S100 1394B over category 5 UTP calculations

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1 Introduction

The loss budget of a S100 1394B UTP link will be a function of cable and connector loss, intersymbol interference and ingress noise. These are discussed, and the maximum cable length is calculated using the current 1394B draft specifications. The potential for reduced transmit voltage, and therefore reduced radiated emissions, is also examined.

2 Cable and connector loss

The primary source of signal degradation in a UTP link is the frequency dependent attenuation of the cable and connectors, which cause the received eye to close. These are well characterised by international cabling standards (e.g. ISO 11801).

3 Intersymbol Interference

In addition to the link loss, some eye closure will occur due to ISI. There are two major sources of ISI:

- baseline wander
- imperfect equalisation

Baseline wander closure can be *estimated* as a fraction of the nominal received eye amplitude by the equation:

$$ISI_{baseline} = \frac{2\pi f_c}{122.88 \times 10^6} \times \text{Runlength} \quad (1)$$

where fc is the transformer high pass cutoff frequency. Using a typical value, fc=50kHz,

$$ISI_{baseline} = 2.5\% \quad (2)$$

(For comparison, the ATM-155 spec. calls for less than 10% baseline wander when a runlength of 100 occurs, which corresponds to 1% baseline wander for a runlength of 10).

ISI due to imperfect equalization is obviously dependent upon the equalizer implementation. However, since we anticipate simple fixed equalizers being used, it is reasonable to expect ISI equal to 10% of the eye amplitude when using a fixed equalizer with 50m of cable. If the same equalizer is used with shorter cables the vertical eye opening will increase i.e. the longest cable is the worst case. i.e.

$$ISI_{eq} = 10\ \% \tag{3}$$

4 Ingress Noise

A recent contribution to 1394b reported a maximum level of ingress noise measured on installed UTP5 cable plant as less than 20mV peak i.e. V_n =20mV.

5 Max. length with current parameters

Transmit voltage: minimum 600mV pk. differential i.e. 1.2V pk-pk, measured at the output of the PHY chip.

Receiver sensitivity: minimum 100mV, measured at the input to the PHY chip.

UTP5 cable attenuation: $2.06\sqrt{f} + 0.013f$ dB per 100m, f in MHz.

Category 5 connector loss: $0.04\sqrt{f}$ dB per mated pair, f in MHz

Magnetics (transformer and common mode choke) loss: 1dB typical

Symbol rate: 122.88 MBaud

Vertical eye closure is caused by loss in coupling transformers, loss in cable and connectors, distortion due to misequalization (ISI) and baseline wander.

Transformer loss = L_t dB per transformer. Typically Lt<=1dB.
For a 122.88MBaud system calculate frequency dependent loss at half the symbol rate:
Cable loss = L_c = 0.17 dB per m, total length of R m.
Connector loss = L_{con} = 0.3 dB per connector, total of N connectors.

$$\text{Total link loss} = 2L_t + RL_c + NL_{con}\text{dB} \tag{4}$$

For a link with 4 connectors and two transformers:

$$\text{Total link loss} = 2 + 1.2 + 0.17R\ \text{ dB} = 3.2 + 0.17R\ \text{ dB} \tag{5}$$

The total loss that may be sustained such that a received signal suffering the ISI levels discussed above still meets the receiver sensitivity spec. may be calculated by:

$$\text{Total sustainable loss} = 20\left(\log\left(\frac{(1 - ISI_{baseline} - ISI_{eq}) \times V_{tx}}{V_n + V_{rx}}\right)\right)\ \text{dB} \tag{6}$$

Considering the case when the tx. and rx. electrical specs. are as given in the current draft:

$$\text{Total sustainable loss} = 20\left(\log\left(\frac{0.875 \times 600}{120}\right)\right) \text{ dB} = 12.8 \text{ dB} \quad (7)$$

$$R = \frac{12.8 - 3.2}{0.17} = 57 \text{ m} \quad (8)$$

This is a worst case calculation.

6 Receiver sensitivity vs transmit voltage

Clearly 50m range is possible with the current specification. It would be desirable to reduce the transmit voltage as much as possible in order to minimise radiated emissions. The ratio of transmit voltage is given by:

$$V_{tx} = \frac{10^{\frac{loss}{20}}(V_{rx} + V_n)}{(1 - ISI_{baseline} - ISI_{eq})} \quad (9)$$

For a 50 m range, the total loss (cable, magnetics and connectors) is 11.7 dB. The transmit voltage is tabulated below for various receiver sensitivity levels:

Table 1: Transmit voltage vs. receiver sensitivity for 50m cable length

V_{rx}	V_{tx}	tx power relative to V_{tx}=600mV
100mV	527mV	-1.1dB
75mV	418mV	-3.1 dB
50mV	308mV	-5.8 dB

Clearly there is significant benefit in reducing the receiver sensitivity as much as possible, in order to reduce radiated emissions from the cable.

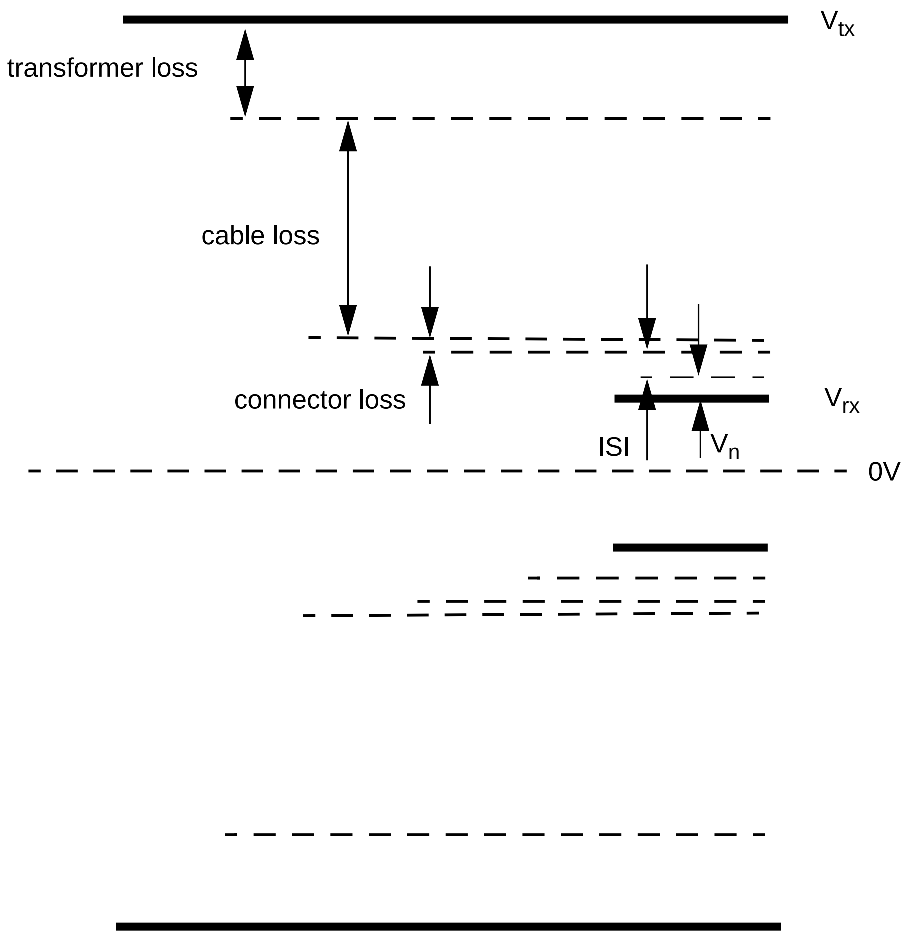

Figure 1: Loss budget diagram