Transparent Factory
Network Design and Cabling Guide

490 USE 13400 eng Version 1.0

35002987

Table of Contents

About the book

At a Glance

Document Scope

This book describes how to design an ethernet network and gives recommendations to perform a good cabling.

Validity Note

Recommendations included in this manual can be applied to any ethernet network.

Revision History

Rev. No.	Changes
1	Initial version.

Related Documents

Product Related Warnings

User Comments

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Introduction to Ethernet Network Design

1

Introduction

Overview

This chapter describes some basic information about the way to design an ethernet network.

What's in this Chapter?

This Chapter contains the following Maps:

Ethernet Network Design overview

Overview

Designing an Ethernet Network starts by a description of the targetted application. Three main aspects must be taken into account in this description :

- the **topological aspect** (Chapter 2)
- the **data flow** evaluation (Chapter 3)
- and the needs for **redundancy** requirements (Chapter 4).

After this first step that defines the requirements of the installation, network design must fullfill these following requirements. To work correctly, the network architecture must comply with specific rules :

- **Ethernet distances and Rules** (Chapter 5)
- **EMC rules** (Chapter 6).

Networking product

End Stations

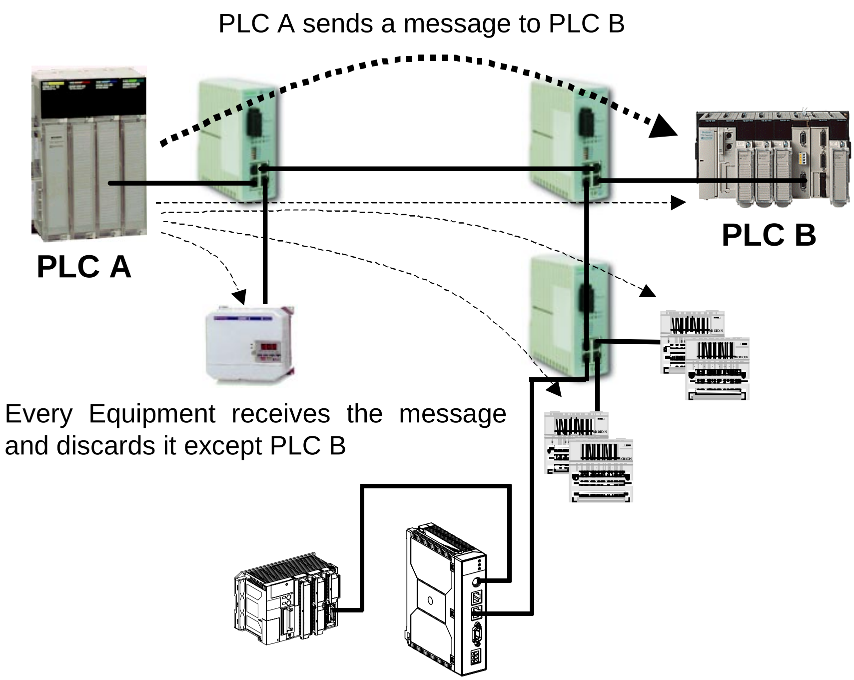
End stations are the devices you want to connect together via the network. They are the entities which communicate, which send and receive datas.
These devices are :

- PC connected to Ethernet using a PCMCIA, PCI or ISA card.
- PLC as Quantum connected with a NOE, Premium using a ETY module, or M1E with an embedded Ethernet connection, Micro using a ETZ module.
- I/O device as Momentum ENT with Ethernet Top_Hat.

These End Stations are called Data Terminal Equipment (DTE) in the Ethernet Standards. Nodes or Stations can also be used in documentations.

Hubs

Hub has several ports for connection, all frames or collided signals received on one port are repeated on all the others ports.
Synonyms : Repeater, Starcoupler
It is possible to cascade several repeaters. In this case crossed cable must be used to connect hubs together.
The figure below shows the functionality of hubs:

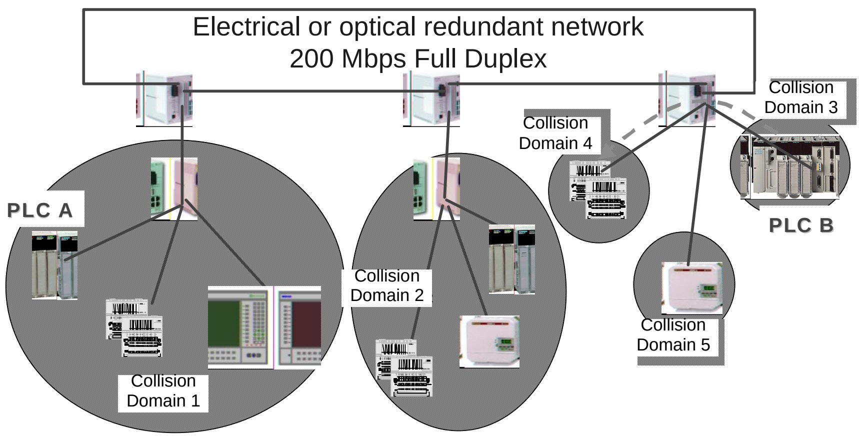


Transceivers

The transceiver functionality is to change the medium. It can have two ports, one is in 10 Base T with copper twisted pair and the other in 10 Base FL with optical fiber for example.

Switches

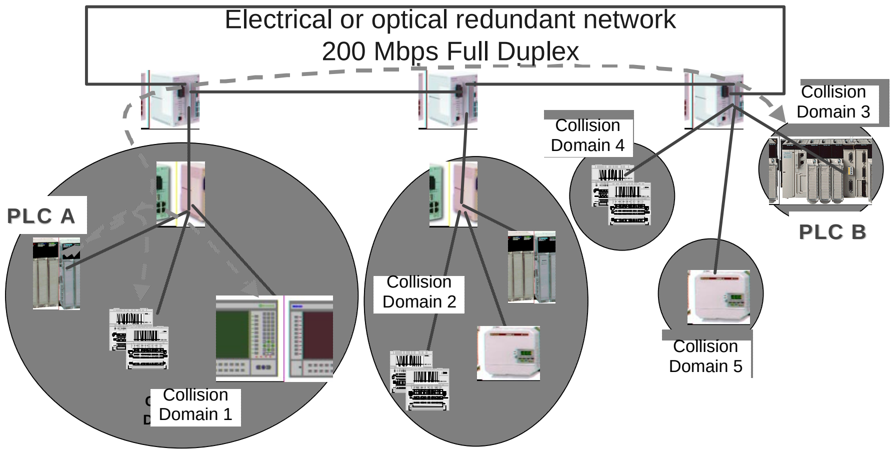
Switches are working at the Level 2 of the ISO model.
When they receive a frame they **discard bad frames** (too long, too short, or with CRC errors) and they do **not propagate collision**. In this way they are used as a border and a link between two collison domains. This feature **expands the length limits** fixed by collision domain rules.
A switch is also **a filter** : it learns MAC address of nodes connected to each port. And when it receives a frame it repeats it only on the port where the node with this destination address is connected.
Obviously, when the destination adress is a broadcast or multicast address, or when address has not been learnt yet, the frame is repeated on all other ports of the switch except if the switch provides of the filtering feature of the multicast frames.
With this filtering feature, when we connect two network segments with a switch, only useful frames are propagated, and so, data bandwith is improved.
Ports of switches can also have full-duplex feature. It means that it is possible to transmit and receive at the same time. The network bandwith is improved up to 200 Mbps. This feature can be used to connect two switches together, or one full-duplex station on one port.
Here is an example of switches:



Global Architecture

Description

The global architecture of an Ethernet Network is divided in different **Collision Domains** which are linked together by **switches**.
In each Collision Domain each node participates in collision resolution protocol and must be compliant with rules and distances of this domain.
Domain can be at 10 Mbps (Ethernet) or at 100 Mbps(Fast Ethernet). The choice of the baud rate depends on technical characteristics of the connected nodes and of the needs of bandwith requested by the application.
Switches are used for **separation of data flow** of different domains, and they are used also to **improve the distances** limited in the domains.
Example:



Site Plan

2

Site Plan is necessary:

Why a site plan is necessary?

The Site Plan must be done to describe the application on a topological and physical point of view, you will find on it :
- Location of different zones and machines
- Location of stations and nodes
- Location of existing networks
- Location of existing cabling path
- Location of hazardous area for EMC
- Location of redundant path

What does it give?

This site plan will give information on:
- relative position of nodes that must be linked together
- distances between nodes
- distances with existing networks
- situation of hazardous area of EMC

Data Flow

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Description

Overview

The Data Flow of the different stations connected together must be described.
For each flow:

- give volume and frequence
- calculate necessary bandwith

All details about data flow per communication services are describe in manual "Transparent Factory Ethernet User and Planning Guide (490USE13300).
Build a cross table of all stations in order to make groupes and so, determine the use of switches

Note: Use 8% to 40% of availabe bandwith on each domain in order to prevent collision avalanches.

Redundancy

4

Introduction

Overview

This chapter explains redundancy of power supply and network.

What's in this Chapter?

This Chapter contains the following Maps:

Power supply redundancy

Overview

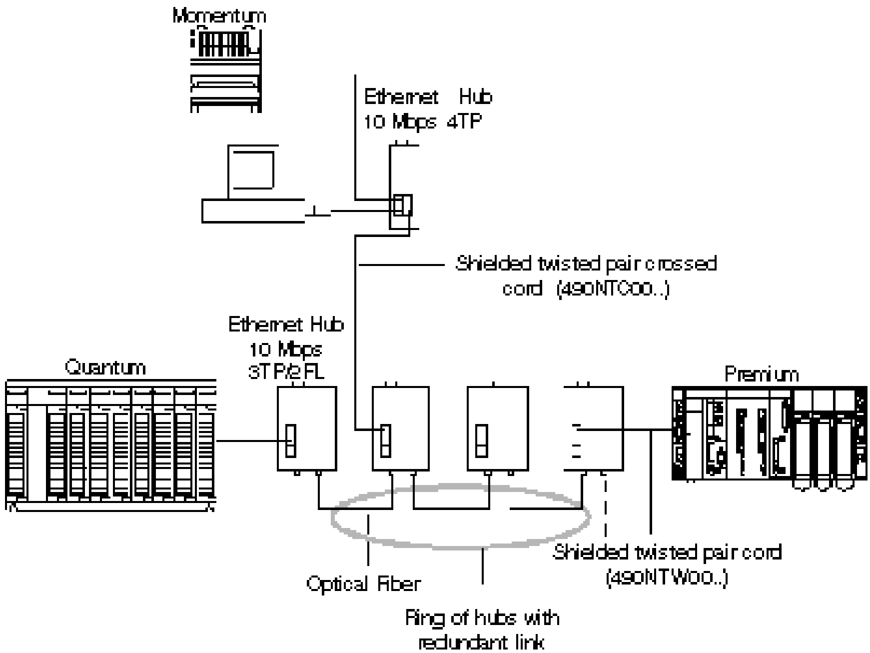
Power supply redundancy is available on each Schneider Automation Hub, Transceiver or Switch.
You can connect two power supplies on the terminal block. Both inputs are decoupled, there is no load distribution, the power pack with the higher output voltage supplies the device.
The failure of at least one power supply is indicated by the indicator contact (relay contact, closed circuit), by leds on the front panel or by SNMP traps on managed products.

Note: If power supply is routed without redundancy, product indicates a failure. You can prevent this message by feeding in the supply voltage through both inputs.

Network redundancy

10 Mbps optical ring

Using the TF Ethernet Hub 3TP/2FL 499NOH00510, it is possible to build a ring of Hubs cascaded together via their optical ports (ports 4 and 5). In case of failure of one Hub or one line, a bus structure is still working.
One of the Hubs on the ring must be the redundancy manager. This function is activated by the dip switch R5. (Default state of this switch is off : redundancy management not activated)
Redundant ring structure via F/O ports of the hub 10 Mbps 3TP/2FL :



Ring of 100 Mbps switches

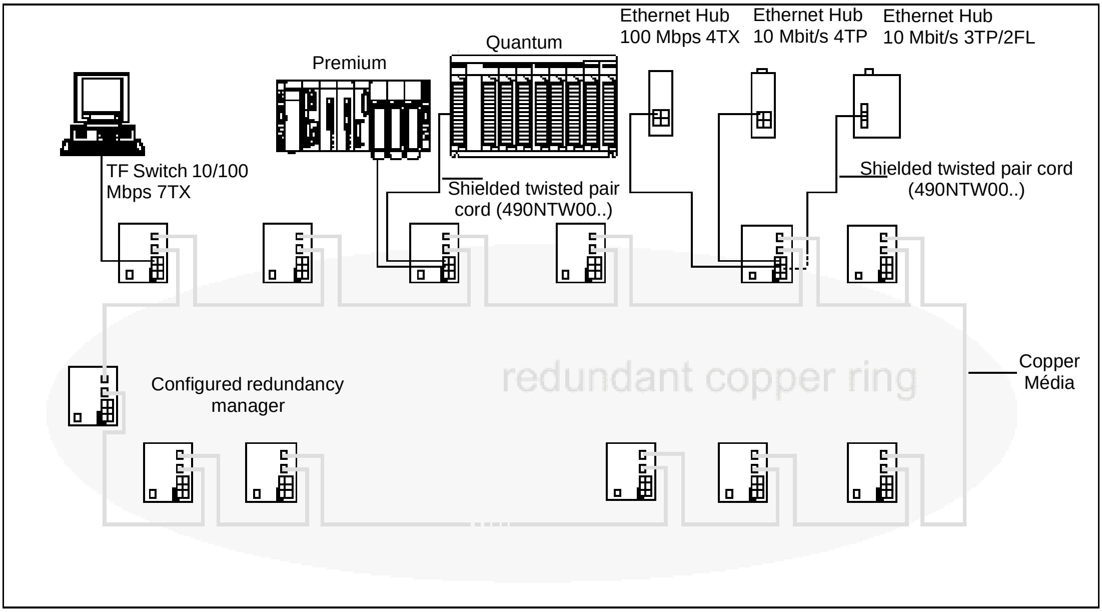
Using the TF Switches 5Tx/2Fx or 7Tx (499NES07100 or 499NOS07100), it is possible to build a ring of Switches linked together via their ports 6 and 7. In case of failure of one Switch or one line, a bus structure is still working in less than 500ms when 50 Switches are connected.

One of the Switches on the ring must be the Redundancy Manager. This function is activated by the dip switch RM.

Default state of this switch is off : redundancy management not activated.

On all switches of the ring the ports 6 and 7 must be in their configuration default settings : 100 Mbps, Full Duplex, Autonegociation.

Redundant copper ring structure



Redundant link between network segments

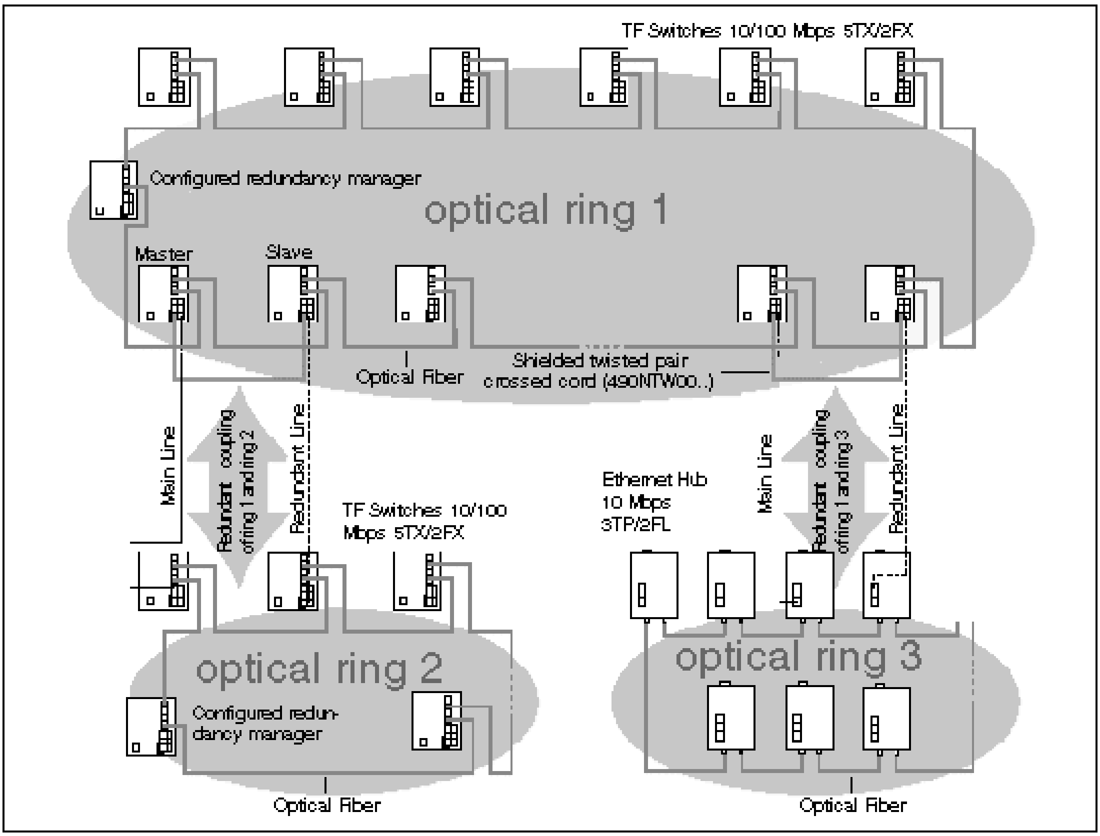
The TF Switches 499NES07100 and 499NOS07100 allow to built a redundant link between two networks segments.

In normal mode the link between the optical ring 1 and the optical ring 2 is managed by the "Master" Switch via the main line on its port 1. In order to create a redundant line between these two rings, a second swich called "Slave" is used :

- Master and Slave are connected together on their Standby port via a crossover twisted pair (490NTC00***).
- The Standby function must be activated on the Slave Switch setting. The Dip-switch standby in the ON position.
- The Slave Switch is linked to the Ring 2 on its Port 1. This link is the redundant link.

If the main line fails, within 0.5s, the redundant NxS releases the redundant link. As soon as the main line is restored to normal operation, the Master NxS informs the redundant NxS. The main line is released and the redundant line is reblocked.

Redundant coupling of optical rings



Distances and rules

5

Introduction

Overview

In this chapter you will find a presentation of rules that must be applied when designing an ethernet network.

What's in this Chapter?

This Chapter contains the following Sections:

5.1 Designing a Single Collision Domain multisegment Network

Introduction

Overview

This section explains how this rules are linked to ethernet behaviour.

What's in this Section?

This Section contains the following Maps:

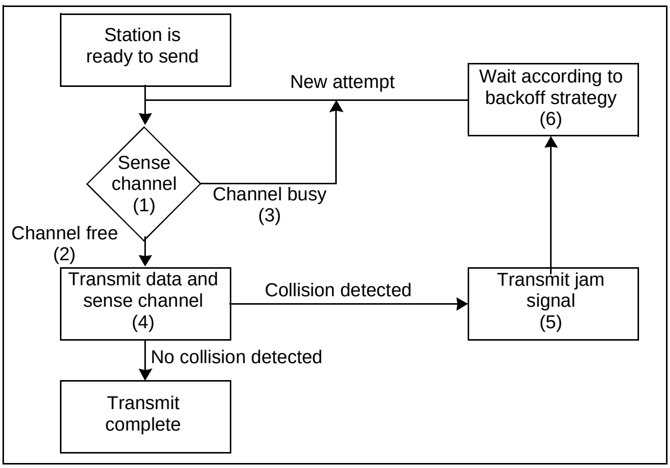
Standard Ethernet Rule 1: Collision Detection and Max Propagation delay

Ethernet Access Method: CSMA/CD Collision Detection

Each End Station (DTE) of the network monitors traffic on the net and , if there is no traffic, it starts transmitting data immediately.
The sequence of a transmission occurrence is the following :

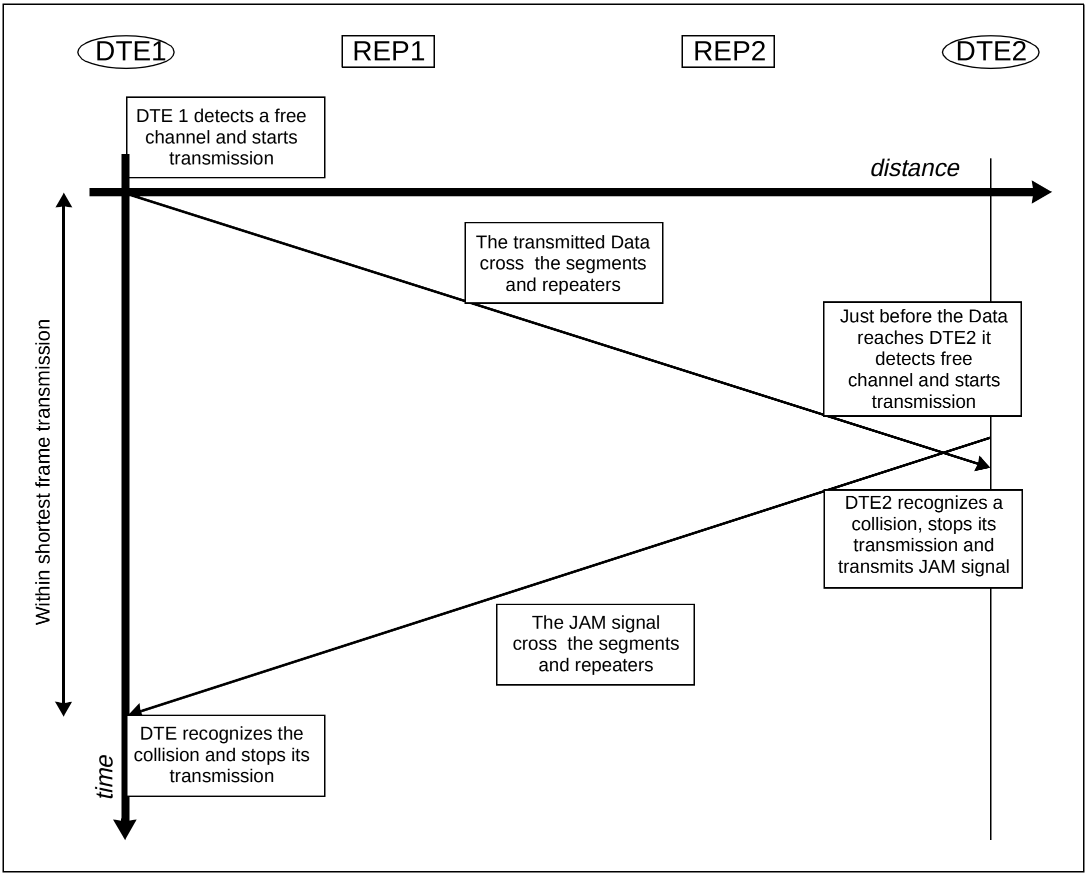
- Carrier Sense : Network members check to see if the transmission medium is available.
- Multiple Access : If the transmission medium is free, any DTE starts transmitting data.
- Collision Detection : If several DTEs send data simultaneously, a data collision will occur.
  Collision is detected by each DTE and transmission is terminated. A random calculation occurs in each DTE to determine when the station will be able to send data again.

The complete sequence to send data is:



Ethernet Rule 1: Maximum Round Trip Collision Propagation Delay

This first rule is the consequence of this Access Method when it's applied to transmission of shortest frames (64 bytes = 512 bits after Start Frame Delimiter). Figure below illustrates transmission of such frame from DTE1 towards DTE2. DTE1 must detect collision created by DTE2 before end of its frame transmission. Signal has time to propagate until the farest station (DTE2) which transmit just before receiving, and the collided signal has time to come back to the first station (DTE1) which detect collision. This time for signal to go to the farest station and come back in the collided form is called the Round Trip Collision Propagation Delay. And so, maximum value of Round Trip Collision Propagation Delay must be below the duration of shortest frame transmission.



As the Calculated Propagation delay is the sum of all delay time of components and media (cables and optical fibers), this rule will limit the number of repeaters (Hubs and Transceivers) and the total length of cables and fiber.

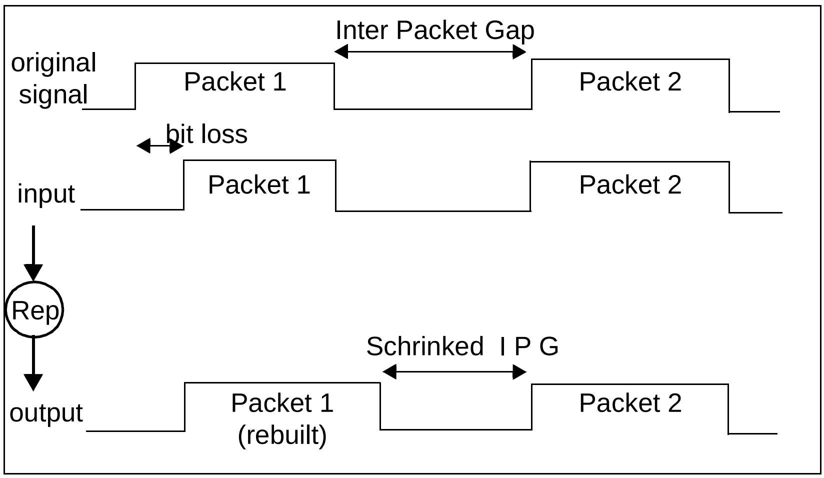
Standard Ethernet Rule 2: Inter Packet Gap Shrinkage

Interframe spacing

Ethernet 10/100 Mbps Standards specify a minimum interframe spacing of 96 Bit Time. This is intended to provide interframe recovery time for other CSMA/CD sublayers and for the physical medium.

Shrinkage of Interpacket gap

The varying bit loss (preamble) of two successive data packets on the same path can cause the interpacket gap to shrink. As a repeater regenerates the lost preamble bits of any packet passing through it, every packet is totally rebuilt. If the first data packet loses more preamble bits than the subsequent packet, then the gap will be reduced.
Exemple of Inter Packet Gap shrinkage:



The following rule fix limit of this Inter Packet Gap shrinkage :
The spacing between two successive non colliding packets can have a minimum value of 47 bit times at the AUI receive line of the DTE. (Std 802.3). That rule allows a schrinkage of 96-47 = 49 bit maximum.
As Inter Packet Gap shrinkage could appear at each pass through a repeater, this rule restricts the amount of Hubs and transceiver between two nodes.

Physical layer limits

Ethernet 10 Mbps

Two different physical layers are used on Transparent Factory Ethernet 10 Mbps:
- Ethernet 10 Base T, using Shielded and Foiled Twisted Pair (SFTP) cables with RJ45 connectors,
- Ethernet 10 Base FL, using 62.5/125 Multi mode fiber with ST connectors.

Both physical layers have physical constraints that limits length of medium.

	Schneider Automation Limits	Std 802.3 Limits
Max length of a twisted pair trunk	100 m	100 m
Max length of a 62,5/125mµ multi mode optical fiber	3100 m	2000 m

Note: These limits must never be overridden.

Ethernet 100 Mbps

Two different physical layers are used on Transparent Factory Ethernet 100 Mbps:
- Ethernet 100 Base Tx, using Shielded and Foiled Twisted Pair (SFTP) cables with RJ45 connectors,
- Ethernet 100 Base Fx, using 62.5/125 Multi mode fiber with SC connectors.

Both physical layers have physical constraints that limits length of medium.

	Schneider Automation limits	Std 802.3 Limits	
Max length of a twisted pair trunk	100 m	100 m	
Max length of a 62,5/125mµ multi mode optical fiber	412 m	412 m	Half duplex
	3000 m	2000 m	Full duplex

Note: These limits must never be overridden.

5.2 Calculation Models in Ethernet 10 Mbps Domain

Introduction

Overview

This section describes the various 10 Mbps ethernet standard models

What's in this Section?

This Section contains the following Maps:

Standard Ethernet model 1

Description

This Model is described in Chapter 13.3 of Standard 802.3, it assumes that communication components are working within the physical limits described in the previous chapter.

This model defines simple rules to implement an Ethernet (10 Mbps) network :

- The transmission path between any two DTE may consist of up to **five** segments and **four** repeaters.
- When a transmission path consists of four repeaters sets and five segments, each individual segment in 10 Base FL shall not exceed 500m.
- When a transmission path consists of three repeaters and four segments the following restriction apply :
  - The maximum length of any inter-repeater fiber segment shall not exceed 1000 m for 10 Base FL.
  - The maximum length of any repeater to DTE fiber segment shall not exceed 400 m for 10 Base FL.

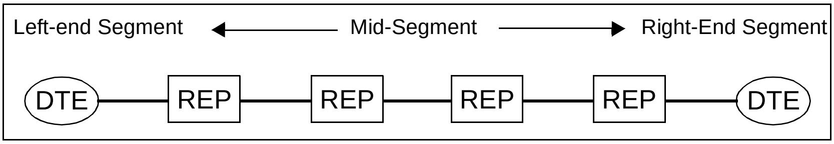
> **Note:** On 10 Base T segments the physical limit described in 5.1.3 must be applied.

> **Note:** Standard 802.3 gives additional rules in case of use of other components or medium such as 10 Base-FB, 10 Base-FP, AUI, etc. You must consult this document if necessary.

Standard Ethernet model 2

Description

The previous model is a simplistic approach that can guide a first level of network design.
Chapter 13.4, Standard 802.3 describes the transmission Model 2 which provides a more precise description on how to calculate the maximum network range.
This model consists of a series of segments including one left end segment, mid-segments, and one right-end segment:



Compliance with rule 1: Path Delay Value (PDV) calculation

The first step consist in selecting the worst –case path through the network. It is the path between two DTE which has the longest round-trip time.
Fixed Delay:
The Standard Ethernet Model 2 defines fixed delay values for each type of segment, depending of its position in the model. It defined also a Round Trip delay for each meter of medium (RT delay/m). Each delay is specified in Bit Time (BT) which represent 100 ns at 10 Mbps.

Segment type	Max length	Left-end Base delay	Mid-segment Base delay	Right-end Base delay	RT delay/m
10 Base T	100 m	15,25 BT	42 BT	165 BT	0,113 BT/m
10 Base FL	2000 m	12,25 BT	33,5 BT	156,5 BT	0,100 BT/m

Note: 0,113 BT = 11,3 ns/m which means a propagation velocity of 5,65 ns/m.

Segment Delay Value :

SDV calculation:
With this table the Segment Delay Value of each segment can be determine with following formula :

SDV = Base delay + [Length*(Round-Trip delay/meter)]

For example the SDV of a Right-End segment of 80 m in 10 Base T is :

SDV = 165 BT + 80m * 0,113 BT/m = 165 BT + 9,04 BT = 174,04 BT

Path Delay Value :

PDV calculation:
The PDV is the sum of all SDVs of the path plus a margin of up to 5 bits.

Note: In application of the Ethernet rule 1 the PDV must not exceed 575 BT

Note: If a candidate for worst case path has end segments of different types, calculation must be performed twice,considering first one end segment as the left end and then the other, and the maximum value obtained used as the PDV.

Note: Standard 802.3 gives additional information in case of use of other components or medium such as 10 Base-2, 10 Base-5, AUI, etc. You must consult this document if necessary.

Compliance with rule 2: Path Variability Value calculation

SVV - Segment Variability Value :
The Standard Ethernet Model 2 defines fixed Segment Variability Values for each type of segment, depending of its position in the model.

Segment type	Transmit End Segment Left-end or Right-end segment	Mid-segment
10 Base T	10,5 BT	8 BT
10 Base FL	10,5 BT	8 BT

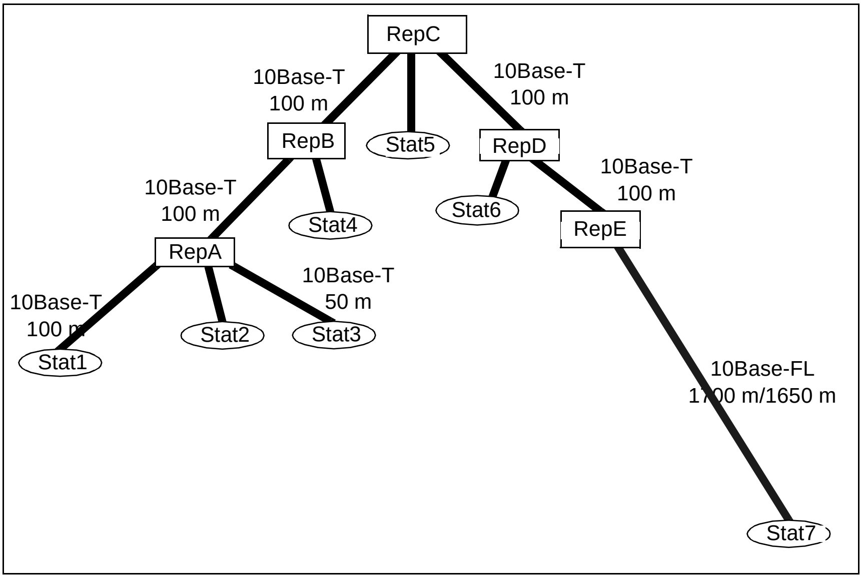
PVV - Path Variability Value :
The worst-case path through the network must be identified (highest number of segments) and its Path Variability Value validated.
In this scenario the receive end segment is not included, so the choosen Transmitting End Segment is the end segment with the worst SVV (it could be the case with other physical layers than above).
The PVV is the sum of all SVV of Mid-segments plus the SVV of the Transmitting End Segment.

Note: In application of the Ethernet Rule 2 the **PVV must not exceed 49 bit times**.

Note: Standard 802.3 gives additional information in case of use of other components or medium such as 10 Base-2, 10 Base-5, AUI, etc. You must consult this document if necessary.

Example of calculation with model 2

Example 1:



In this architecture the worst path is between Station 1 and Station 7: there are 5 repeaters on the path and the total distance is 2200 or 2150 m.

Standards Caracteristics

The First Table below makes the calculation of the Path Delay Value and of the Path Variability Value when the length of Optical fiber between Repeater E and Station 7 is 1700 m.

	Standard fixed SDV				**Standard fixed SVV**		
Segment type	Left-end seg. Base delay	Mid-seg. Base delay	Right-end seg. Base delay	RT delay/m	Transmit-end seg.	Mid-segment	Max length
10 Base T	15,250 BT	42,000 BT	165,000 BT	0,113 BT/m	10,5 BT	8 BT	100 m
10 Base FL	12,250 BT	33,500 BT	156,500 BT	0,100 BT/m	10,5 BT	8 BT	2000 m

Calculation for example 1 with 1700 m between RepE and Station 7

	PDV calculation				**PVV caculation**		
First-end		Left-end	Right-end		Computed SVV	Segt’s SVV	
Type	10 Base T	15,250 BT	165,000 BT		10,5 BT	10,5 BT	
Length	100 m	11,300 BT	11,300 BT		8 BT	8 BT	
Mid-seg 1							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Mid-seg 2							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Mid-seg 4							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Last-end							
Type	10 Base FL	156,500 BT	12,500 BT		0,0 BT	10,5 BT	
Length	1700 m	170,000 BT	170,000 BT				
Margin		5,000 BT	5,000 BT				
						Max =	Total length
	Total PDV	571,250 BT	576,750 BT	575 BT	42,5 BT	49,0 BT	2200 m
		OK	ERROR		OK		

The conclusion is that this architecture is not valid : The PVV is right, and the PDV starting from Station1 to Station 7 is also right. But the PDV from Station 7 to Station 1 is above the limit of 575 BT.

If we limits the length of optical fiber to 1650 m, the architecture becomes valid, as it is shown in the following table :

	PDV calculation				**PVV caculation**		
First-end		Left-end	Right-end		Computed SVV	Segt's SVV	
Type	10 Base T	15,250 BT	165,000 BT		10,5 BT	10,5 BT	
Length	100 m	11,300 BT	11,300 BT		8 BT	8 BT	
Mid-seg 1							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Mid-seg 2							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Mid-seg 4							
Type	10 Base T	42,000 BT	42,000 BT		8 BT	8 BT	
Length	100 m	11,300 BT	11,300 BT				
Last-end							
Type	10 Base FL	156,500 BT	12,500 BT		0,0 BT	10,5 BT	
Length	1650 m	165,000 BT	165,000 BT				
Margin		5,000 BT	5,000 BT				
						Max =	Total length
	Total PDV	566,250 BT	571,750 BT	575 BT	42,5 BT	49,0 BT	2150 m
		OK	OK		OK		

Note: This example shows that , when we have an asymetrical network, it is important to calculate the PDV in both way.

Note: We can see also that the Model 2 improves the maximum number of allowed repeaters which is five in this example.

Schneider Automation calculation model

Overview

The Schneider Automation Calculation Model is derived from Standard Ethernet Model 2. It has been optimally tailored to calculate a network entirely made up of Schneider Automation Network components. Just like Model 2, it includes all network components found in the signal path. The form of the simplification has been changed, which leads to a much more precise calculation of maximum network range, taking into account the hight quality of the components and the corresponding improvement in their transmission characteristics.

Compliance with Ethernet rule 1

Propagation Equivalent Parameter:
In order to simplify calculation for validation of a 10 Mbps Domain, all propagation delays are specified in Propagation Equivalent Distances.
So, each Schneider Automation product is characterized by this parameter as mentioned in the following table:

Product characteristics			**Propagation Equivalent**
Hub 4 ports 10BT	499 NEH00410	TP<>TP	190 m
Hub 5 portd BT/FL	499 NOH00410	TP<>TP	190 m
		TP<>FO	360 m
		FO<>FO	260 m
Transceiver TP/FL	499 NTR 00010	TP<>FO	50 m
Data Terminal Equipment		TP port	140 m

Maximum Diameter:
Limitation of the Diamater of an Ethernet 10 Mbps Domain is fixed to **4520m**, which correspond to a signal velocity of 5,66ns/m during 25,6s (half time of transmission of the shortest frame of 512 Bits).
The validation consits of calculating the Propagation Equivalent Distance of a path by summing all the component crossed throught :

- The Propagation Equivalent Distance which is the sum of the Propagation Equivalent Parameter of each repeater, plus the total length of cables, optical fiber, along the path.
- The PED of any path within the same domain should be less than 4520m.

Compliance with Ethernet rule 2

Variability Value:

As in Ethernet Model 2, each repeater can shrink the Inter Frame Gap, so each Schneider Automation Product is caracterized by a Variability Value, in accordance with following table.

Product characteristics			**Propagation Equivalent**
Hub 4 ports 10BT	499 NEH00410	TP<>TP	4,0 BT
Hub 5 portd BT/FL	499 NOH00410	TP<>TP	3,0 BT
		TP<>FO	6,0 BT
		FO<>FO	3,0 BT
Transceiver TP/FL	499 NTR 00010	TP<>FO	1,0 BT

Starting from the 49 BT allowed by Ethernet Model 2, the Variability Value is decreased by 9BT corresponding to :

- the clock skew 2,5 BT
- the start-up delay in first DTE 3,5 BT
- a safety margin 3,0 BT

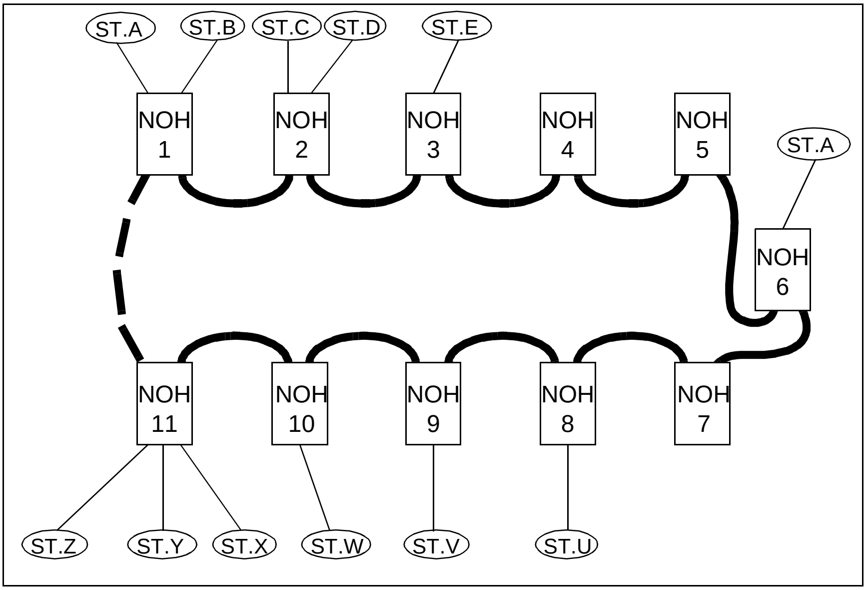
A value of 40 BT remains as the budget for the other transmission components in the signal path.

The Variability Value of a path is the sum of the Variability Value of each repeater along the path.

The VV of any path within the domain should not exceed 40BT.

Validation of a configuration: Example 1

This example is the validation of the optical bus of 11 cascaded Hubs 499NOH00510 which could be closed in a ring :



Calculation for validation

The worst path in this case is the path between Station A (ST.A) and Station Z (ST.Z) when there is no link closing the ring.

Standards Values :

The table below gives a way for calculating the two caracteristics of this worst path: the Propagation Equivalent distance and the Path Variability Value:

Product characteristics			**Propagation Equivalent**	**Variability value**
Hub 4ports 10BT	499 NEH 00410	TP<>TP	190 m	4 BT
Hub 5 ports TP/FL	499 NOH 00510	TP<>TP	190 m	3 BT
	499 NOH 00510	TP<>FO	360 m	6 BT
	499 NOH 00510	FO<>FO	260 m	3 BT
Transceiver TP/FL	499 NTR 00010	TP<>FO	50 m	1 BT
Data Terminal Equipment	DTE	TP port	140 m	

Calculation :

Worst path detection

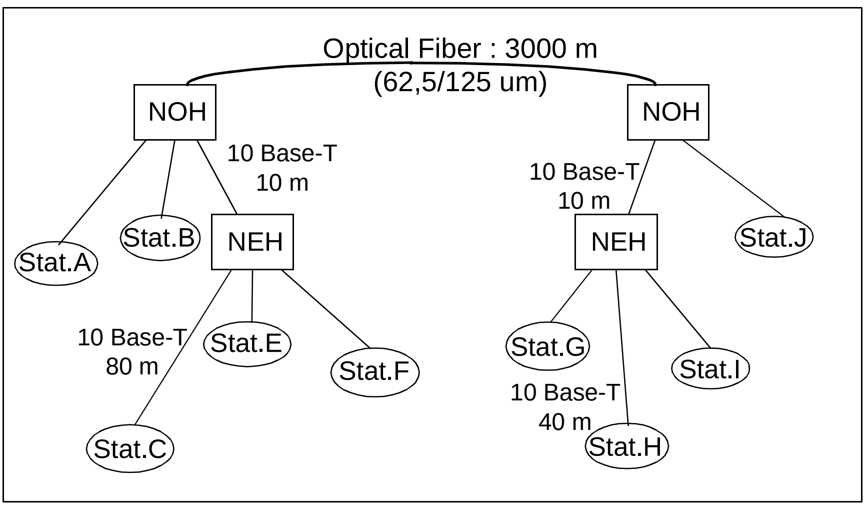
Product	Type	Propagation Equivalent	Variability Value	Nbr	Propagation Equivalent	Variability Value
DTE	TP port	140 m	0,0 BT	2	280 m	0,0 T
499 NEH 00410	TP<>TP	190 m	4,0 BT	0	0 m	0,0 T
499 NOH 00510	TP<>TP	190 m	3,0 BT	0	0 m	0,0 BT
499 NOH 00510	TP<>FO	360 m	6,0 BT	2	720	12,0 BT
499 NOH 00510	FO<>FO	260 m	3,0 BT	9	2340	27,0 BT
499 NTR 00010	TP<>FO	50 m	1,0 BT	0	0 m	0,0 BT
	Total Propagation Equivalent				3340 m	
		TOTAL PVV				39,0 BT
			Maxima		4520 m	40,0 BT
			Margin		1180 m	1,0 BT

Note: the maximum number of cascaded Hubs is 11.

This table can be put in a simple spreadsheet, the only entries are the number of components on the path (grey squares), and the Margin gives the length available for cables.

Example 2:

This configuration includes some optical fiber:



Product Characteristics :

The identified worst path is between Station C and Station H, the table below describes entirely the path between these two Stations and calculate the Total Propagation Distance and the Path Variability Value.

Product characteristics			**Propagation Equivalent**	**Variability value**
Hub 5 ports TP/FL	499 NOH 00510	TP<>TP	190 m	3 BT
	499 NOH 00510	TP<>FO	360 m	6 BT
	499 NOH 00510	FO<>FO	260 m	3 BT
Transceiver TP/FL	499 NTR 00010	TP<>FO	50 m	1 BT
Data Terminal Equipment	DTE	TP port	140 m	

Calculation :

Worst Path Description

Product	**Type**	**Propagation Equivalent**	**Variability Value**
DTE	TP port	140 m	
Twisted pair		80 m	
499 NEH 00410	TP<>TP	190 m	4,0 BT
Twisted pair		10 m	
499 NOH 00510	TP<>FO	360 m	6,0 BT
Optical Fiber		3000 m	
499 NOH 00510	TP<>FO	360 m	6,0 BT
Twisted pair		10 m	
499 NEH 00410	TP<>TP	190 m	4,0 BT
Twisted pair		40 m	
DTE	TP port	140 m	
	Total Cables	3140 m	
	Total Used	4520 m	20,0 BT
	Maxima	4520 m	40,0 BT
	Margin	0 m	20,0 BT

Example 3:

In this example we calculate the maximum number of Electrical Hubs 499NEH00410 that can be cascaded :

Product characteristics			**Propagation Equivalent**	**Variability value**
Hub 4ports 10BT	499 NEH 00410	TP<>TP	190 m	4 BT
Hub 5 ports TP/FL	499 NOH 00510	TP<>TP	190 m	3 BT
	499 NOH 00510	TP<>FO	360 m	6 BT
	499 NOH 00510	FO<>FO	260 m	3 BT
Transceiver TP/FL	499 NTR 00010	TP<>FO	50 m	1 BT
Data Terminal Equipment	DTE	TP port	140 m	

Worst path detection

Product	**Type**	**Propagation Equivalent**	**Variability Value**	**Nbr**	**Propagation Equivalent**	**Variability Value**
DTE	TP port	140 m	0,0 BT	2	280 m	0,0 BT
499 NEH 00410	TP<>TP	190 m	4,0 BT	10	1900 m	40,0 BT
499 NOH 00510	TP<>TP	190 m	3,0 BT	0	0 m	0,0 BT
499 NOH 00510	TP<>FO	360 m	6,0 BT	0	0	12,0 BT
499 NOH 00510	FO<>FO	260 m	3,0 BT	0	0	27,0 BT
499 NTR 00010	TP<>FO	50 m	1,0 BT	0	0 m	0,0 BT
	Total Propagation Equivalent				2180 m	
		TOTAL PVV				40,0 BT
			Maxima		4520 m	40,0 BT
			Margin		2340 m	0,0 BT

This calculation shows that we can put 10 Hubs 499NEH00410 in cascade and that the distance available for cables is 2340m. However, as all interfaces are for twisted pair, the max length between two components must be 100m. So, the total length of cable shall not exceed 11x100 = 1100m between the two end stations.

5.3 Calculation Models in Ethernet 100 Mbps Domain

Introduction

Overview

This section describes the various 100Mbps ethernet standard models

What's in this Section?

This Section contains the following Maps:

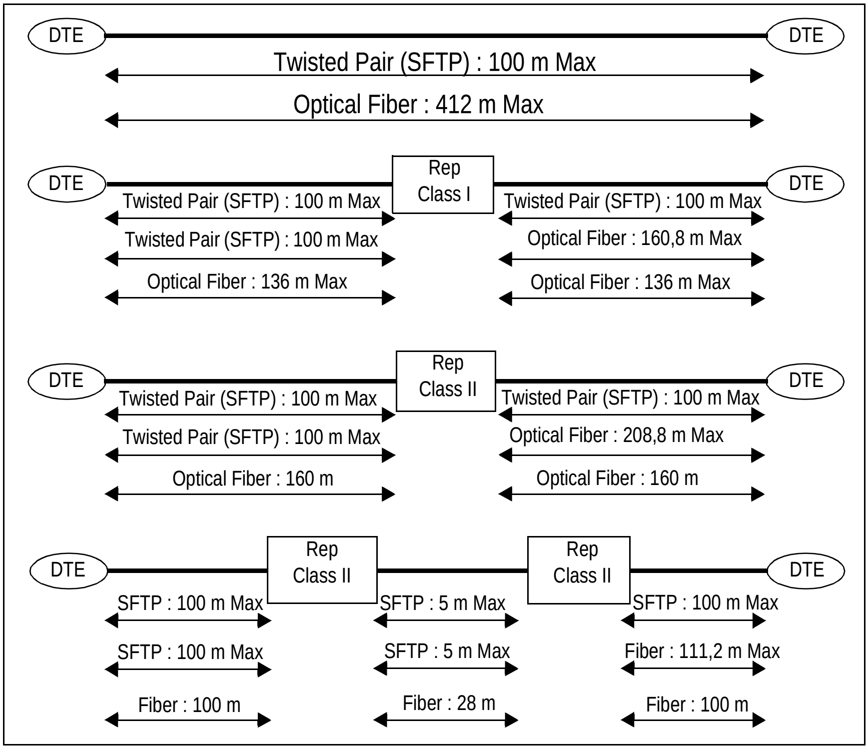
Standard Transmission model 1

Topology and rules

Standard defines two types of repeaters that comply with the following rules :

- Only one Class I repeater can reside within a single collision domain.
- Two Class II repeater can reside within a single collision domain.

The Transmission Model 1 defines the following topologies and associated rules for 100 Base Tx and 100 Base Fx physical Layers :



Standard Transmission model 2

Table and Worst-case path delay

This transmission model 2 is derived from model 2 defined for 10 Mbps Domains and adapted for 100 Mbps.
This Model provides a table of maximum values of propagation delay for repeaters and medium, in wich we can add manufacturer defined parameters.

Network Component delay	**Length**	**Round trip delay in BT/m**	**Max round trip delay in BT**
Two Tx/Fx DTE			100,00 BT
SFTP cable	100 m	1,112 BT/m	111,20 BT
Optical fiber	412 m	1,000 BT/m	412,00 BT
Class I repeater			140,00 BT
Class II repeater (Tx/Fx port)			92,00 BT
499NEH04100	Hub 4 ports Tx		92,00 BT
499NTR00100	Trcvr Tx/Fx		84,00 BT

The Model defines a method of calculation of the Worst –case Path Delay Value through a network and so, allows to validate if it is compliant with Ethernet Rules. This method is described in following table :

Worst-case Path Description	**Length**	**Round trip delay in BT/m**	**Max round trip delay in BT**
Two Tx/Fx DTE			100,00 BT
SFTP cable	50 m	1,112 BT/m	56,60 BT
499NEH04100			92,00 BT
SFTP cable	10 m	1,112 BT/m	11,12 BT
499NTR00100			84,00 BT
Optical fiber	165 m	1,000 BT/m	165,00 BT
Safety Margin			4,00 BT
TOTALS	225 m		511,72 BT
			OK

5.4 Connecting Switches

Connecting Switches

Recommen-dation

When connecting two switches , the line can be in full duplex and no collision appears on this segment. The rules applied in Collision Domain must not be used and the limits are set by the used Physical layer.
For example it is possible to connect two switches on 100 Base Fx ports with an optical fiber of 3000 m length.

Cabling Recommendation

6

Introduction

Overview

This chapter gives all recommendation about cabling an ethernet network.

What's in this Chapter?

This Chapter contains the following Sections:

6.1 Basic rules

Rules and precautions

Introduction

The following chapter describes the rules and precautions to be taken to install ethernet cabling under the optimum conditions.

What's in this Section?

This Section contains the following Maps:

Presentation

Description

You have to take some precautions before installing a Transparent Factory system. The following explains which cabling to choose, why and how to install it to obtain entire satisfaction.

Principles

- Equipment complying with industrial standards (electromagnetic compatibility or "EMC") works well independently.
- Precautions must be taken when equipment is connected so that it works in its electromagnetic environment depending on its destination.

Exclusive use of Transparent Factory insulated optical fiber cables is the way to get over any EMC problems on these links.

Note: EEC labeling must be used in Europe. This labelling does not guarantee the actual performance of the systems with regard to CEM.

Electromagnetic Compatibility (EMC)

Description

Electromagnetic compatibility is the ability of a piece of equipment or a system to operate in its electromagnetic environment without causing intolerable electromagnetic interference for this environment or for any neighbouring equipment.
If there are any problems (EM incompatibility), modification costs go up quickly whereas many good EMC options are free. Let us avoid bad EMC choices, especially expensive ones!

Earth and ground connections

Introduction

An earthing network carries leakage current and fault current from equipment, common mode current from external cables (electricity and telecoms mainly) and direct lightning currents into the earth.

Description

Physically, weak resistance (relative to a distant earth), does not concern us as much as the local equipotentiality of the building. In fact the most sensitive lines are those that connect equipments together. In order to restrict the circulation of common mode currents on cables which do not leave the building, it is necessary to restrict the voltage between interconnected equipments within the site.
A mechanical ground is any hardware conducting part which is exposed, which is not normally live, but which could be in case of a failure.

CAUTION

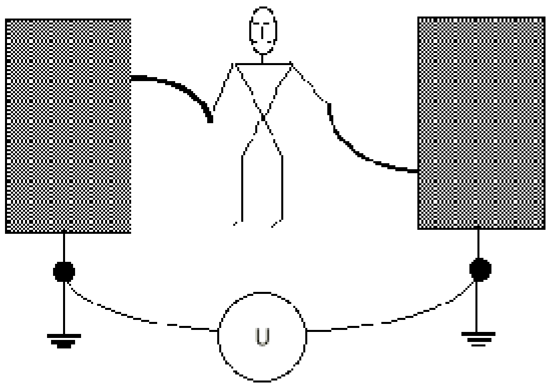
Simultaneous accessibility of 2 mechanical grounds

Two mechanical connections which are simultaneously accessible must have a lower contact voltage "U" than the conventional limit contact voltage (25 or 50 V depending on the case).

Failure to observe this precaution can result in injury or equipment damage.

Principle

Basically nothing else has any effect on people's safety, in particular the earthing resistance or the method of connecting the mechanical grounds to the earth.



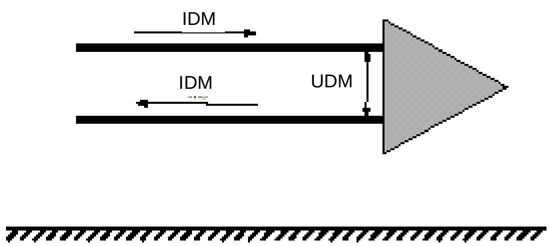
Equipments and electronic systems are interconnected. The best way to ensure that everything works properly is to maintain good equipotentiality between equipments. Besides the safety of the personnel, which is a LF (Low Frequency) constraint, equipotentiality between equipments must be satisfactory, especially for digital equipments even at very high frequencies.

⚠	**CAUTION**
	Safety regulations In case of dispute, safety regulations take precedence over EMC constraints. If there is a difference between the recommendations of this manual and the instructions of a particular piece of equipment, the equipment instructions take precedence. **Failure to observe this precaution can result in injury or equipment damage.**

Differential Mode and Common Mode

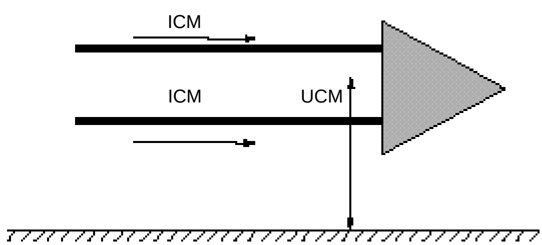
Differential Mode

Differential mode is the normal way of transmitting electric and electronic signals. The Transparent Factory data in electric form are transmitted in differential mode. The current is propagated on one conductor and returned on the other conductor. The differential voltage is measured between the conductors.
When the one way and return conductors are side by side as in Transparent Factory cables and far away from disturbing currents, **the differential mode** disturbance **is usually not significant**.
Differential Mode



Common Mode

Common mode is an interference mode where the current is propagated in the same direction on all the conductors and returns via the mechanical ground.
Common Mode



A mechanical ground (a conducting frame for instance), serves as a potential reference for the electronics and as a return for common mode currents. Any current, even a strong one, coming in one cable, in common mode into a unit which is insulated from the ground connections, comes out through the other cables, including Transparent Factory cables when they exist.

Wiring the ground connections and the neutral

Linking the ground connections

When the ground connections are not linked properly, a cable, bearing a common mode current, disturbes all the others (including the Transparent Factory electric cables). Proper interlinking of ground connections reduces this.
Good methods for wiring the ground connections and therefore for interlinking them, applicable for cabinets and also for machines and buildings, are explained in the TSX DG KBL E manual which can be ordered separately.

Note: HF interference, conducted in common mode cables, is the main problem in EMC.

Wiring the neutral

The TN-C neutral diagram, which confuses the neutral conductor (marked N, which is live) with the shielding conductor (marked PE) allows strong currents to pass through the ground connections.
The TN-C neutral diagram is therefore harmful to the magnetic environment.
The TN-S neutral diagram (with or without shielding from residual differential current) is much better.

Note: However, local safety regulations must always be scrupulously observed.

Choice of Transparent Factory electric wiring

Screened cables

The choice of screen quality depends on the type of connection. SCHNEIDER ELECTRIC defines the cables for each field bus and each local network in order to ensure the installation's electromagnetic compatibility.
A screened cable provides excellent protection against electromagnetic disturbance, especially at high frequencies. The efficiency of a screened cable depends on the choice of the screen and, to a greater extent, on how it is implemented.

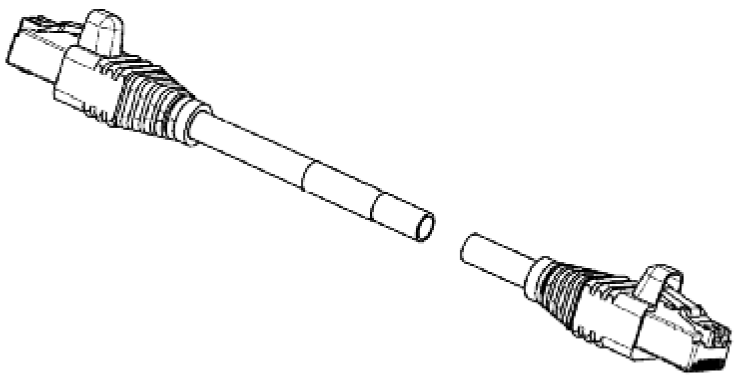
Note: Transparent Factory cables have a ring and a braid.

Ring cables

The problem with ring cables is that they are fragile. The HF protective effect of a ring cable is damaged through the general handling of the cable.
Always reduce any pulling or twisting of Transparent Factory cables to a minimum, especially on installation.
The protective effect can reach several hundreds with a simple braid from a few MHz upwards, when the screen connections are acceptable.

Note: Bilateral connection of the screen to the exposed conductive parts protects against the most severe disturbance.
This is why it is essential to properly equip each end of the Transparent Factory screened cables with RJ45 screened connectors.

Twisted pair, screened and ring cables



Sensitivity of the different families of cables

Description

Descriptive table

Family	Cables	Composition	EMC behavior
1	…analog	supply and reading circuits for analog sensors	These signals are sensitive
2	….digital and telecomm	digital and data bus circuits including Transparent Factory	These signals are sensitive They are disturbing for family 1 if they are not enough shielded
3	….relaying	dry contact circuits with refiring risks	These signals interfere with families 1 and 2
4	…supply	supply and power circuits	These signals cause disturbance

6.2 Wiring regulations

Rules to follow by the fitter

Introduction

The fitter must, except if it's not possible, follow the following rules.

What's in this Section?

This Section contains the following Maps:

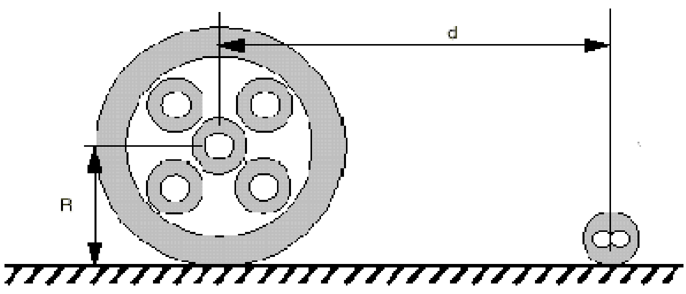
First wiring rule

Principle

It is desirable to flatten any connection against equipotential exposed conducting structures in order to take advantage of the HF protection effects.
Using conductor cable runs leads to a satisfactory level of protection in most cases. As a minimum requirement, you should ensure that connecting cables between or inside buildings also have a ground connection: earthing cable or cable run.
For internal connections to cabinets and to machines, the cables shall be systematically flattened against the metal supports.
To maintain the correct protective effect it is advisable to observe a distance between cables of more than 5 times the radius "R" of the largest one:

$$d > 5R$$

Positioning the cables



Interference cable Signal cable

Second wiring rule

Principle

Only analog, digital and telecommunication signal pairs can be tight together in one bundle.
The relay, variator, supply and power circuits shall be separated from the pairs above.
Take special care when setting up the variable speed controllers to separate the power connections from the data connections.
Everytime it is possible a duct should be reserved for power connections, even in the cabinets.

Third wiring rule

Principle

The power cables do not need to be shielded if they are filtered.
Thus, the power outputs of the variable speed controllers must be either shielded or filtered.

6.3 Using the cable runs

Basics

Introduction

This chapter describes the basics about cable runs installation.

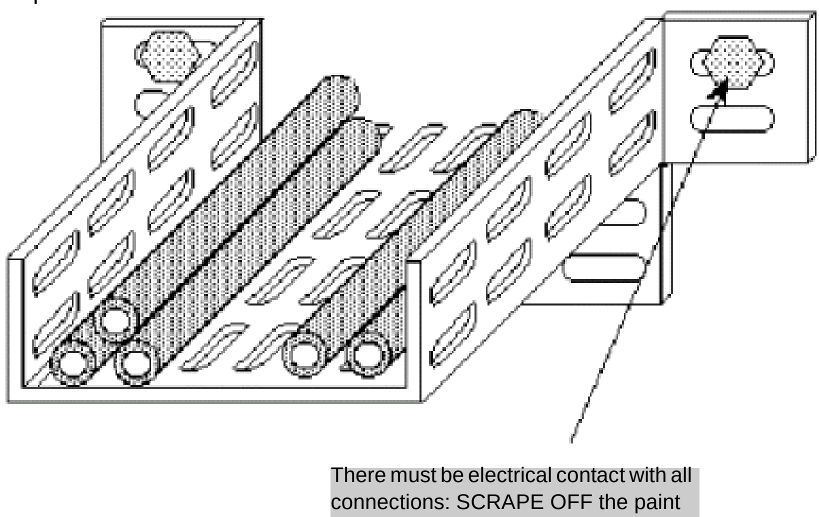
What's in this Section?

This Section contains the following Maps:

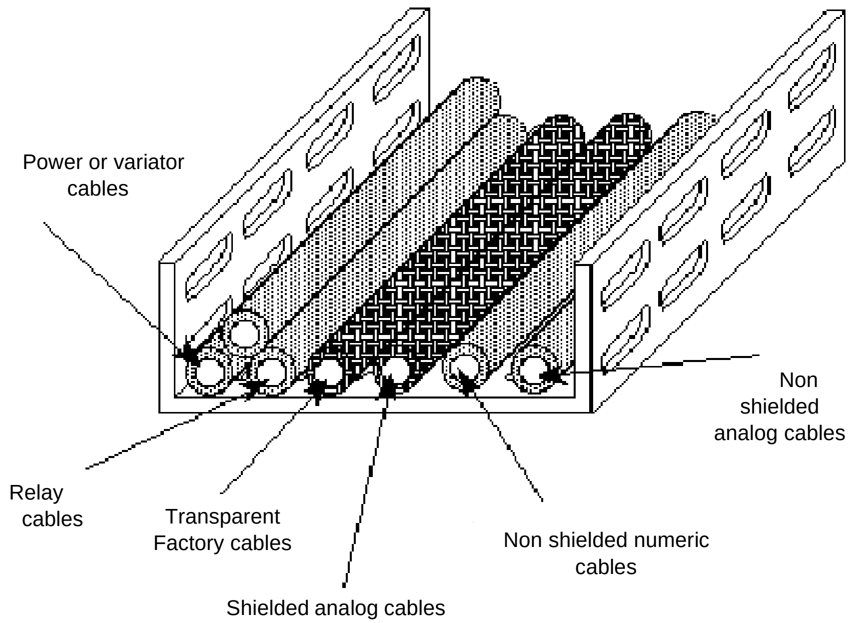
Basics on how to use cable runs

Metal cable runs

Outside the cabinets, beyond a distance of 3 m, the **ducts** must be **metal**. These cable runs must have electrical continuity from end to end via fish plates or foils.
It is very important to set up connections using fish plates or foils rather than using a braid or even a round conductor. These cable runs must be connected in the same way to the cabinet and machine connections, if necessary after scraping away the paint in order to ensure contact.
An accompanying cable will only be used when there is no other solution.
Example: Use of a metallic duct

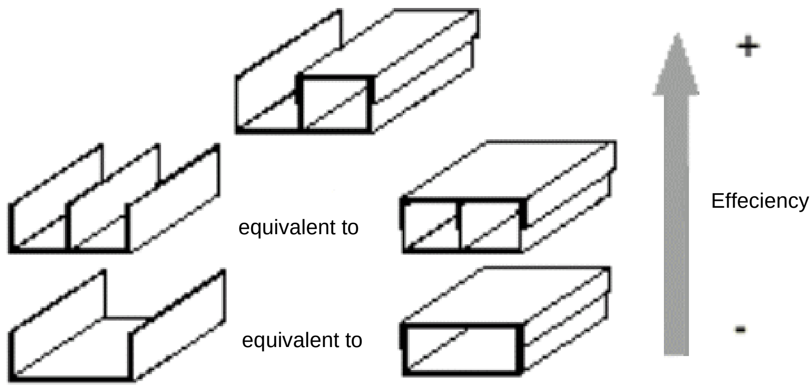


Non-shielded cables must be fixed in the corners of the ducts as shown in the illustration below.



Future developments

Bear in mind future developments. Vertical separation in the duct avoids mixing incompatible cables. A metal cover on the signals half duct is desirable. You must be aware that a complete metal cover on the duct does not improve the EMC. Efficiency of the various types of ducts



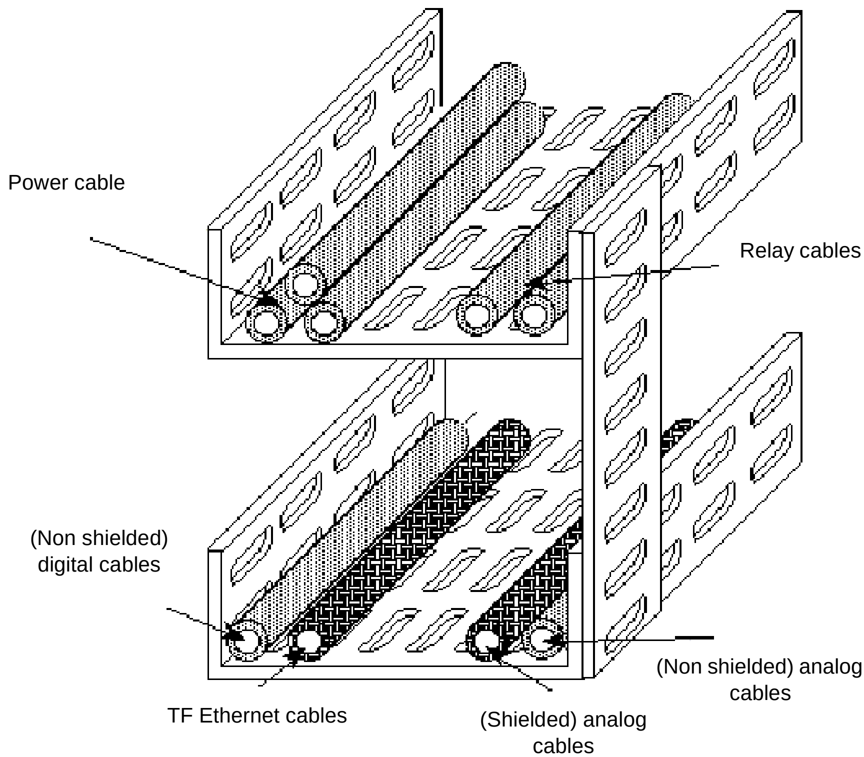
Transparent Factory

For Transparent Factory, as for each communication network, an initial maximum limit for **segment length (without repeater)** must be observed. This limit of **100 metres** , can only be achieved if installation conditions are satisfactory with regard to the EMC (especially: cables placed in metal ducts with end to end electrical continuity connected to frame ground mesh and to earth system).
It is therefore necessary to define **a maximum theoretical length** for electromagnetic compatibility. This second limit is theoretical and is used to optimize installation conditions and must be observed **at the same time** as the previous limit. **The theoretical EMC length is 400 meters for Transparent Factory.**

Separating the cables according to their type

Except when it is not possible, **two metal ducts** will be used:
- one reserved for power, relays and variators
- the other for signal cables (sensors, data, telecoms..).

These two ducts can be in contact if they are shorter than 30 m. From 30 to 100 m they shall be spaced 10 cm apart, either side by side or one above the other.
Example of installation with 2 ducts



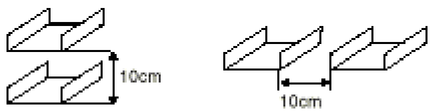
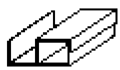
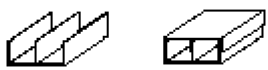
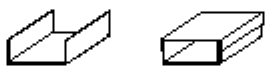
All these particular limits come from the same EMC Theoretical Length, or "ETL". To reach this ETL it is assumed that the following two optimum conditions have been fulfilled:
- a second duct, at least 30 cm away, is reserved for power and relay cables,
- the ducts are not filled to more than 50% of their capacity.

Ki Coefficient

Depending on the type of communication network this value can be different.

- Everytime one of both conditions is not fulfilled from end to end and in order to observe electromagnetic compatibility, a coefficient must be assigned to the physical duct length. These Ki coefficients, defined in the table below, measure the decrease of the protective effect. The resulting authorized length will then be less than the ETL.
- Similarly, in the case of a single duct for power and signal cables, the coefficient will take into account the lack of a metal separation or metal covering on the signal half duct.

Summary table

Symbol	**Condition**	**Illustration**	**Coefficient**	**Total length (1)**
			Ki	**ETL x 1/Ki**
K50	Single duct filled to 50% or more		2	200 m
K10	Ducts 10 cm apart (instead of 30 cm)		2	200 m
K6	Single duct or 2 contiguous ducts with separation and cover on the signal half duct		4	100 m
K8	Single duct or 2 contiguous ducts without cover on the signal half duct		6	60 m
K0	Single duct or 2 contiguous ducts without separation		12	30 m

(1) Maximum total length if it’s the unique condition against (with ETL = 400m)

Verification modes of the length of a homogeneous cable

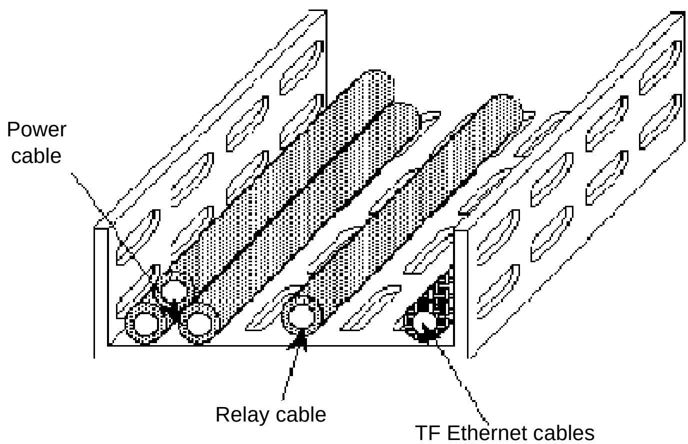
Introduction

There are two ways of using the Ki coefficients.

- To obtain the authorized physical length, you take the ETL and divide it by Ki, (examples 1 and 2 below).
- On the contrary, when particular physical lengths are imposed necessary, multiply them by Ki and compare the result with the ETL to check that you are compliant with the EMC requirements (examples 3,4, and 5).

Example 1: Transparent Factory links less than 30m

Wiring can then be done in a single metal run (for ETL = 400 m or more).
If the duct is not filled to more than 50% (bear in mind future developments), only the Ko coefficient must then be taken into account, which gives a maximum length of 400 m: 12 = 30 m.
The power cables and shielded digital connections shall be fixed in the corners of the duct as shown in the illustration below:



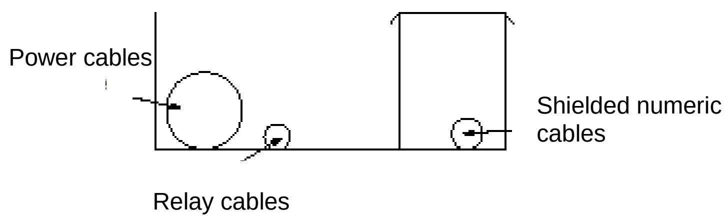
Example 2: Transparent Factory links up to less than 100m

If length calculated in an installation condition is insufficient (30 m in the first example) it will be necessary to improve the EMC aspect of the configuration. Vertical separation in the duct avoids mixing incompatible cables. A metal cover on the half duct of the signal cables restricts signal interference.
That’s why the coefficient value then goes from 12 (=K0) to only 4 (=K6), which, (with ETL=400) gives the maximum length: ETL / 4 = 100 m.
The EMC conditions to be observed are then:

- each half duct is filled to 50% max.,
- the separation is metallic and in contact with the duct along the whole length,
- the cover is in contact with the separation along the whole length.

Note: Bear in mind future developments.

Illustration



Example 3: Plan for laying 30m of Transparent Factory cable

It is planned to lay the cable in a single duct filled to 70% without separation, together with a power cable and an analog cable.
This installation condition, according to the Ki symbols table, is linked to two coefficients: K0 (=12) et K50 (=2); you must therefore multiply the physical length by 2 and by 12.
As the result 720m (30m x12) is greater than ETL=400m, the 30m installed length will not comply with EMC requirements. Example 4 (next §) explains a possible solution.

Verification mode of a the length of a heterogeneous cable

Introduction

When there are multiple installation conditions along the length of a cable run, each physical length of the same laying type must be multiplied by the relevant coefficients following the same rules as above.
The sum of the various results must be less than ETL (Transparent Factory).

Example 4: New laying plan for 30m of Transparent Factory cable

The signal cable in example 3 is laid along 10m according to the laying type above; the remaining 20m are laid 10 cm away from the first one, in a separate duct from the power cable, but placed .
Calculation table

Length	Ki coefficients	Calculations	Results
10 m	K0 (=12) et K50 (=2)	10 m x 24	240 m
20 m	K10 (=2) et K50 (=2)	20 m X 4	80 m
Total (30 m)		240 m + 80 m	**320 m**

As the resulting 320m is now less than ETL = 400m, the 30 m installed length will comply with EMC requirements.

Example 5: Laying plan for a 1000m FIP cable

The documentation for the system shows that the first limit is observed, provided only if main cable (150 ohms single pair large gage) is used.
The ETL value for this technology is 2000 m.
Let us assume that the 2 optimum conditions are observed for 700m and that for the rest of the length the power duct is:
- filled to more than 50%,
- and only 10cm away from the signal duct.

Calculation table

Length	Ki coefficients	Calculations	Results
700 m	no		700 m
300 m	K50 (=2) et K10 (=2)	300 m X 4	1.200 m
Total (1.000 m)		700 m +1.200 m	**1.900 m**

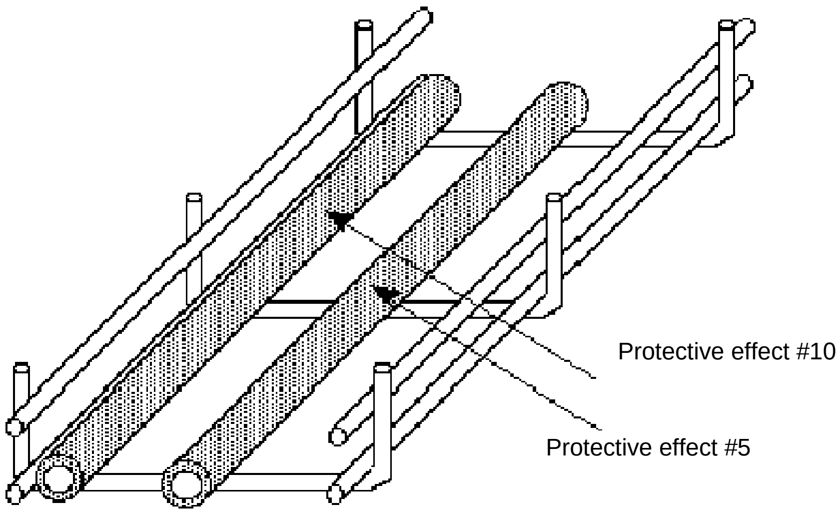
As the result 1900m is less than ETL=2000m, the installed length will comply with EMC requirements and only the previous contingency remains (no small gage pair).

Other protective effects

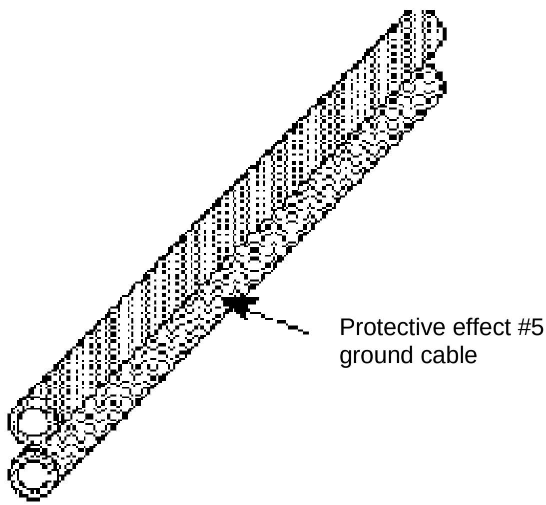
Introduction

The protective effect of a cable run is about 50 between 1 MHz and 100 MHz.
If you cannot use this type of hardware, other protective effects are possible.
Soldered wire cable runs "cablofils" are less effective and often more expensive than metal ducts.

Cablofil



Grounding cable



6.4 Inter building links

Introduction

Presentation

This chapter gives the precautions and recommendations for inter building wiring.

> **Note:** It is strongly recommended to use optical fiber cable for data links and therefore for Transparent Factory between buildings. This type of link is used to eliminate loop problems between buildings.

What's in this Section?

This Section contains the following Maps:

Wiring electrical connections

Principle

Inter building links present two special features that can introduce risks for the installation:
- the poor equipotentiality between installation grounds,
- the large areas of loops between the data cables and the grounds.

Note: Before installing and connecting a data cable between two buildings, you must check that the two ground connections (one at each building) are interconnected.

All the exposed metal parts accessible at the same time must be connected to the same ground connector (or at least to a set of interconnected ground connections). This requirement is fundamental to ensure people's safety.
The second risk associated to inter building connections is the area of loop included between the data cables and the connections.
This loop is particularly critical when there is an indirect blasting of the site. The overvoltage caused in these loops by an indirect blasting is approximately of 100 volts per m.

Note: In order to reduce this risk, all cable runs between two buildings must be doubled up with a large section equipotential line (»35 mm 2).

Protection against intrusion

Principle

Common mode currents coming from outside must be discharged to the ground network at the entrance to the site in order to limit voltages between equipments.

> **Note:** Any conducting lines (conducting cable, conducting pipework or insulating pipework carrying a conducting fluid), entering in a building must be connected to a ground at the entrance of the building and at the shortest possible distance.

Surge absorbers must be placed on electricity, telecommunications and signal cable (for data, alarms, access checks, video supervision,….) at the entrance to the buildings. The effeciency of such devices is largely influenced by the way they are installed.
The surge absorbers (varistors, discharge gaps etc.) must be connected directly to the ground connection on the electrical panel or to equipments they are protecting. Simply connecting surge absorbers to earth (instead of the mechanical ground) is not effecient.
As far as possible the panels, where the electrical, telecommunications and signal protectors are installed, must be placed close to a grounding strip.

6.5 Using optical fiber

Choosing and Fitting Optical Fiber

Introduction

This chapter gives the necessary recommendations for choosing optical fibers.

What's in this Section?

This Section contains the following Maps:

Choosing the optical connection type

Choosing the optical fibers

Schneider Electric supplies Transparent Factory equipments with optical ports: modules, hubs and switches. What all those equipments have in common is that it is used to connect **silica multimode fibers**. Each optical connection needs two fibers.
From one end to the other these fibers must be **62.5/125 type** and specified to allow communication on wavelengths **850 nm and 1300 nm**.

Choosing the optical cables

The cable must include a minimal amount and maximal quality of fibers as described in the previous paragraph. Furthermore, it can contain other fibers or electrical conductors.
Its **protection** must be compatible with the installation conditions.

Fitting the optical patches

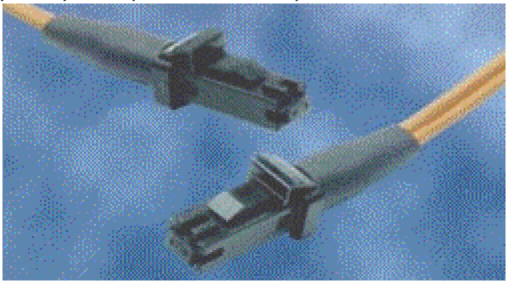
Definition

The optical strings necessary to connect the TF Ethernet Intranet modules, hubs and switches are supplied in 5 meter lengths with the options of suitable optical connectors.

MT-RJ / SC duplex optical patch (490NOC00005)

MT-RJ / ST duplex optical patch (490NOT00005)

MT-RJ / MT-RJ optical patch (490NOR00005)



Two important precautions must be taken by the installer and the user :

- 1. Do not bend these stringss (**the minimum radius is 10 cm**).
- 2. Pull or twist the cable and its connectors as less as possible.

On the other hand, **there is no minimum distance** to be observed between an optical cable and any cable or equipment which could interfere with it. Special cases of strong ionizing rays is not the purpose of this manual.