S100 1394B and UTP

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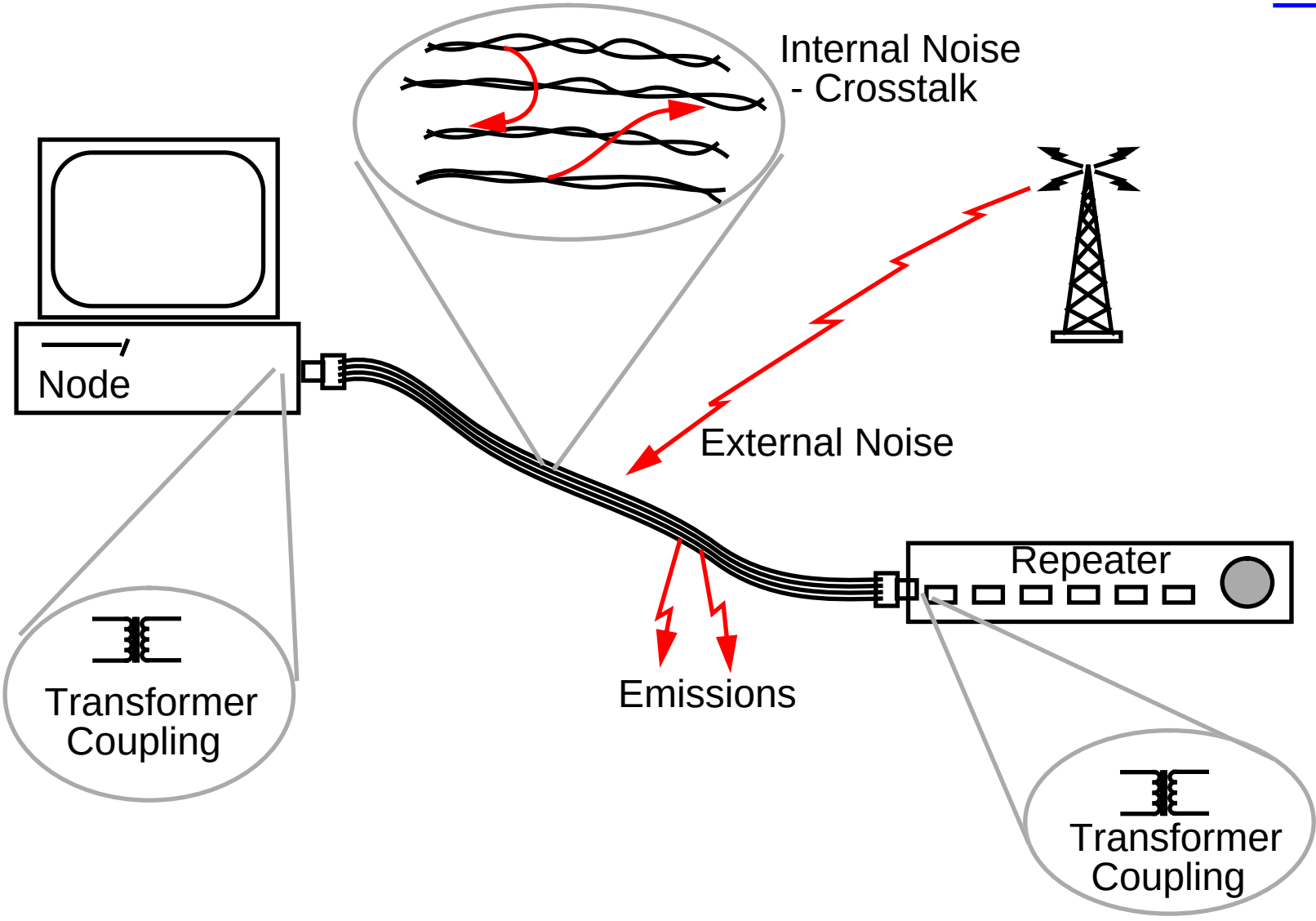
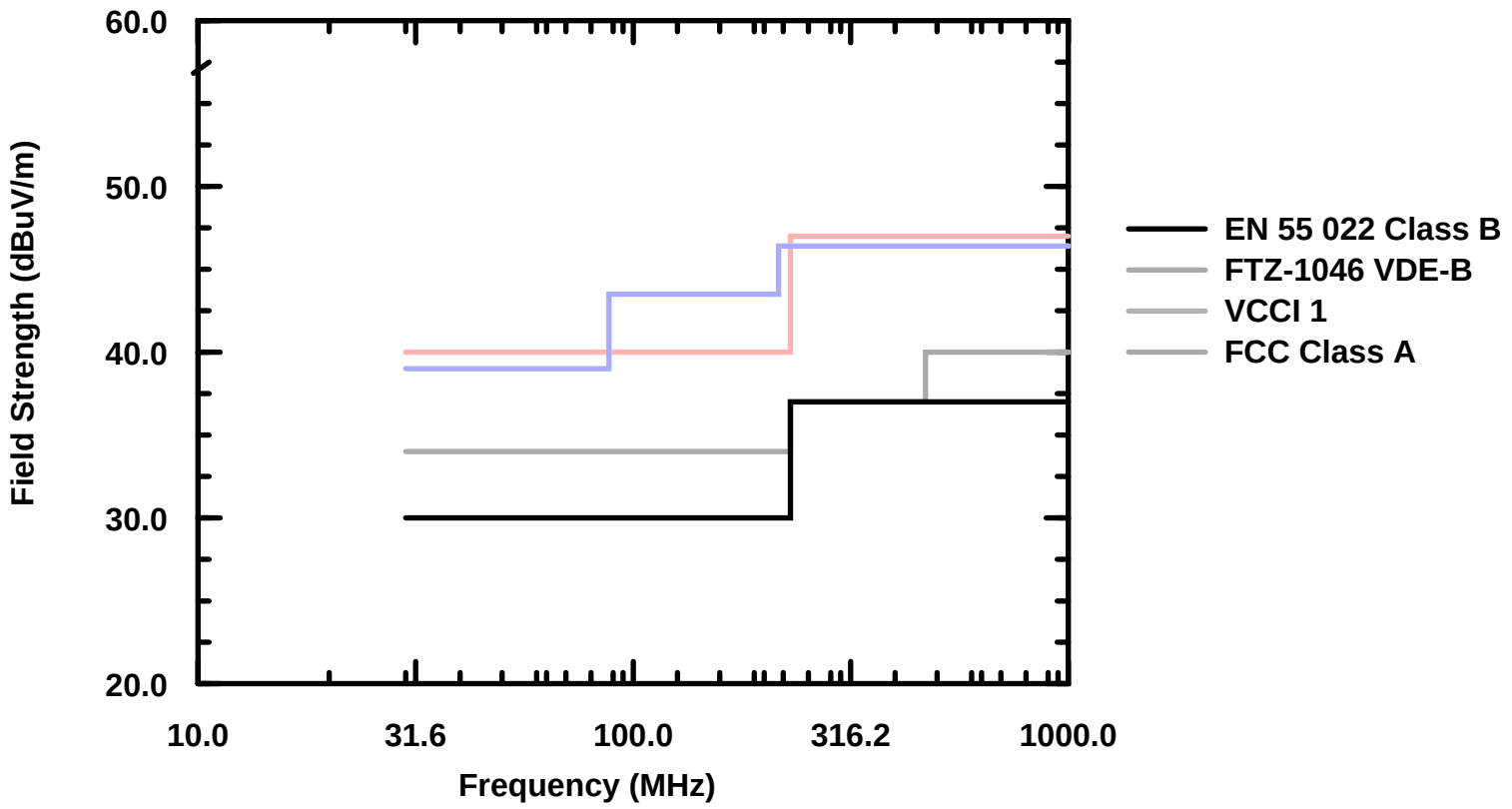
Background

- During the last five years several LAN standards have specified ~100Mb/s cat. 5 UTP physical layers:
  - FDDI TP-PMD, 100Base-T, ATM-155
- All of these support 100m of cat. 5 UTP
  - Distance specified in ISO 11801 and TIA 568 wiring standards for commercial premises.
- FCC class B radiated emissions has presented a major challenge for all of these standards.
  - Many measurements made, often with conflicting results (pass v. fail).

Twisted Pair Transmission Issues



Radiated Emissions

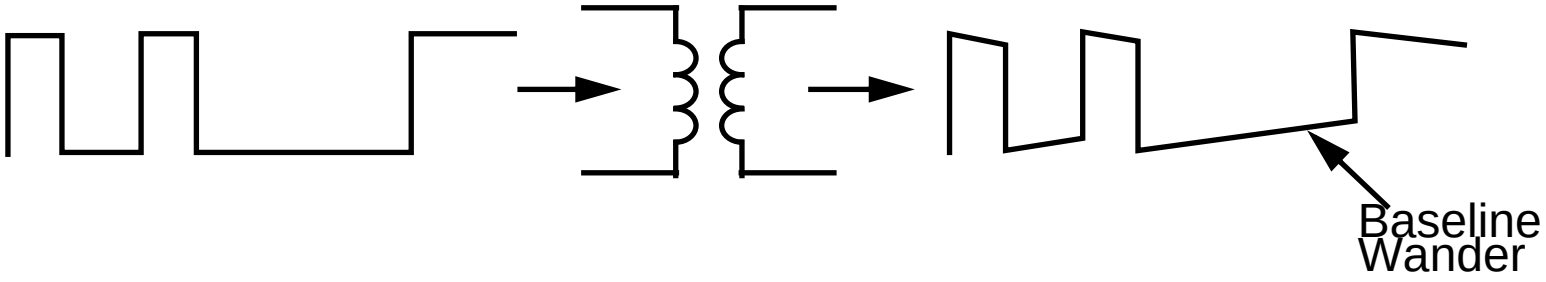


- Radiated emissions must not violate local regulations.

AC Coupling

- Transmitters and receivers are coupled to twisted pairs via transformers. Fiber optic receivers are also ac coupled.

- Signals with d.c. content or long runs of identical symbols will suffer *baseline wander.*

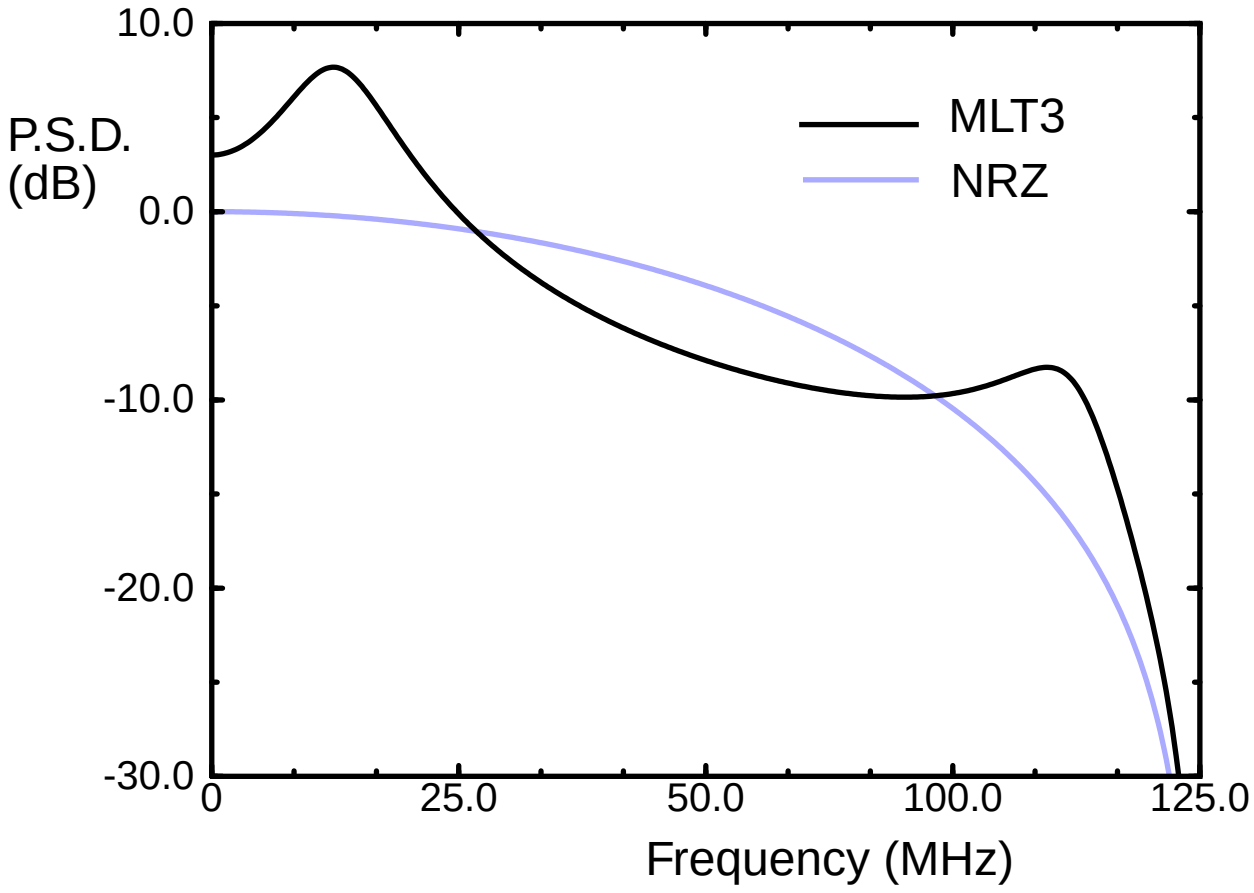


- Signals must be d.c. balanced and have small running digital sum - typical data is unbalanced and may have long runs of 1's or 0's !

100BaseTX/FDDI Approach: MLT3

- MLT3 is a three level line code which cycles through output states 0, +1, 0, -1, 0, +1..... An input of 1 causes a change of output state and an input of 0 causes no change of output state.
- MLT3 is a “pseudo-ternary” code: it does not reduce symbol rate nor the channel bandwidth requirement when compared with binary NRZ.
- MLT3 concentrates energy at low frequencies.
- The MLT3 p.s.d. is less than the binary NRZ p.s.d. at frequencies greater than 0.25 x bitrate - this allegedly results in lower radiated emissions.
- MLT3 has been adopted by FDDI TP-PMD and 100BASE-TX for 100 Mb/s transmission on a single cat. 5 twisted pair.

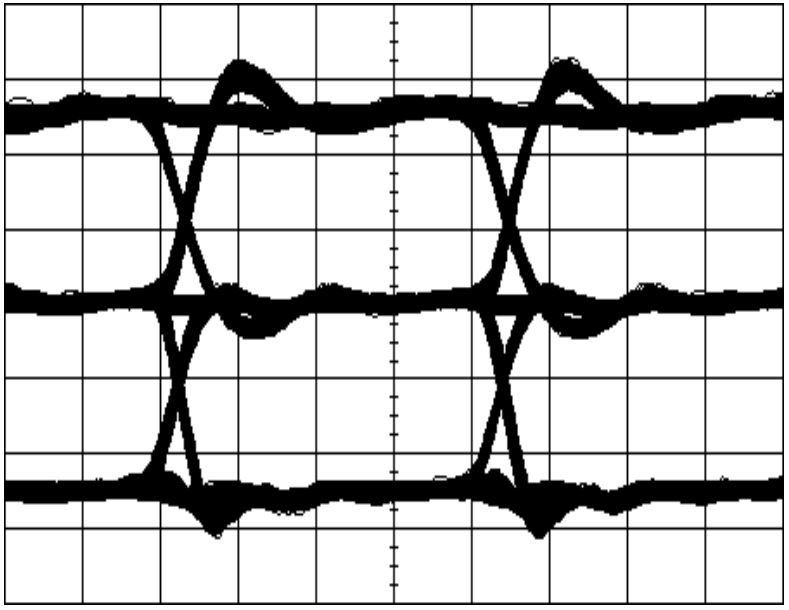
MLT3 Power Spectral Density



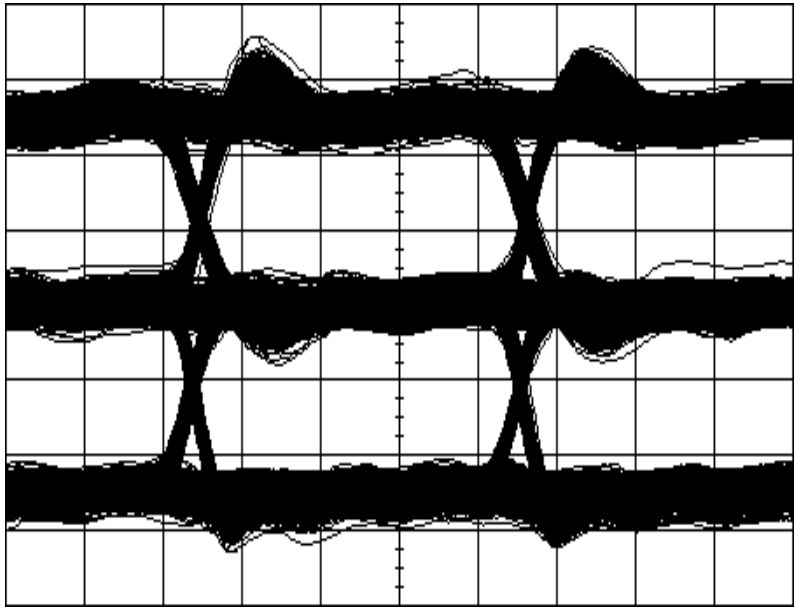
MLT3 Drawbacks

- **D.C. Content** - MLT3 has an unbounded running digital sum which can cause undesirable baseline wander.

with dc coupling

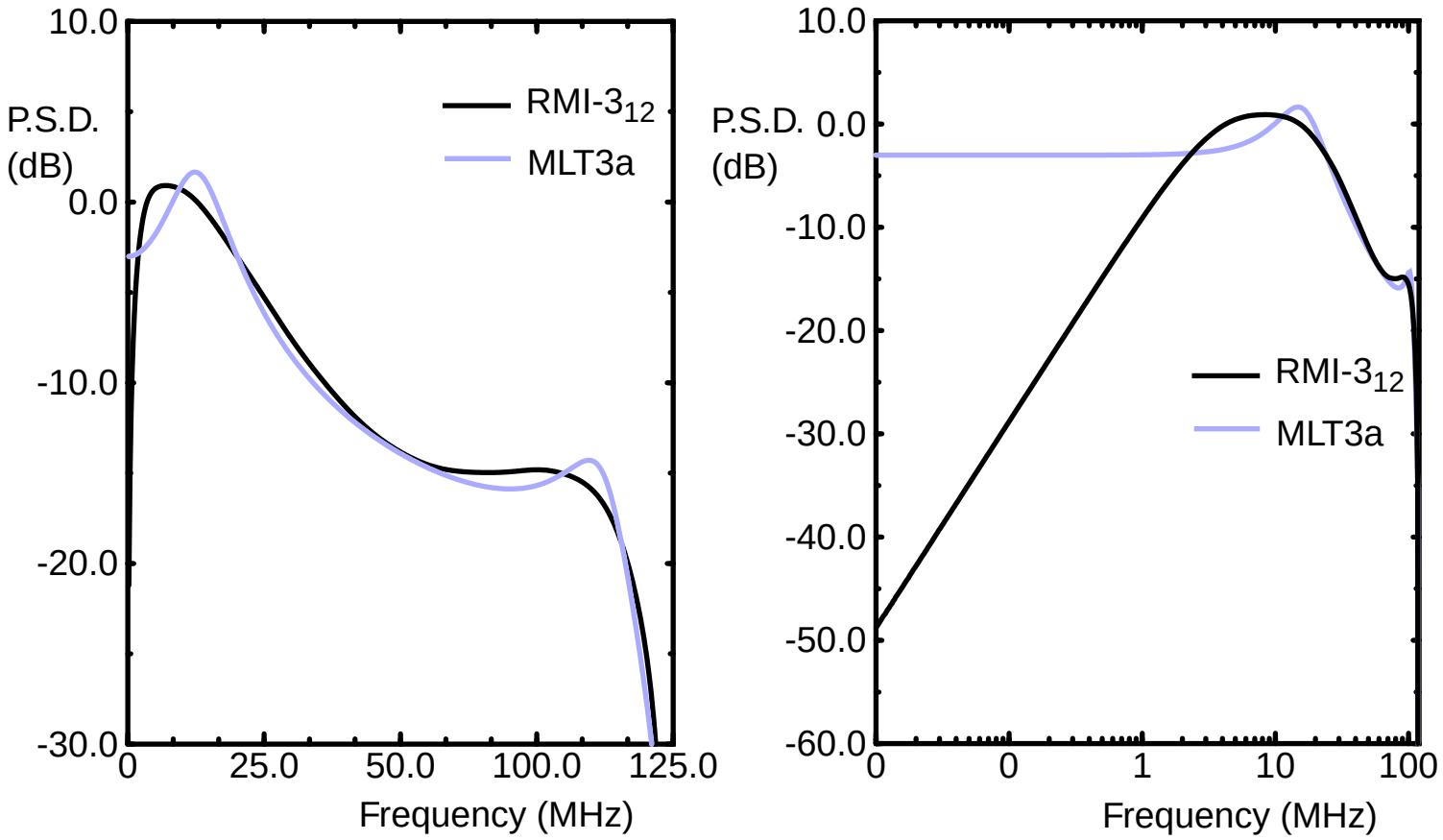


with ac coupling



- **Result:** reduced noise margin and need for dc restoration.

RMI-3: An improved 3 level code



- To fix the baseline wander problem, HP Labs developed the RMI code which is dc balanced and has similar psd to MLT3.

A. Coles, "New pseudoternary line code for high speed twisted pair data links", Electronics Letters, vol.31, 23, November 1995, p1976.

Drawbacks of MLT3 and RMI-3

- Three level pseudoternary codes can be used for spectral shaping, but they introduce a number of other problems:
  - For MLT3, dc restoration is needed.
  - For both MLT3 and RMI-3, two sampling thresholds are needed in receivers, and these must be adaptable to compensate for varying cable lengths (a two level system has a fixed threshold at zero).
  - For both MLT3 and RMI-3, better equalization is required to reach the same level of intersymbol interference as the equivalent two level system.

- The sampling errors and distortion introduced in practice negate the benefits of the spectral shaping.

- **Two level systems are *much easier* to build.**

Another way to reduce emissions...

...is to reduce the maximum cable length.

- Category 5 UTP attenuates 100Mb/s (125Mbaud) signals by 1.7dB per 10m.

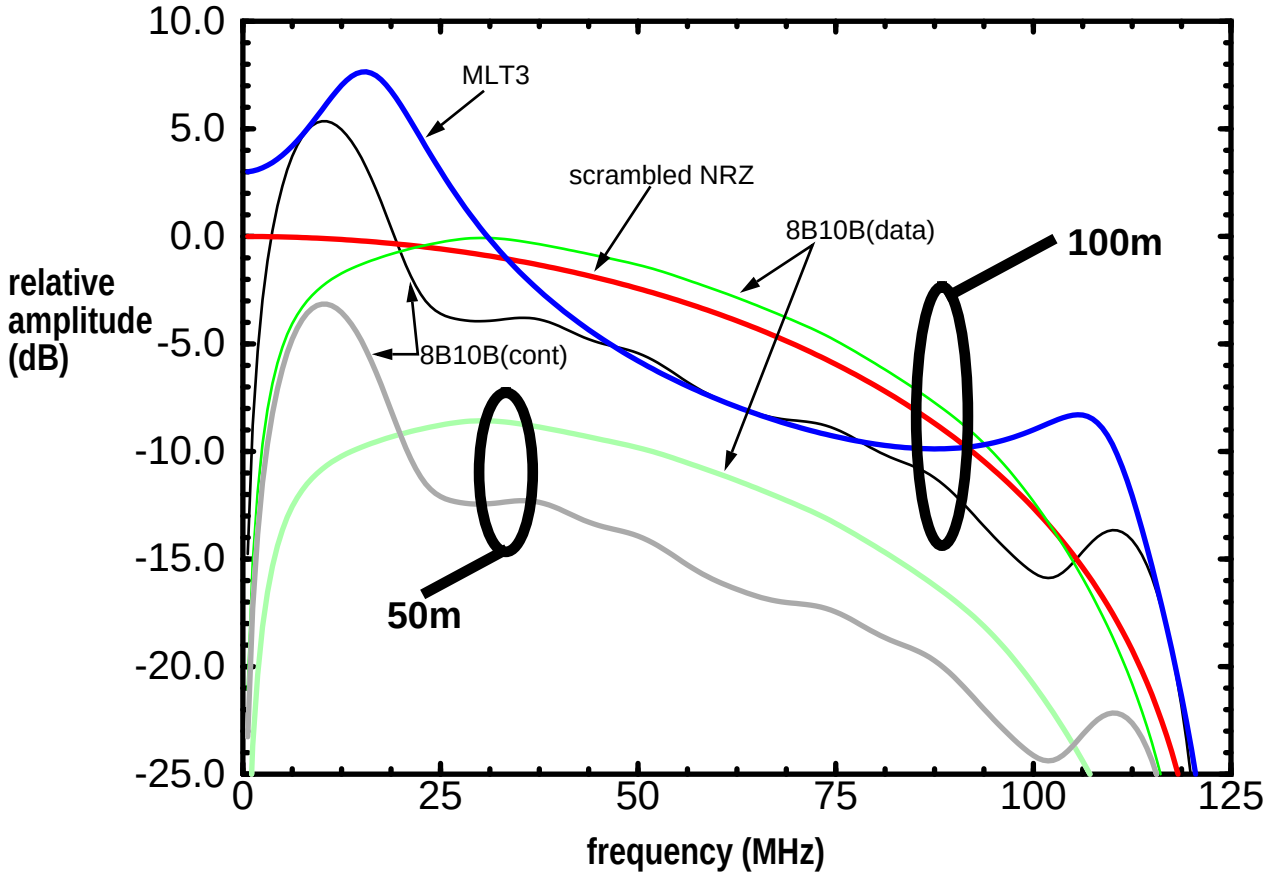
$$\text{Atten} = 2.06 \times \sqrt{\text{Freq (MHz)}} + 0.013 \times \text{Freq (MHz)} \quad \text{dB/100m}$$

Atten = 17 dB/100m @ 62.5 MHz

- Reducing the cable length by 25m and transmit voltage accordingly achieves the same emissions reduction as MLT3 in theory, more in practice.
  - Also allows simpler equalization.

- Since likely S100 1394B applications are not constrained by commercial wiring standards, lengths shorter than 100m should be considered.

S100 spectra v. cable length



All spectra calculated assuming equal symbol separation and noise margin at the receiver input.

Coding options for S100 1394B

- MLT3 should not be considered due to baseline wander problems and implementation complexity.
- Scrambled 4B5B and modified 8B10B spectra are equivalent.
  - Major differences are below 30 MHz where radiated emissions regulations do not apply.
- Scrambled 4B5B is unbalanced and baseline wander is still a problem.
- 8B10B has approx. 40 nsecs greater latency than 4B5B.
  - Equivalent to approx. 10% of a 75m cable.
- An 8B10B S100 extender has been demonstrated by HP Labs, and is being redesigned with modified 8B10B scheme.

Summary

- Existing 100Mb/s cat. 5 UTP solutions (FDDI, 100BaseTX) suffer from baseline wander and implementation complexity, and should not be adopted for S100 1394B.
- Two level coding schemes are much easier to build.
- ***Modified 8B10B scheme is suitable for S100 on UTP and POF, as well as higher speeds.***
- Allows common approach to all 1394B speeds and distances.
- Maximum UTP cable lengths shorter than 100m should be considered (*for any coding scheme*).
  - Lower emissions
  - Easier equalization