。
- 全双工操作模式
- 向下兼容10M/100M/1000M BASE-T
- 在所有的支持的距离和传输线上，支持低于或等于 $10E-12$ 的BER
- 比光纤传输成本低



Next Big Thing

# 我们所熟悉的1000BaseT

- PAM5编码 - 5级电平编码, 分别是-2, -1, 0, +1, +2
- 模板测试, Droop - Test Mode 1

模式1信号是由+2, 然后接着127个0, -2, 然后接着127个0, +1, 然后接着127个0, -1, 然后接着127个0, 接着是128个+2, 128个-2, 128个+2, 128个-2, 最后是1024个0

验证的目的是:

接口有否驱动足够的能量将信号传送100米距离。

上升时间是否足够快得以实现快速的数据交换

信号是否对称, 即A与B, C与D是否对称

- 抖动测试 – Test Mode 2 (主模式抖动) 和 Test Mode 3 (从模式抖动)
- 传输失真测试 – Test Mode 4
- Return Loss

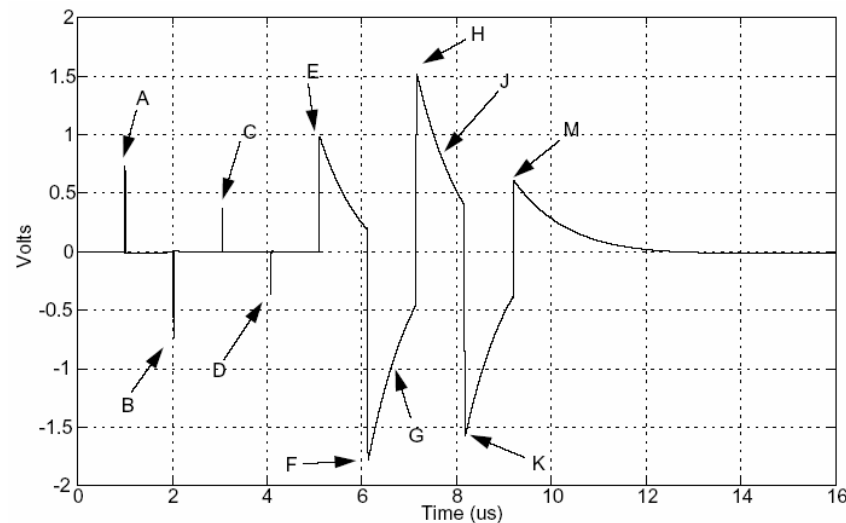


Figure 40-19—Example of transmitter test mode 1 waveform (1 cycle)

## 与 1000BaseT的对比

| 1000BASE-T                                                                      | 10GBASE-T                                                                                                               |
|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| PAM 5 调制                                                                        | PAM 16 调制                                                                                                               |
| Peak voltage, Amplitude symmetry, Droop                                         | Linearity, Droop                                                                                                        |
| Jitter with Tx_Clk, Filtered, Unfiltered, as master and slave (300 picoseconds) | Master Jitter and slave Jitter (5.5 picoseconds RMS), Clock frequency measurement                                       |
| Distortion test limit is 10mV                                                   | Power Spectral Density measured to be within mask limits.<br><br>The transmit power shall be between 3.2dBm and 5.2dBm. |
| Return Loss (扫频信号:100 MHz)                                                      | Return loss (扫频信号:500 MHz)                                                                                              |
| 在所有四对传输线上均需完成所有测量项目                                                             | Jitter Slave仅需在Pair D上测量。在所有四对传输线上均需完成其余测量项目                                                                            |

# 10GBaseT的测试模式

**Table 55–7—MDIO management register settings for test modes**

| 1.132.15 | 1.132.14 | 1.132.13 | Mode                                                                                                |
|----------|----------|----------|-----------------------------------------------------------------------------------------------------|
| 0        | 0        | 0        | Normal operation.                                                                                   |
| 0        | 0        | 1        | Test mode 1—Setting of MASTER transmitter required by SLAVE for transmit jitter test in SLAVE mode. |
| 0        | 1        | 0        | Test mode 2—Transmit jitter test in MASTER mode.                                                    |
| 0        | 1        | 1        | Test mode 3—Transmit jitter test in SLAVE mode (if loop timing is supported).                       |
| 1        | 0        | 0        | Test mode 4—Transmit distortion test.                                                               |
| 1        | 0        | 1        | Test mode 5—Normal operation with no power backoff. This is for the PSD mask and power level test.  |
| 1        | 1        | 0        | Test mode 6—Transmitter droop test mode.                                                            |
| 1        | 1        | 1        | Test mode 7—Pseudo random test mode for BER Monitor.                                                |

# XGbT – 10GBASE-T 发送端测试

|    | Measurement                                              | Test Mode                                   | XGbT Features / Notes                                                                                                                                                                                                 | Does XGbT cover this measurement? |
|----|----------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| 1  | Maximum output droop                                     | Sub clause 55.5.3.1, Test Mode 6            | Flexibility to test beyond compliance – XGbT provides the flexibility to perform testing beyond what is specified in IEEE standard 802.3an-2006. It helps users to analyze their PHY in addition to compliance tests. | Yes                               |
| 2  | Transmitter timing jitter – Master                       | Sub clause 55.5.3.3, Test Mode 2            | Measure Jitter down to just few picoseconds. Software Filters are designed and applied on the acquired data automatically while performing measurements.                                                              | Yes                               |
| 3  | Transmit clock frequency                                 | Sub clause 55.5.3.5, Test Mode 2            | Exact value PPM for measured clock frequency is provided                                                                                                                                                              | Yes                               |
| 4. | Transmitter timing jitter – Slave                        | Sub clause 55.5.3.3, Test Mode 1 and Mode 3 | Measure Jitter down to just few picoseconds. Software filters are designed and applied on the acquired data automatically while performing measurements.                                                              | Yes                               |
| 5  | Transmitter linearity                                    | Sub clause 55.5.3.2, Test Mode 4. Tones 1-5 | Spectral Features of the scope are used to perform the measurement, a methodology that is unique to Tektronix and approved by UNH-IOL                                                                                 | Yes                               |
| 6  | Transmitter power spectral density (PSD) and power level | Sub clause 55.5.3.4, Test Mode 5            | Spectral Features of the scope are used to perform the measurement, a methodology that is unique to Tektronix and approved by UNH-IOL                                                                                 | Yes                               |
| 7. | Return Loss                                              | Sub clause 55.8.2.1, Test Mode 5            | Return Loss is not part of XGbT solution for now, however it will finally be released in next version. For time gap arrangement please request product line for Return Loss utility                                   | Yes**                             |



# XGbT – 10GBASE-T 自动测量方案

- 针对10GBASE-T物理层一致性测试的完备的自动测量方案。
- XGBT方案覆盖了某些基于频谱的测量选项，如PSD(功率谱密度), Linearity(线性度), 这些都可以通过一台示波器来完成
- 一键测试，支持多种测试项目，支持四通道测量。
- 详细的测试报告，包含余量和统计信息，便于后续分析。
- 简单而高效的自动测试流程。
- 特殊测试环境下(thermal chambers, power supplies)，支持通过NI LabVIEW 或 NI TestStand™ 进行远程启动XGbT应用。

# Maximum Output Droop 最大输出调萎

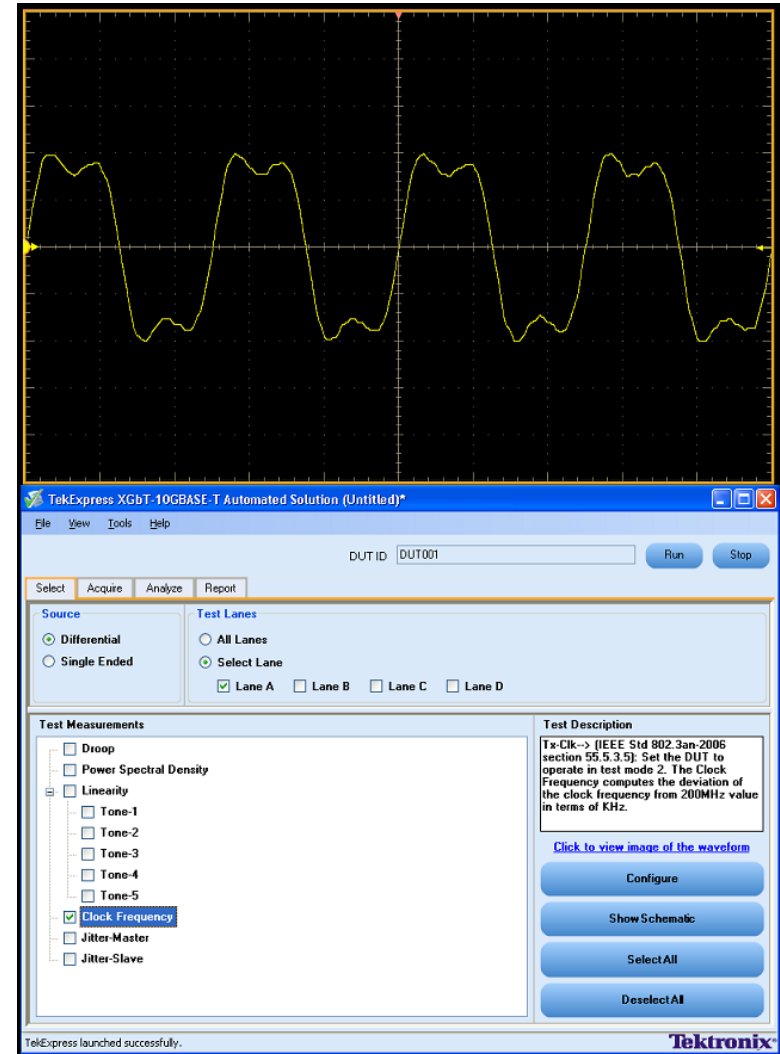
- 目的 – 确保发送端输出电平的衰减满足规范的要求。
- 无论正调萎还是负调萎，其衡量方法为:以过零点作为参考，从第10ns到第90ns，电平幅度的调萎不超过10%。
- DUT 需进入Test Mode 6
- IEEE 标准802.3an-2006, 55.5.3.1条目
- Test Mode 6 :  
{128个“+16” symbols, 128个“-16” symbols} 循环



# Transmitter Clock Frequency

## 发送端时钟频率

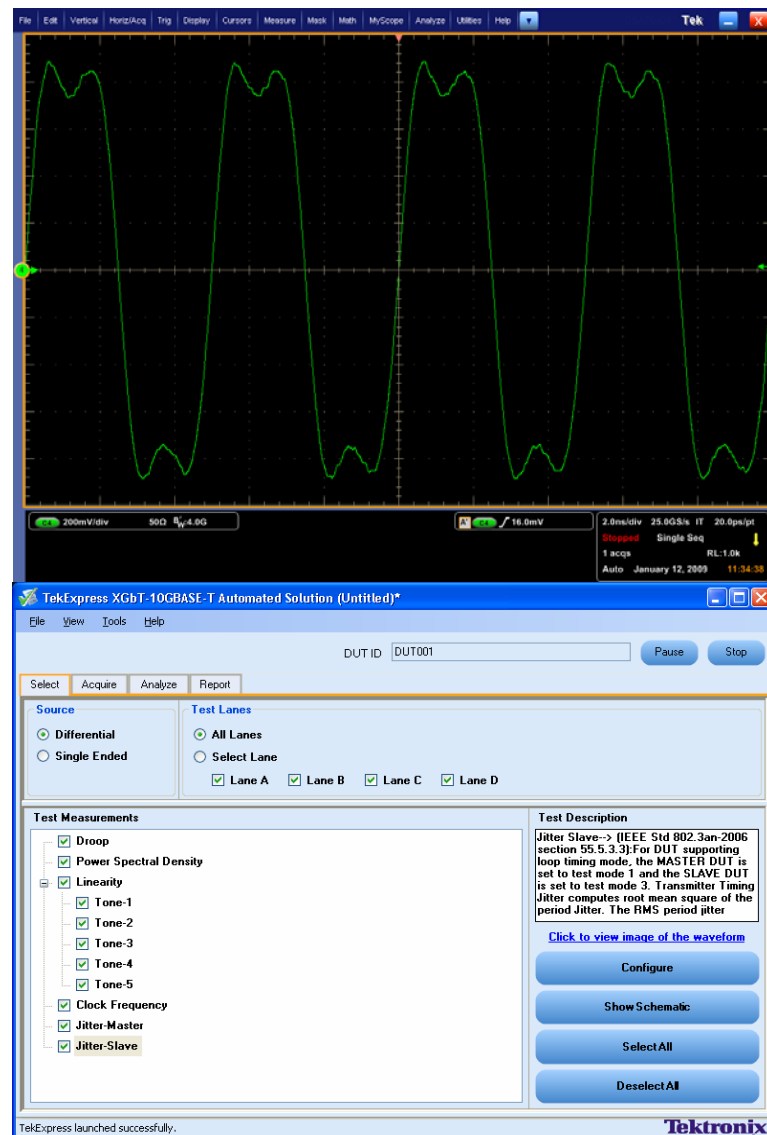
- 目的 – 确保发送端时钟频率满足规范的要求。
- 频率测量结果应该在  $\pm 50$  ppm 的范围之内。
- DUT需进入Test Mode 2
- 软件精确计算并显示时钟频率波动的ppm值。
- IEEE 标准802.3an-2006, 55.5.3.5条目
- Test Mode 2:  
{2个“+16” symbols, 2个“-16” symbols} 循环  
实际输出为200MHZ的时钟波形



# Transmitter Timing Jitter – Master

## 发送端抖动 – 主模式

- 目的 – 确保发送端信号的抖动满足规范的要求。
- 周期抖动(Period Jitter)的测量结果-RMS值应该在5.5ps范围之内。
- DUT需进入Test Mode 2。
- IEEE 标准 802.3an-2006, 55.5.3.3 条目。
- XGbT方案可加入软件滤波器(Fc=200MHZ, Bn=2MHZ), 保证了测量的精确性。
- Test Mode 2:  
{2个“+16” symbols, 2个“-16” symbols} 循环  
实际输出为200MHZ的时钟波形



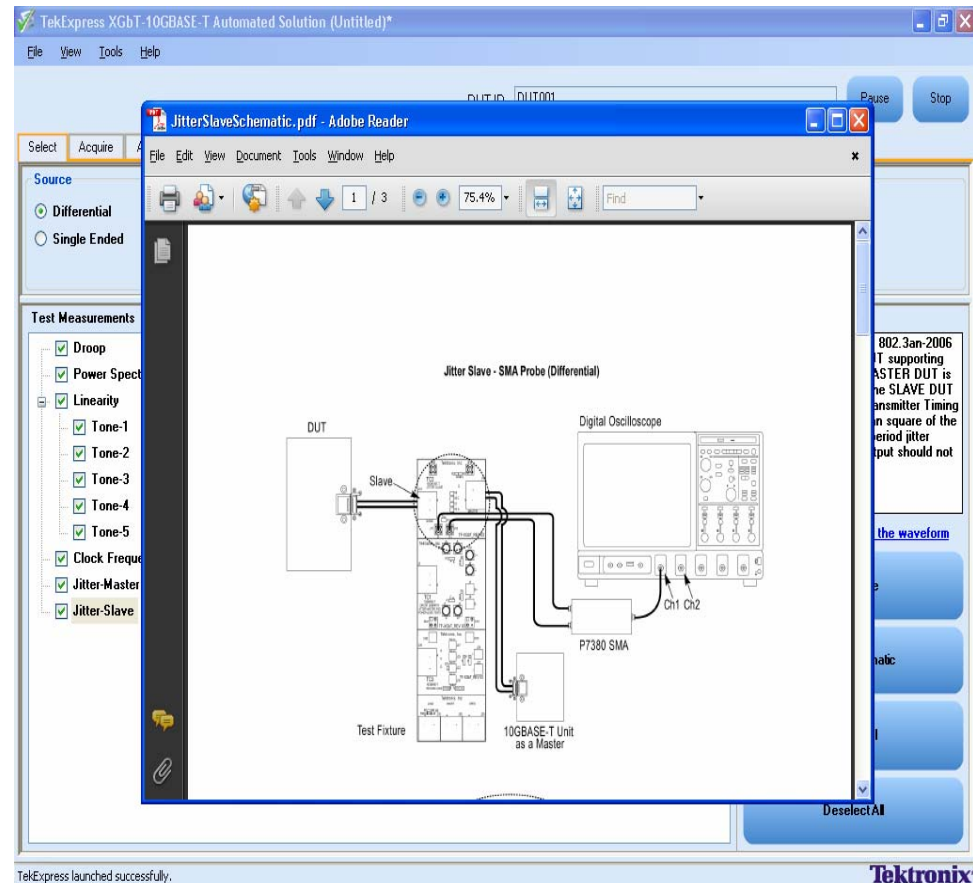
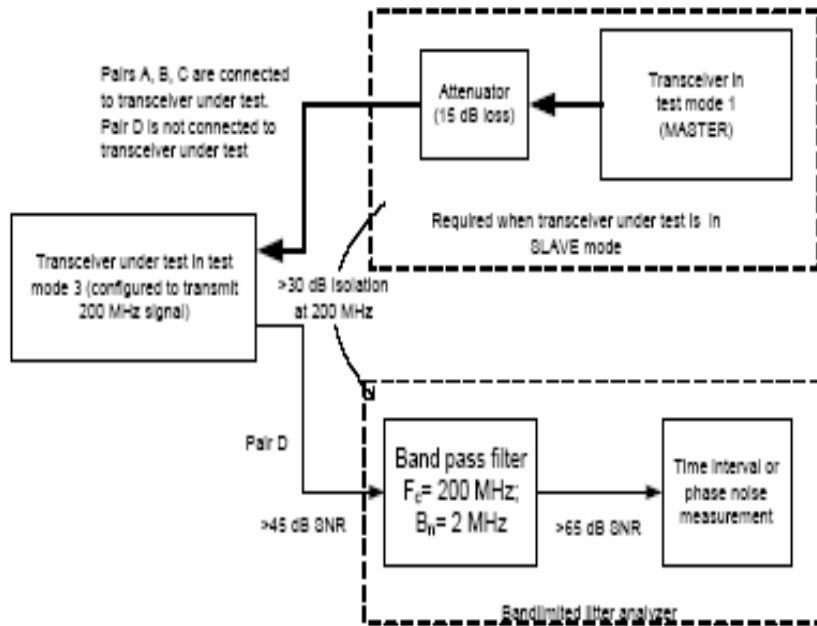
# Transmitter Timing Jitter – Slave

## 发送端抖动 – 从模式

- 目的 – 确保发送端信号的抖动满足规范的要求。
- 周期抖动(Period Jitter)的测量结果- RMS 值应该在5.5ps范围之内。
- 主模式 LP进入Test Mode 1  
从模式DUT进入Test Mode3。
- IEEE 标准 802.3an-2006, 55.5.3.3条目。
- XGbT方案可加入软件滤波器( $F_c=200\text{MHz}$ ,  $B_n=2\text{MHz}$ ), 保证了测量的精确性。
- Test Mode 1:  
训练码型(PRBS33) @ Pair A,B,C  
Test Mode 3:  
{2个 “+16” symbols, 2个 “-16” symbols}  
200MHz时钟 @ Pair D  
时钟是从Pair A,B,C恢复出来的



# 抖动测试框图 & 滤波器



# Transmitter Linearity

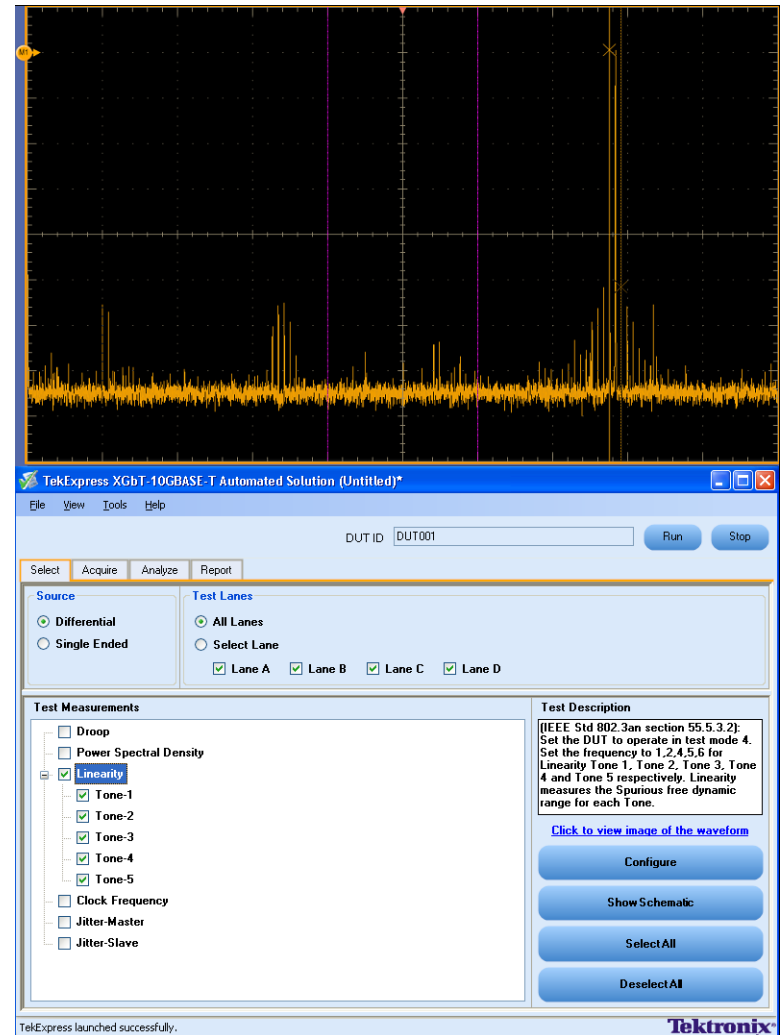
## 传输线性度

- 目的：观察和验证发送端差分信号输出的频谱特性。
- 测量结果SFDR应满足：  

$$SFDR \geq 2.5 + \min\{52, 58 - 20 \times \log_{10}(f/25)\}$$
- 需进入Test Mode 4
- IEEE 标准 802.3an-2006, 55.5.3.2条  
目。
- Test Mode 4:  
发出”双音(Dual Tone)”信号, 共5组

Table 55-8—MDIO management register settings for transmit frequencies in Test mode 4

| 1.132.12 | 1.132.11 | 1.132.10 | Output waveform frequencies in MHz             |
|----------|----------|----------|------------------------------------------------|
|          |          |          | Two tone frequency pairs                       |
| 0        | 0        | 0        | Reserved                                       |
| 0        | 1        | 1        | Reserved                                       |
| 1        | 1        | 1        | Reserved                                       |
| 0        | 0        | 1        | $(800/1024) \times 47, (800/1024) \times 53$   |
| 0        | 1        | 0        | $(800/1024) \times 101, (800/1024) \times 103$ |
| 1        | 0        | 0        | $(800/1024) \times 179, (800/1024) \times 181$ |
| 1        | 0        | 1        | $(800/1024) \times 277, (800/1024) \times 281$ |
| 1        | 1        | 0        | $(800/1024) \times 397, (800/1024) \times 401$ |



# Transmitter Power Spectral Density (PSD) and Power Level

## 发送端功率谱密度及功率值

- 目的：确保发送端功率谱密度和功率值满足规范要求。
- 功率值应在3.2dBm~5.2dBm范围内  
功率谱密度曲线应介于规范要求的上下限曲线之间。
- 需进入Test Mode 5
- IEEE 标准 802.3an-2006, 55.5.3.4条目。
- Test Mode 5:  
正常操作模式





# Transmitter Power Spectral Density (PSD) and Power Level

## 发送端功率谱密度及功率值

$$\text{Upper PSD } (f) \leq \begin{cases} -78.5 \text{ dBm/Hz} & 0 < f \leq 70 \\ -78.5 - \left(\frac{f-70}{80}\right) \text{ dBm/Hz} & 70 < f \leq 150 \\ -79.5 - \left(\frac{f-150}{58}\right) \text{ dBm/Hz} & 150 < f \leq 730 \\ -79.5 - \left(\frac{f-330}{40}\right) \text{ dBm/Hz} & 730 < f \leq 1790 \\ -116 \text{ dBm/Hz} & 1790 < f \leq 3000 \end{cases}$$

$$\text{Lower PSD } (f) \geq \begin{cases} -83 \text{ dBm/Hz} & 5 \leq f \leq 50 \\ -83 - \left(\frac{f-50}{50}\right) \text{ dBm/Hz} & 50 < f \leq 200 \\ -86 - \left(\frac{f-200}{25}\right) \text{ dBm/Hz} & 200 < f \leq 400 \end{cases}$$

# 频谱分析？示波器的精度够吗？

## Ethernet的”ATC”: UNH-IOL 推荐泰克方案



### *The University of New Hampshire InterOperability Laboratory*

#### Appendix 55.5.A – Transmitter Test Setups

**Purpose:** To present an example of test setups and connecting hardware that may be used to implement the 10GBASE-T PMA test suite.

#### **Tektronix-based Resource Requirements:**

- Digital Oscilloscope  
DPO7354\*/DPO70404B/DPO70604B/DPO70804B/DPO71254B/DPO71604B  
DPO72004B/DSA70404B/DSA70604B/DSA70804B/DSA71254B/DSA71604B/DSA72004B.
- Arbitrary Waveform Generator\*<sup>1</sup>, AWG7000B including AWG7122B, AWG7121B, AWG7062B, AWG7061B
- Oscilloscope Probes, P6330\*<sup>2</sup>/ P7380SMA\*<sup>3</sup>
- 10GBASE-T Test Fixture, TF-XGbT Compliance Software XGbT

\*DPO/DSA70404B or higher bandwidth oscilloscope recommended for maximum margin on the linearity test however the DPO7354 oscilloscope meets all compliance limit requirements and may be used as a lower bandwidth alternative

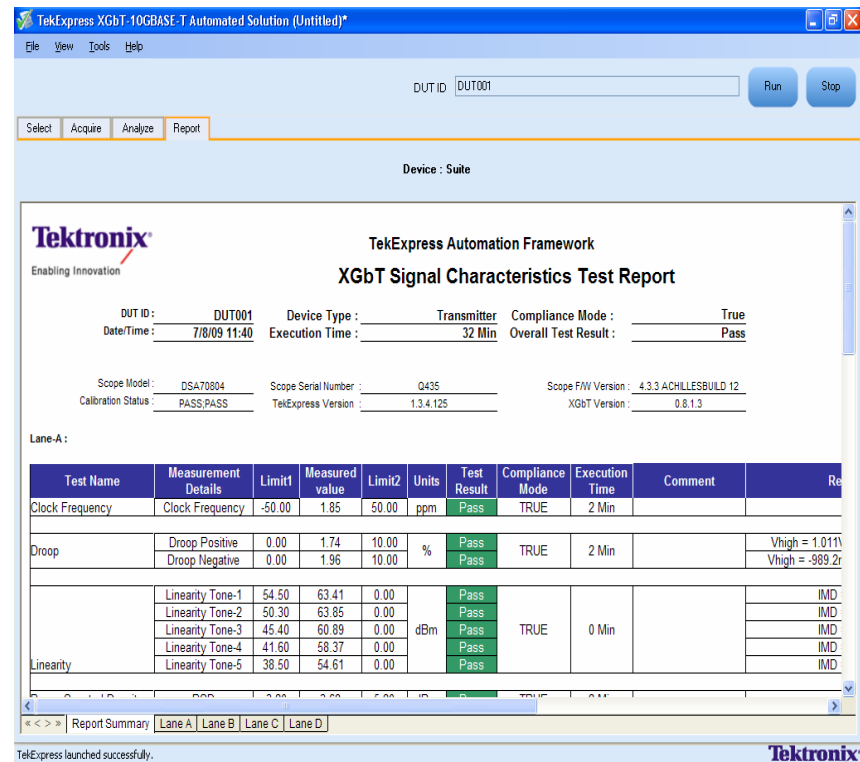
\*<sup>1</sup> Signal Source is only required for Return Loss measurement

\*<sup>2</sup> Recommended to work only with DPO7354 oscilloscope. For Return Loss 2 # P6330 probes are needed

\*<sup>3</sup> Recommended to work only with DPO/DSA70000B oscilloscopes. For Return Loss 2 # P6330 probes are needed

# XGbT – 报告

- TEKEXP 软件提供.mht格式(网页格式)的测试报告，包括测量概要及 Pass/Fail结果。
- 针对每条lane测量的详细报告，包括测量配置，波形图片，余量分析等
- 测试报告还提供额外的相关信息，如仪器型号，校验状态，探头型号，软件版本等。



# 示波器带宽要求

- 10GBASE-T 提供10Gbit/second的总传输速率，每对传输线2.5Gbit/sec。基于PAM16编码技术，每个symbol包含3.125bit的信息。
- $2.5\text{Gbps}/3.125 = 800\text{ MHz}$
- 基频 =  $800/2 = 400\text{ MHz}$
- 为捕获5次谐波分量，示波器的带宽要求至少2GHZ带宽。考虑到PSD项目的测试要求，则至少3GHZ带宽。
- DPO70404B 或更高带宽的示波器对于传输线性度测试有更高的精度。DPO7354也能满足所有的测量项目。

# XGbT 推荐仪器

| Oscilloscopes | Required Software | Required Accessories                                  | Test Fixture                | AWG**   |
|---------------|-------------------|-------------------------------------------------------|-----------------------------|---------|
| DPO7354*      | TEKEXP & XGbT     | P6330 / Matched pair SMA cables(SMA-BNC connector)    | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA70404B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA70604B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA70804B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA71254B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA71604B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |
| DPO/DSA72004B | TEKEXP & XGbT     | P7380SMA / Matched pair SMA cables(TCA-SMA connector) | TF-XGbT – Tektronix Fixture | AWG7K/B |

- 如果客户已经有 TEKEXP 选件，则只需购买XGbT选件即可。

\*DPO70404B 或更高带宽的示波器对于传输线性度测试有更高的精度。DPO7354也能满足所有的测量项目。

\*\* 回波损耗需要用到AWG7K/B (至少5GS/s) & 2根 P6330 (相同的探头也用于 ET3的回波损耗测量)。

# TF-XGbT 测试夹具

- 对于IEEE802.3an-2006 55.5.3 & 55.8.2.1条目中涉及的一致性测试，XGbT测试夹具提供便捷的连接探测。夹具与XGbt – 10GBASE-T自动测量软件配合使用，可以让信号验证和设计调试又快又精准。XGbT夹具覆盖所有的7项测试(包括回波损耗)。



Fig 1: XGbT Test Fixture main board



Fig 2: Calibration Board



Figure 3: RJ45 Shielded Patch cord

# XGbT : 特点与优点

- 简单的仪器/软件设置 – 节省时间和资源
- 支持4通道差分和单端采集方式均支持
- 余量测试能力
- 一键测试
- 自动测试
- 支持LabView远程控制
- 详细的测试报告

# 竞争概要 – Agilent U7236A

- Agilent方案需要一台示波器 + 频谱分析仪 + 矢量网络分析仪
- Agilent方案使用SMA线缆进行信号探测。受示波器和频谱仪通道所限，用户无法进行全自动测量。分别进行四对信号的测量，是相当费时间的。
- 三台仪器的复杂体系  
示波器, 频谱分析仪 & 矢量网络分析仪通过USB-GPIB或以太网接口互联
- U7237A 是一套非常昂贵的系统。完整的U7237A方案需要\$100K ~ 200K 美元



## 相关资源

- Ethernet Alliance
  - [\*http://www.ethernetalliance.com/library/technology-overview.html#10GBASE-T\*](http://www.ethernetalliance.com/library/technology-overview.html#10GBASE-T)
- IEEE
  - [\*www.standards.ieee.org\*](http://www.standards.ieee.org)
  - [\*www.ieee.org\*](http://www.ieee.org)
  - [\*www.ieee802.org\*](http://www.ieee802.org)
- 10GBASE-T Study Group web page URL:
  - [\*http://www.ieee802.org/3/10GBT/\*](http://www.ieee802.org/3/10GBT/)
- 10GBASE-T UNH-MOI:
  - [\*ftp://ftp.iol.unh.edu/pub/10gec/testsuites/10GBASE-T\\_PMA\\_Electrical\\_v1.2.pdf\*](ftp://ftp.iol.unh.edu/pub/10gec/testsuites/10GBASE-T_PMA_Electrical_v1.2.pdf)