Introduction

Apart from applications in the field of telecommunications, fibre optic technology is of great importance in the industrial market sector.

In telecommunications there are requirements for:

- High transmission capacity
- Low cable attenuation
- No crosstalk

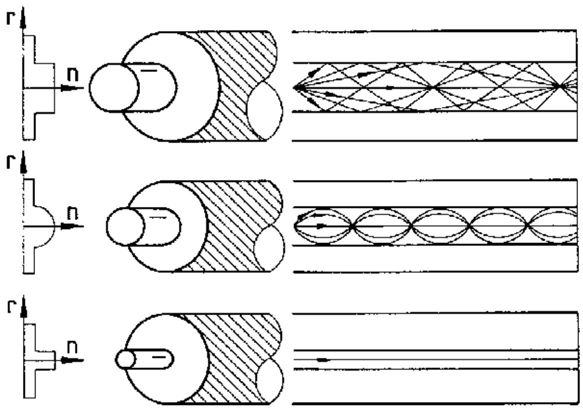
These features are also required in the industrial sector along with the following major considerations:

- Zero susceptibility to electromagnetic interference
- Electrical insulation between transmitter and receiver
- Small cable diameter

Fibre optic communication works by pulses of light. When feeding them in at one end of the fibre optic cable, the pulses are passed to the other end by total internal reflection.

Total internal reflection occurs at the boundary layer between core and cladding by virtue of the different values of optical refractive index (n) between the two materials (n cladding less than n core).

There are three different types of optical fibres:



	Typical Dimensions Core/Cladding Ø	Attenuation
Step index (SI) fibre HCS / POF	200 / 230 µm	5 ... 8 dB/km 0.2 dB/m
Gradient index (GI) fibre	50 / 125 µm	2.6 dB/km 3.2 dB/km
Single modem fibre	9 / 125 µm	< 0,3 dB/km

The single-mode fibre is mainly used in telecommunications because of its low attenuation and wide bandwidth.

The gradient index fibre and the step fibre with their large core diameters are chiefly used as communication cables in industrial applications due to their easy handling and relatively low costs. The link length ranges from several meters to several kilometers.

Mounting of connectors for gradient fibres is achieved by the use of adhesive.

For POF[2)] or HCS[1)] fibres, the crimping technique eases the connector attachment. With the advanced HARTING quick assembly components, POF-cables can be mounted without the need of special tools.

HARTING F.O. systems are designed for gradient index fibres with a core diameter of 50 and 62.5 µm as well as for 200 µm (HCS) and 1 mm (POF) step index fibres.

The typical operating wavelengths are 660 nm (POF, HCS), 850 nm (GI, HCS) and 1300 nm (GI).

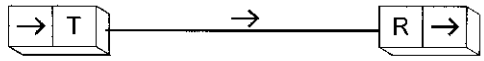
[1)] HCS® (=Hard Clad Silica) is registered trade mark of SpecTran Corporation

[2)]POF = Polymer Optical Fibre

System Technique

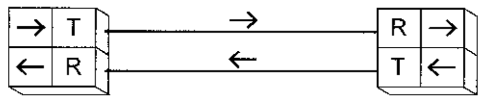
Electrical signals to be transmitted by fibre optic cable must be converted into pulses of light and vice versa. For this purpose there are electro-optic converters available as transmitter (T) and receiver (R) modules.

Simplex



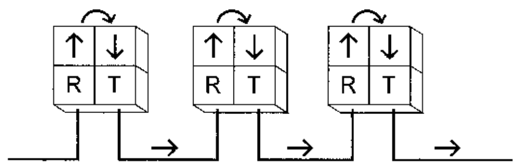
A simplex link is defined by the signal transmission in a single direction. Data transmission in two directions is performed in a duplex link. With these configurations, point-to-point links can be realized. Usually separate fibres for each direction are used.

Duplex



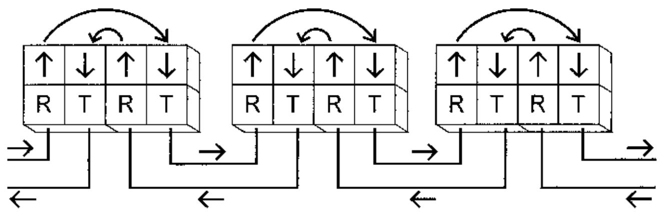
The interconnection of multiple units in a communication system can be done in different configurations. At the optical line signals are passed through each participant only in one direction. Each participant transmits the received optical signal to the next station (repeater functionality). If the optical line is closed to a ring-structure, bi-directional communication between the participants, is possible.

Optical line, optical ring



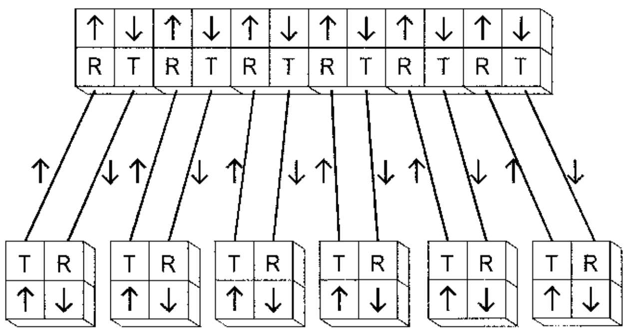
The linear duplex bus is the combination of two contrary lines. Each participant has two transmitting and receiving modules passing received optical signals to the opposite direction and vice versa (repeater functionality).

Linear duplex bus



In a star configuration a central point is the connection mode for each participant. A transceiver module for each participant is equipped at this point. Each star shaped split can be enlarged with the a.m. configurations.

Star configuration (star coupler)



Dimensioning of F.O. Transmission Systems

For reliable operation of a F.O. data transmission system it is essential that the transmitted optical signals arrive at the receiver with sufficient amplitude. The incident power should at least exceed twice (+ 3 dB) the value of the minimum sensitivity of the receiver. Otherwise, the inherent noise of the system may result in increasing randomly distributed transmission errors in the data transfer. Therefore, in system design the power budget of the optical path has to be checked. The following aspects have to be considered:

- **Optical power output of the transmitter**
  The optical power generated by the LED does mainly depend on the applied forward current.
  Typical power levels coupled into the core are
  50/ 125 µm GI fibre: 80 µW } at
  200/ 230 µm SI fibre: 250 µW } 850 nm
  980/1000 µm Polymer fibre: 600 µW 660 nm

- **Specific attenuation-coefficient of the fibre**
  The specifc attenuation of optical fibres depends on the wavelength applied and is specified in dB/km.
  Typical values for glass-fibres are
  50/ 125 µm GI fibre: ---3 dB/km } at
  200/ 230 µm HCS: ---5 dB/km } λ = 850 nm
  for Polymer fibre:
  980/1000 µm (PMMA): ---0.2 dB/m λ = 660 nm.
  The fibre loss usually contributes to the highest amount to the overall transmission index of the optical link.

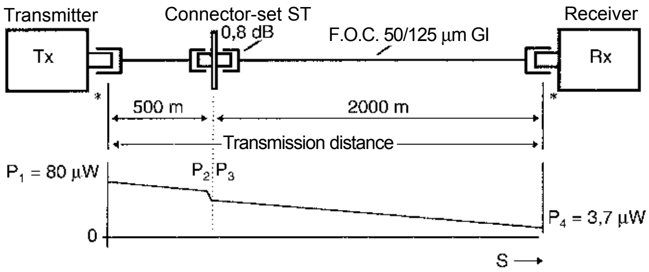
- **Additional interconnections in the cable system**
  Interconnections in the optical link create some further attenuation for the travelling optical signals.
  Typical insertion loss is
  for a spliced connection ≤0.3 dB
  for a connector-set 0.8 - 0.5 dB
  depending on the type of fibre and the connectors applied.

- **Sensitivity of the optical receiver**
  DC-coupled optical receivers, commonly used, with SI-diodes as receiving elements show typical minimum sensitivities of
  ≤ 3 µW at 850 nm (glass fibre systems)

- **Temperature dependence and ageing of LED, thermal influence on cable loss**
  These items should be taken into account with an amount of 2 dB. Thus, in total a system reserve of 5 dB has to be considered in the link power budget.

Examples

a) Glass fibre system (λ = 850nm)



Link budget analysis:
Transmitter
P_1 = 80 µW = -11 dBm
power coupled into fibre core

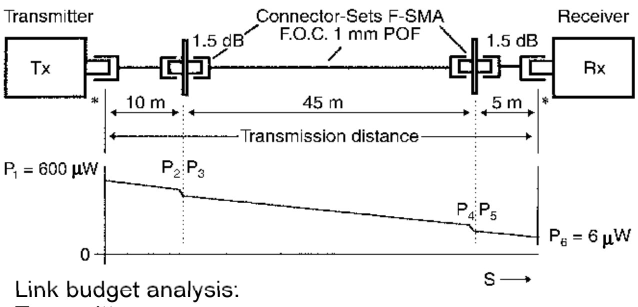
Cable Loss: 2.5 km x 3 dB/km	= 7.5 dB
Loss per connector set ST	= 0.8 dB
System reserve (3 dB + 2 dB)	= 5.0 dB
Total system losses:	13.3 dB

Incident power at receiver: P_4 = - 24.3 dBm = 3.7 µW

This satisfies the required minimum-conditions ≥ 3 µW

* The injection- and decoupling-loss at the transmitter- and receiver-ends of the fibre has not additionally to be taken into account as they are alraedy included in the given power ratings of these elements.

b) Polymer fibre system (λ = 660nm)



Link budget analysis:
Transmitter
P_1 = 600 µW = -2.2 dBm
power coupled into fibre core

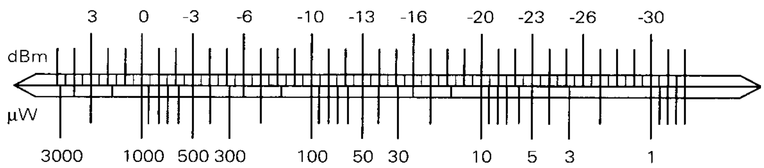
Cable loss: 60 m x 0,2 dB/m	= 12 dB
2 connector-sets F-SMA (2 x 1.5 dB)	= 3.0 dB
System reserve (3 dB + 2 dB)	= 5.0 dB
Total system losses:	20.0 dB

Incident power at receiver: P_6 = - 22.2 dBm = 6.0 µW

This satisfies the required minimum-conditions ≥ 5 µW

Omitting the additional interconnections in the cable (here e.g. the 2 F-SMA connector sets) results in larger maximum transmission distances.

Conversion-Diagram



Tables of Interface Standards and Fieldbus Systems

For the most well-known electrical interface standards HARTING offers suitable connection systems and converters, especially designed for the conversion of electrical signals into optical signals.

Table of electrical interface standards

	TTL	RS 232	RS 422	RS 485
Interface logic	voltage level	voltage level	differential voltage	differential voltage
Transmission principle	application specific	bi-directional fullduplex on min. 3[1)] to 9[2)] wires	fullduplex, bi-directional on two twisted pair cables	halfduplex, bi-directional on one twisted pair cable
Logic level "high" Logic level "low"	2.4 ... 5 V 0 ... 0.8 V	-15 V ... -3 V +3 V ... +15 V	Δ U > 0.2 V Δ U < -0.2 V	Δ U > 0.2 V Δ U < -0.2 V
Max. data rate	application specific	19.2 kBit/s 115 kBit/s	12 MBit/s (20m) 100 kBit/s (1.2 km)	12 MBit/s (100m) 100 kBit/s (1.2 km)
Max. link length with Cu-wires	application specific	20 m	20 m - 1.2 km	100 m - 1.2 km

[1)] software-handshake, [2)] hardware-handshake

HARTING media converters for fieldbus systems

Fieldbus system	HARTING product	Page
Profibus FMS	Media Converter MCP 12 and MCP 12 P	9 - 11
Profibus DP		
Sinec L2		
Suconet P		
Suconet K	RS 485 Converter	12, 13
CS 31 (ABB)		
Modbus Plus	RS 485 MB + Converter	12, 14
Interbus-S	RS 422 Converter	15, 16
Suconet S		
ARCNET ®3)	Arcnet Converter	17, 18

Concerning electro-magnetic compatibility HARTING Media Converter comply with the relevant specifications

[3)] ARCNET® is registered trade mark of Datapoint Corporation