

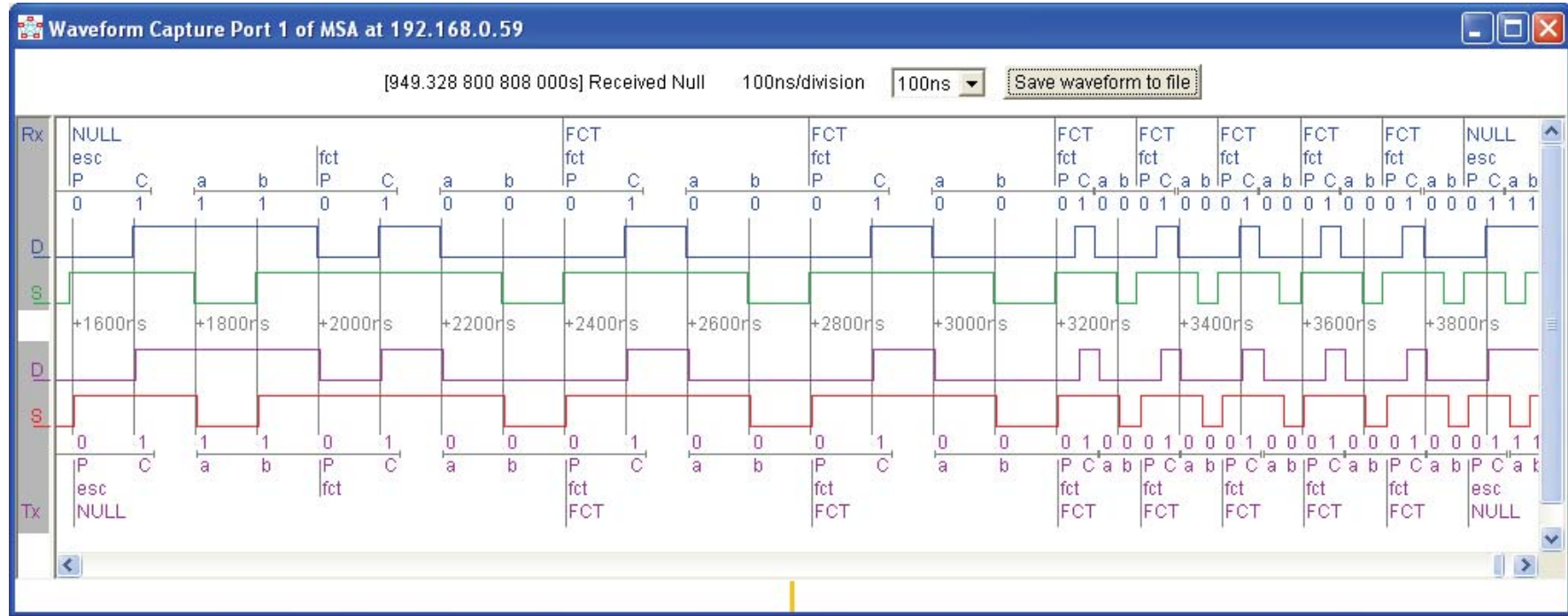


# Measuring Time and Time-related Aspects of SpaceWire

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# SpaceWire signals



- Initialization sequence, 10Mbits/s to 30Mbits/s
- Adjacent bits can be different lengths
- SpaceWire data reception is Asynchronous

# Asynchronous design



- **SpaceWire's Data/Strobe makes clock recovery easy**
- **But**
- **The recovered clock is Asynchronous**
- **Tools for Asynchronous design are much less well developed than for synchronous design**
- **Asynchronous design presents traps, even for experienced designers**
- **So SpaceWire developers need to measure time**
- **And they need to test for time**

# Measuring Time 1



```
ESL-RG408 v0.9 @192.168.1.150 4Links
-----
SPW  R T 444Mb/s | Remote R T 1Gb/sF
Link 8 Rx 444Mb/s | 192.168.1.10:1166
```

- Front panel display shows not only transmit speed but also the receive speed
- Measured by counting the number of Rx clock cycles in so many cycles of a reference (system) clock

# Measuring Time 2



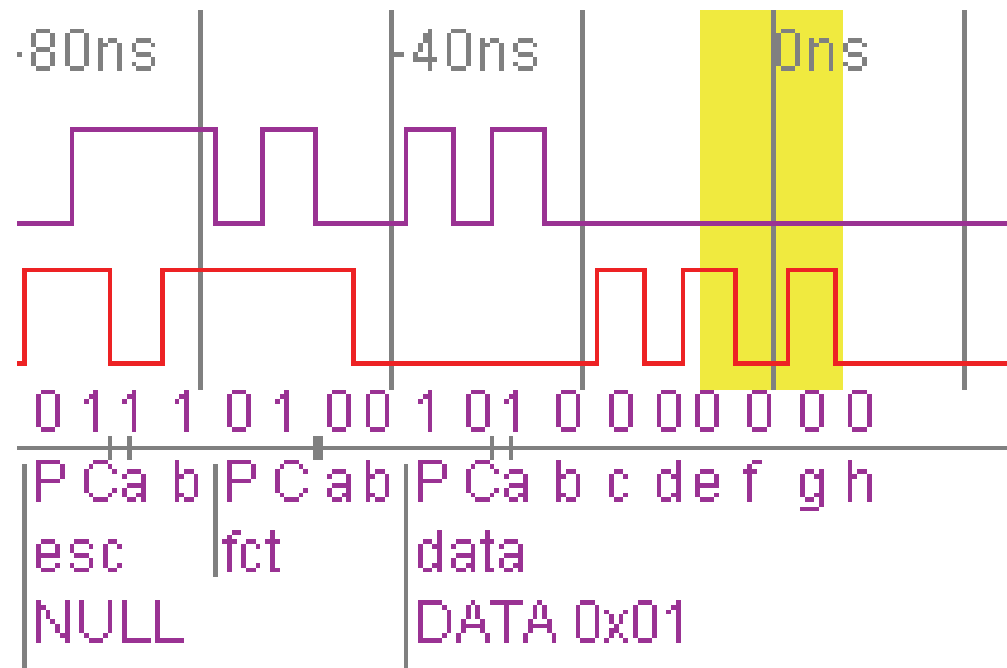
- Initialization sequence, 10Mbits/s to 100Mbits/s
- Time Tags set to record FCTs (after first FCT)

```
Rx:@1 /*664.606 343 013 3s*/ FCT
      /*664.606 343 413 3s*/ FCT // 400ns
      /*664.606 343 813 3s*/ FCT // 400ns
      /*664.606 343 853 3s*/ FCT // 40ns
      /*664.606 343 893 3s*/ FCT // 40ns
      /*664.606 343 933 3s*/ FCT // 40ns
```

# How to measure time



- Signals are sampled at close to 1GSample/s
- State of wires is recorded on every sample
- Interesting Events trigger Waveform Capture and/or Time Tag
- Time Tag has resolution of sampling interval



# Unifying time across a (large) system



// Test 1

// Check alignment of received timetags (Specification is within +/- 3ns)

// Generate synchronized outputs from C, receive on A, B & C

Tx:@C@1 +

Tx:@C@2 +

Tx:@C@3 +

Tx:@C@1 [ | #01 #01 #C1 #A1 EOP ]

Tx:@C@2 [ | #01 #01 #C2 #B1 EOP ]

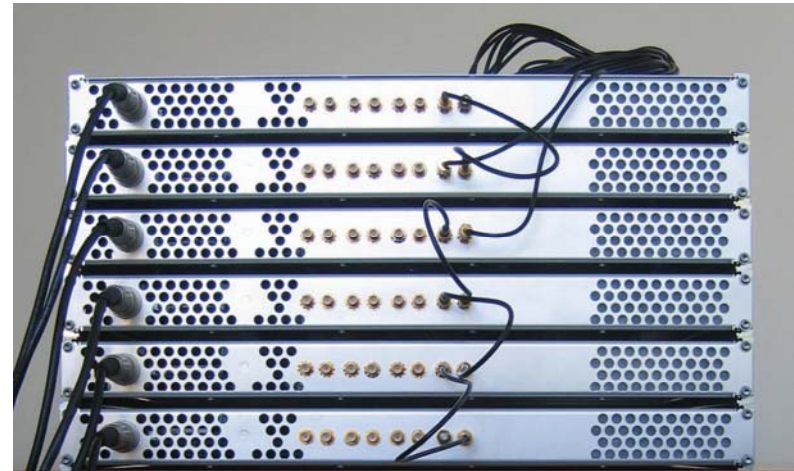
Tx:@C@3 [ | #01 #01 #C3 #C4 EOP ]

// @C Barrier lifted at T=6705.304 943 739 9s

Rx:@A@1 /\*6705.304 943 738 9s\*/ #01 #01 #C1 #A1 EOP

Rx:@B@1 /\*6705.304 943 741 1s\*/ #01 #01 #C2 #B1 EOP

Rx:@C@4 /\*6705.304 943 740 0s\*/ #01 #01 #C3 #C4 EOP



**Total spread 2.2ns, well within +/- 3ns**

# Testing time-related behaviour



## How to do time-related tests?

- **Control the transmit speed over a wide range (1Mbit/s to 400Mbit/s) in small increments (1Mbit/s or less)**
- **Insert arbitrary gaps between D and S transitions**
- **Synchronize outputs, both within a box and between boxes**
- **Use these testing tools together with measurement and comprehensive diagnostics to determine behaviour**

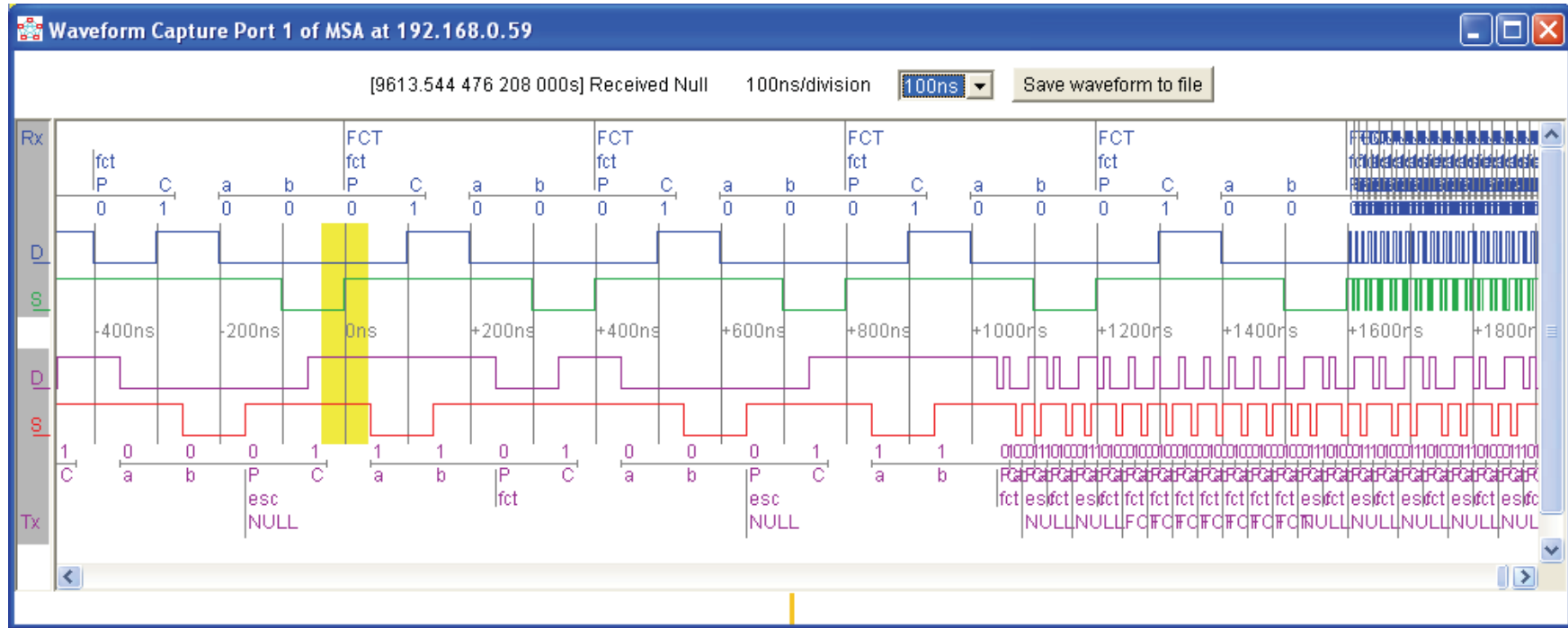


# Testing time-related behaviour



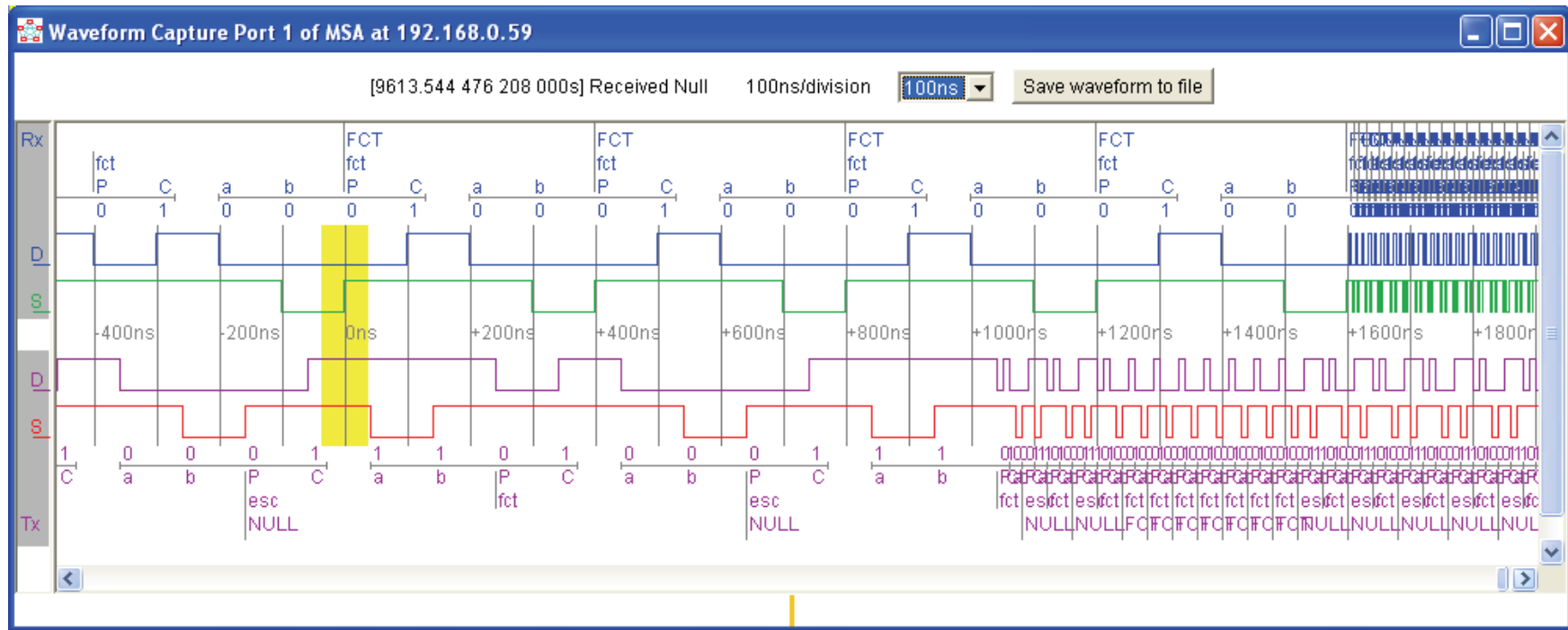
- **Two examples shown, many more possible:**
- **Simulating noise**
- **Measuring Disconnection Timeouts**

# Simulating Noise: Fast and slow SpaceWire



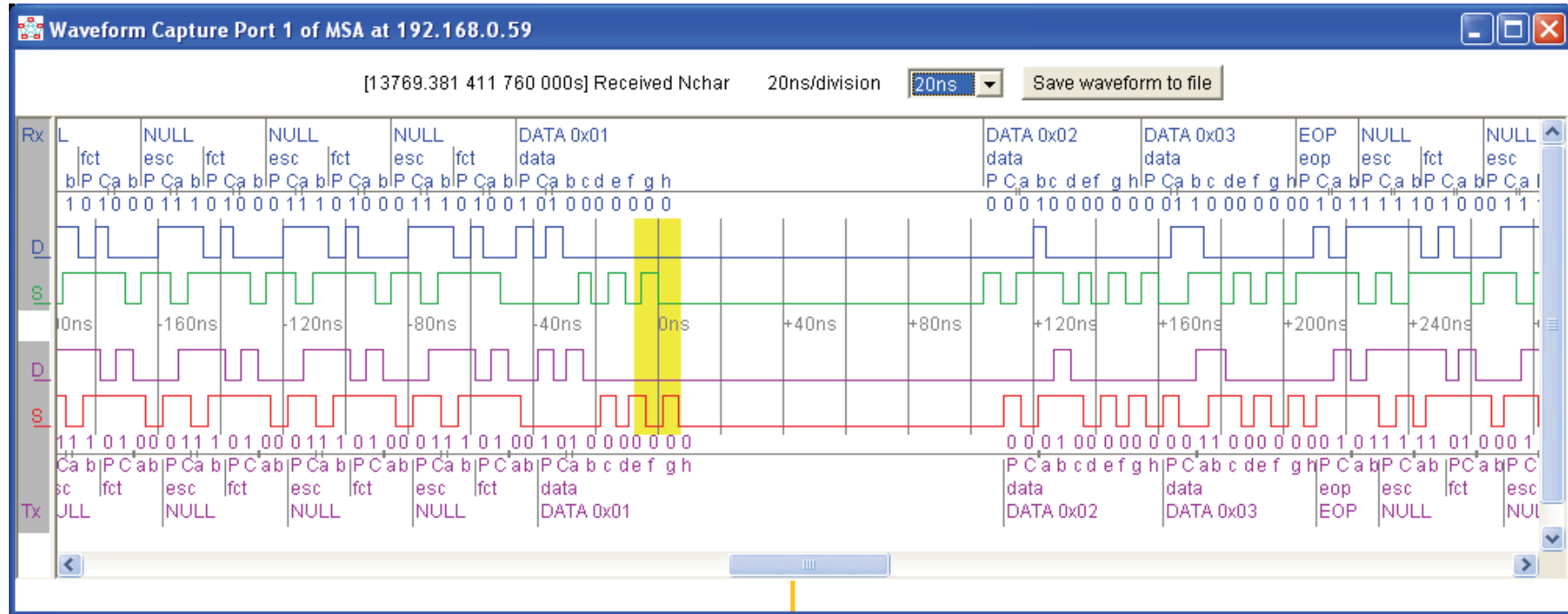
- One end starts and changes to 100Mbits/s
- The other end starts and changes to 400Mbits/s
- If the first end can't receive at 400Mbits/s: What then?

# Simulating noise: Fast and slow SpaceWire



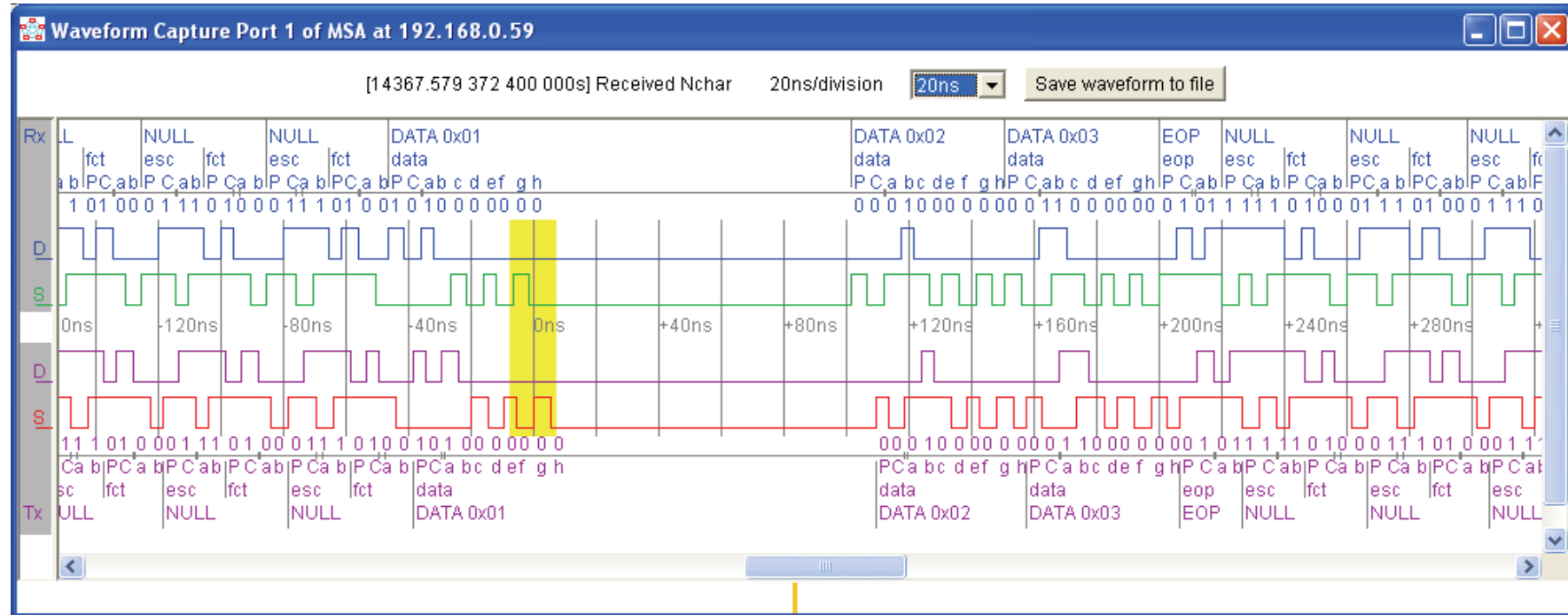
- **If the first end can't receive at 400Mbits/s: What then?**
- **Two out of two designs we have tested like this have locked up. Disconnection does not remove the lock-up**
- **Both need a full reset to recover**

# Inserting a gap between transitions



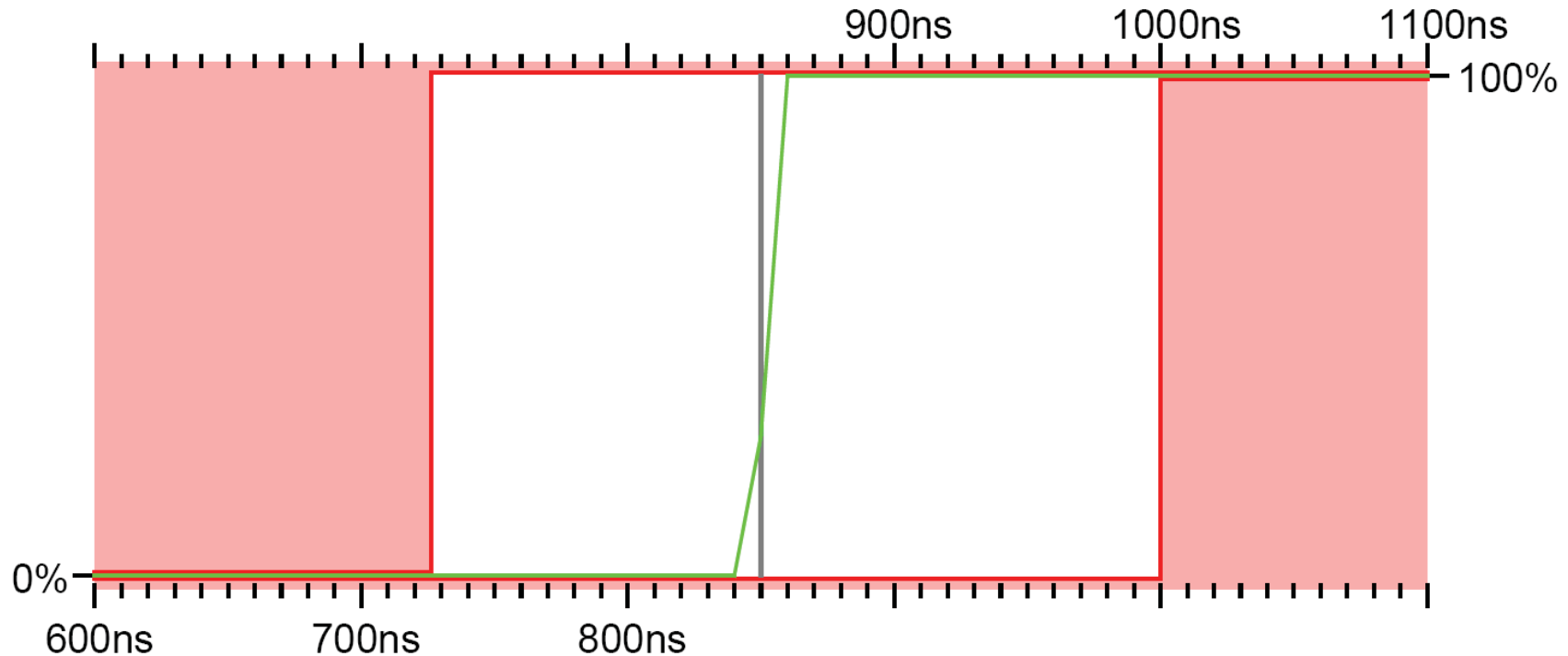
- For test purposes, gaps can be inserted between bits
- Gap here is 21 bit-times at 200Mbits/s, or 105ns

# Fine tuning Tx Link speed



- Links speed set to 203Mbits/s (for example)
- Useful for testing operating margins of receiver
- 21 bit-time gap at 203 Mbits/s is 103.4ns
- Can fine tune gap to measure Disconnection Timeout

# Disconnection Timeout SpaceWire design A



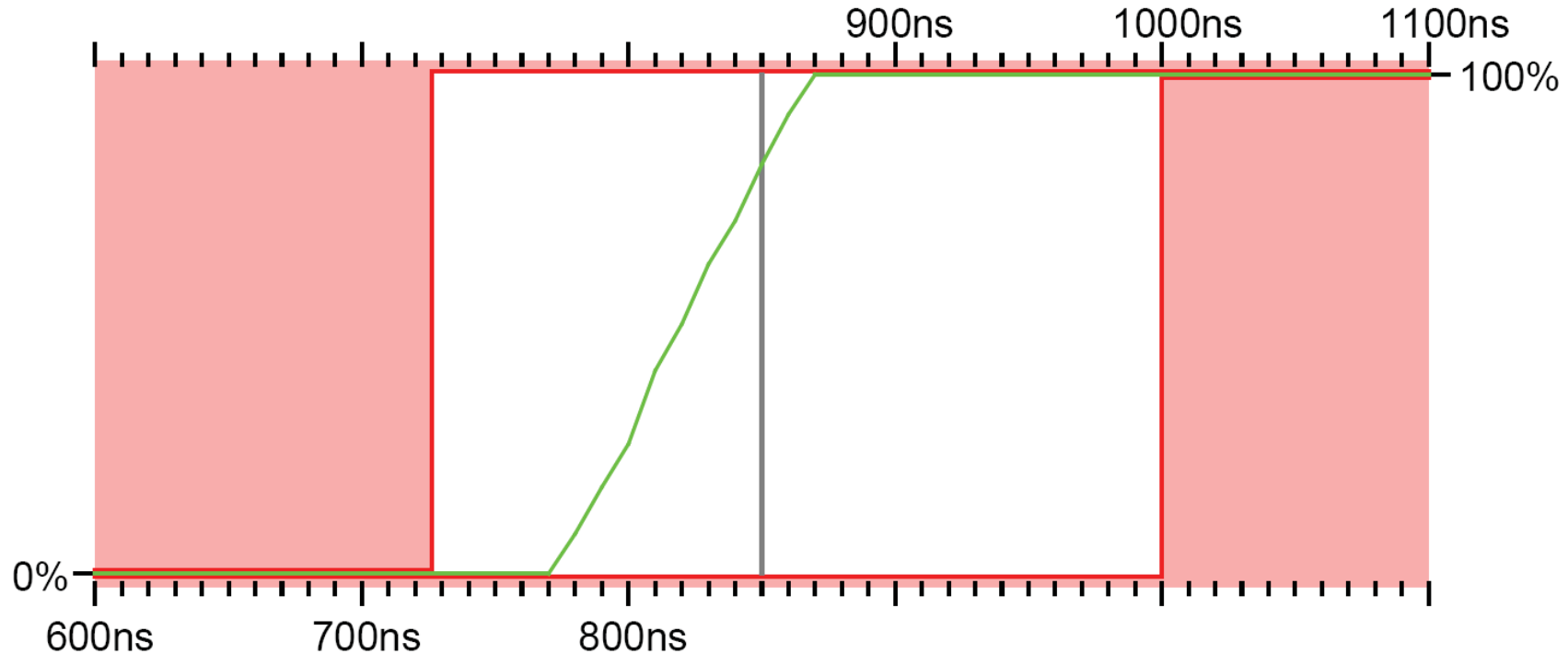
**The ECSS Standard specifies nominal timeout of 850ns:**

**727ns must never disconnect**

**1000ns must always disconnect**

**Design A never disconnects at 840ns, always at 860ns, OK**

# Disconnection Timeout SpaceWire design B

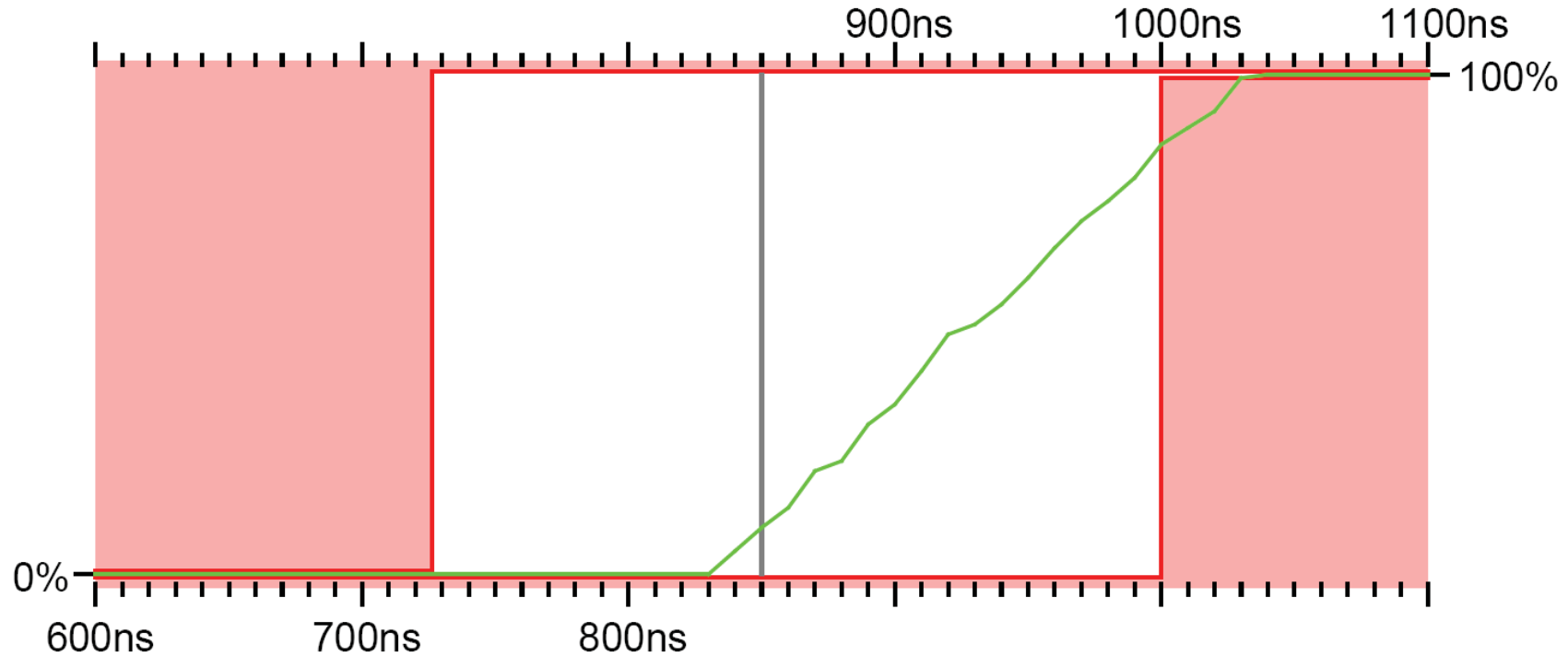


**727ns must never disconnect**

**1000ns must always disconnect**

**Design B never disconnects at 770ns, always at 870ns, OK**

# Disconnection Timeout SpaceWire design C



**Design C never disconnects at 830ns,  
Does not always disconnect at 1000ns,  
Fails to comply with ECSS standard**



# Conclusions



- **Asynchronous design is not easy**
- **‘Mature’ designs have been found to contain bugs in their time-related behaviour**
- **If these tests have not been completed successfully, can you honestly say that**
  - 1. Your design works ?**
  - 2. Your design complies with the ECSS standard ?**
- **Equipment is available to perform these tests, not only on individual devices but on large systems and with extraordinary consistency and resolution**