FAST/GIGABIT ETHERNET CONSORTIA

Ethernet Cable Plants

Technical Document

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MODIFICATION RECORD

- December 10, 2004 (Version 3.0)
  Jon Beckwith: Added percent attenuation cable plant section
  Added GEC Standards
  Changed formatting, added TOC and modification record

- February 6, 2003 (Version 2.0)
  Austin Boech: Changed formatting, and added several figures

- January 8, 2003 (Version 1.0)
  Austin Boech: Initial Release

Purpose

This Document is to assist any Fast Ethernet technicians in the creation of a high and low attenuation cable plant.

Equipment/Tools

A technician will need Cat-5 cable (preferably both solid and stranded), wire cutters, RJ-45 terminals, RJ-45 crimper, wire punch-down, 2 Ethernet patch panel, razor blade, DSP-4000 Flukes with the standard setting at Category 5n Channel, 100 Ohm UTP cable, and 50-60˚ C temperature.

Attenuation

Attenuation is a general term that refers to any reduction in the strength or intensity of a signal. In the case of Fast Ethernet it is the loss of an analog signal on pairs 1,2 and 3,6 over category-5 unshielded twisted pair (UTP) cable. Sometimes called *loss*, attenuation is a natural consequence of signal transmission over long distances. Attenuation results from the absorption of energy and of the signal scattering out of the path to the detector, however it does not include the reduction due to geometric spreading. The extent of attenuation is usually expressed in units called decibels (dBs).

Crosstalk

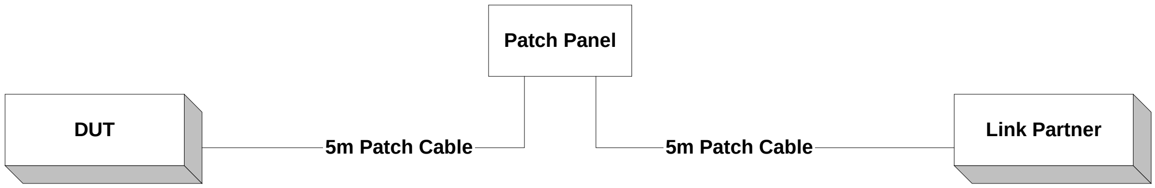
Crosstalk is a disturbance caused by the electric or magnetic fields of one telecommunication signal affecting a signal in an adjacent circuit. The phenomenon that causes crosstalk is called electromagnetic interference (EM). In the case of Fast Ethernet it is caused when one twisted pair's signal interferes with another. This phenomenon will cause noise that in turn may cause the device to misinterpret the signal.

Patch Cables

Annex N.3.4.4 in the ANSI-TIA-EIA-568-B-2001 standard states that category 5 UTP patch cables should be made out of stranded conductors. A benefit of using stranded cabling is its versatility. The solid cabling is more rigid and not as convenient to work with. The patch cables should be 5 meters in length. There should be 2 pass-through cables and one crossover. Each patch cable should be labeled with colored tape for convenience.

Low Attenuation Cable Plant

The back of a patch panel has 2 rows of cable slots, usually labeled by a color scheme of something like brown, green, orange and then blue. The top row is identical to that of the bottom. Take enough Cat-5 cable to connect the bottom row of pair-slots to that of the top, strip off the plastic coating of the cable to make it easier to work with. Connect the top row pairs to that of the bottom rows, so brown with brown, orange with orange, etc. Now if 2 patch cables are plugged into the appropriate ports of the patch panel, the total length of the plant is approximately 10 meters. This is what is used for the low attenuation cable plant and the setup should appear as follows:



Use the DSP-4000 Fluke to make sure the connection is good (no crossover or broken link) and that the NEXT and NEXT-at-REMOTE (cross-talk) values pass. If the cross-talk values do not pass, make sure that the wires connecting from the top row to the bottom row are straight and don't touch other pairs or cross over with them. If they still fail, fiddle with the wire arrangement or start all over (this occurrence is rare, cross-talk usually passes over low attenuation).

High Attenuation Cable Plant

Derivation of Insertion Loss Values.

The standard defines the maximum length allowed for Fast Ethernet cable as 100 meters. In order to create a high attenuation cable plant, the total length that a signal will travel over will be about 120-130 meters. This is because a cable of this length will approach the actual limit of attenuation that the standard defines. The high attenuation cable plant is made to account for all possible cable plant scenarios that may exist in the real world. The job of the technician is to tune the plant to be between 1-5% above the margins specified in ANSI-TIA-EIA-568-B-2001 or other applicable specifications. In annex N.3.4.1 it states that the worst case insertion loss for any pair, measured at or corrected to 20^{o}C, should in accordance with ASTM D4566 should be less than or equal to the value determined by the following equation

$$InsertionLoss \le 1.967\sqrt{f} + 0.023f + \frac{0.05}{\sqrt{f}} \qquad (1)$$

Where f is frequency in MHz.

Most of the power in Fast Ethernet technology is transmitted at a power where the frequency equals 16 MHz, therefore the reference frequency that FE uses to determine the high attenuation insertion loss is 16 MHz. The worst-case (high attenuation) channel scenario is listed in section 11.2.4.4 of the ANSI-TIA-EIA-568-B-2001 standard and the insertion loss is derived as the sum of:

a) The insertion loss of 4 connectors
b) The insertion loss of 10m of UTP patch cablemoq2
c) The insertion loss of 90m of cable at 20^{o}C

The insertion loss of connecting hardware is specified in section N.3.4.3 where at 16 MHz, the insertion loss should not exceed 0.2 dB. The total length of sections b and c of the channel only add to 100m but our concern is not length but attenuation. The insertion loss for 16MHz using equation N-5 equals 8.2485 dB. this value must be corrected according to the note under table 11-2 in the ANSI-TIA-EIA-568-B-2001 standard, insertion loss increases with temperature and must be increased by 0.4% per degree Celcius. We want the worst case cable plant scenario so we tune our plant to a temperature of 60^{o}C.

The following calculations show the derivation of an attenuation of 10.4 dB at 16 MHz@60^{o}C:

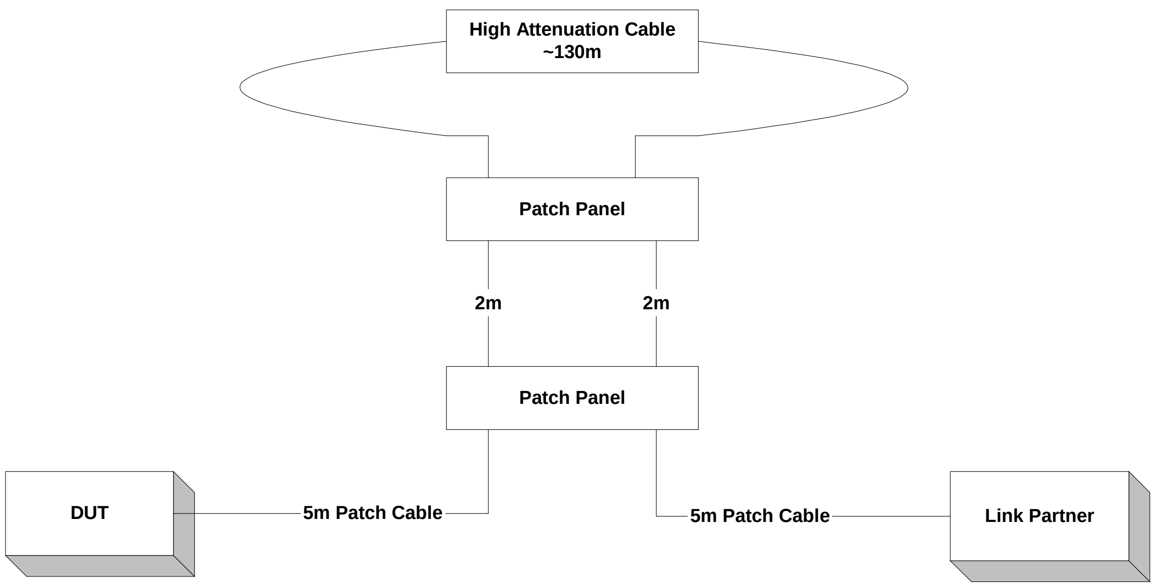
$$\text{Insertion Loss}_{total} = \text{Insertion Loss}_{channel@20^oC} + \text{Insertion Loss}_{4\ connectors} + \text{Insertion Loss}_{correction@60^oC}$$

a) $\text{Insertion Loss}_{channel@20^oC} = 1.967\sqrt{(16)} + 0.023(16) + \frac{0.05}{(16)}$ = 8.2485 dB

b) Insertion $\text{Loss}_{4\ \text{connectors}}$ = 4dB(0.2) = 0.8 dB
c) Insertion $\text{Loss}_{\text{correction@60}^{o}\text{C}}$ = 0.004(60°C - 20°C)(8.2485dB) = 1.31976 dB
d) Insertion $\text{Loss}_{\text{total}}$ = a + b + c = 10.36826 dB ~ 10.4 dB

Creating a High Attenuation Cable Plant

To begin the development of a high attenuation cable plant a technician should measure out two 2m lengths of category-5 UTP cable and punch them down between two patch panels. These 2m lengths of cable are used to damper out any reflection effects that the patch panels create. Measure out 130 meters of Cat-5 UTP cable and terminate both ends with RJ-45s, this will be used as the main attenuation cable. Connect both ends of the 130m cable into one of the cable plants. Connect the two 5m patch cables that were previously made into the appropriate ports on the other patch panel. The set up should appear as follows:



Measure the attenuation of the high attenuation cable plant by connecting the free ends of the patch cables in the Fluke DSP-4000 devices. Cut the attenuation cable accordingly (don't cut too much initially try 0.5m to start) until the readout on pairs 1,2 and 3,6 are 10.4 dB@16MHz. If the attenuation on pairs 1,2 and 3,6 are not the same then find which pairs have the same attenuation and change the pair sequence in the patch panels accordingly. Switch one of the patch cables with the crossover patch cable and make sure that the attenuation readings are ~10.4 dB@16MHz.

High Attenuation Crosstalk

The ANSI-TIA-EIA-568-B-2001 standard states that from 1 to 100 MHz, the minimum category 5 NEXT loss for any pair combination at room temperature should be greater than the value determined by equation (2):

$$NEXT \geq 32.3 - 15\log\left(\frac{f}{100}\right) dB \qquad (2)$$

Where f is the reference frequency, again for Fast Ethernet we use 16 MHz. This gives a minimum NEXT value of 44.2382 ~44.2 dB.

Plug the high attenuation cable plant into the Fluke DSP-4000 and test the near end cross talk or NEXT. The readout should pass on all pairs and should be 44.2 dB @16MHz on pairs 1,2 and 3,6. Now test the NEXT at remote, the readout should pass on all pairs and should be 44.2 dB @16MHz on pairs 1,2 and 3,6. To tune the crosstalk to these specifications, take the 2m lengths of cable and pull the end that is connected to the furthest patch panel. Try different combinations of twisting pairs together and overlapping them, untwisting pairs and twisting the individual wires with different wires, then punch the pairs back down into the patch panel and retest. The process of tuning crosstalk is one of trial and error.

Percent Attenuation Cable Plants

To test a range of attenuation values, you need several percent attenuation cable plants. Unfortunately, there is no easy way to do this. You need to start with a cable plant that is too long and cut it shorter to obtain the percent attenuation you are looking for. Follow the same procedure outlined in the high attenuation cable plant section above (measure the attenuation, cut off 0.5m, etc.).

Calculating the percent attenuation can be a bit tricky. The formula for calculating percent attenuation is given below.

$$\% Atten = 100 - (((Limit - Attenuation) / Limit) * 100) \tag{3}$$

Because going back and forth between the Fluke and the PC would be incredibly tedious, the table below shows the attenuation values at 16 and 32MHz for the limit given in equation (1). Checking these two frequencies gives us confidence that the entire cable plant will accurately represent the desired percent attenuation.

Table 1: Attenuation values for calculating percent attenuation for the FEC limit

Percent Attenuation	Attenuation at 16MHz	Attenuation at 32MHz
10%	0.82	1.19
20%	1.65	2.37
30%	2.47	3.56
40%	3.30	4.75
50%	4.12	5.94
60%	4.95	7.12
70%	5.77	8.31
80%	6.60	9.50
90%	7.42	10.68
100%	8.25	11.87

Gigabit Ethernet Standard

These values are only valid for Fast Ethernet. For Gigabit Ethernet, the maximum attenuation and NEXT are specified in IEEE 802.3-2002 Clause 40.7. This equation is an approximation to the one found in the TIA/EIA 568-B-2 in section 4.3.4.7. In this case, the following equations and tables apply.

$$InsertionLoss \leq 1.967\sqrt{f} + 0.023 \cdot f + \frac{0.050}{\sqrt{f}} \tag{4}$$

$$NEXT \geq 35.3 - 15\log_{10}(f/100) \quad (5)$$

The insertion loss specification shall be elevated by a factor of 0.4% increase per °C. This leads to the values in table 2.

Table 2 shows the attenuation values for 16 and 32MHz for the limit given in equation (4).

Table 2: Attenuation values for calculating percent attenuation for the GEC limit

Percent Attenuation	Attenuation at 16MHz	Attenuation at 32MHz
10%	0.96	1.38
20%	1.91	2.75
30%	2.87	4.13
40%	3.83	5.51
50%	4.78	6.89
60%	5.74	8.26
70%	6.70	9.64
80%	7.65	11.02
90%	8.61	12.39
100%	9.57	13.77

References:

1) ANSI/TIA/EIA-568-B-2001; Section 11.2.4.4; Annex N.3.4

2) IEEE Std 802.3, 2001

3) ASTM D4566