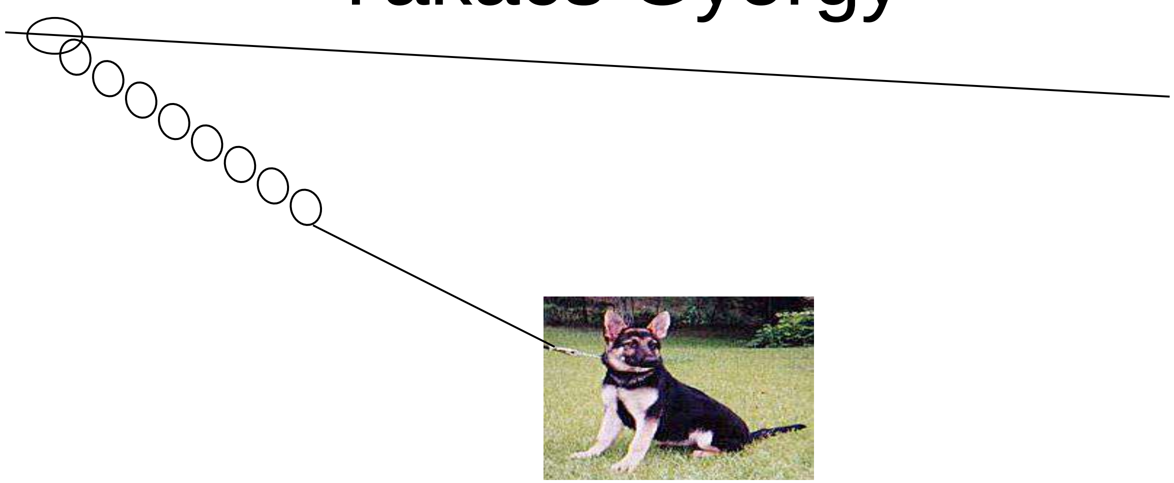
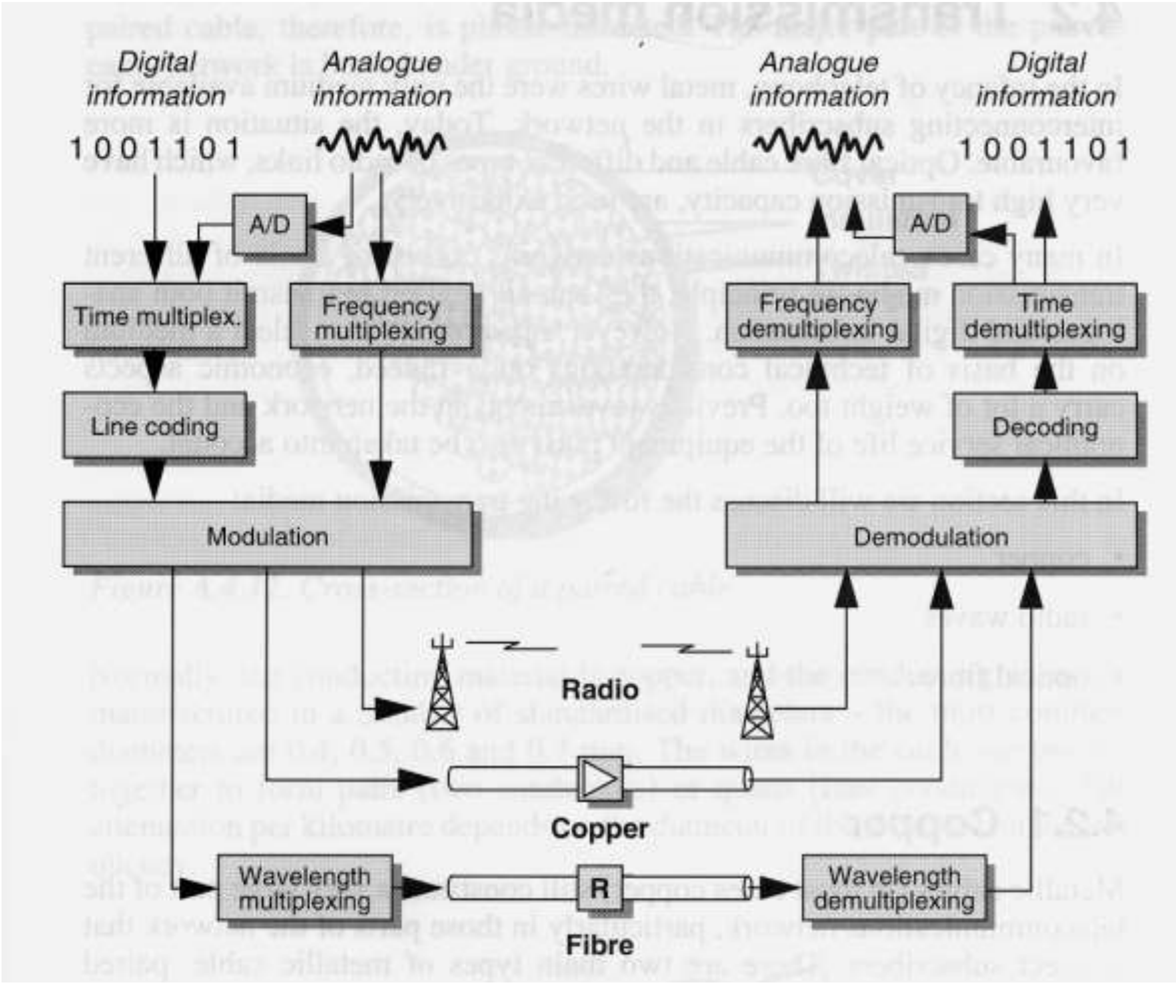
Infocommunication systems
Infokommunikációs rendszerek
Lesson 2. előadás
Vezetékes átviteli közegek
Wire-line transmission

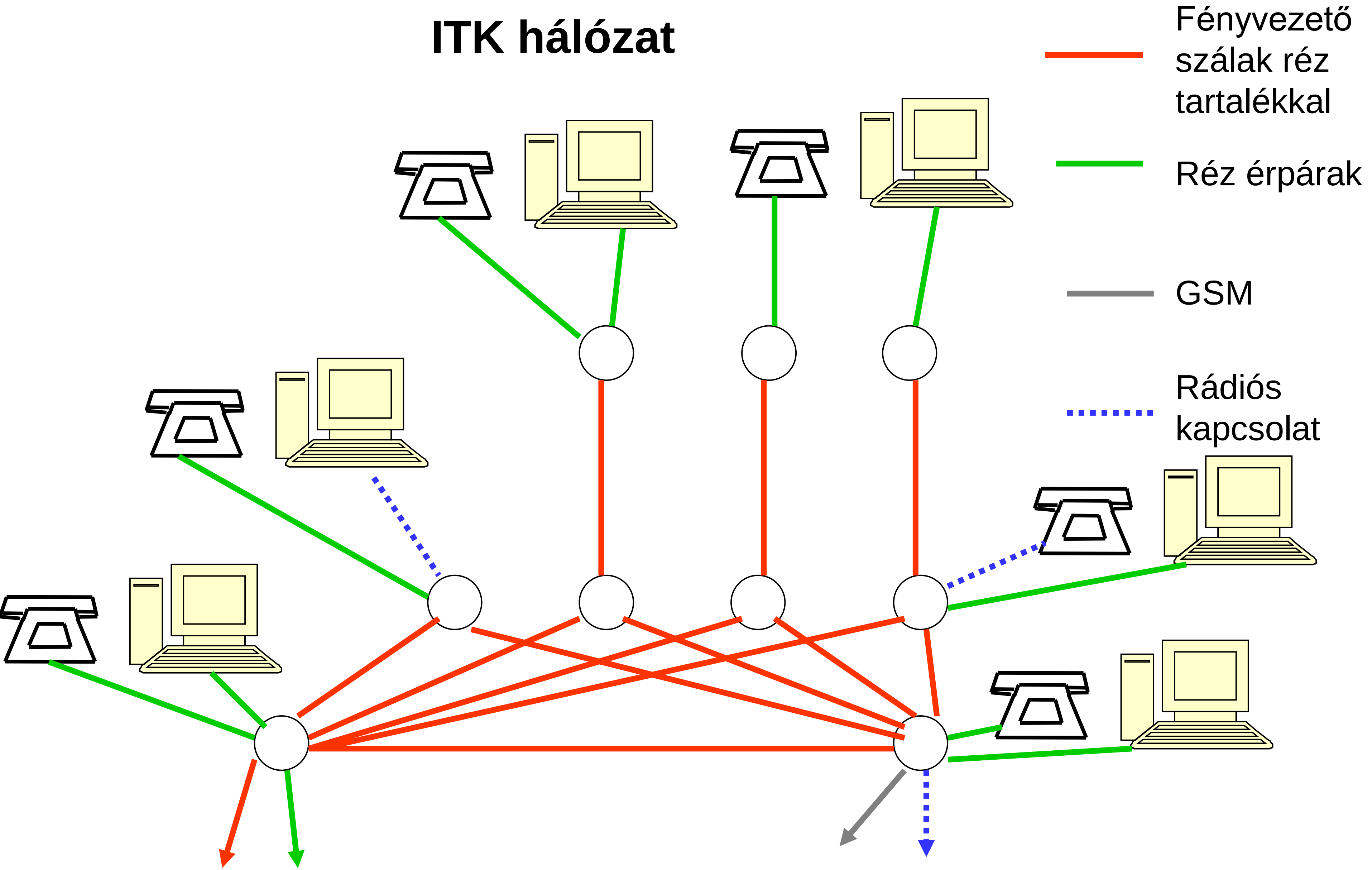
Takács György



Melyik átviteli közeg jobb?

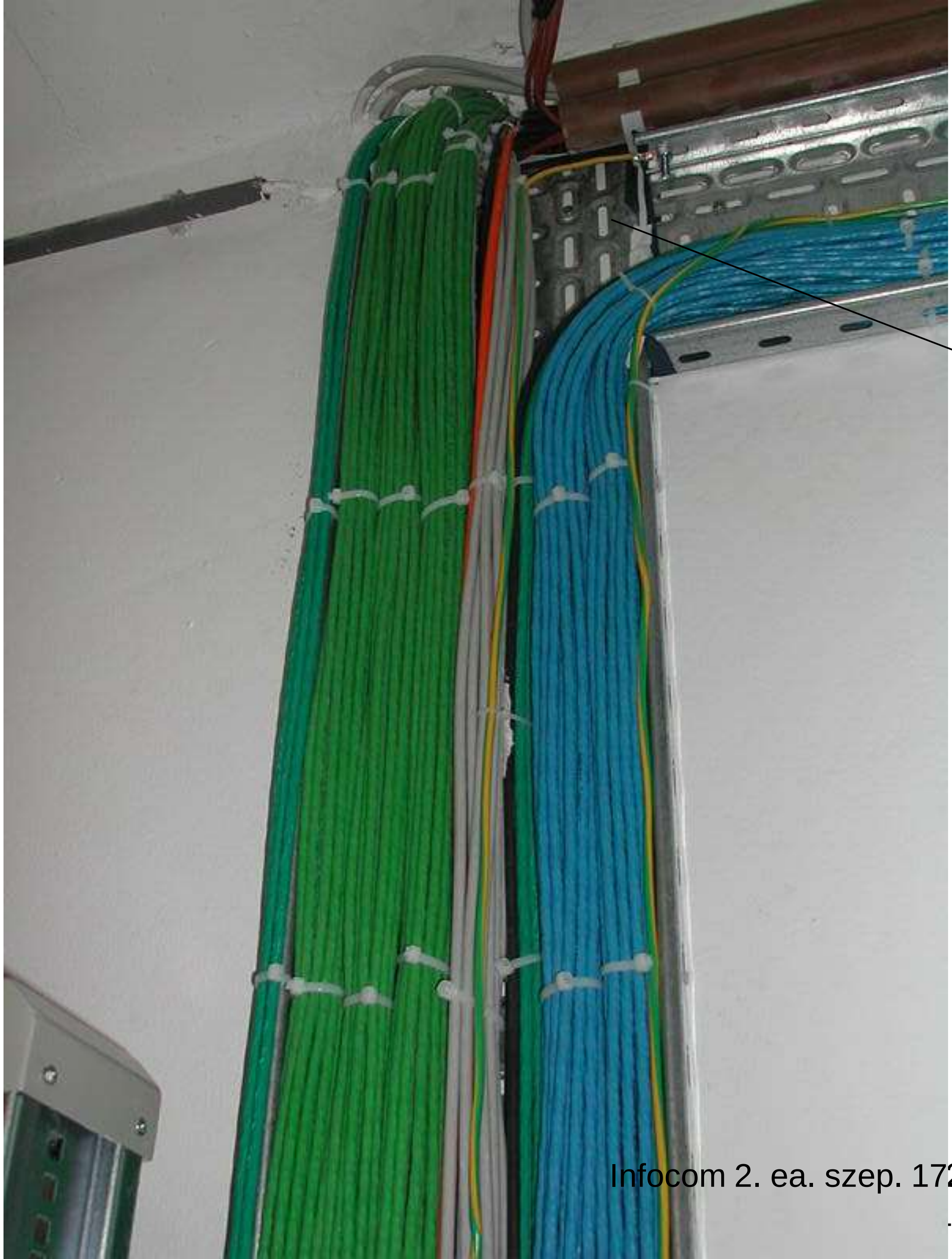


ITK hálózat


Fényvezető szálak réz tartalékkal
Réz érpárak
GSM
Rádiós kapcsolat

Vezetékes átviteli közegek

- Sodrott érpáras rézkábelek
- Koaxiális kábelek
- Fényvezető kábelek



A további infrastruktúra tartalék helye

Közeg jellemzők

- Átviteli tulajdonságok (csillapítás, késleltetés, reflexió, diszperzió, áthallás, zajok, zavaró hatások)
- Fektetési, kötési kérdések
- Illesztések, szerelvények, végződtetések
- Hibák, hibahely-behatárolás

Wireline transmission media

- Symmetrical twisted pair copper cable
- Coaxial cable
- Optical fibre cable
- Constuction issues, connecting, error detection, error localosation.

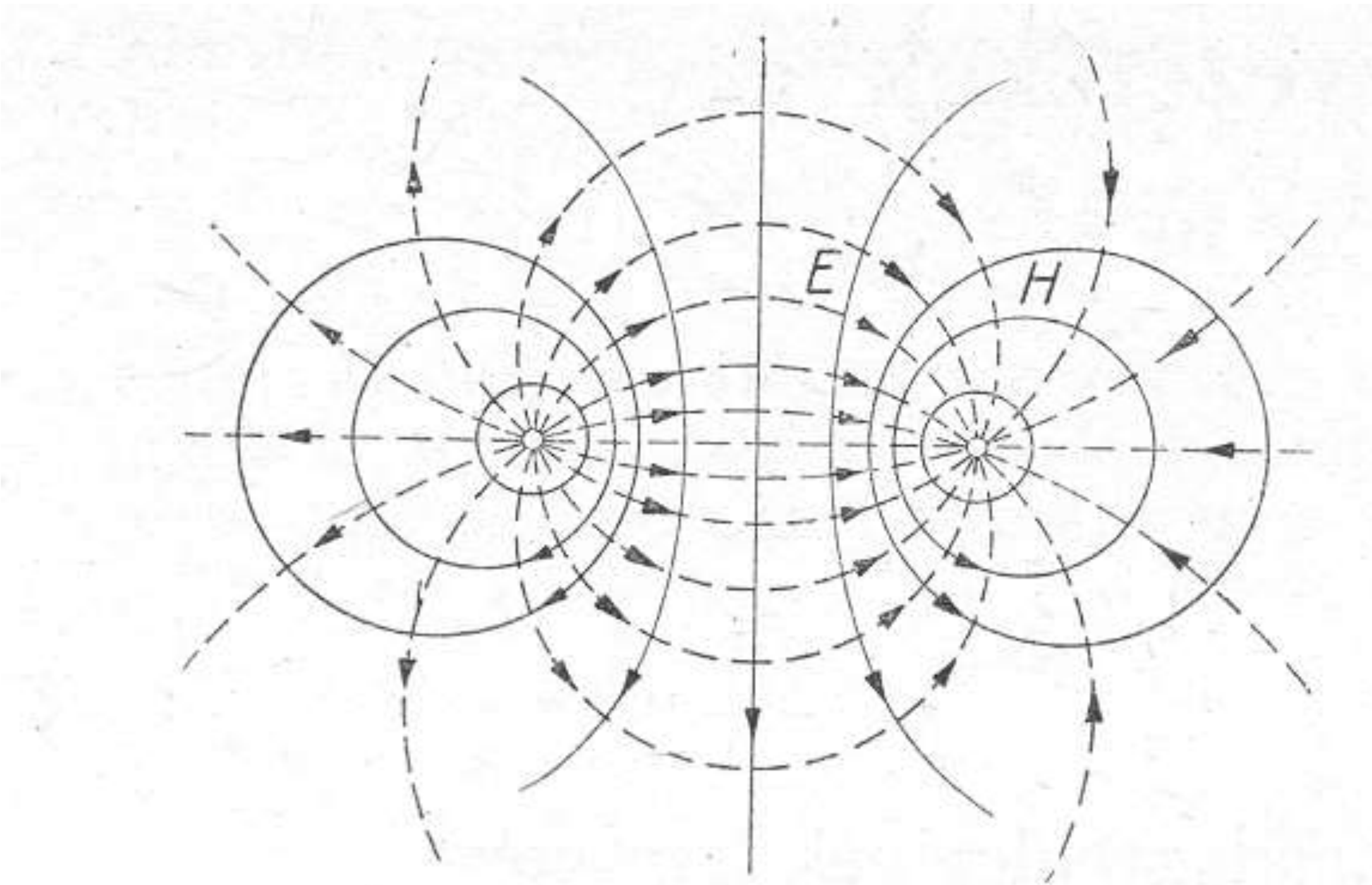
Media and cable characteristics

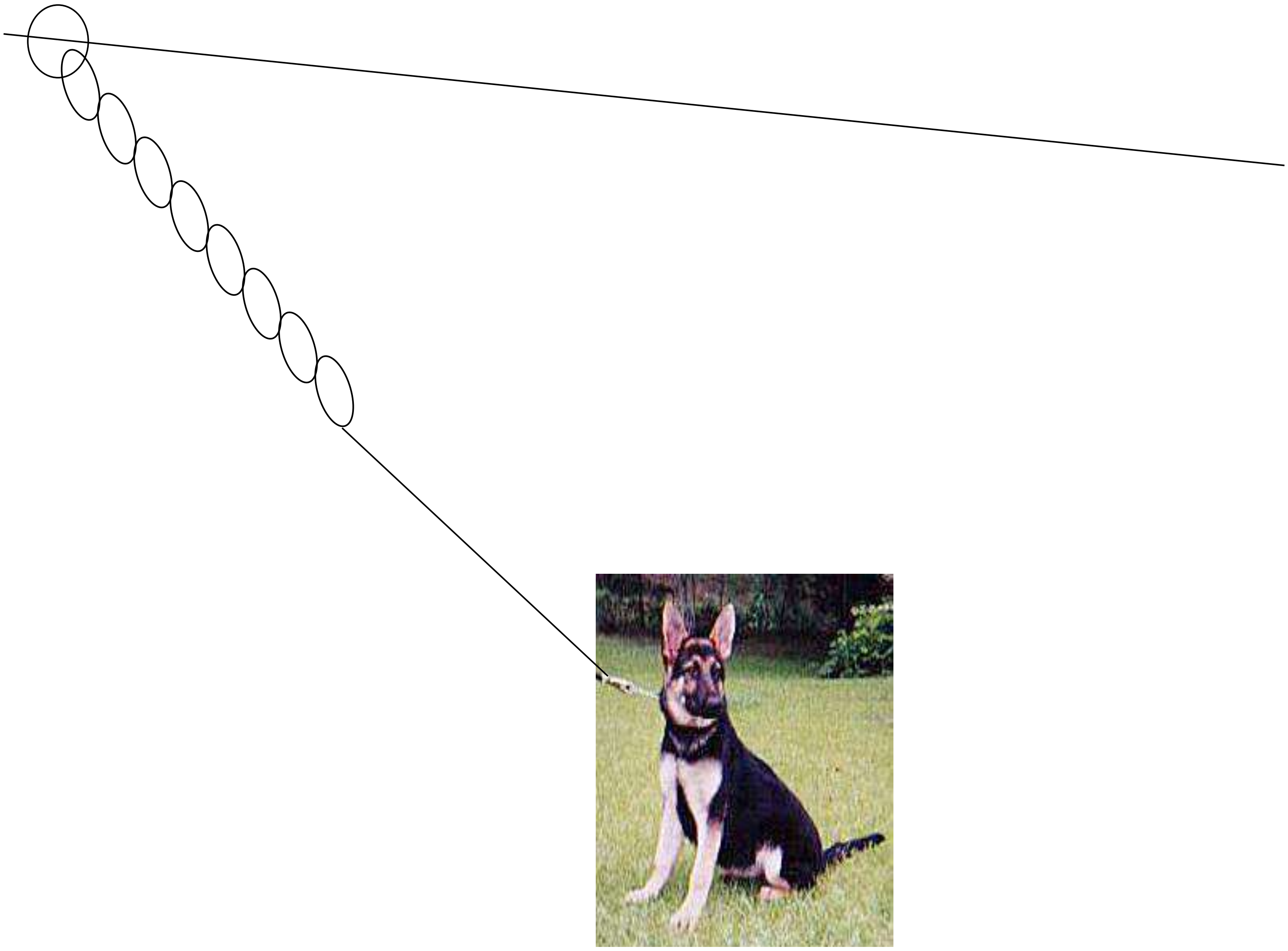
- Transmission parameters (attenuation, delay, reflection, crosstalk, noises, interferences)
- Laying, connecting technologies
- Faults, fault localization
- Matching, accessories, termination

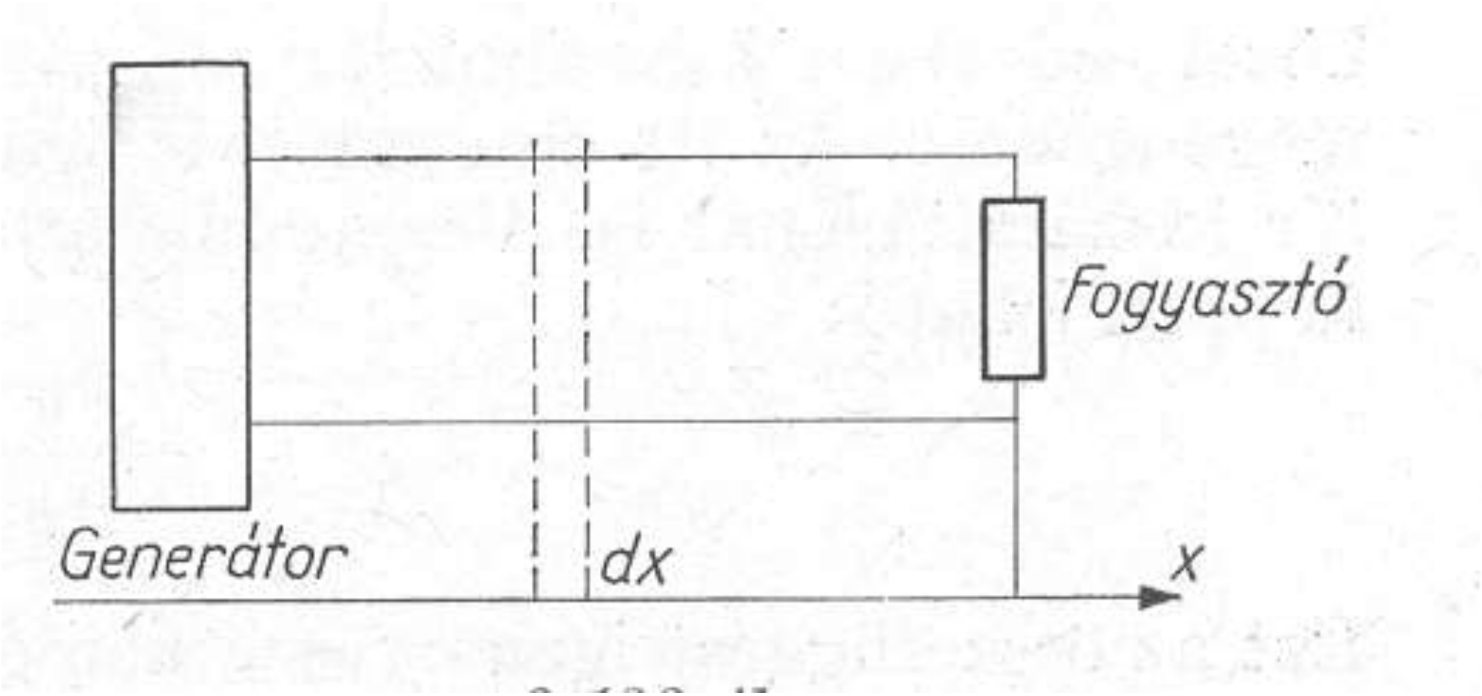
Symmetric or asymmetric?

- Related to the ground
- To protect from interferences
- The basic equations and characteristics of wires are very similar

Electromagnetic field around the symmetric wire





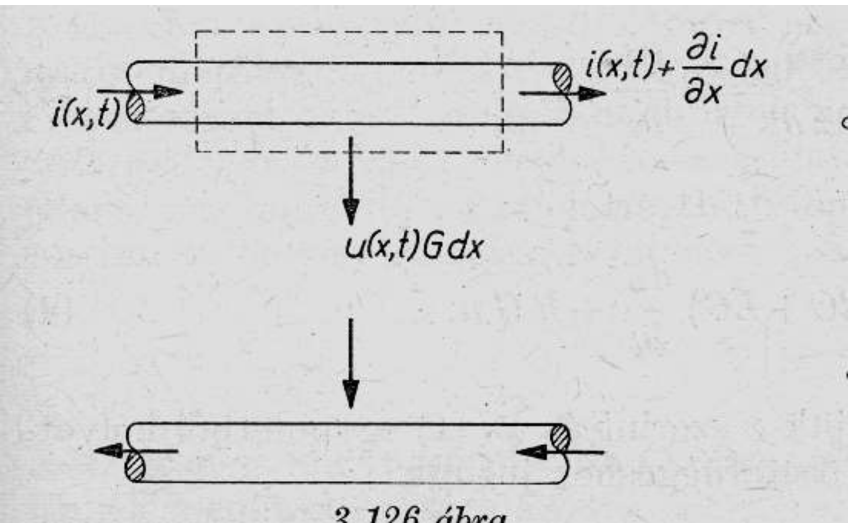


Fogyasztó
Generátor
dx
x

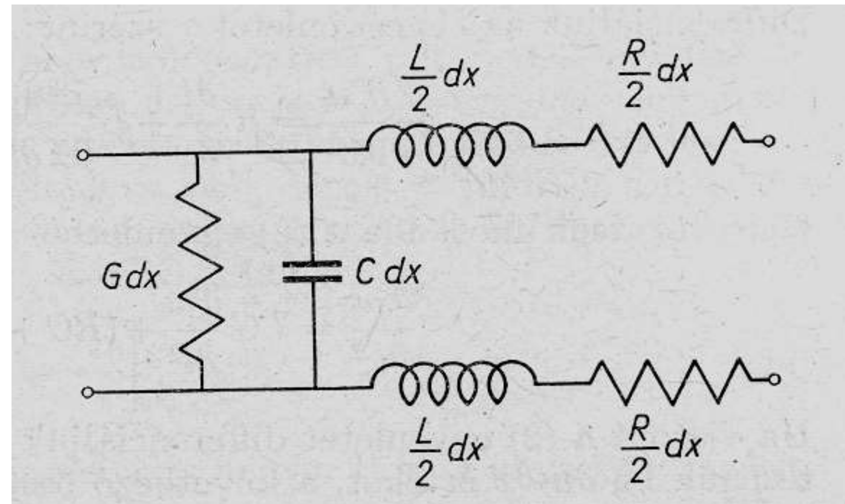
Jelölések

- u(x,t) feszültség, a távolság és idő függvénye
  voltage as the function of time and distance
- i(x,t) áram, a távolság és idő függvénye
  current as the function of time and distance
- γ (gamma) komplex csillapítási együttható
  Attenuation coefficient
- R,G,C,L egységnyi hosszú kábelszakasz ellenállása,
  átvezetése, kapacitása, induktivitása
  resistance, conductivity, capacity, inductivity of the unit length cable
- Z a kábel komplex bemenő impedanciája
  The complex input impedance of the cable.
- Zo A kábel hullámimpedanciája
  The characteristic impedanceof the cable

Equivalent circuit for a (*dx*) fragment of a wire



3.126 ábra



3.127 ábra

The basic equations for wires

$$-\frac{\partial u}{\partial x} = R\, i + L \frac{\partial i}{\partial t},$$

$$-\frac{\partial i}{\partial x} = G\, u + C \frac{\partial u}{\partial t}.$$

The solution of basic equations

$$u = U_0 \, e^{j\omega t - \gamma x}.$$

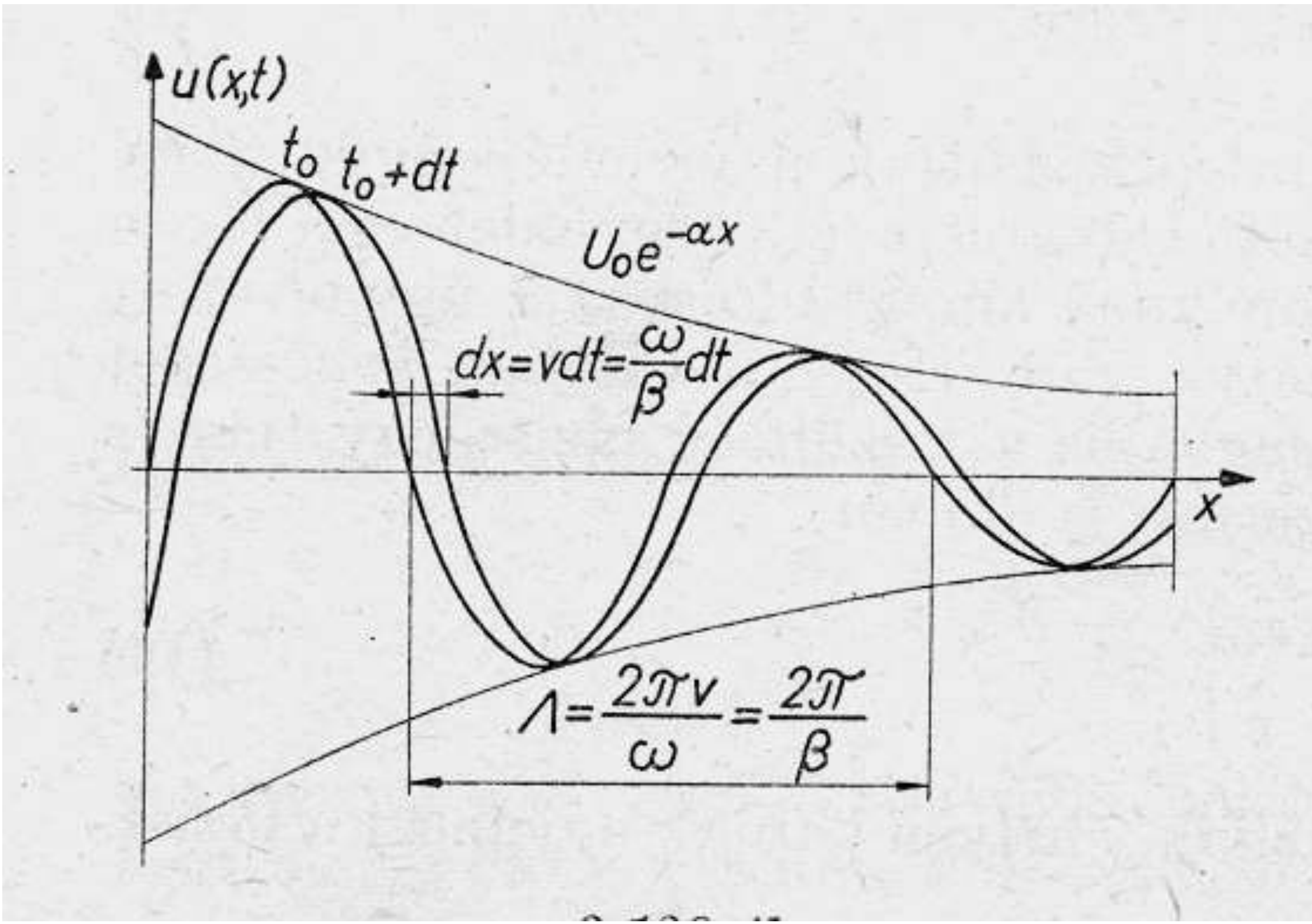
$$\gamma = \alpha + j\beta.$$

$$\gamma = \pm \sqrt{(R + j\omega L)(G + j\omega C)}.$$

$$u(x, t) = u^+ + u^- = U_0^+ \, e^{j\omega t - \gamma x} + U_0^- \, e^{j\omega t + \gamma x},$$

$$i(x, t) = i^+ + i^- = I_0^+ \, e^{j\omega t - \gamma x} + I_0^- \, e^{j\omega t + \gamma x};$$

Consequence No.1 waveform of voltage as a function of distance along the wire



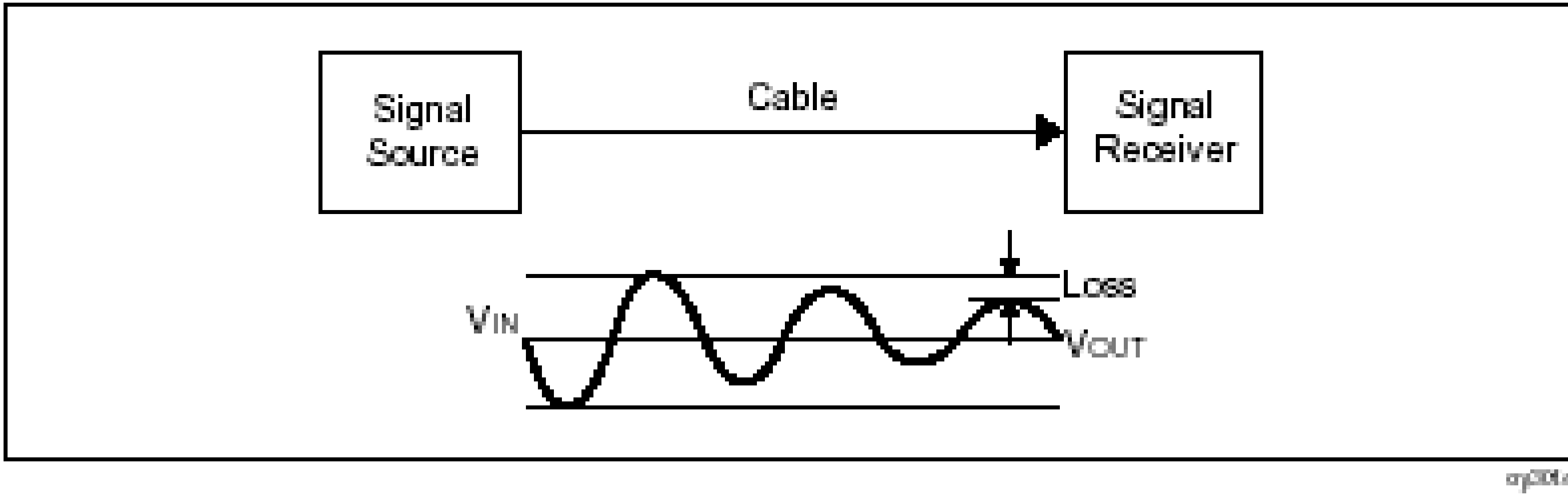
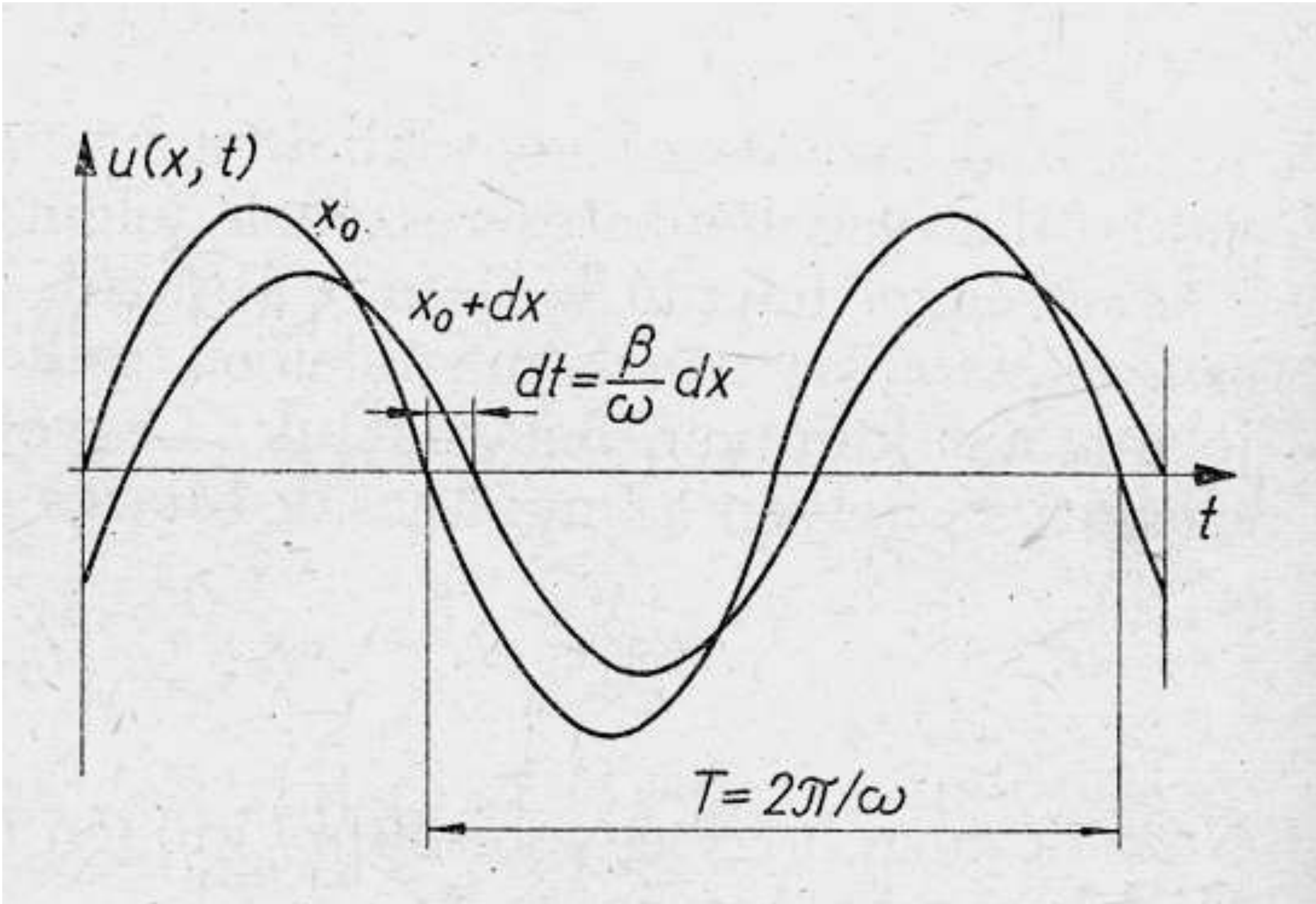


Figure 7-7. Attenuation of a Signal

Consequence No.2 waveform of voltage as a function of time



Transmission properties of wires: attenuation, phase shift, characteristic impedance

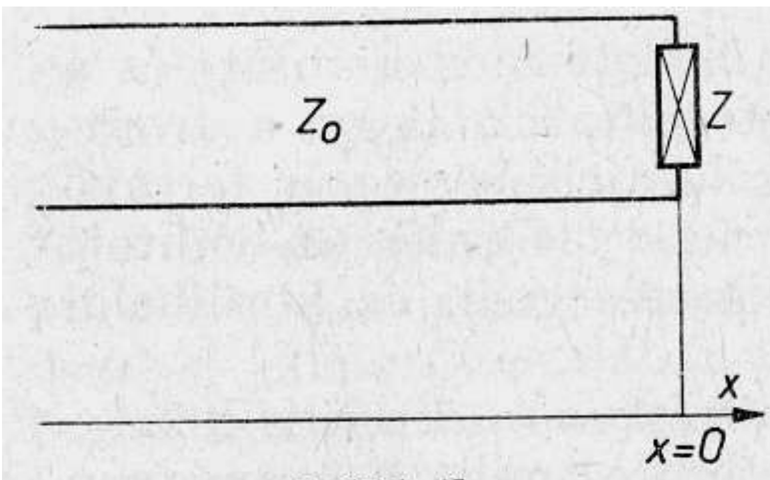
$$\alpha = \pm \sqrt{\frac{1}{2}(RG - \omega^2 LC) + \frac{1}{2}\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)}}.$$

$$\beta = \pm \sqrt{\frac{1}{2}(\omega^2 LC - RG) + \frac{1}{2}\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)}}.$$

$$Z_0 = \sqrt{\frac{R + \mathrm{j}\,\omega L}{G + \mathrm{j}\,\omega C}}$$

Phenomenon at the end of terminated wire

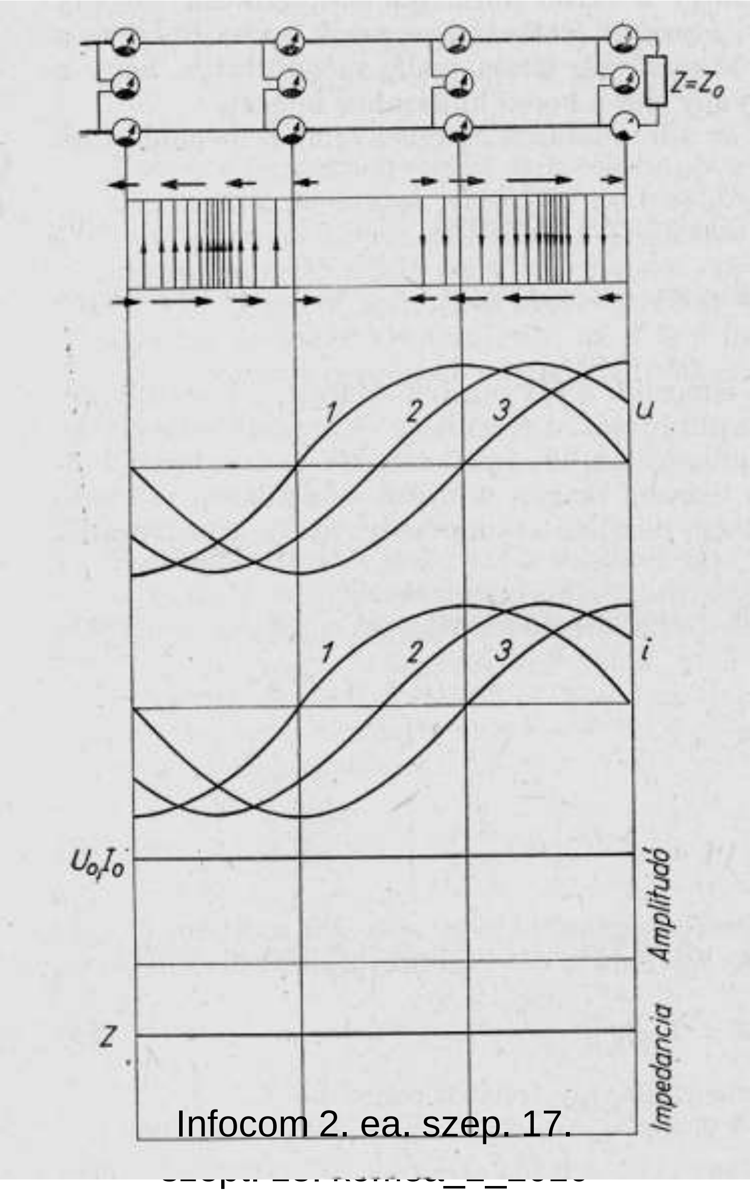
Reflection coefficient



$$r = U_0^- / U_0^+$$

$$r = \frac{Z - Z_0}{Z + Z_0}.$$

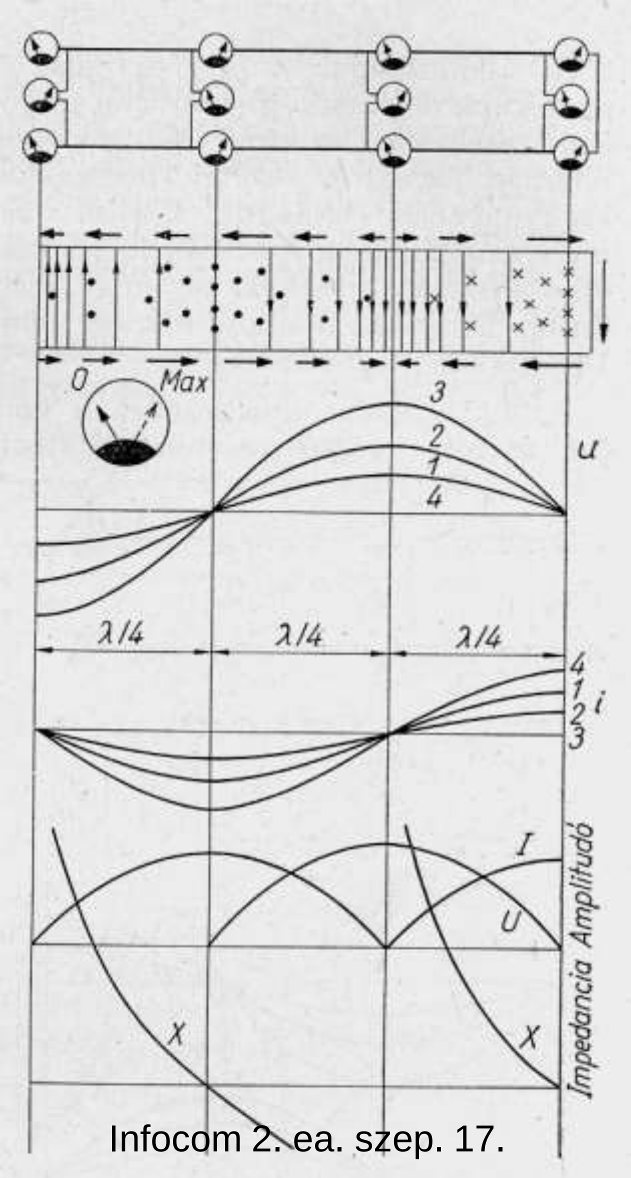
Phenomenon at the end of terminated wire example No1. : matched termination



$Z=Z_0$

NO reflection!

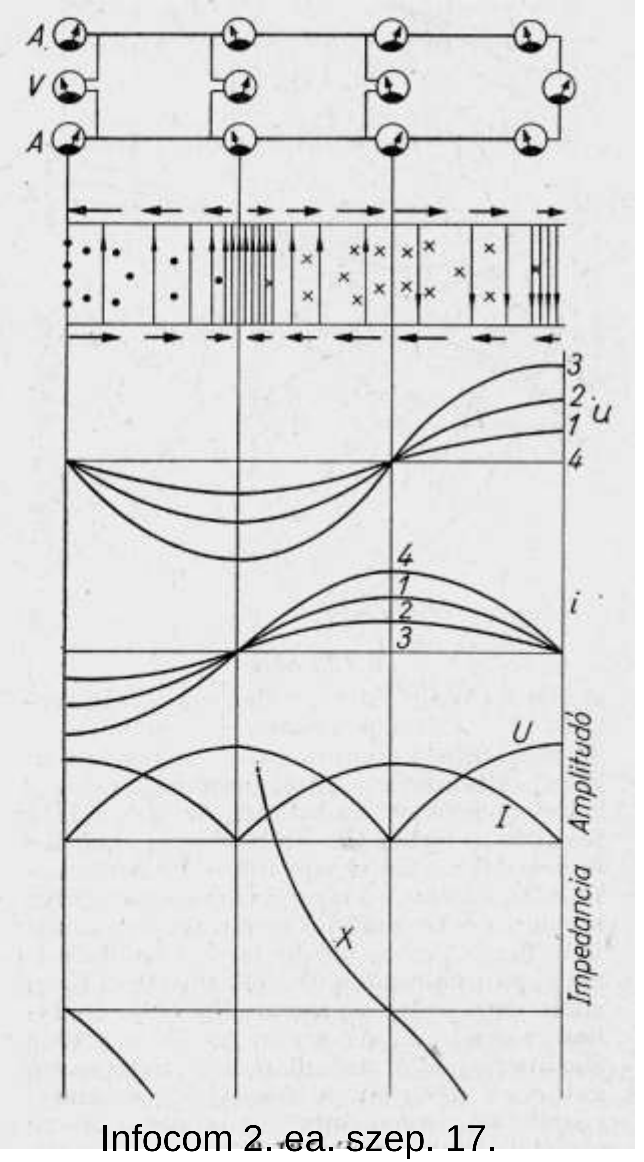
Phenomenon at the end of terminated wire example No2. : shortcut at the end



Z=0

FULL **(negative) reflection**!

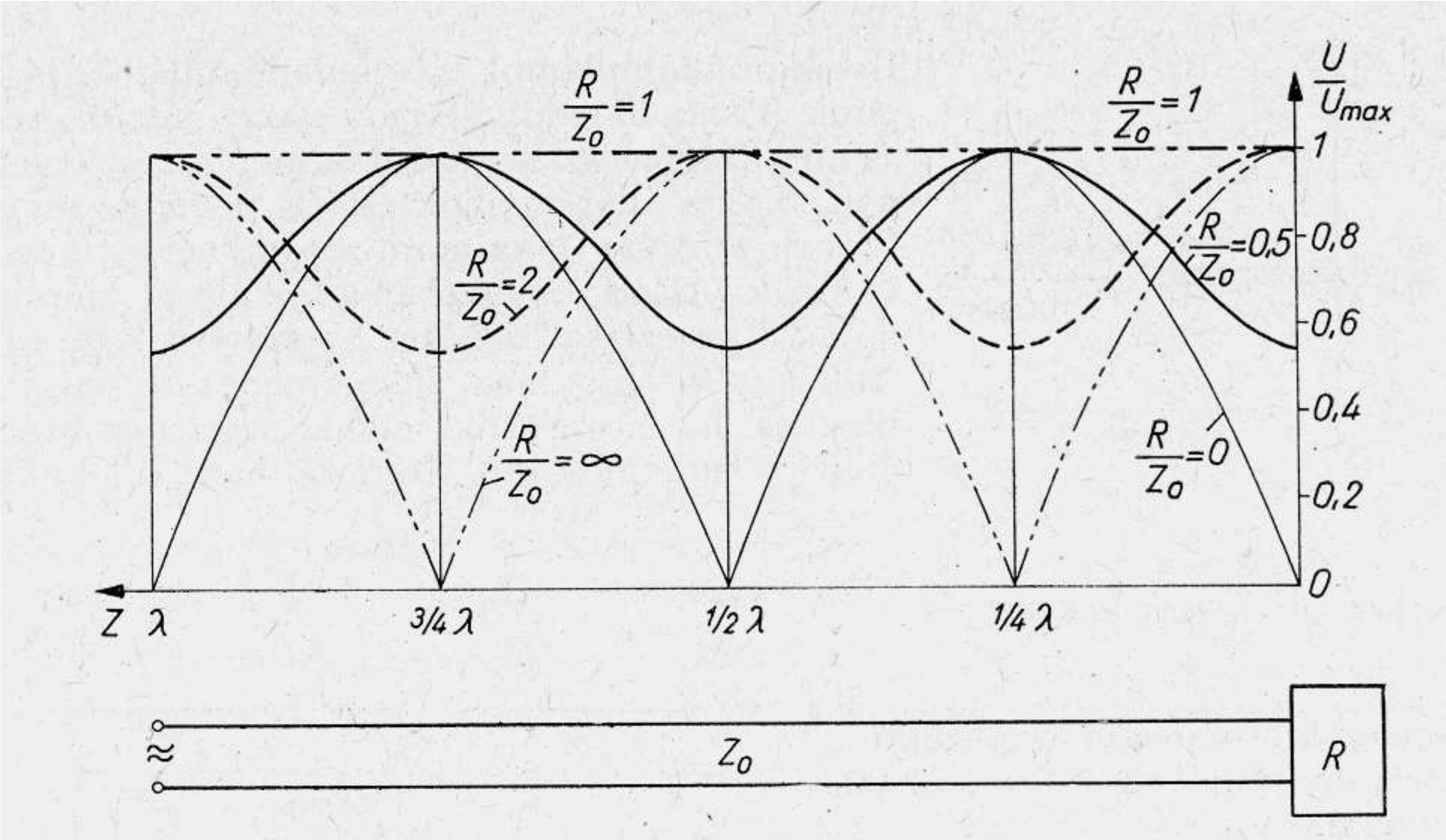
Phenomenon at the end of terminated wire example No3. : open end

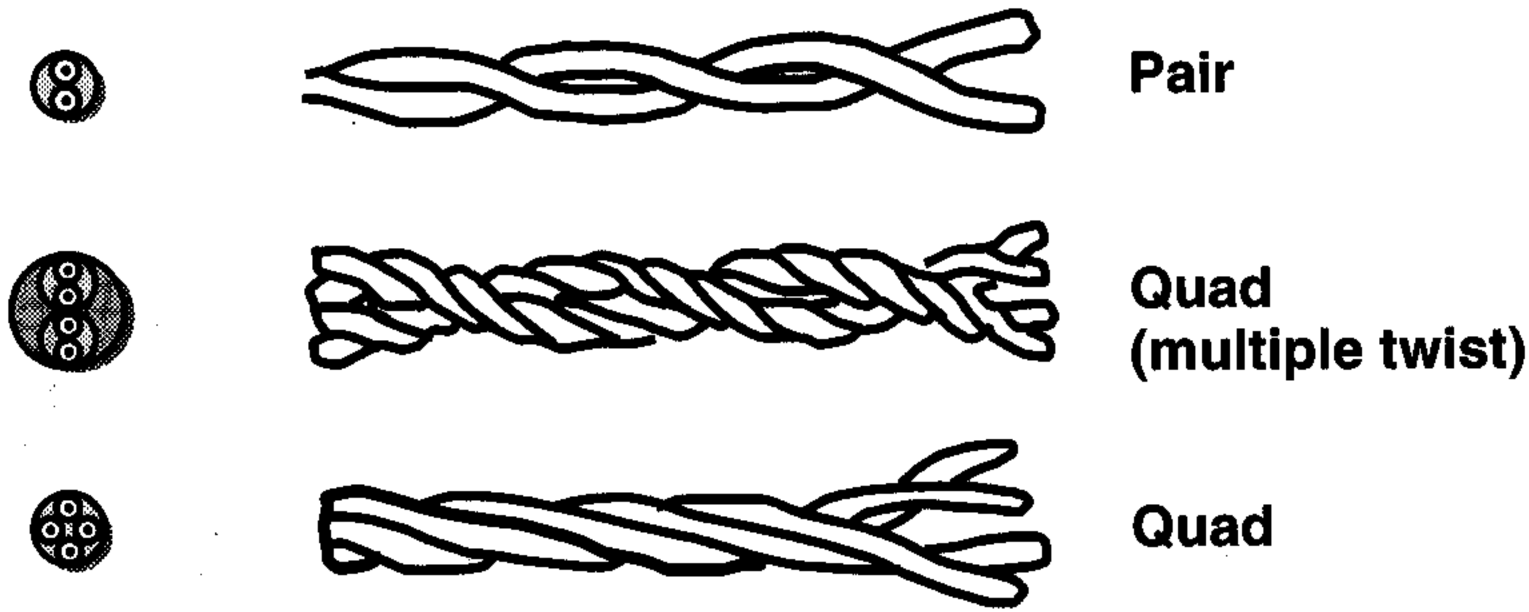


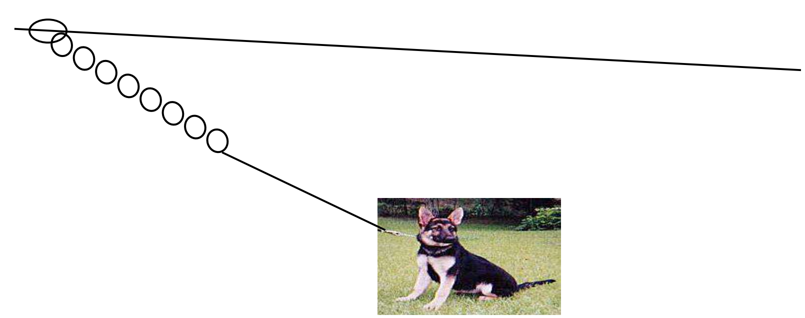
Z=∞

FULL reflection!

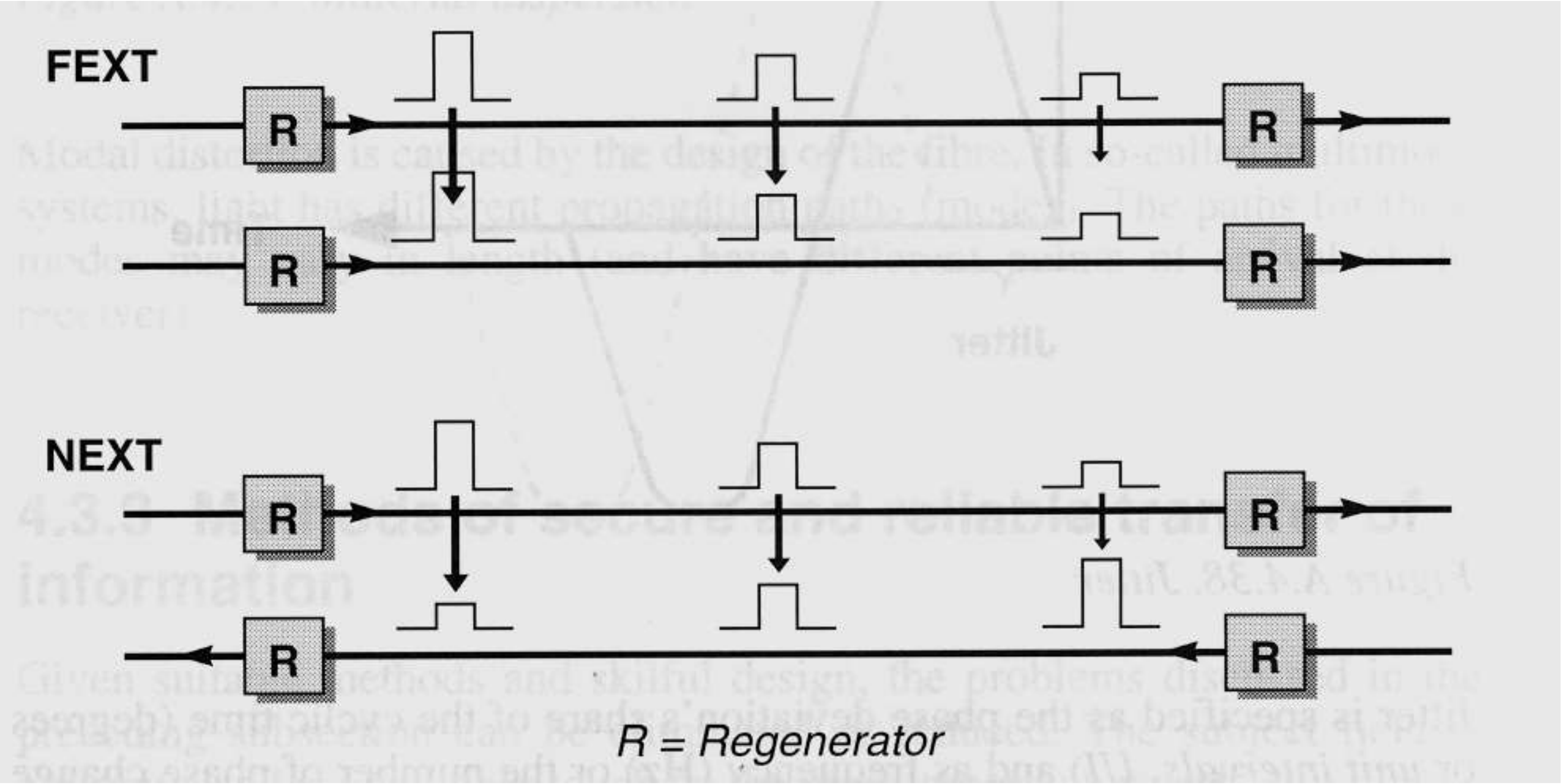
Phenomenon at the end of terminated wire example No4. : ohmic termination




Pair
Quad
(multiple twist)
Quad



Far end crosstalk and near end crosstalk



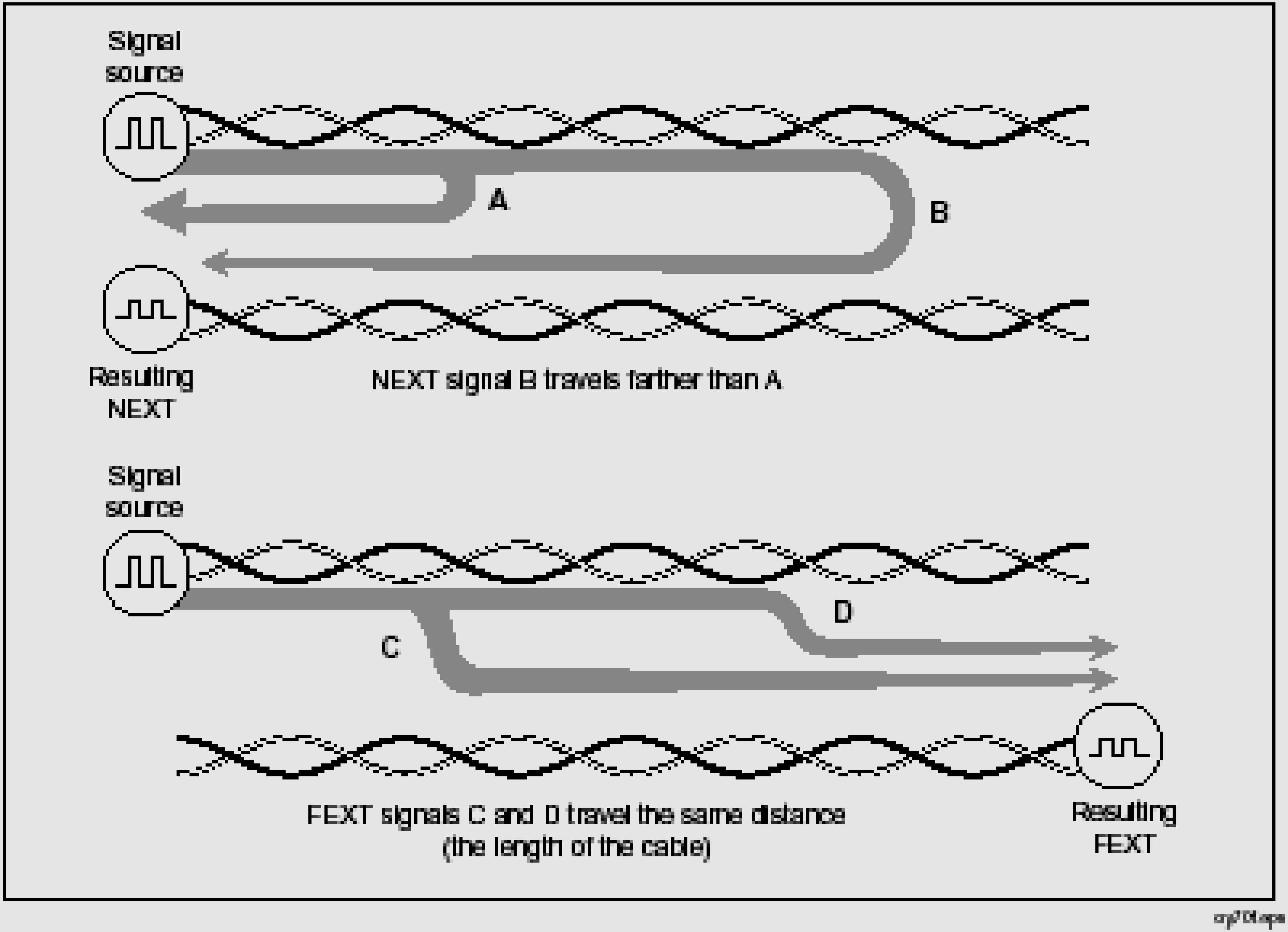
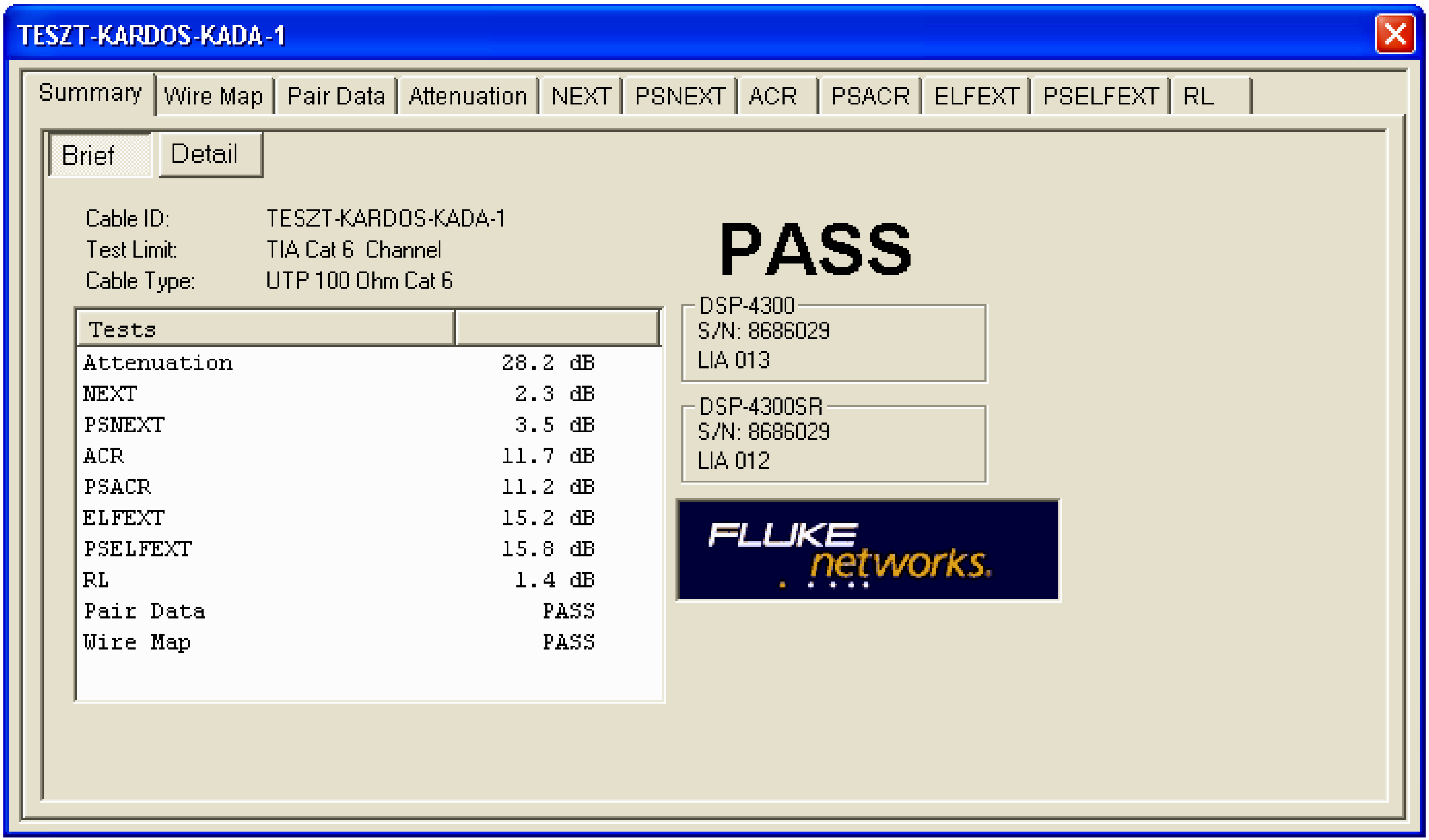


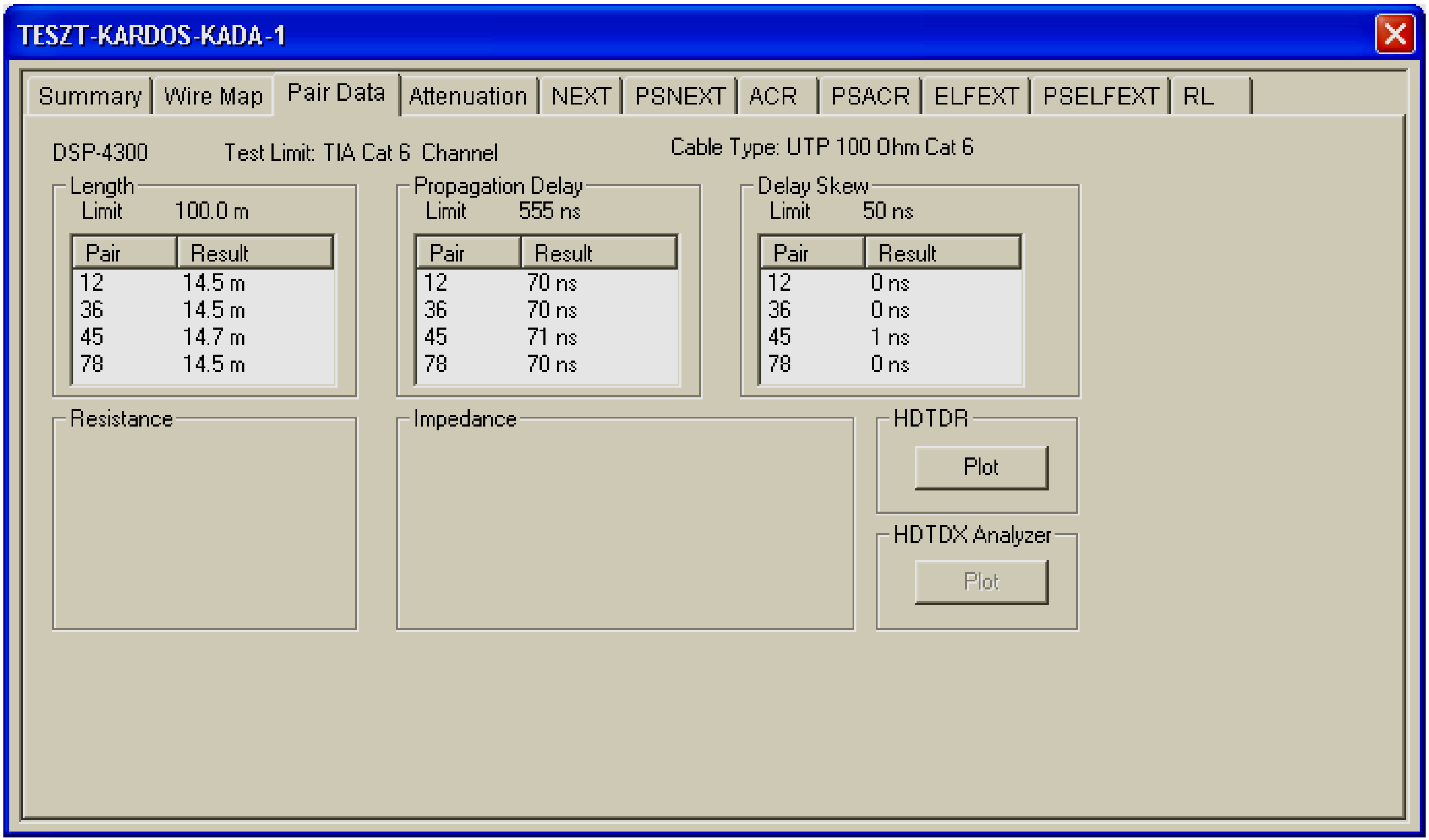
Figure 7-9. How FEXT Signals are All Equally Attenuated

Infocom 2. ea. szep. 17.

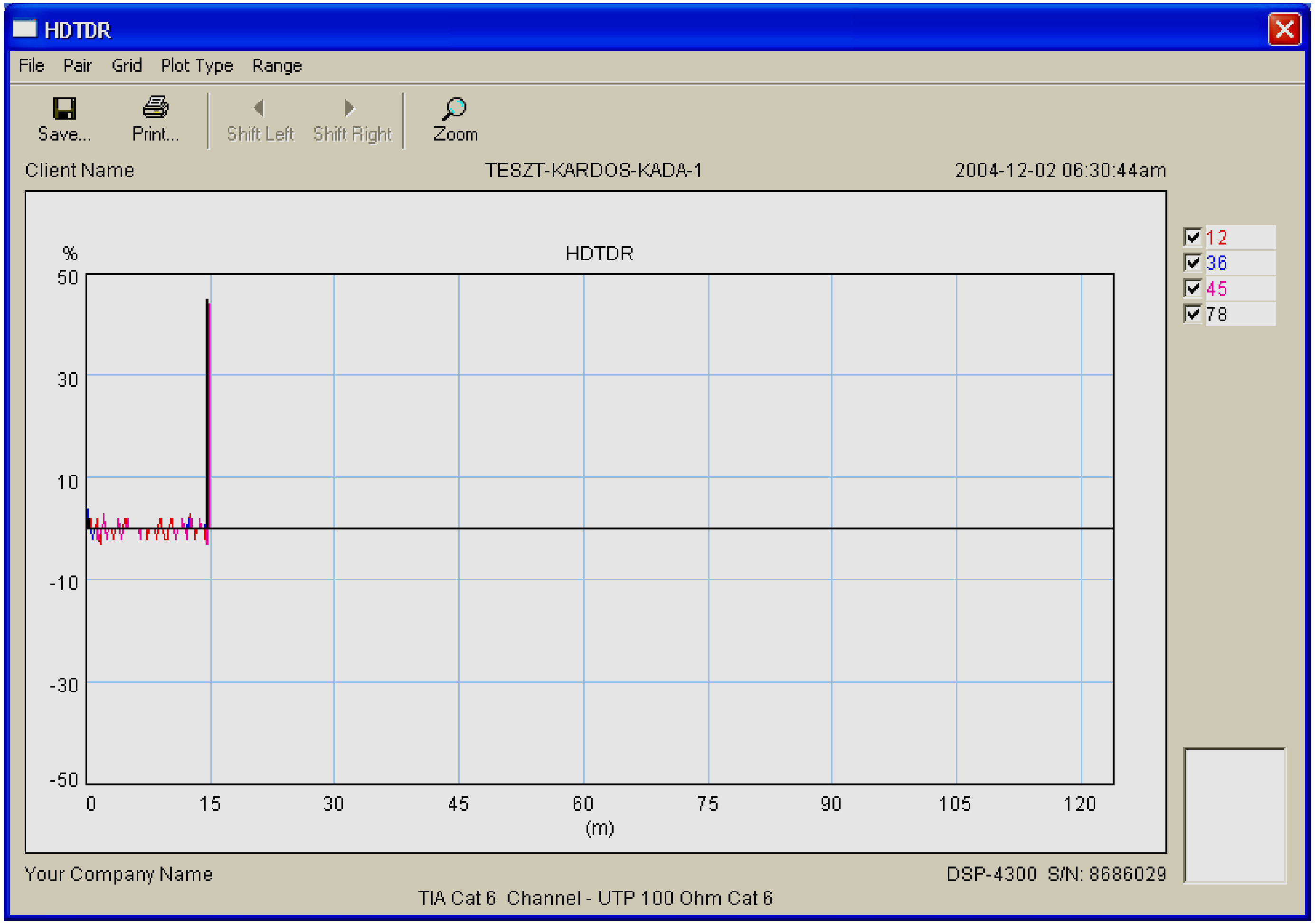
Characteristics of an UTP cabeling passing the CAT6 specifications



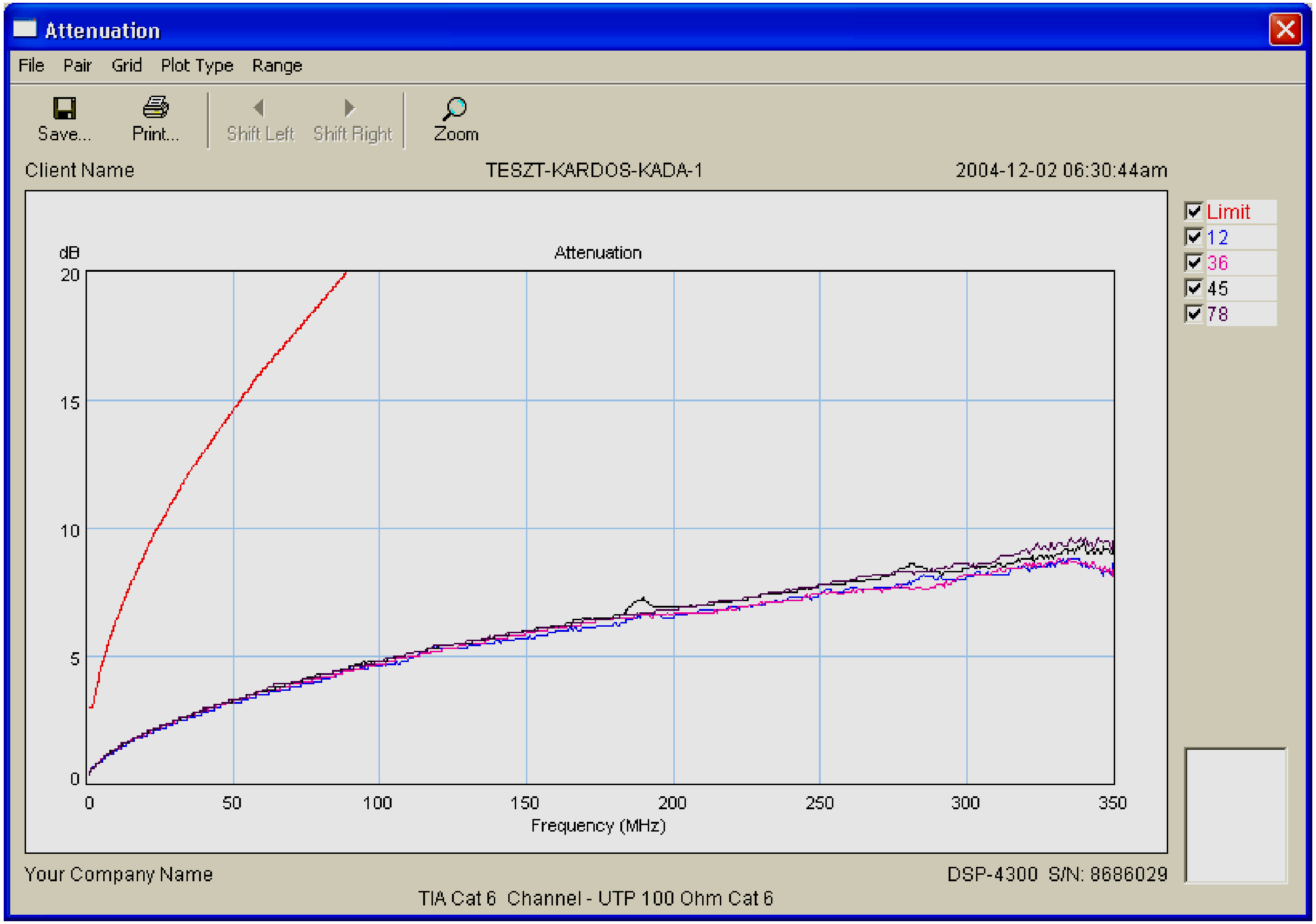
Propagation delay parameters
The propagation speed is about 70% of light speed



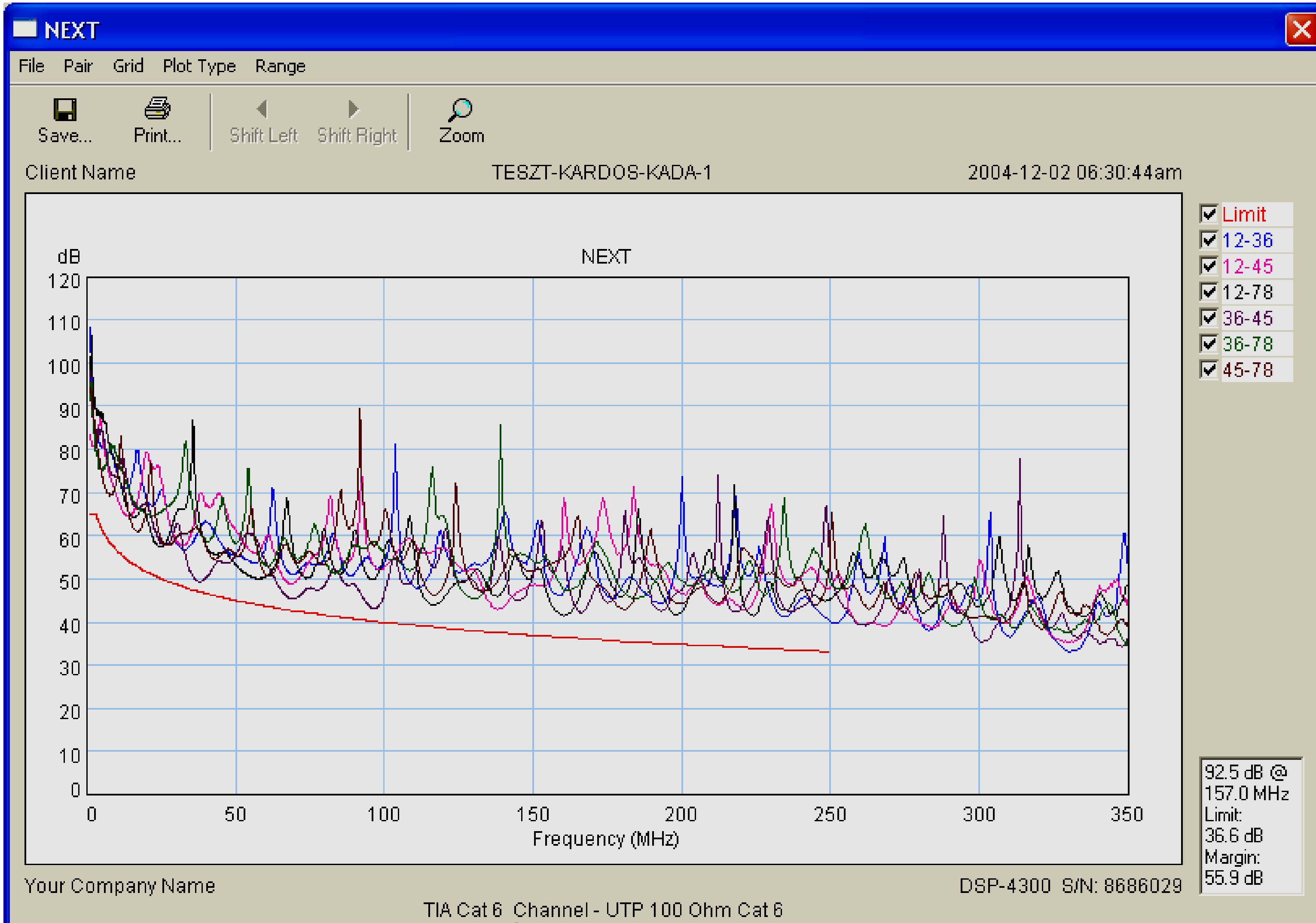
The reflected signal response at the cable input after sending a nerrow pulse. The far end is terminated by open end!



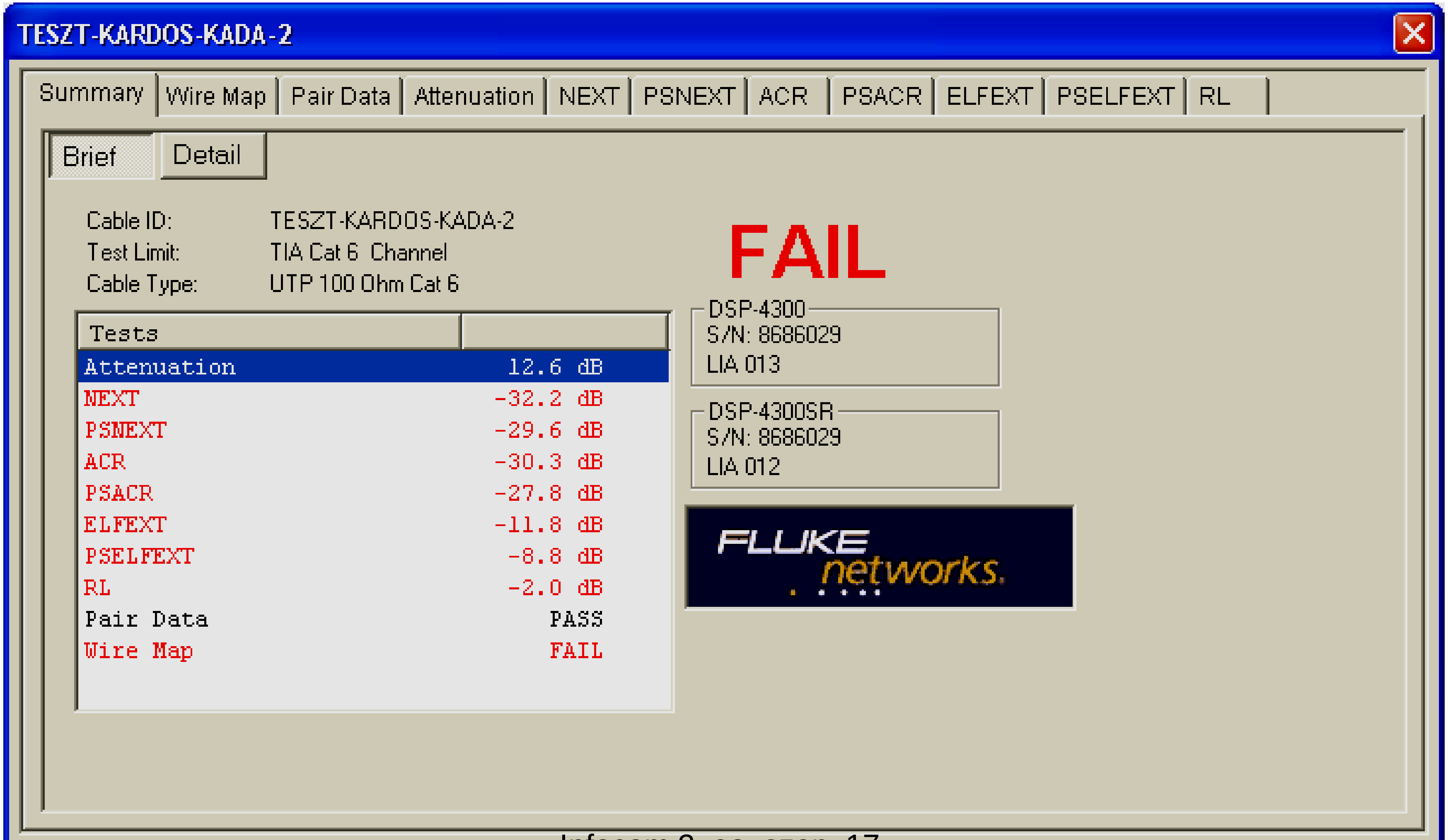
Attenuation – as a function of frequency



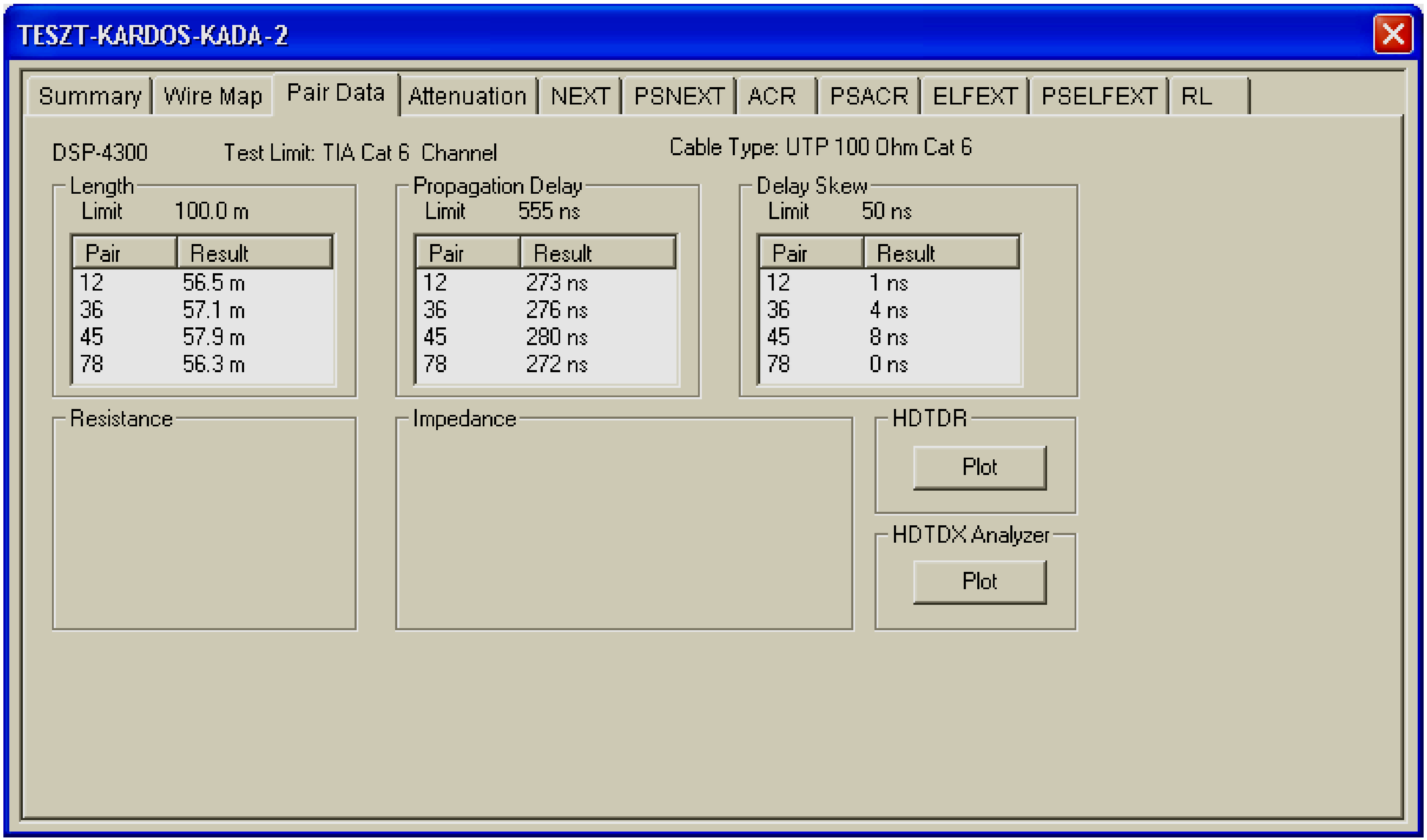
Near end crosstalk as a function of frequency



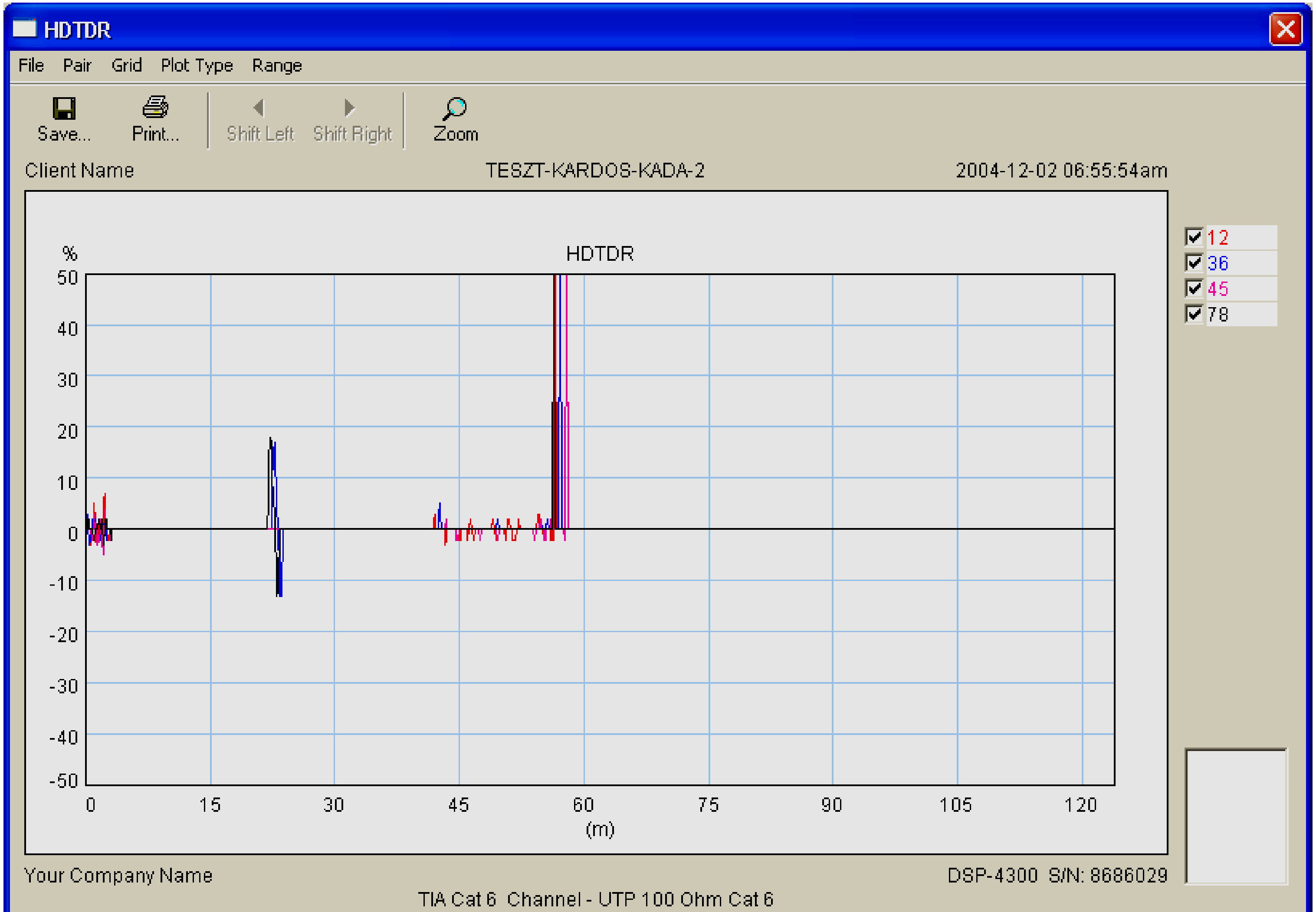
Characteristics of an UTP cabeling failing the CAT6 specifications
What is the problem with this cable?



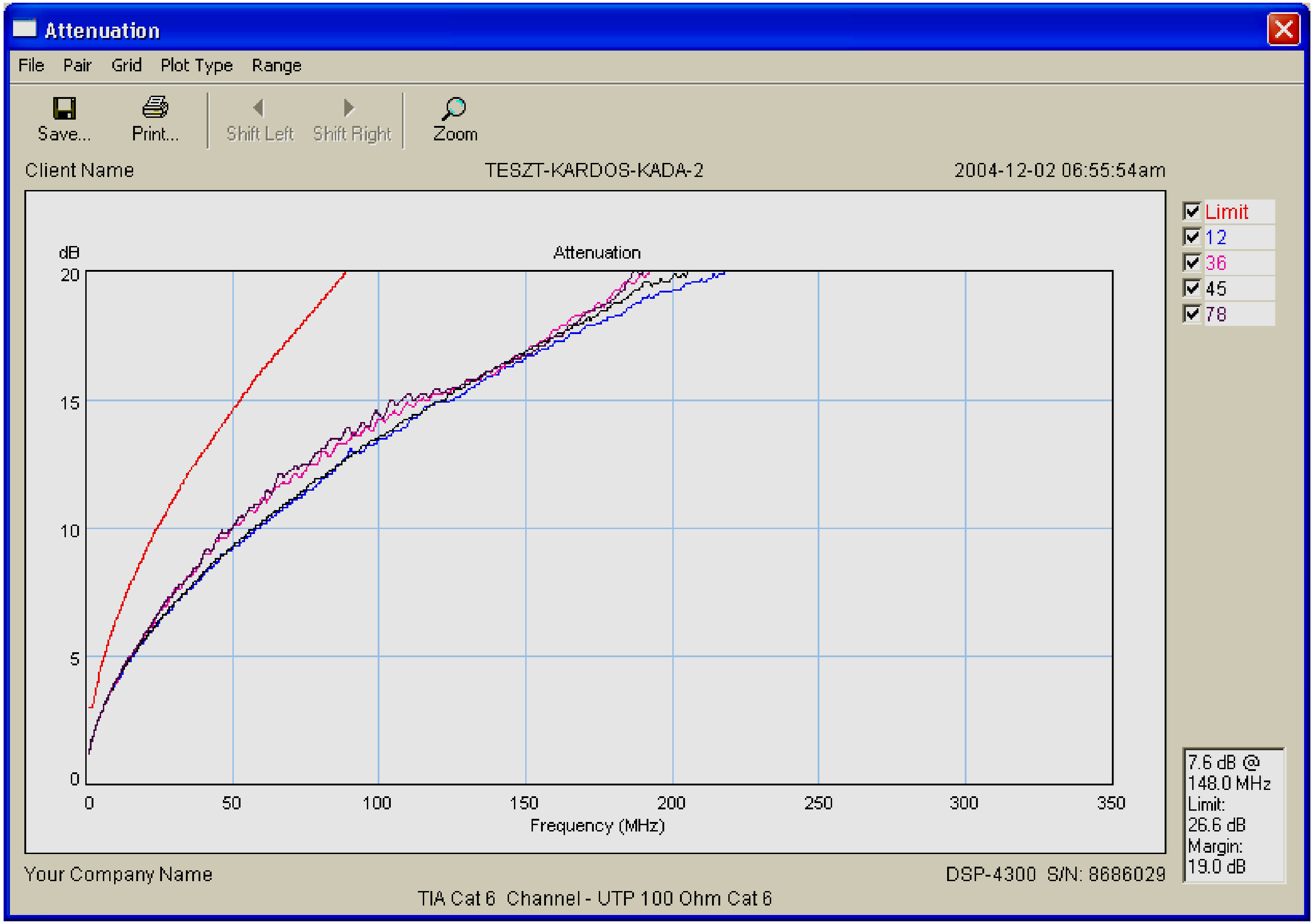
Propagation delay parameters
The propagation speed is about 70% of light speed



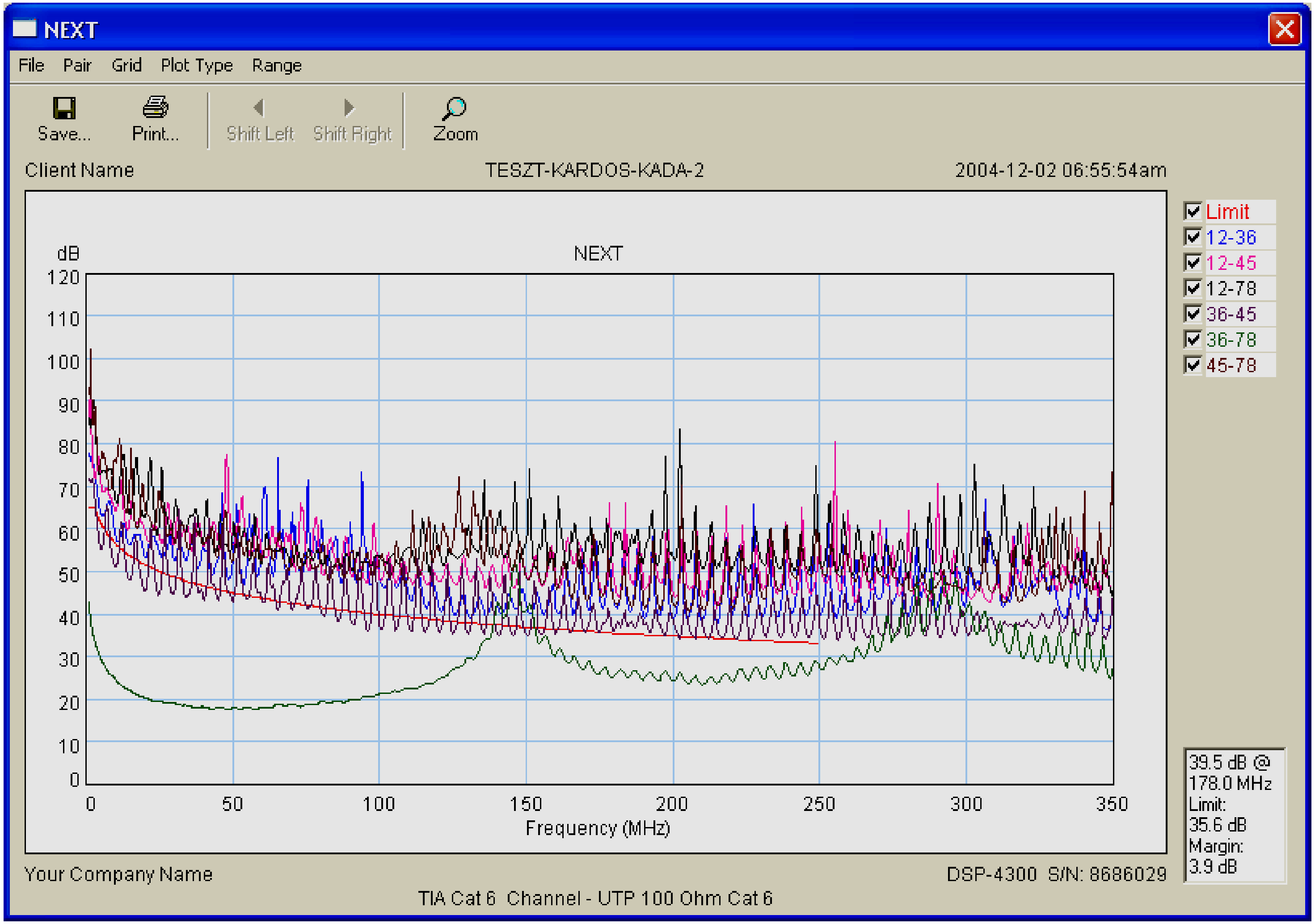
The reflected signal response at the cable input after sending a nerrow pulse. The far end is terminated by open end! There are reflections from a mid position but only in pairs 36-78!



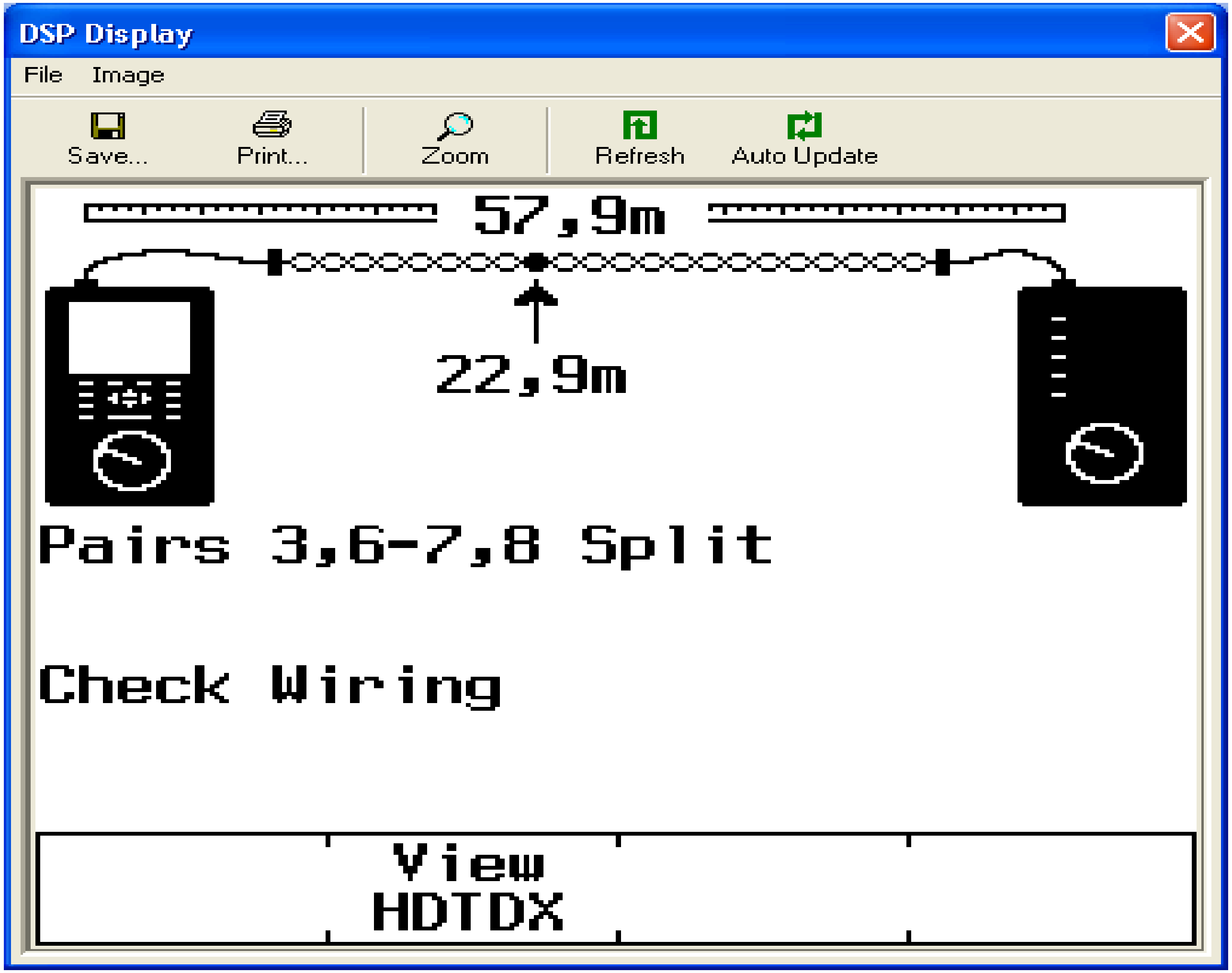
The attenuation is OK!



Near end crosstalk failed at pairs 36-78!



The problem is in the cable a wire split at 22,9 m !



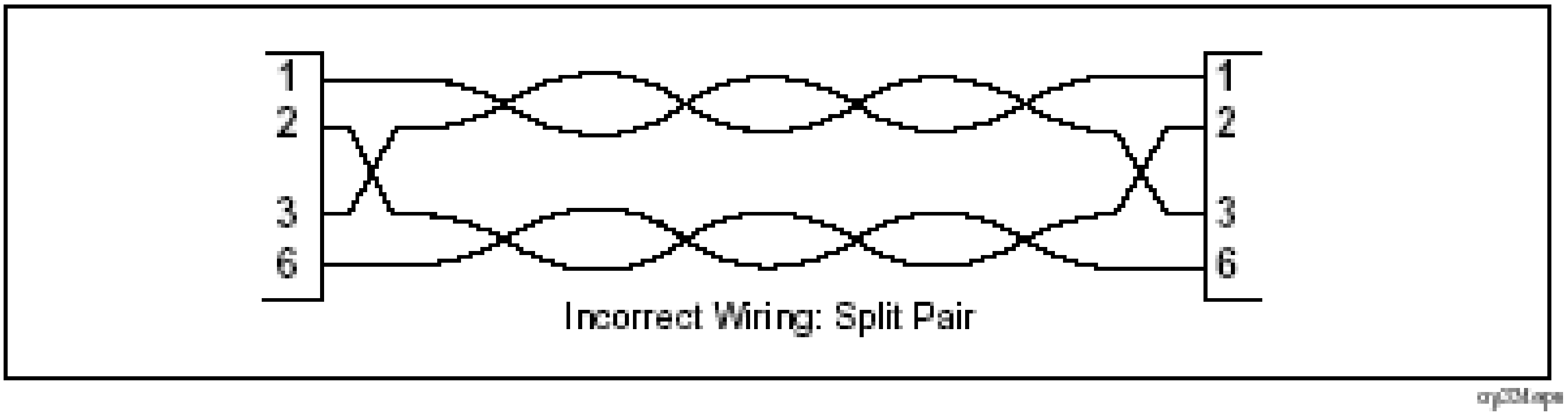
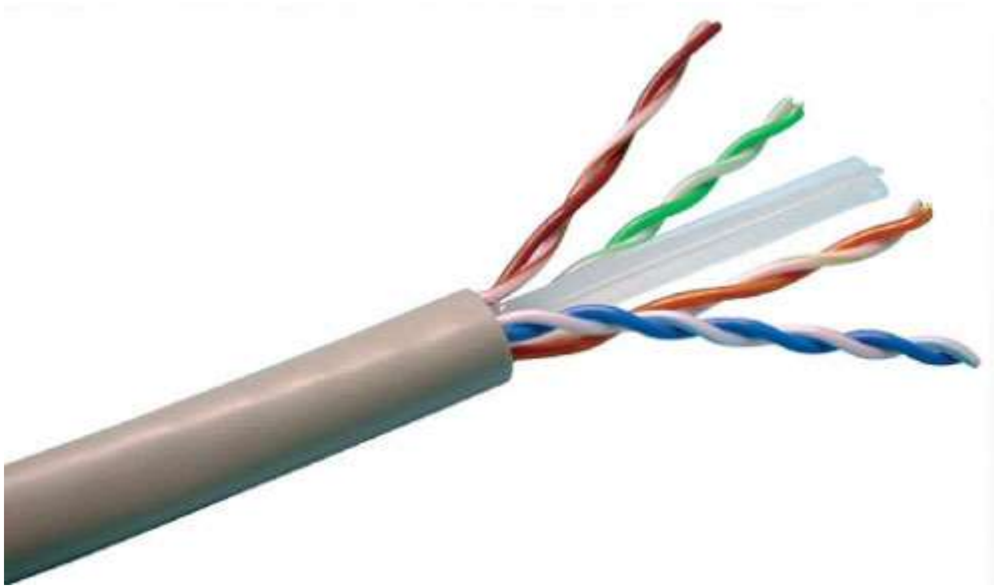


Figure 7-11. Split Pair Wiring


Cat5e
Cat6
Cat6a
Cat7a
Cat8
FASTER
Class D
100MHz
1000Base-T
100m max run
Class E
250MHz
1000Base-T
100m
Class Ea
500 MHz
10GBase-T
100m
Class F or Fa
600 to 1000MHz
10GBase-T
100m
Class II Cat8.2
1600 to 2000MHz
25/40GBase-T
30m

UTP = Unshielded Twisted Pair

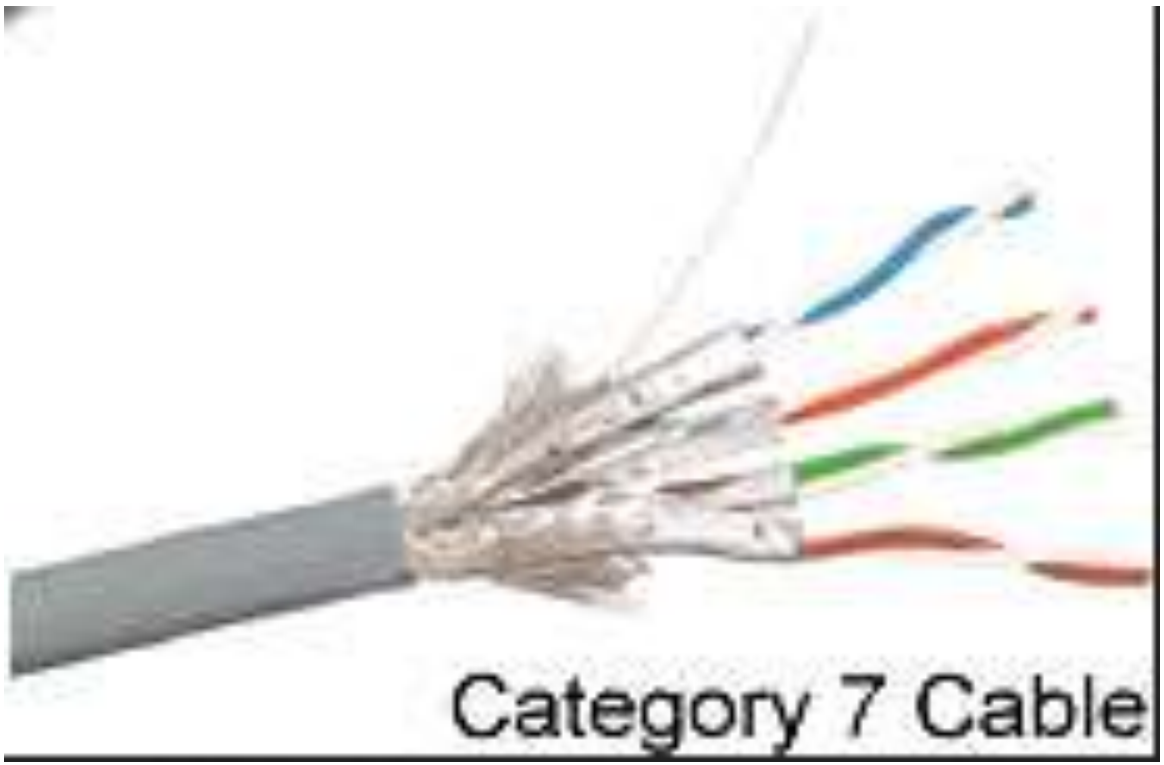
Cat-6 twisted pair cabling



CAT-6 250 MHz UTP cable supports 1 Gbps Ethernet 1-100-m LAN applications.

CAT-6 250 MHz UTP cable only supports 10 Gbps short length applications from 35-55 m depending on crosstalk environment.

Cat-7 twisted pair cabling



CAT-7 600MHz individually shielded pair cabling with overall cable shield was initiated by European market leaders and standards bodies for 10 Gbps 100-m Ethernet LAN applications

Cat-8 twisted pair cabling

IEEE-802.3bq committee, primarily targeting 40GBaseT applications. CAT-8 cabling types are already in production

CAT-8 cabling is larger in diameter size

CAT-8 Cable 40 Gbps

Cat.8 UCFUTURE COMPACT22 S/FTP 4P 2000MHz LSHF-FR

Vissza: Cat.6A, Cat.7 és Cat.8 fali kábelek

Cat.8 UCFUTURE COMPACT22 S/FTP 4P 2000MHz LSHF-FR

With shipment Futár for 1537 Ft

Webshop ár: 826 Ft

Nettó webshop ár: 650 Ft

1 Kosárba tesz

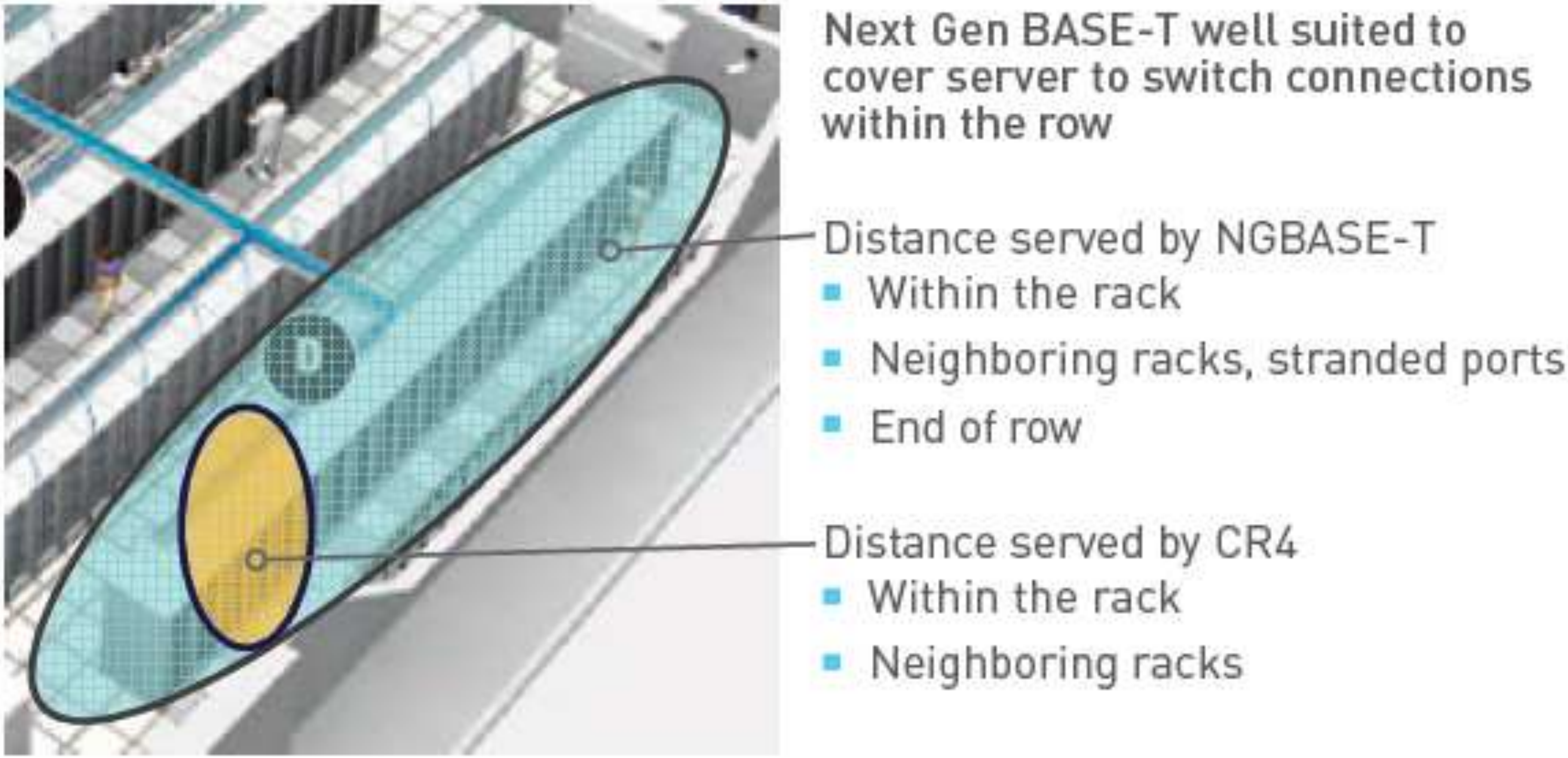
Cat.8 UCFUTURE COMPACT22 S/FTP 4P 2000MHz LSHF-FR

Leírás

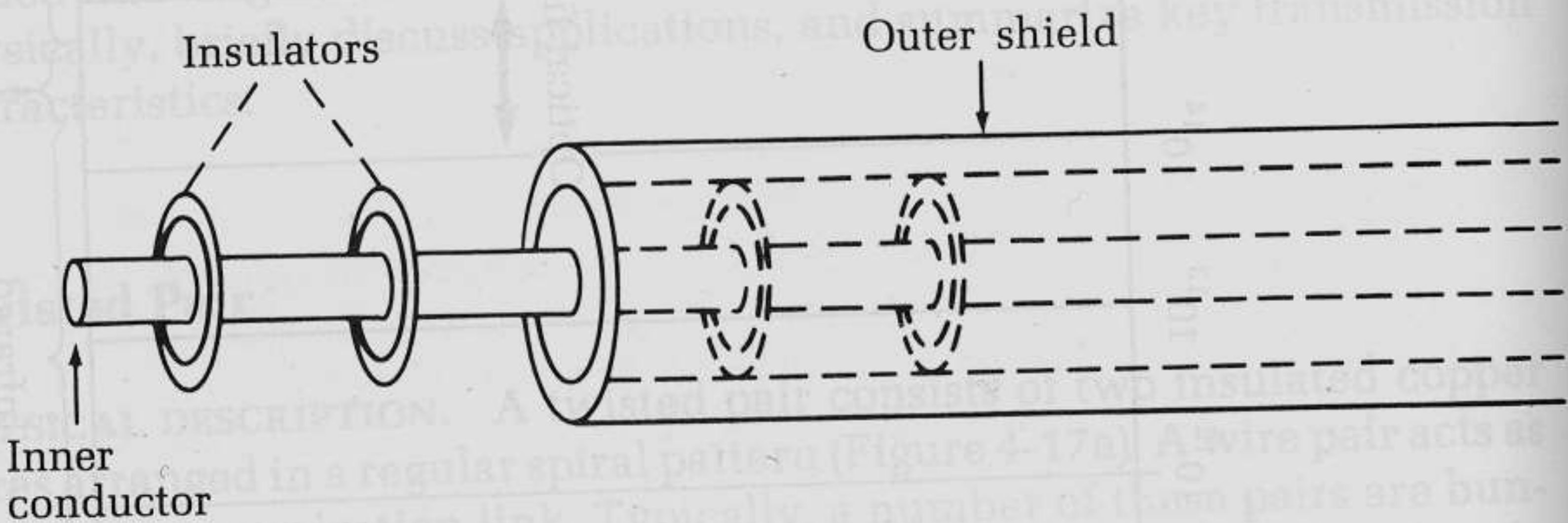
Cat.8.2 UCFUTURE COMPACT22 S/FTP 4P 2000MHz LSHF-FR

2000Mhz sávszélesség, mely már a Cat8.2 szabványnak is megfelel

Figure 2: Applications for 40GBASE-T



Structure of a coaxial cable

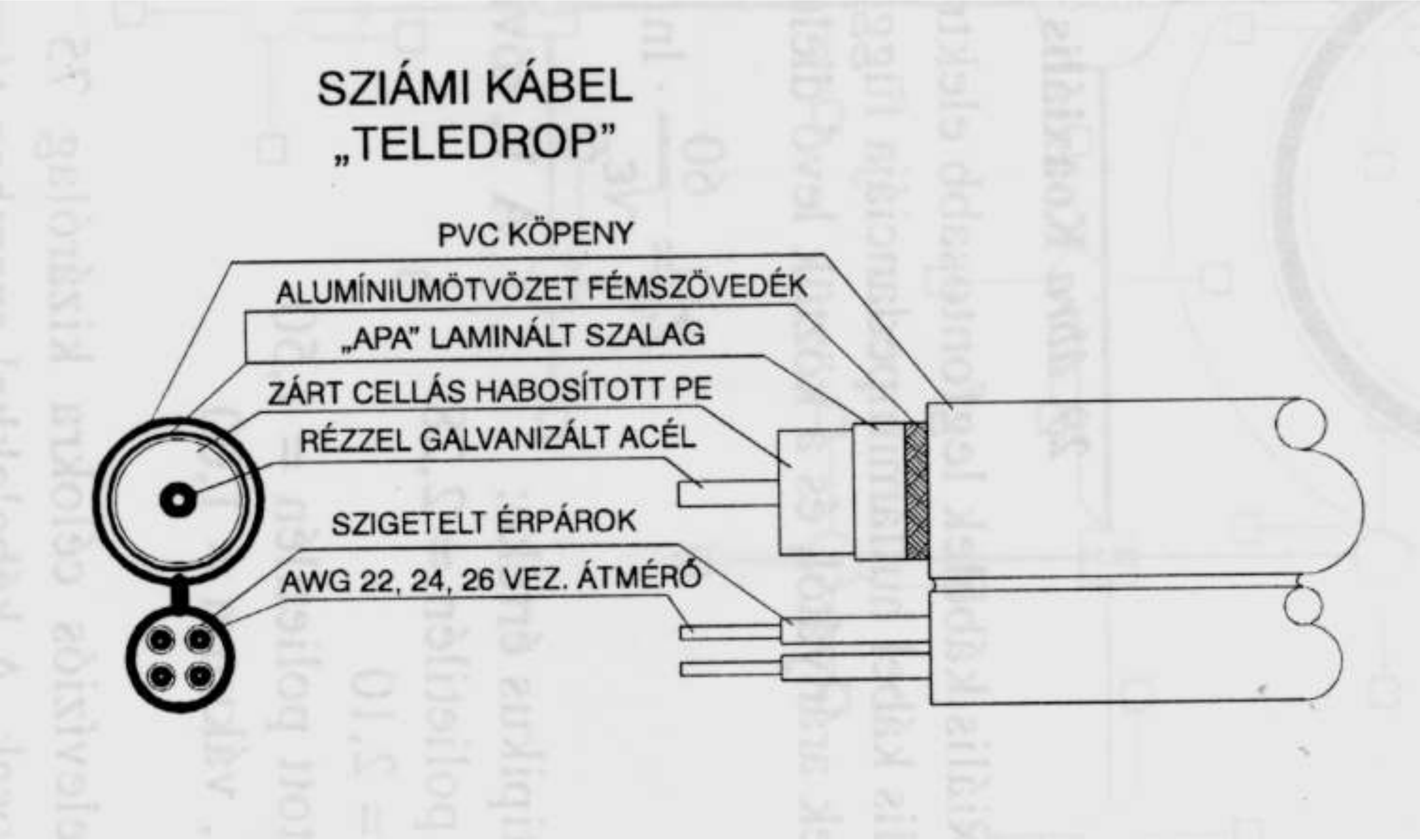


- Outer conducter braided shield
- Inner conducter solid metal
- Separated by insulating material
- Covered by padding

(b) Coaxial cable

Figure A.4.14 Coaxial cable

Figure A.4.15 Coaxial tube with plastic washers


SZIÁMI KÁBEL
„TELEDROP"
PVC KÖPENY
ALUMÍNIUMÖTVÖZET FÉMSZÖVEDÉK
„APA" LAMINÁLT SZALAG
ZÁRT CELLÁS HABOSÍTOTT PE
RÉZZEL GALVANIZÁLT ACÉL
SZIGETELT ÉRPÁROK
AWG 22, 24, 26 VEZ. ÁTMÉRŐ

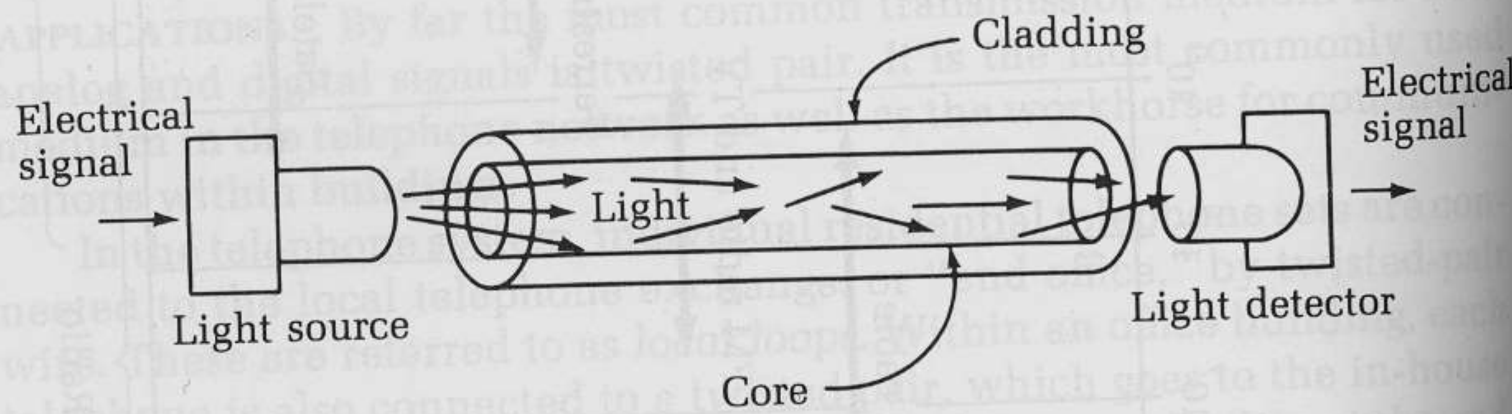
Twinax, is a type of cable similar to coaxial cable, but with two inner conductors instead of one. Due to cost efficiency it is becoming common in modern very-short-range high-speed differential signaling applications.

- 100 Gbit Ethernet

- 40GBASE-CR4 and 100GBASE-CR10 physical layers using 7 m twin-axial cable are being developed as part of the 100 Gbit Ethernet specifications by the IEEE 802.3bj workgroup; 100G QSFP28 DAC is the main type for this application.

Cisco SFP+ Copper Twinax direct-attach cables are suitable for very short distances and offer a cost-effective way to connect within racks and across adjacent racks. Cisco offers passive Twinax cables in lengths of 1, 1.5, 2, 2.5, 3 and 5 meters, and active Twinax cables in lengths of 7 and 10 meters.

Principle of optical fibre

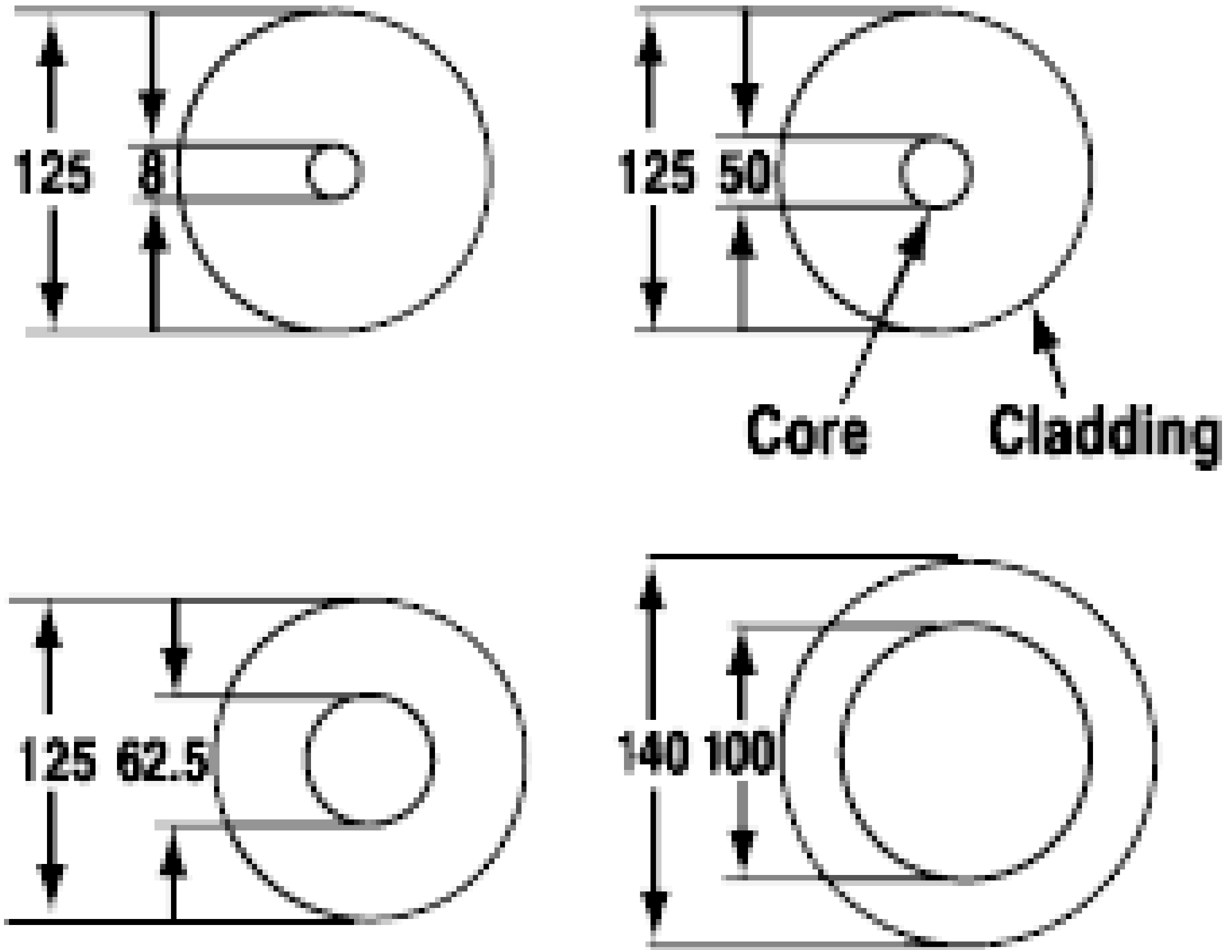


- Glass surrounded by cladding
- Laser or light emitting diode
- Specially designed jacked
- Small size and weight

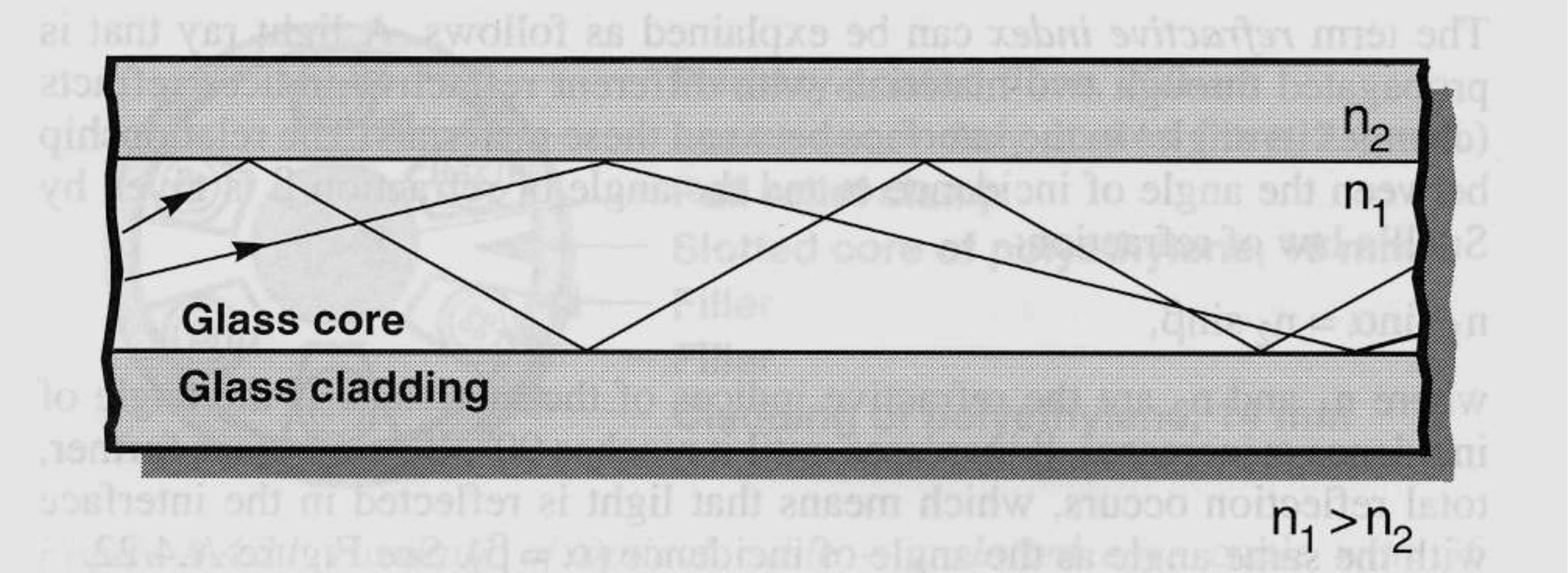
(c) Optical fiber

Fibre diameter 125μm !!!!

Typical core and cladding diameters -Sizes are in microns

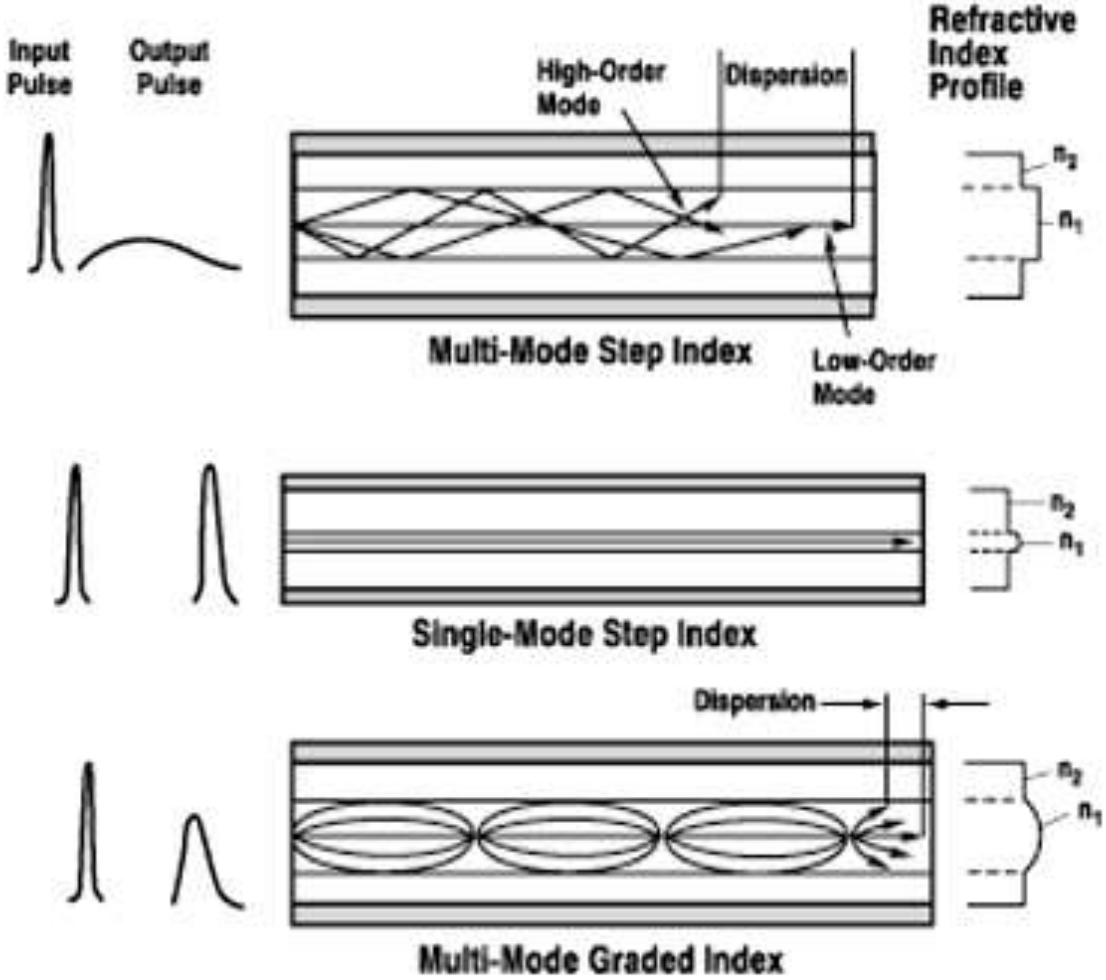


Transport of light in an optical fibre

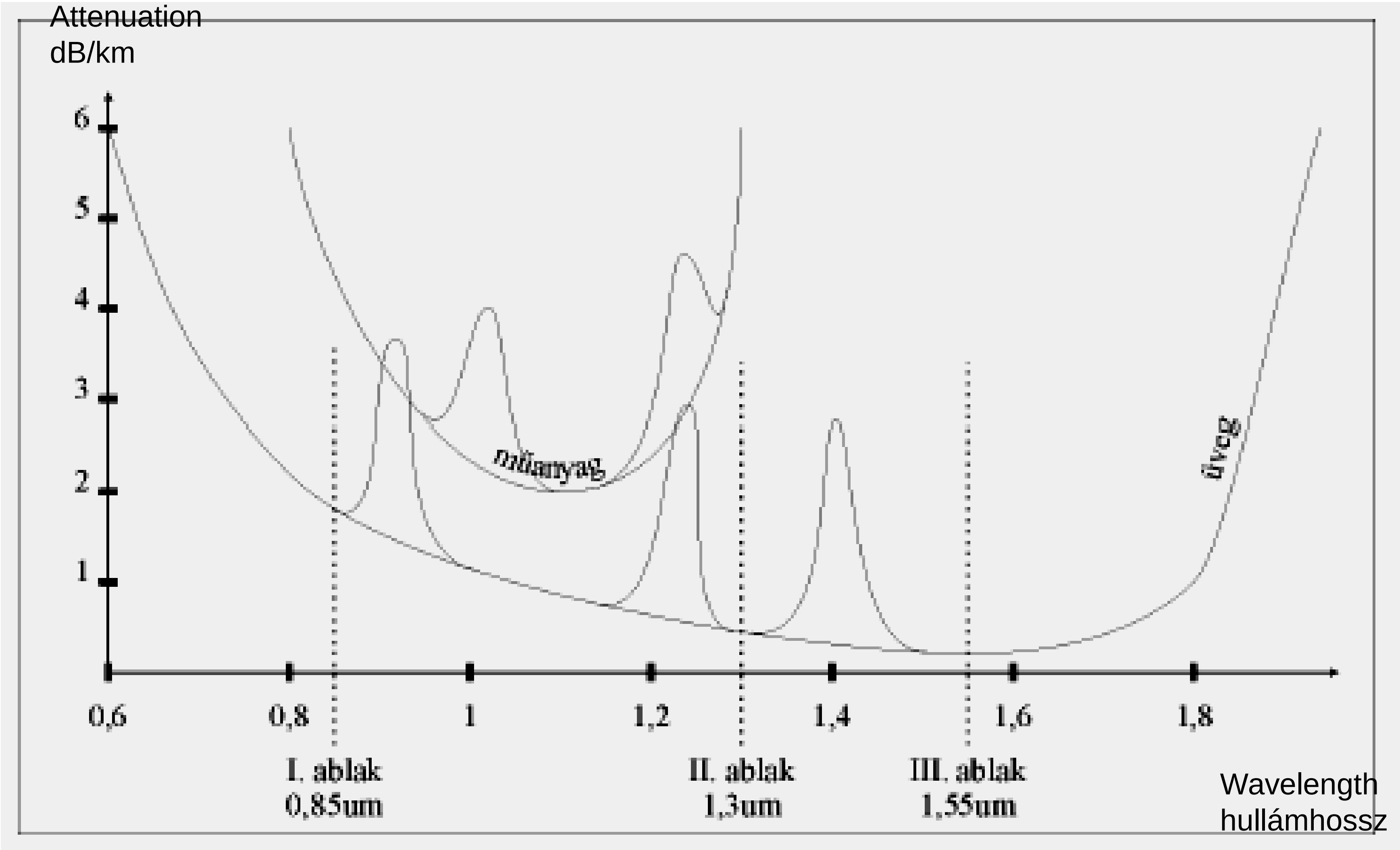


n refractive index

Types of mode propagation in fiber optic cable

- 

Cisco SFP+	Wavelength (nm)	Cable Type	Core Size (Microns)	Modal Bandwidth (MHz*km)***	Cable Distance*
Cisco SFP-10G-SR-S Cisco SFP-10G-SR Cisco SFP-10G-SR-X	850	MMF	62.5 62.5 50.0 50.0 50.0 50.0	160 (FDDI) 200 (OM1) 400 500 (OM2) 2000 (OM3) 4700 (OM4)	26m 33m 66m 82m 300m 400m
Cisco SFP-10G-LRM	1310	MMF SMF	62.5 50.0 50.0 G.652	500 400 500 -	220m 100m 220m 300m
Cisco SFP-10G-LR-S Cisco SFP-10G-LR Cisco SFP-10G-LR-X	1310	SMF	**8**	-	10km
Cisco SFP-10G-ER-S**** Cisco SFP-10G-ER****	1550	SMF	**8**	-	40km**
Cisco SFP-10G-ZR-S Cisco SFP-10G-ZR	1550	SMF	**8**	-	80km

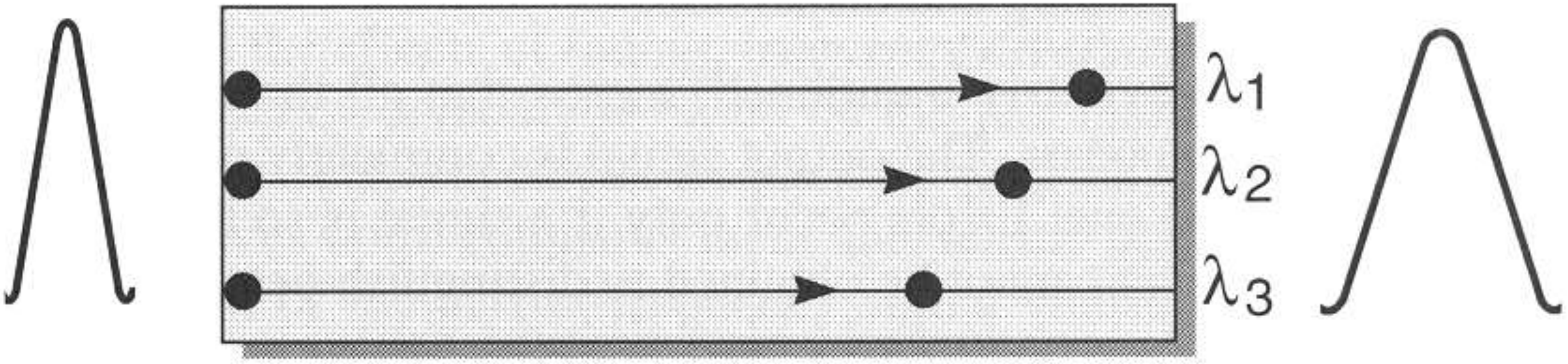

Attenuation
dB/km
6
5
4
3
2
1
0,6
0,8
1
1,2
1,4
1,6
1,8
műanyag
üveg
I. ablak
0,85um
II. ablak
1,3um
III. ablak
1,55um
Wavelength
hullámhossz

The intermodal dispersion discussed above can be characterized by the intermodal dispersion coefficient

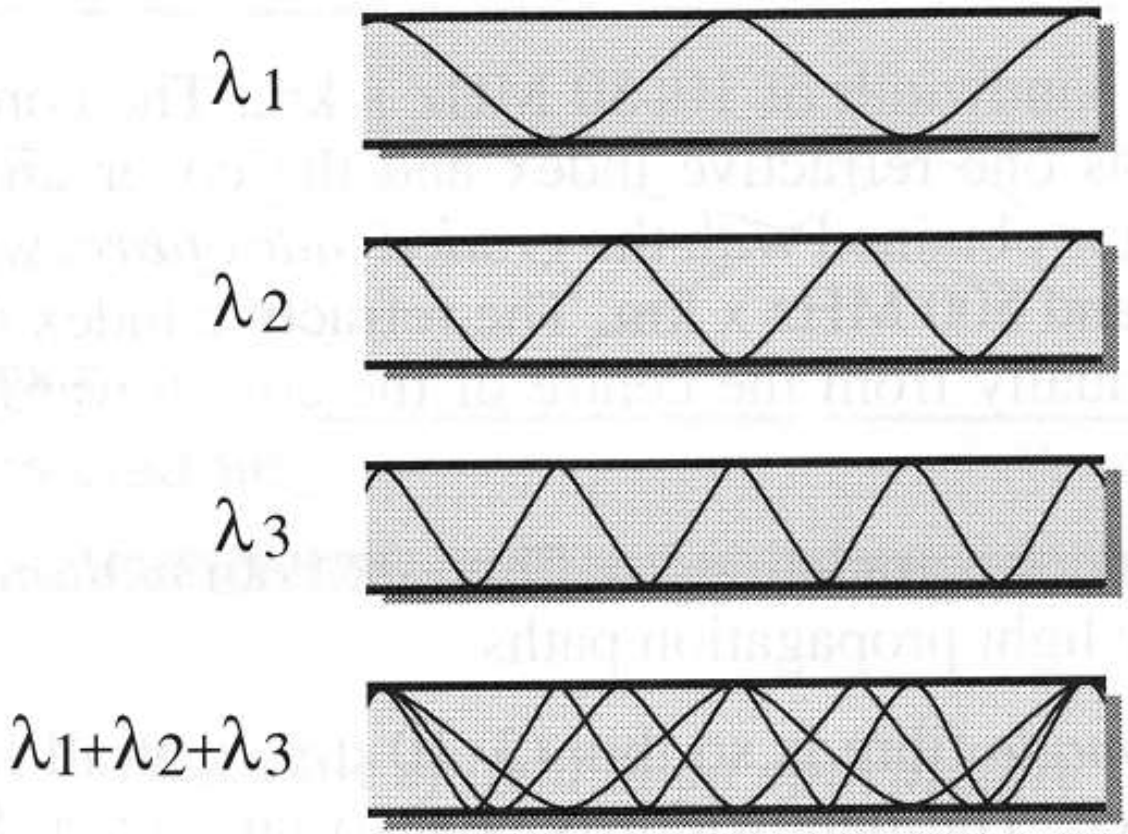
$$D_{im} = \frac{\Delta\tau}{L} \quad \text{[ns/km]} \qquad (2.1.4.6)$$

where $\Delta\tau$ is the group delay difference between the slowest and fastest mode and L is the length of the cable. For SI fibre

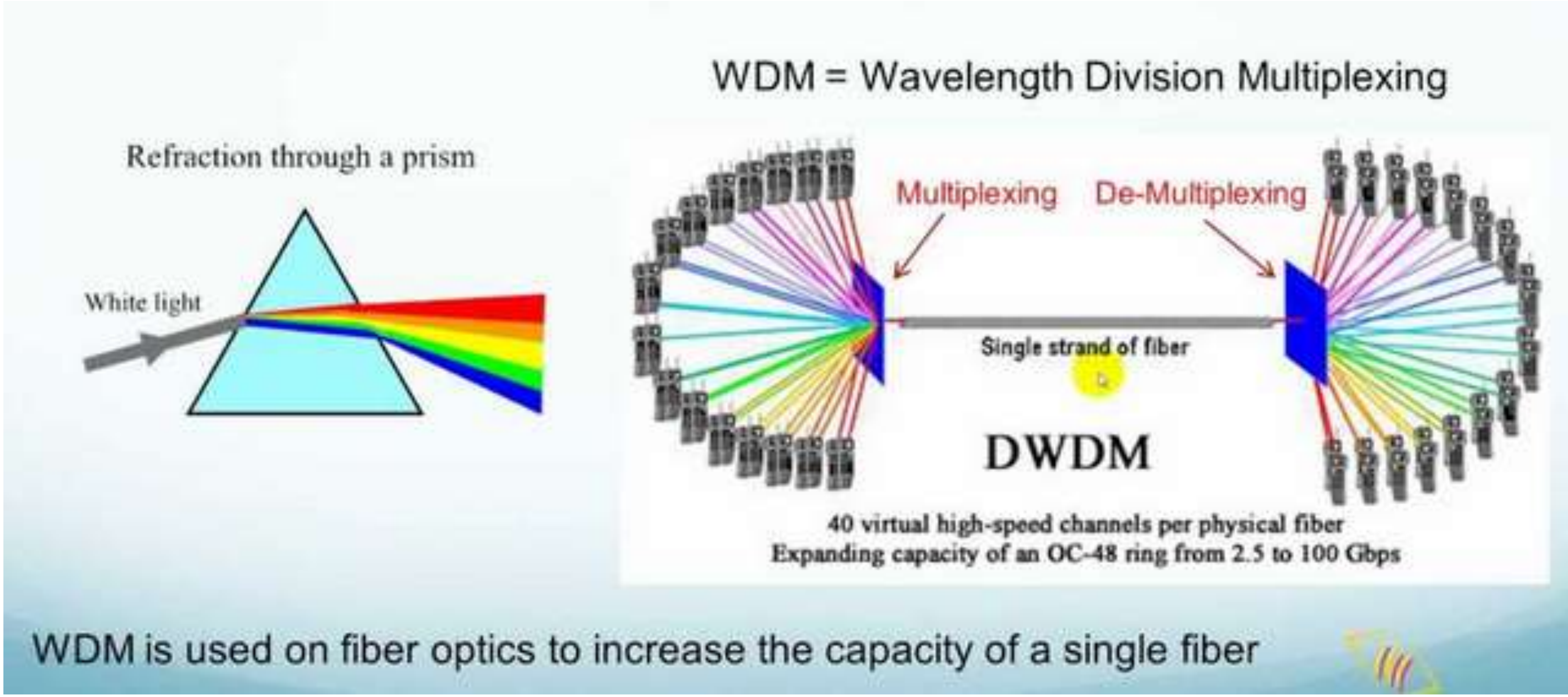
Chromatic dispersion



Principle of Wavelenght division multiplexing (example with three wavelength)

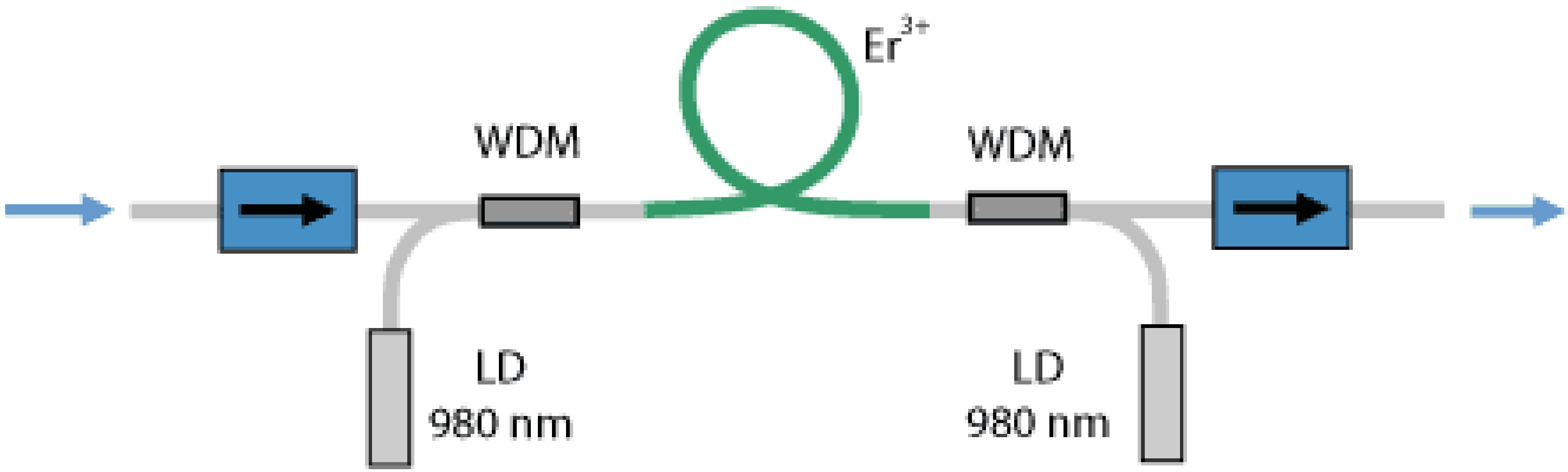


Wavelenght division multiplexing by passive optical devices



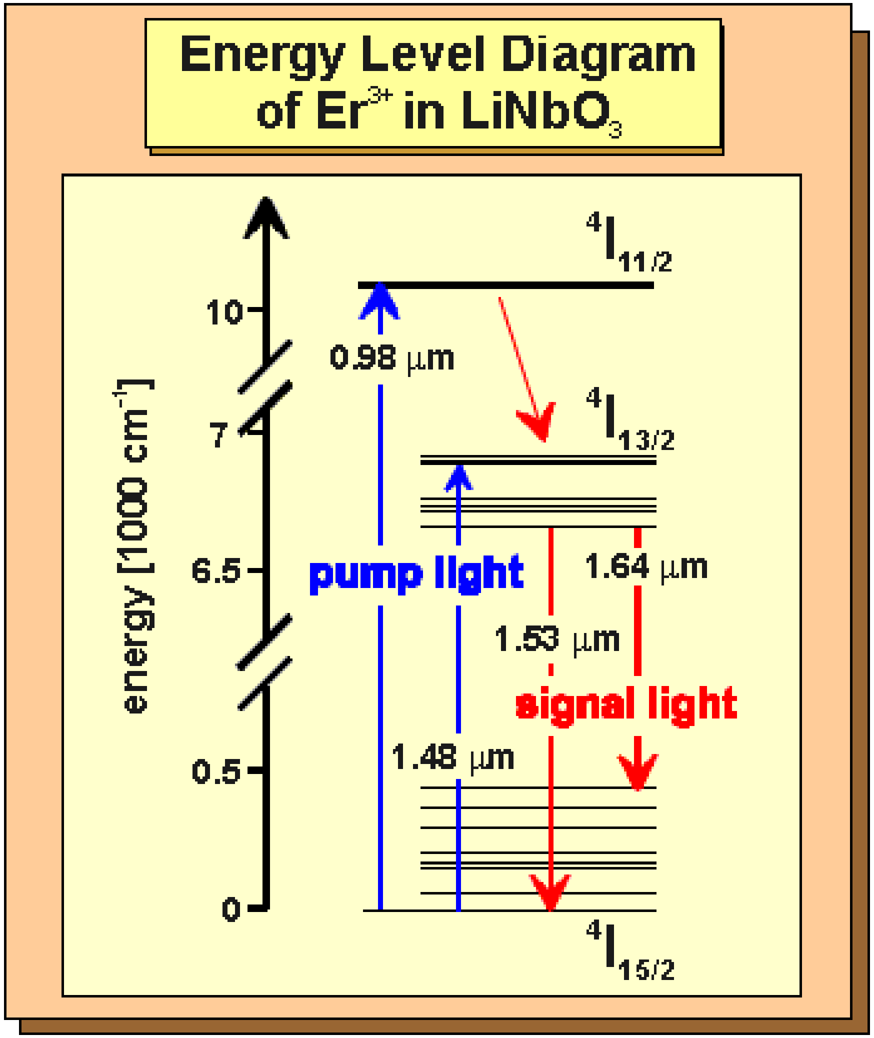
Schematic setup of a simple erbium-doped fiber amplifier. Two laser diodes (LDs) provide the pump power for the

erbium-doped fiber

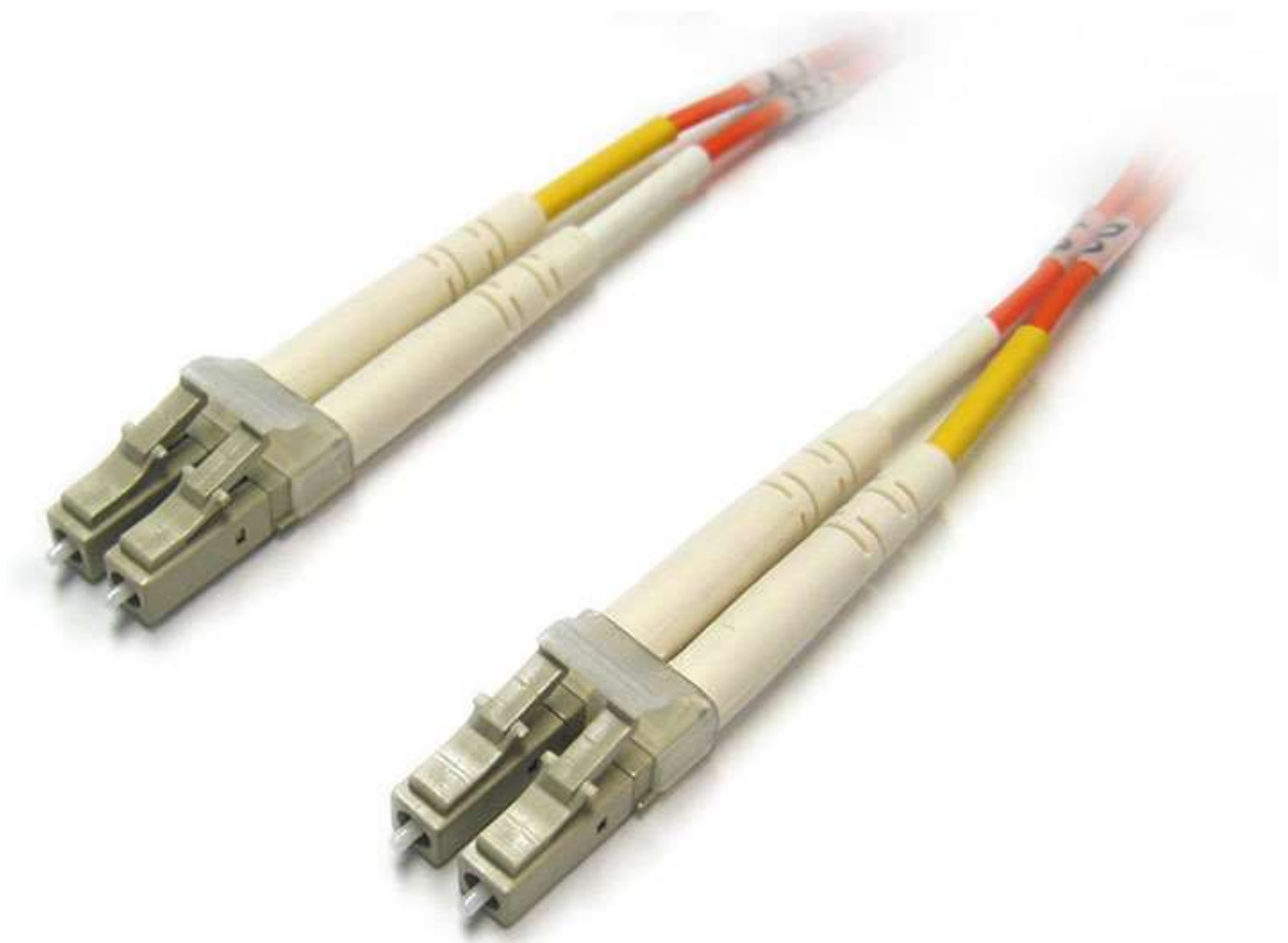


Specifications

Description	Units	LLOA-C-14BM	LLOA-C-17BM	LLOA-C-20BM	LLOA-C-22BM	LLOA-C-20BM-GF
Noise Figure (Max.)	dB	5.0	5.0	5.3	5.3	5.3
Wavelength	nm	1528-1562	1528-1562	1528-1562	1528-1562	1528-1562
Polarization Dependent Gain (Max.)	dB	±0.2	±0.2	±0.2	±0.2	±0.2
Optical Return Loss	dB	50	50	50	50	50
Optical Input Power[1]	dBm					
Saturation Mode		0-10	0-10	0-10	0-10	n/a
Power Lock		0-10	0-10	0-10	0-10	n/a
Gain Lock		-10 to 3	-10 to 3	-10 to 3	-10 to 3	-7 to 3
Minimum Output Power[2]	dBm					
Saturation Mode		14	17	20	22	n/a
Power Lock		14	17	20	22	n/a
Gain Lock		4	7	10	12	10
Gain[3]	dB					
Saturation Mode		n/a	n/a	n/a	n/a	n/a
Power Lock		n/a	n/a	n/a	n/a	n/a
Gain Lock		11-14	14-17	17-20	19-22	16.5-17.5
Static Gain Flatness[4] (Max.)	dB					
Saturation Mode		2.0	2.0	2.0	2.0	2.0
Power Lock		3.0	3.0	3.0	3.0	3.0

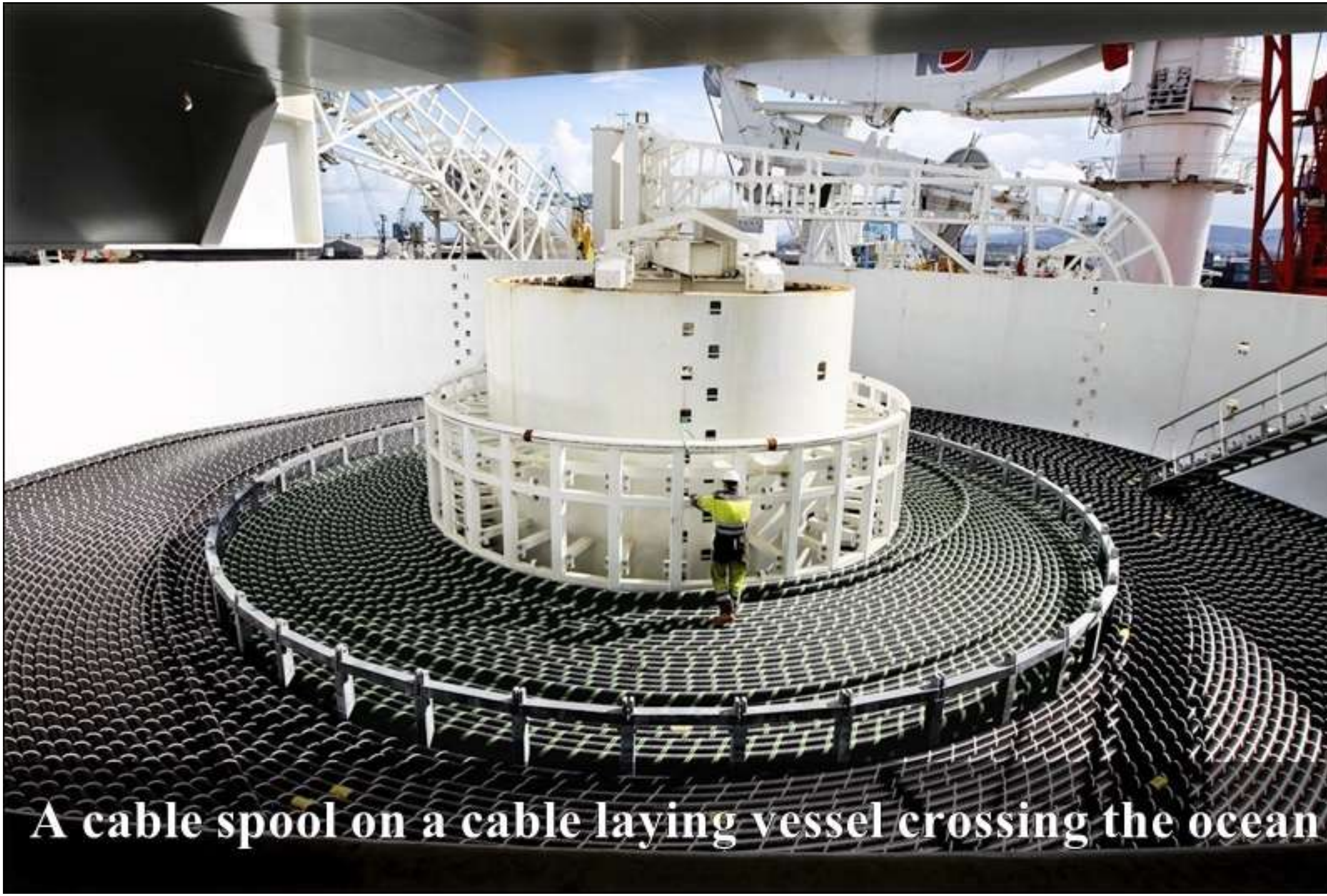

Energy Level Diagram
of Er3+ in LiNbO3
energy [1000 cm-1]
10
7
6.5
0.5
0
4I11/2
4I13/2
4I15/2
0.98 µm
pump light
1.48 µm
1.64 µm
1.53 µm
signal light


Optical Cable Corporation's
GX-Series Subgrouping Cable

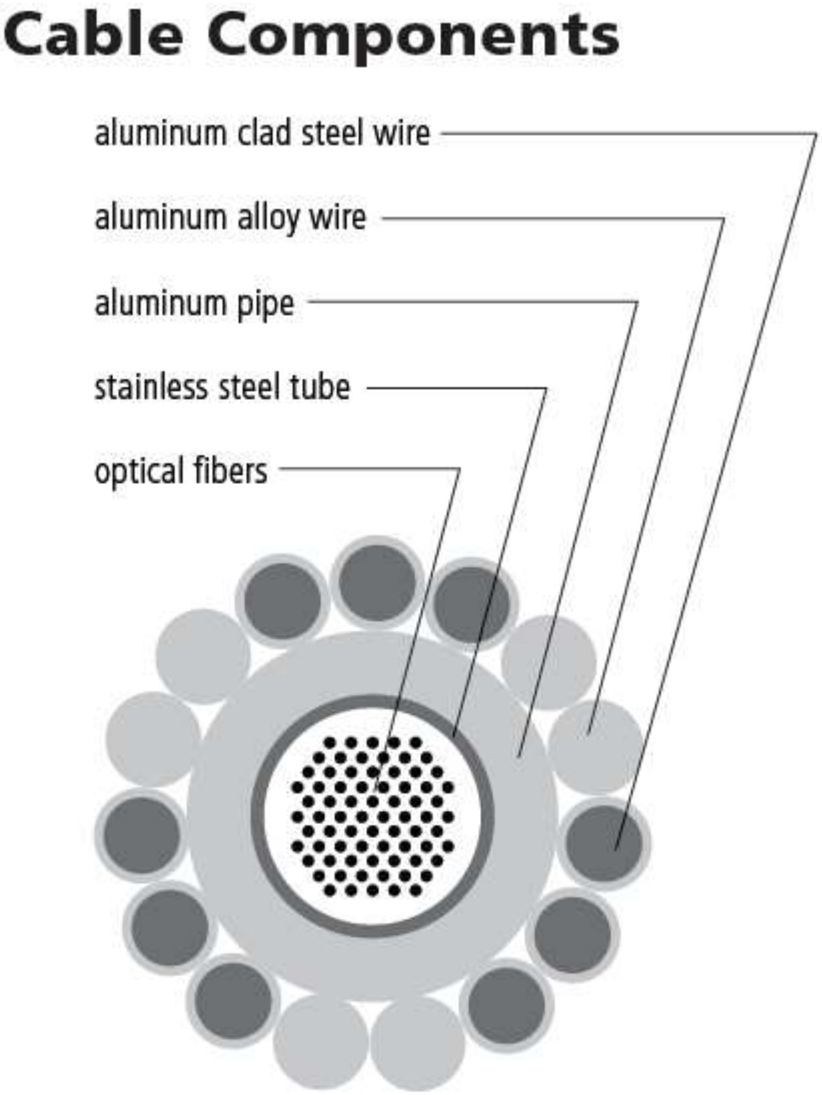


Specifications:

Part Number		R-1-48C	R-1-96C	R-1-192C	R-1-288C
Fibre Count (Max)		48	96	192	288
Strength Member		FRP			
Filling Compound		Jelly Compound			
Wrapping		Plastic Tape			
Inner Sheath		Black Polyethylene			
Armour		Corrugated Steel Tape			
Outer Sheath		Black Polyethylene			
Cable Diameter (approx.)		15.5mm	16.5mm	22.0mm	23.0mm
Weight (approx.)		215kg/km	250kg/km	375kg/km	455kg/km
Maximum Tensile Strength		1800N	1900N	1900N	2000N
Minimum Bending Radius	Loaded:	350mm		20D*	
	Unloaded:	200mm		10D*	

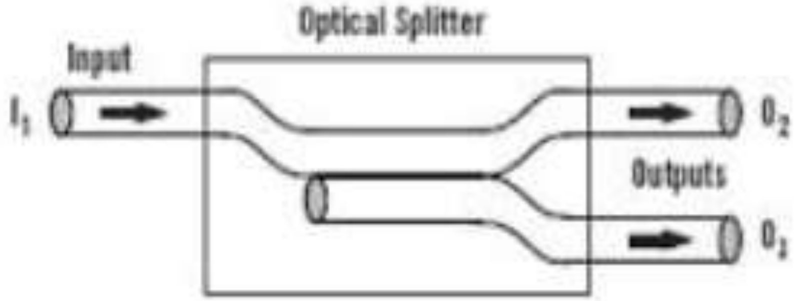

A cable spool on a cable laying vessel crossing the ocean

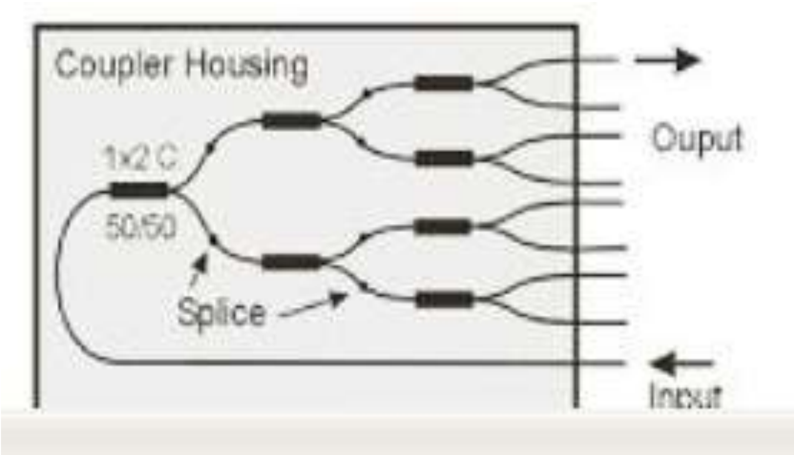
optical ground wire (OPGW)
used in the construction of electric power transmission
combines the functions of grounding and communications.

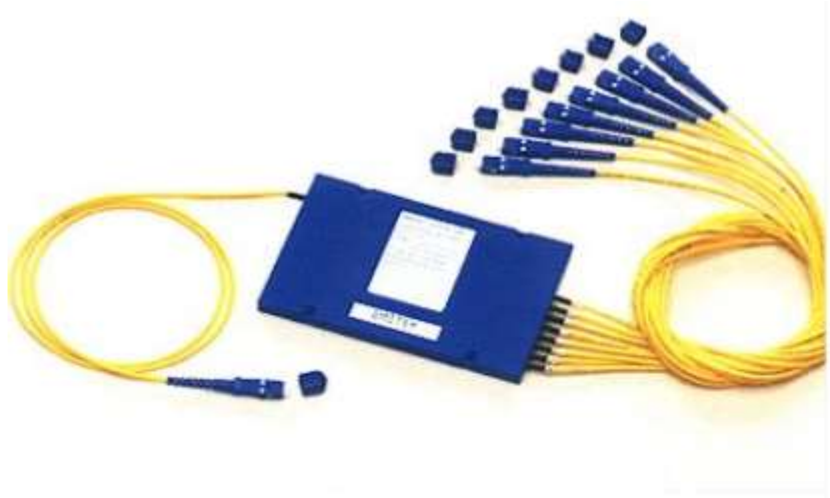


OPGW

Passive optical splitter



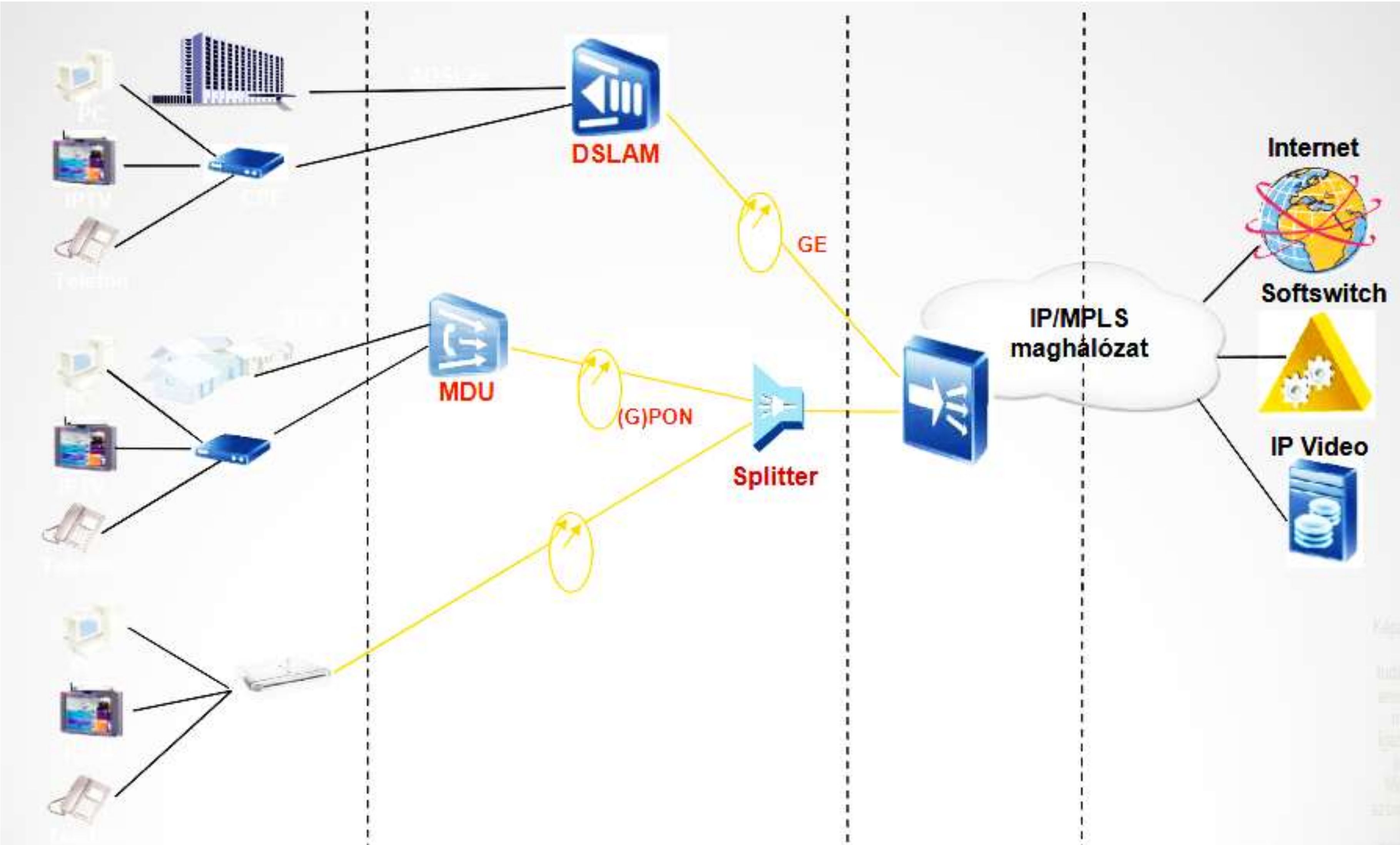




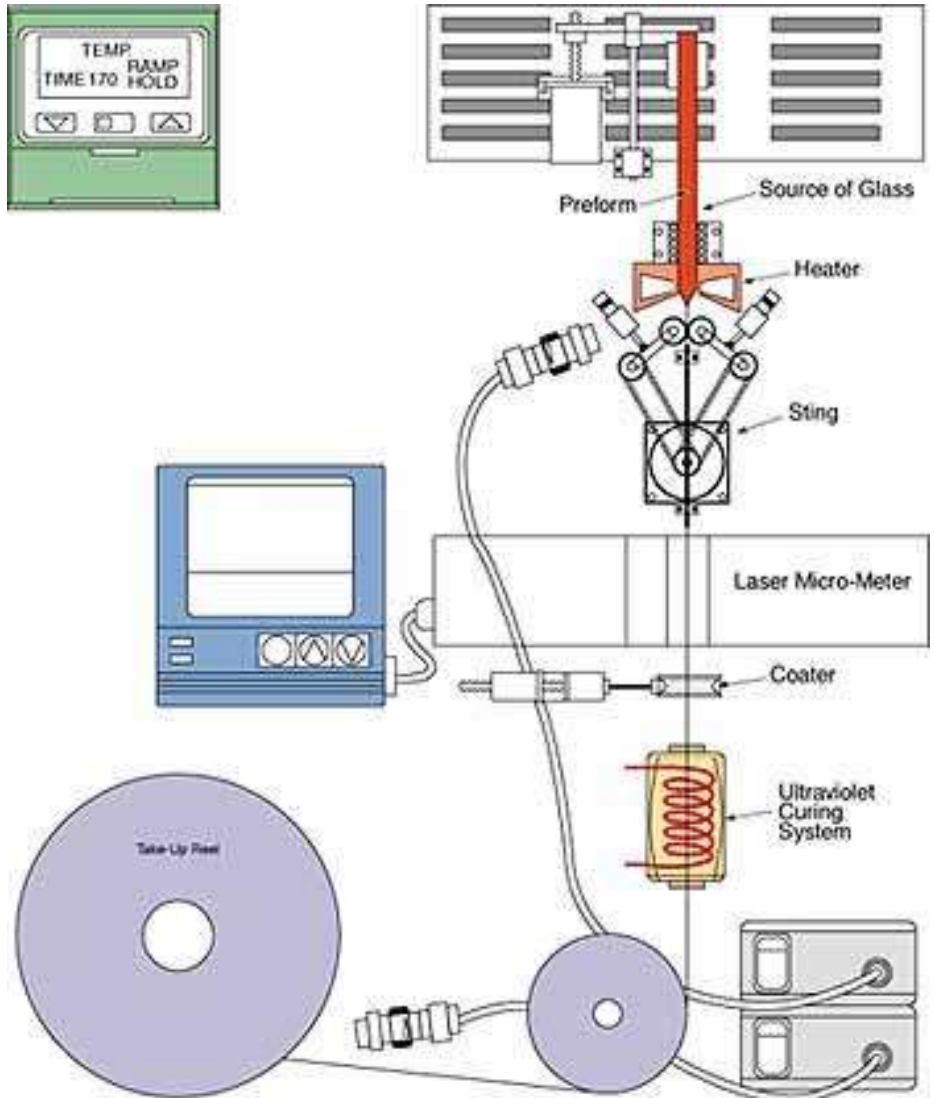
Passive optical splitter

Table 1: Common optical splitter loss and uniformity values

Operating Wavelength Range					
1260-1360 and 1480-1580 nm (or 1650nm)					
Splitting ratio	Max. Insertion Loss[1] (dB)	Max. Uniformity[1] (dB)	PDL[1,2]	Return Loss[1]	Directivity[1]
1x4	<7.3	<0.5	<0.2 dB	>55 dB	>55 dB
1x8	<10.5	<0.8			
1x16	<13.8	<1.0			
1x32	<17.1	<1.3			


DSLAM
GE
Internet
Softswitch
IP/MPLS
maghálózat
MDU
(G)PON
Splitter
IP Video

Simple production of glass fibre



Physical layer	40 Gigabit Ethernet	100 Gigabit Ethernet
Backplane	40GBASE-KR4	100GBASE-KP4
Improved Backplane		100GBASE-KR4
7 m over twinax copper cable	40GBASE-CR4	100GBASE-CR10
30 m over "Cat.8" twisted pair	40GBASE-T	
100 m over OM3 MMF	40GBASE-SR4	100GBASE-SR10
125 m over OM4 MMF[16]		
10 km over SMF	40GBASE-LR4	100GBASE-LR4
40 km over SMF		100GBASE-ER4
2 km over SMF, serial	40GBASE-FR	

What is cheaper?

- Cooling the servers in Europe ir in US?
- Travel bits even to the Arctic or Antarctic and operate servers (like Google, Facebook, Twitter, Amazon, Apple, Microsoft) in naturally cold areas?

Behind every Google search, Facebook update, or Twitter tweet lies a gigantic computing infrastructure, at the heart of which sit massive server farms that collectively account for some 230 million tons of carbon dioxide emissions annually -- more than emitted by the entire country of Argentina. Air-conditioning can consume as much as half the total power that digital giants like Google, Facebook, Twitter, Amazon, Apple, Microsoft, and IBM need to run their huge server facilities, and these are growing rapidly.

One solution is to move to a place that's already cold. Naturally cold air and, better yet, cold water, can result in significant energy savings. Locations for server farms are being explored across the far north, from Alaska to Iceland. Google is operating a site in the Finnish town of Hamina. Facebook is building a server farm in Luleå, Sweden, just south of the Arctic Circle. Lefdal, which offers an abundance of clean, renewable energy from nearby hydroelectric dams and wind farms, as well as a unique cooling system that will pump icy cold water from about 650 feet below sea level, is expecting its first tenant to be IBM Norway.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1. This is Facebook's massive Arctic Sever Farm: