# IEEE 1394 Ideal for Long-Haul Automotive, Consumer, Industrial, Security and PC Applications

***How to Use FireWire for Innovative New Designs without Distance Constraints***

Les Baxter, Baxter Enterprises

## Introduction and overview

Since 1995, FireWire has been a proven and popular interface for short haul audio and video transfer in PCs, storage products and consumer electronics. To date over 1 billion ports have shipped. Now the 1394b version of FireWire (known as Beta mode), which runs at up to 3200 Megabits/second, is becoming an interface of choice for innovative and advanced long haul applications. Since the publication of the 1394 Copper Automotive Specification in 2008, there has been significant interest in FireWire for automotive applications as well.

It is a common misconception that IEEE 1394 links are limited to 4.5 m in length. This perception is no doubt caused by the statement found in the IEEE 1394 standard that all three types of cables (4-, 6-, and 9-pin) have "a suggested maximum length of 4.5 m." The 1394 standard goes on to point out that longer length cables are possible, but this has been largely overlooked and misunderstood. Additionally, IEEE 1394-2008 contains several clauses that specify long-haul media, which can support much longer distances.

The diagram below illustrates a typical IEEE 1394 network with standard cables of 4.5m lengths, which can support up to 63 nodes.

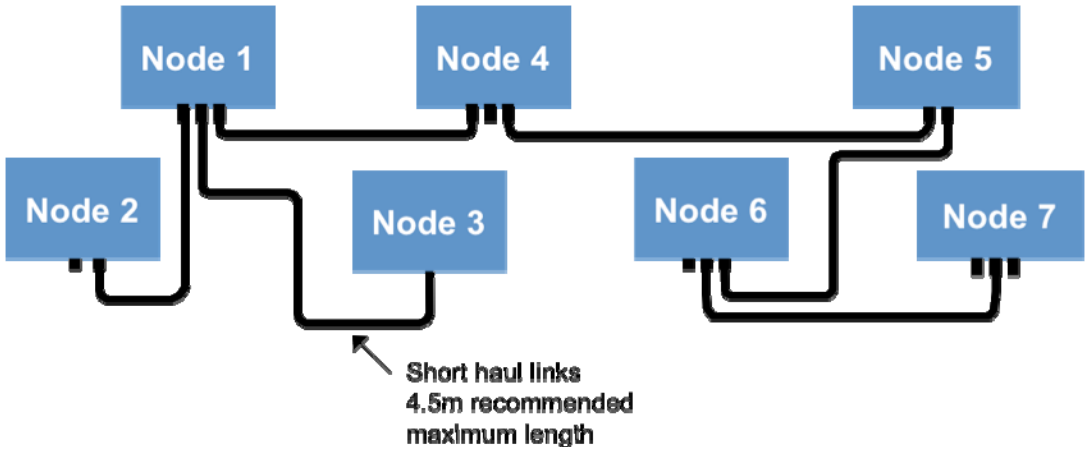


**Figure 1 – Typical 1394 Network**

There are two ways of extending the distance of a 1394 link – either use a lower-loss cable, or use one of several longer-distance media (UTP, coax, or fiber). This white paper will consider these methods and give additional details on automotive applications

Figure 2 shows the same network as Figure 1 except that the network is divided into two clusters of nodes. A pair of repeaters and a long haul link is used to connect the two clusters.

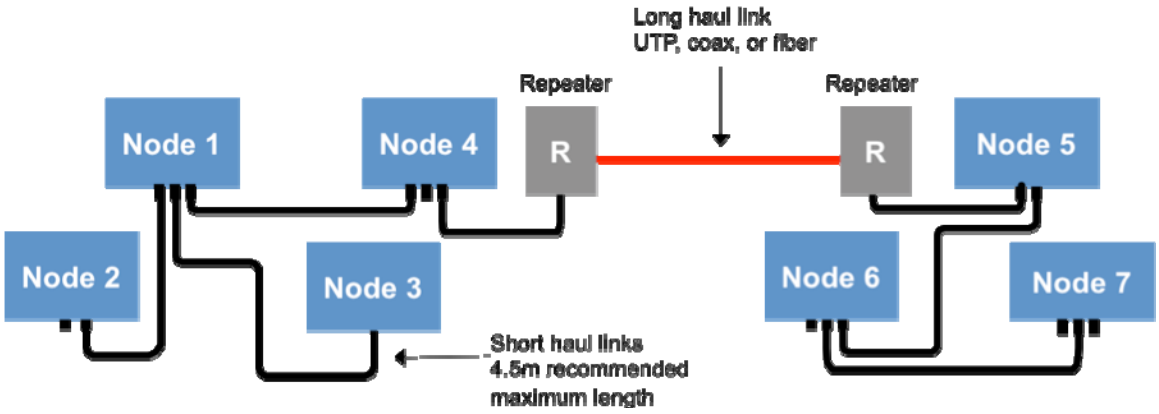


**Figure 2 – 1394 Network with Repeaters**

Instead of using repeaters, it is also possible to design Nodes 4 and 5 with long haul ports so that they can be directly connected. This is illustrated in Figure 3.

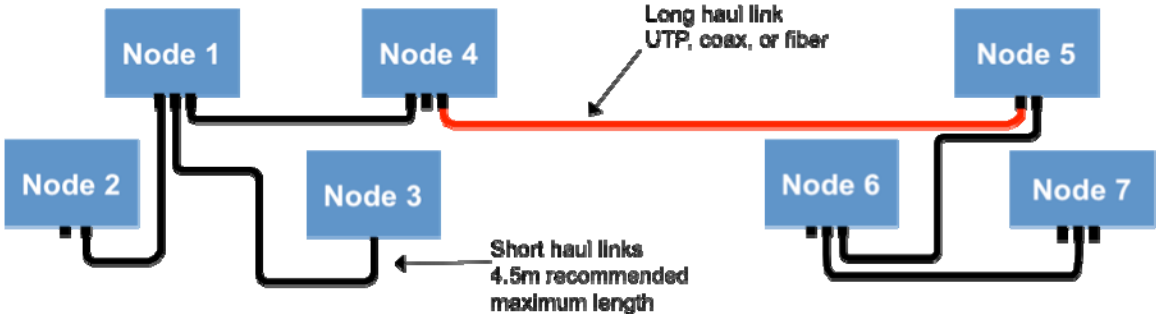


**Figure 3 – 1394 Network with Long Haul Ports**

## Longer distances with low-loss IEEE 1394 cables

The recommended 4.5m cable length is based primarily on the attenuation of both the signal pairs and the power pair of the IEEE 1394 cable. By using a lower-loss cable, it is possible to go further. See Table 5 for a listing of companies that make extended-distance 1394 cables. The 1394 Copper Automotive Standard specifies distances of up to 8 meters with 5 inline connectors using low loss copper cables and equalized coax cable.

Especially in industrial and automotive applications where each link is engineered, with careful design of the interface and cable, it is possible to go somewhat further than 10m, possibly 15m or more. Note that in all cases, connectors that are fully compliant with the IEEE 1394 requirements must be used.

Beta mode interfaces may also use equalizers to compensate for high-frequency loss and extend the signal even further.

## Long-haul media

If links longer than 10 meters or so are required, IEEE 1394 supports a wide variety of long-haul media, which can operate over distances of up to 2 km. The long-haul interface can either be incorporated into 1394 Beta mode port, or an external repeater can be used with a standard 1394 port (operating in either Alpha or Beta mode.)

The IEEE-1394 long-haul media options include unshielded twisted pair (UTP cable), 50 and 75 ohm coaxial cable, and various types of optical fiber. Each of these will be briefly considered. Table 5 lists manufacturers of repeaters and interface chips.

### *UTP Cable*

The transmission of baseband IEEE 1394 signaling over UTP cable is specified in Clause 12 of IEEE 1394-2008. Both Cat 5e and Cat 6 UTP cabling can be used. Cat 6 UTP supports transmission distances of 100m at S100 and S200 and 75m at S400. Cat 5e UTP supports transmission distances of 100m at S100, 75m at S200, and 50m at S400.

IEEE 1394 PHY chips supporting UTP are available from several vendors including TI, LSI, Fujitsu, and Symwave. These PHY chips can be combined with transceiver and equalizer chips to create long haul solutions.

In addition to baseband UTP operation, Clauses 20 and 21 of IEEE 1394-2008 describe a technique known as T-mode, which involves sending an S800 Beta mode signal over a Gigabit Ethernet PHY. This requires a custom PHY chip which has not been commercially implemented. However, Point Grey Research and Quantum Parametrics offer a similar product, known as FirePRO LDR, which uses a 1000BASE-T PHY to support S800 links over up to 100m of UTP.

All the UTP options support the provisioning of cable power.

### *Optical Fiber Cable*

Transmission over 50μ multimode glass optical fiber (GOF) is specified in clause 10 of IEEE 1394-2008. This specification supports data rates of S400, S800, and S1600 over distances of up to 100m. However, commercially available repeater products support distances of up to 500m.

Clause 11 of IEEE 1394-2008 specifies transmission over plastic optical fiber (POF) and hard polymer clad fiber (H-PCF) at data rates of S100 and S200. Transmission distances can be up to 50m for POF and 100m for HPCF. Currently available POF and HPCF technologies can support data rates of S400 and S800.

Single-mode fiber transmission is specified in 1394 Trade Association document 2008004. Single-mode fiber supports transmission distances of up to 2000m at data rates of S800, S1600, and S3200

### *Coaxial cable*

Baseband IEEE 1394 signals can be transmitted over either 50 or 75 ohm coaxial cable as specified in 1394 Trade Association document 2007005. The transmission distance depends on the attenuation of the particular type of coaxial cable used. Transceivers are now available that enable distances up to 70 meters at S800 with power over 75 ohm coax. For 50 ohm coax, typical transmission distances range from 25 to 70m at S400 and 15 to 50m at S800. For 75 ohm coax, typical transmission distances for popular cable types like RG59 and RG6 range from 100 to 160m at S400 and 70 to 100m at S800. Both PHY chips and repeaters for coaxial cable are commercially available (see Table 5.) Baseband coaxial cable supports the transmission of cable power.

The 1394 Trade Association has issued a series of specifications to support ultra-wideband (UWB) transmission over coaxial cable. UWB has the unique capability to pass through splitters in both directions. Typical transmission distances for UWB over 75 ohm coax (without a splitter) for RG59 and RG6 range from 120 to 170m at S400.

UWB coaxial cable can support the transmission of cable power for links, which do not contain splitters

## Automotive Applications

The 1394 Copper Automotive Specification and previous IDB-1394 specification provide detailed information on using several transmission media in 1394 Automotive networks. Table 1 gives information about various types of fiber.

**Table 1 – Automotive Applications of FireWire over Fiber**

| Type | Core/Fiber Diam. (μm) | Bandwidth & Loss | Temp. & Bend Radius | Inline connection loss (dB) | Data Rate & Distance |
|---|---|---|---|---|---|
| GOF/AGF | 50/125 | 10GHz·20m<br><10 dB/km | -40 ~ +115°C<br>9mm | 3 × 1.0 | S3200<br>10 – 18m |
| H-PCF | 200/230 | 1GHz·20m<br><10 dB/km | -40 ~ +115°C<br>9mm | 3 × 2.0 | S800<br>10 – 18m |
| Low-NA POF | 970/1000 | 500MHz·10m<br><230 dB/km | -40 ~ +85°C<br>15mm | 3 × 2.5 | S400<br>10 – 18m |
| High-NA POF | 970/1000 | 250MHz·10m<br><250 dB/km | -40 ~ +85°C<br>15mm | 3 × 2.5 | S200<br>10 – 18m |

Three different copper transmission media are available for automotive networks: shielded twisted pair (STP), shielded twisted quad (STQ) and coaxial cable. The

requirements for bit rates and transmission distances STP and STQ are identical and are summarized in Table 2.

**Table 2 – Automotive Applications of STP and STQ Cabling**

| Data Rate | Cable Loss (dB/m) | Loss/In-line Connection (dB) | Differential Amplitude (mV) | Number of Inline Connections | Min. Total Interconnect Length (m) |
|---|---|---|---|---|---|
| S400 | 0.60 | 0.1 | 475 | 0 | 8.80 |
| | | | | 1 | 8.65 |
| | | | | 2 | 8.50 |
| | | | | 3 | 8.30 |
| | | | | 4 | 8.15 |
| | | | | 5 | 8.0 |
| S800 | 0.85 | 0.1 | 600 | 0 | 8.80 |
| | | | | 1 | 8.65 |
| | | | | 2 | 8.50 |
| | | | | 3 | 8.30 |
| | | | | 4 | 8.15 |
| | | | | 5 | 8.0 |

50-ohm coaxial cable is specified for automotive networks. The coaxial specifications are summarized in Table 3.

**Table 3 - Automotive Applications of Coaxial Cables**

| Cable type | Data rate | Number of inline connections | Inline connection loss (dB) | Cable loss (dB/m) | Design margin | Total interconnect length (m) |
|---|---|---|---|---|---|---|
| Sample RG-174 | S400 | 0 | 0 | 0.46 | 0 | 26 |
| | | 5 | $5 \times 0.15$ | 0.46 | 0 | 24 |
| | S800 | 0 | 0 | 0.7 | 0 | 17 |
| | | 5 | $5 \times 0.15$ | 0.7 | 0 | 16 |
| Sample RG-58 | S400 | 0 | 0 | 0.27 | 0 | 44 |
| | | 5 | $5 \times 0.15$ | 0.27 | 0 | 41 |
| | S800 | 0 | 0 | 0.41 | 0 | 29 |
| | | 5 | $5 \times 0.15$ | 0.41 | 0 | 27 |
| Sample RTK-031 | S400 | 0 | 0 | 0.26 | 0 | 46 |
| | | 5 | $5 \times 0.15$ | 0.26 | 0 | 43 |
| | S800 | 0 | 0 | 0.39 | 0 | 30 |
| | | 5 | $5 \times 0.15$ | 0.39 | 0 | 28 |

## General system considerations

If the 4.5m cable length recommendation is followed, an IEEE 1394 bus can support the maximum size configuration (63 nodes.) If longer links are used, then the maximum propagation delay across the bus may become an issue. Clause 16.4.9 of IEEE 1394-2008 provides guidance for implementing large diameter networks. Specifically, it allows for increasing two parameters (BOSS_RESTART_TIME and TEST_INTERVAL) so that large networks with longer links can be supported.

## Summary

There are many ways to extend non-automotive IEEE 1394 links beyond the typical 4.5m distance. Low-loss IEEE-1394 cables are available in lengths up to 10m from multiple vendors. For greater distances, use one of the IEEE 1394 long-haul media. The various options are summarized in the table below.

**Table 4 – IEEE 1394 Extended Distance Technologies**

| Media | Speed | Maximum Distance |
|---|---|---|
| IEEE 1394 low-loss cables (Alpha mode) | S100, S200, S400 | 10m or more |
| IEEE 1394 low-loss cables (Beta mode) | S400, S800 | 10m or more |
| UTP (Cat 5e) | S100 | 100m |
| | S200 | 75m |
| | S400 | 50m |
| UTP (Cat 6) | S100 | 100m |
| | S200 | 100m |
| | S400 | 75m |
| UTP (Cat 5e or 6) / GbE | S800 | 100m |
| Baseband coax (50 ohm) | S400 | 25 – 70m |
| | S800 | 15 – 50m |
| Baseband coax (75 ohm) | S400 | 100 – 160m |
| | S800 | 70 – 100m |
| UWB coax | S400 | 120 – 170m |
| POF | S100, S200 | 50m |
| H-PCF | S100, S200 | 100m |
| Multimode fiber | S400, S800, S1600 | 100 - 500m |
| Singlemode fiber | S800, S1600, S3200 | 2000m |

## Vendors

The following table lists vendors who provide extended-distance IEEE 1394 products.

**Table 5 –IEEE 1394 Extended Distance Products and Some Vendors**

| Company | Products | Web site |
|---|---|---|
| Comoss | Extended-distance 1394 cables, repeaters and dongles | www.comoss.com |
| Components Express Inc. | 1394 over standard 75Ω Coax Cables, up to 60 meters | http://www.componentsexpress.com/ |
| DAP Technology | Copper and fiber repeaters | www.daptechnology.com |
| EqcoLogic | Transmitter, Receiver and Equalizer chips for UTP and Coax Cable (with Power over Cable) | www.eqcologic.com |
| Fujitsu | IEEE 1394 PHY chips - 1394 Automotive Grade | www.fujitsu.com |
| Gefen | Repeaters | www.gefen.com |
| Granite Digital | Extended-distance 1394 cables | www.granitedigital.com |
| IOI | UTP repeaters | www.ioi1394.com |
| LSI | IEEE 1394 PHY chips | www.lsi.com |
| Markertech | Extended-distance 1394 cables, repeaters | http://audio-video-supply.markertek.com |
| Network Technologies | Copper and fiber repeaters | www.networktechinc.com |
| Newnex | Extended-distance 1394 cables; UTP, coax, and fiber repeaters | www.newnex.com |
| Opticis | Fiber repeaters | www.opticis.com |
| Point Grey Research | UTP repeaters (FirePRO LDR) | www.ptgrey.com |
| Pulse~Link | UWB chips and repeaters (sample quantities) | www.pulselink.net |
| Quantum Parametrics | UTP repeaters (FirePRO LDR) | www.quantumparametrics.com |
| Symwave | IEEE 1394 PHY chips | www.symwave.com |
| Synchrotech | Extended-distance 1394 cables, repeaters | www.synchrotech.com |
| TI | IEEE 1394 PHY chips | www.ti.com |
| ULAN Co. Ltd. | UTP and coax repeaters | www.ulancable.com |
| Unibrain | 20 meter and 40 meter small diameter 75Ω cables | www.unibrain.com |

## Glossary

Alpha mode – an operating mode in which a port uses data-strobe (DS) transmission and arbitration as defined in IEEE 1394a-2000. Alpha mode ports use either a 6-pin or 4-pin connector.

Beta mode – an operating mode in which a port uses 8B/10B symbol encoding and the bus owner/supervisor/selector (BOSS) arbitration protocol as originally defined in IEEE 1394b-2002. Beta mode ports use a 9-pin connector.

Equalizer – a circuit or device which applies selective amplification and signal filtering to compensate for the attenuation characteristics of a communication channel or cable.

GOF – glass optical fiber

H-PCF -- hard polymer clad fiber

POF – plastic optical fiber

STP – shielded twisted pair

STQ – shielded twisted quad

T-mode – an operating mode in which a port transmits data over an unshielded twisted pair (UTP) link utilizing an IEEE 802.3 gigabit media independent interface (GMII.) T-mode ports use a modular jack (RJ-45) connector.

Speeds-

S100 = 100Mbps

S200= 200Mbps

S400 = 400Mbps

S800= 800Mbps

S1600= 1.6 Gbps

S3200= 3.2Gbps

Ultra-wideband (UWB) – a wireless communication technique, which uses short, ultra-low power, bursts of radio-frequency pulses.

UTP unshielded twisted pair

## References


IEEE Std. 1394-2008, *IEEE Standard for a High-Performance Serial Bus*, Oct. 21, 2008.

1394 Trade Association Document 2008001, *1394 Copper Automotive Standard*, June 20, 2008.

1394 Trade Association Document 2008004, *IEEE 1394 Single-mode Fiber PMD Specification*, Jan. 16, 2009.

1394 Trade Association Document 2007005*, IEEE 1394 Baseband Coax PMD Specification*, May 5, 2009.

1394 Trade Association Document 2006019, *Networking IEEE 1394 Clusters via UWB over Coaxial Cable- Part 1: Continuous Pulse (C-UWB) PHY*, June 29, 2007.

1394 Trade Association Document 2006015, *Networking IEEE 1394 Clusters via UWB over Coaxial Cable—Part 2: L3 IP Bridges*, May 2, 2008

1394 Trade Association Document 2006021, *Networking IEEE 1394 Clusters via UWB over Coaxial Cable—Part 3: FCP and CMP over IPv4*, July 12, 2008.

1394 Trade Association Document 2007004, *Networking IEEE 1394 Clusters via UWB over Coaxial Cable—Part 4: AV/C Relay Agents*, May 27, 2008.