MEDIUM FISIK JARINGAN

Sumber : Bab 4
Data & Computer Communications, 7th Edition
William Stallings

TUJUAN

- Tujuan yang ingin dicapai dari pembahasan modul ini adalah :
  1) Faktor-faktor yang mempengaruhi perancangan jaringan
  2) Mahasiswa mampu memahami jenis-jenis medium fisik yang digunakan pada komunikasi data
  3) Mahasiswa mampu memahami sifat/karakteristik dari masing-masing media transmisi

Spektrum Electromagnetic

- Faktor Perancangan jaringan
  1. Bandwith → menentukan laju data yang dicapai
  2. Keterbatasan transmisi → menentukan coverage(cakupan), contohnya : noise, redaman, derau
  3. Interferensi → gangguan dari sinyal yang pita frekuensinya sama dapat menyebabkan distorsi, bahkan menghancurkan sinyal kirim.
  4. Jumlah penerima → guided media yang digunakan sebagai shared link dapat menyebabkan peningkatan redaman dan distorsi.

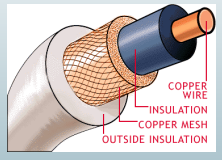
Spektrum Electromagnetic

- **Guide Media**
  1. Twisted pair (10 Hz - 100 MHz)
  2. Kabel koaksial (1 kHz – 1 GHz)
  3. Serat optik (100 – 1000 THz)
- **Unguide Media**
  1. Radio
  2. Gelombang Mikro

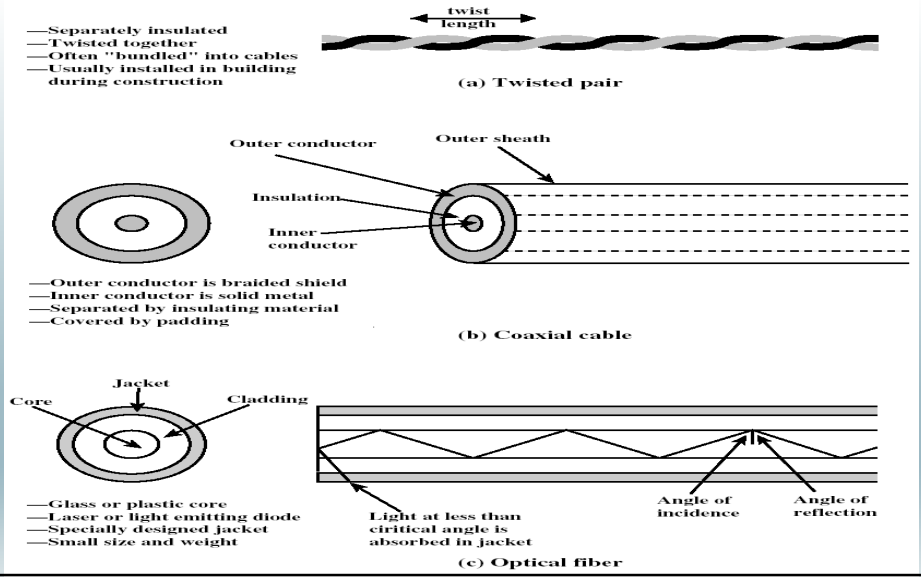
MEDIA FISIK JARINGAN

Terdapat beberapa media yang sering digunakan dalam mentransmisikan data dari node-1 ke node yang lain, diantaranya :

1) Twisted Pair
2) Coaxial Cabel
3) Optic Fiber
4) Wireless



MEDIA FISIK JARINGAN



TWISTED PAIR

- **Karakteristik :**
  1. Paling murah dan paling banyak digunakan
  2. Panjang pilinan 5-15 cm, ketebalan 0,4 - 0,9 mm
  3. Laju data 64 kbps untuk PBX digital, 4 Mbps untuk aplikasi jarak jauh, 10 Mbps untuk LAN (jarak 1 km), 100 Mbps-1 Gbps untuk jumlah terminal terbatas (jarak puluhan meter)
  4. Jarak amplifier 5-6 km untuk sinyal analog, jarak repeater 2-3 km untuk transmisi digital
  5. Redaman sangat sensitif terhadap kenaikan frekuensi

TWISTED PAIR

- **Twisted Pair, terdiri dari 2 jenis :**
  1. Unshielded → merupakan kawat telepon biasa, tipe 100-ohm banyak dijumpai di gedung perkantoran
  2. Shielded → memiliki kinerja lebih baik pada laju data yang tinggi, twisted pair dilindungi oleh logam untuk mengurangi interferensi
- **EIA-568-A memperkenalkan 3 kategori kabel UTP**
  1. Kategori 3: karakteristik transmisi hingga 16 MHz, twist length 7,5-10 cm
  2. Kategori 4: karateristik hingga 20 MHz
  3. Kategori 5: karakteristik hingga 100 MHz, twist length 0,6-0,85 cm
- **Kabel kategori 3 (voice-grade) dan kategori 5 (data-grade) banyak digunakan untuk aplikasi LAN**

TWISTED PAIR

❖ Redaman Twisted Pair

	Category 3 Class C	Category 5 Class D	Category 5E	Category 6 Class E	Category 7 Class F
Bandwidth	16 MHz	100 MHz	100 MHz	200 MHz	600 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	UTP/FTP	SSTP
Link Cost (Cat 5 =1)	0.7	1	1.2	1.5	2.2

UTP = Unshielded twisted pair
FTP = Foil twisted pair
SSTP = Shielded screen twisted pair

- Tabel di samping menunjukkan kinerja UTP kategori 3, 5, dan STP
- Skema pengkabelan baru berada pada level yang lebih tinggi, yaitu kategori 5E (enhanced), 6, dan 7

TWISTED PAIR

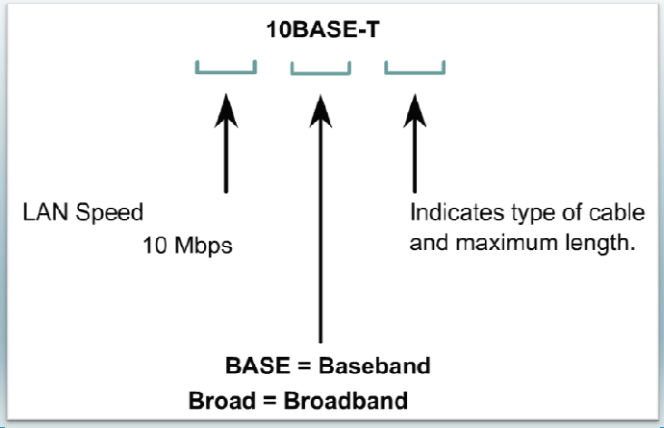
❖ Alternatif Pengkabelan

Name	Construction	Expected Performance	Cost
Category 5 UTP	Cable consists of 4 pairs of 24 AWG (0.50 mm) copper with thermoplastic polyolefin or fluorinated ethylene propylene (FEP) jacket. Outside sheath consists of polyvinylchlorides (PVC), a fire retardant polyolefin or fluoropolymers.	Mixed and matched cables and connecting hardware from various manufacturers that have a reasonable chance of meeting TIA Cat 5 Channel and ISO Class D requirements. No manufacturer's warranty is involved.	1
Enhanced Cat 5 UTP (Cat 5E)	Cable consists of 4 pairs of 24 AWG (0.50 mm) copper with thermoplastic polyolefin or fluorinated ethylene propylene (FEP) jacket. Outside sheath consists of polyvinylchlorides (PVC), a fire retardant polyolefin or fluoropolymers. Higher care taken in design and manufacturing.	Category 5 components from one supplier or from multiple suppliers where components have been deliberately matched for improved impedance and balance. Offers ACR performance in excess of Cat 5 Channel and Class D as well as a 10-year or greater warranty.	1.2
Category 6 UTP	Cable consists of 4 pairs of 0.50 to 0.53 mm copper with thermoplastic polyolefin or fluorinated ethylene propylene (FEP) jacket. Outside sheath consists of polyvinylchlorides (PVC), a fire retardant polyolefin or fluoropolymers. Extremely high care taken in design and manufacturing. Advanced connector designs.	Category 6 components from one supplier that are extremely well matched. Channel zero ACR point (effective bandwidth) is guaranteed to 200 MHz or beyond. Best available UTP. Performance specifications for Category 6 UTP to 250 MHz are under development.	1.5
Foil Twisted Pair	Cable consists of 4 pairs of 24 AWG (0.50 mm) copper with thermoplastic polyolefin or fluorinated ethylene propylene (FEP) jacket. Pairs are surrounded by a common metallic foil shield. Outside sheath consists of polyvinylchlorides (PVC), a fire-retardant polyolefin or fluoropolymers.	Category 5 components from one supplier or from multiple suppliers where components have been deliberately designed to minimize EMI susceptibility and maximize EMI immunity. Various grades may offer increased ACR performance.	1.3
Shielded Foil Twisted Pair	Cable consists of 4 pairs of 24 AWG (0.50 mm) copper with thermoplastic polyolefin or fluorinated ethylene propylene (FEP) jacket. Pairs are surrounded by a common metallic foil shield, followed by a braided metallic shield. Outside sheath consists of polyvinylchlorides (PVC), a fire retardant polyolefin, or fluoropolymers.	Category 5 components from one supplier or from multiple suppliers where components have been deliberately designed to minimize EMI susceptibility and maximize EMI immunity. Offers superior EMI protection to FTP.	1.4
Category 7 Shielded-Screen Twisted Pair	Also called PiMF (for Pairs in Metal Foil), SSTP of 4 pairs of 22-23AWG copper with a thermoplastic polyolefin or fluorinated ethylenepropylene (FEP) jacket. Pairs are individually surrounded by a helical or longitudinal metallic foil shield, followed by a braided metallic shield. Outside sheath of polyvinylchlorides (PVC), a fire-retardant polyolefin, or fluoropolymers.	Category 7 cabling provides positive ACR to 600 to 1,200 MHz. Shielding on the individual pairs gives it phenomenal ACR.	2.2

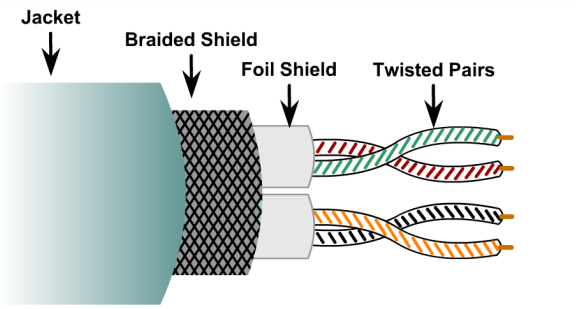
- ACR = Attenuation to Crosstalk Ratio
- EMI = Electromagnetic Interference

TWISTED PAIR

❖ Istilah dalam penamaan kabel



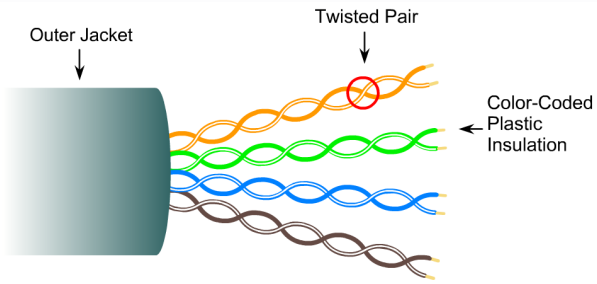
TWISTED PAIR



SHIELDED TWISTED PAIR (UTP)

- Speed and throughput: 0 - 100 Mbps
- Cost: Moderate
- Media and connector size: Medium to Large
- Maximum cable length: 100m

TWISTED PAIR

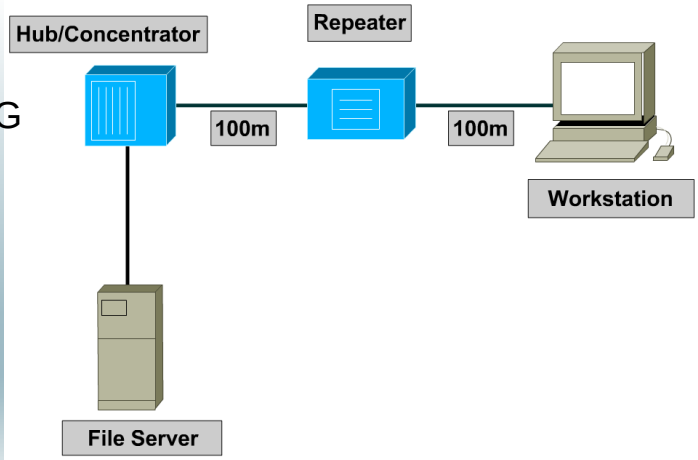


UNSHIELDED TWISTED PAIR (UTP)

- Speed and throughput: 10 - 100 - 1000 Mbps (depending on the quality/category of cable)
- Cost: Least Expensive
- Media and connector size: Small
- Maximum cable length: 100m

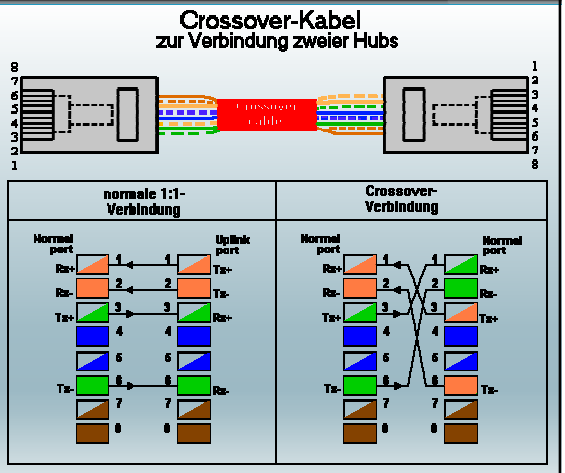
TWISTED PAIR

UTP CABLING



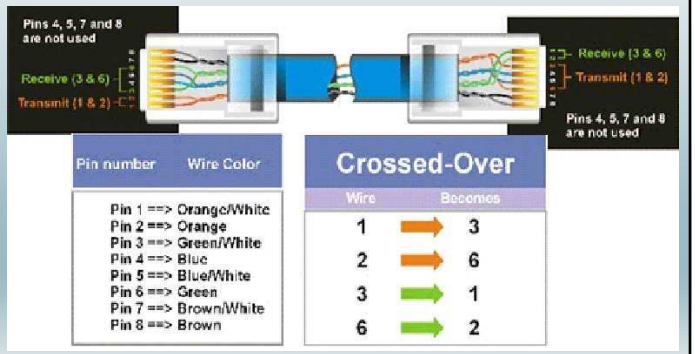
TWISTED PAIR

STRAIGHT CABLE



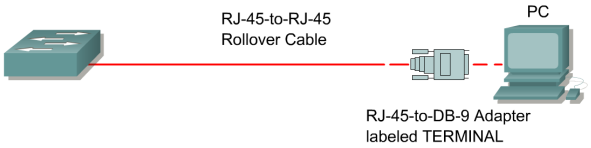
TWISTED PAIR

CROSS CABLE

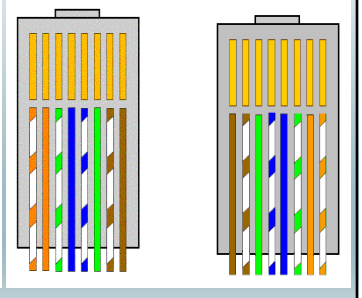


TWISTED PAIR

ROLLOVER CABLE



- PCs require an RJ-45 to DB-9 or RJ-45 to DB-25 adapter.
- COM port settings are 9600 bps, 8 data bits, no parity, 1 stop bit, no flow control.
- This provides out-of-band console access.
- AUX switch port may be used for a modem-connected console.



TWISTED PAIR

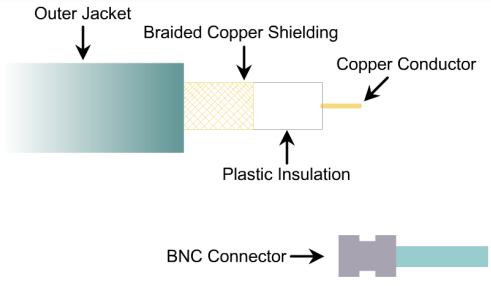
LAN TESTER

COAXIAL CABLE

❖ **Karakteristik :**

1. Terdiri dari 2 konduktor dengan konstruksi yang berbeda dengan twisted pair
2. Konduktor dalam ditahan oleh beberapa cincin insulasi atau bahan dielektrik padat, konduktor luar ditutup dengan jaket
3. Diameter 1-2,5 cm, kapasitas 10.000 kanal suara
4. Spektrum dapat mencapai 500 MHz
5. Laju data ratusan Mbps untuk jarak 1 km
6. Jarak antar repeater 1 km
7. Aplikasi: distribusi TV, SLJJ, LAN
8. Lebih tahan terhadap interferensi dan crosstalk dibanding twisted pair, jarak jangkauan lebih jauh

COAXIAL CABLE



- Speed and throughput: 10 - 100 Mbps
- Cost: Inexpensive
- Media and connector size: Medium
- Maximum cable length: 500m

COAXIAL CABLE

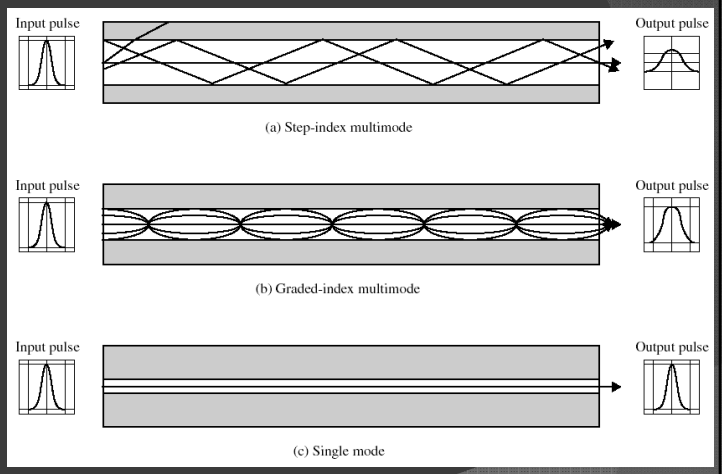
SERAT OPTIK

❖ **Karakteristik :**

1. Medium yang tipis dan fleksibel, mampu merambatkan sinar optik
2. Diameter inti 2-125 μm
3. Karakteristik yang membedakan serat optik dari twisted pair atau kabel koaksial:
   - ✓ Kapasitas lebih besar
   - ✓ Ukuran lebih kecil dan lebih ringan
   - ✓ Redaman lebih rendah
   - ✓ Isolasi elektromagnetik
   - ✓ Jarak antar repeater lebih jauh
4. Laju data ratusan Gbps untuk jarak puluhan km
5. Long haul 1500 km dengan kapasitas 20.000-60.000 kanal suara
6. Metropolitan trunking (12 km) dengan 100.000 kanal suara
7. Sentral rural memiliki panjang sirkit 40-160 km dan < 5000 kanal suara
8. LAN dikembangkan dengan kapasitas 100 Mbps hingga 10 Gbps

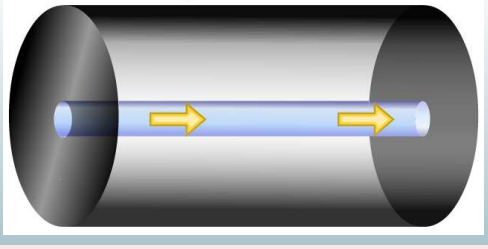
SERAT OPTIK

MODE TRANSMISI



SERAT OPTIK

Single Mode



Karakteristik

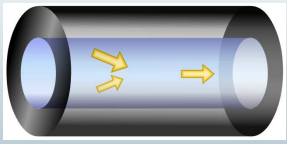
* diameter inti kecil sekali.
* diameter core : 2 ~ 10 μm
* diameter cladding : 50 ~ 125 μm
* diameter coating : 250 ~ 1000 μm
* Redaman : 1 ~ 5 dB/km
* Bandwidth : 500 ~ 50.000 MHz

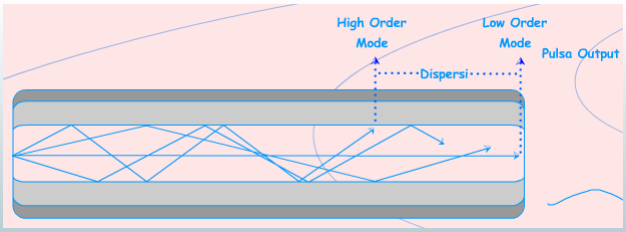
+++
+ BW yang sangat besar
+ dispersi yang kecil sekali dibanding serat lain
+ redaman paling kecil
+ dipakai untuk jarak jauh

- pembuatan sangat sulit
- Harganya pun mahal

SERAT OPTIK

Multimode Step-Index





Karakteristik

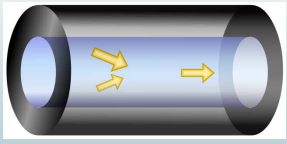
* indeks bias inti konstan
* diameter core : 50 ~ 250 μm
* diameter cladding : 125 ~ 400 μm
* diameter coating : 250 ~ 1000 μm
* Redaman : 4 ~ 20 dB/km
* Bandwidth : 6 ~ 25 MHz

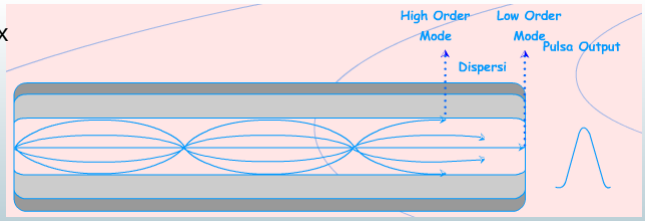
+++
+ pembuatan mudah
+ penyambungan mudah
+ harga relatif murah

- BW rendah
- banyak terjadi dispersi
- redamannya besar
- digunakan untuk jarak pendek

SERAT OPTIK

Multimode Graded-Index





Karakteristik

* indeks bias inti bertingkat dengan indeks bias tertinggi pada pusat core
* diameter core : 30 ~ 60 μm
* diameter cladding : 100 ~ 150 μm
* diameter coating : 250 ~ 1000 μm
* Redaman : 2 ~ 10 dB/km
* Bandwidth : 150 ~ 2000 MHz

+++
+ BW yang lebih besar
+ dispersi yang lebih sedikit
+ redaman lebih kecil
+ dipakai untuk jarak menengah

- pembuatan lebih sulit
- Harganya lebih mahal

SERAT OPTIK

❖ **Penggunaan Frekuensi**

1. Serat optik berfungsi sebagai bumbung gelombang untuk frekuensi dalam range sekitar 10^{14} hingga 10^{15} Hz, meliputi infra merah dan spektrum cahaya tampak.
2. Jendela transmisi
   - ✓ Lebar pita pada masing-masing window adalah 33 THz, 12 THz, 4 THz, dan 7 THz.
   - ✓ Berada dalam porsi frekuensi infra merah, di bawah porsi cahaya tampak (400-700 nm).
3. Sistem WDM dapat mengirimkan 100 berkas dalam sebuah serat, tiap berkas beroperasi pada 10 Gbps

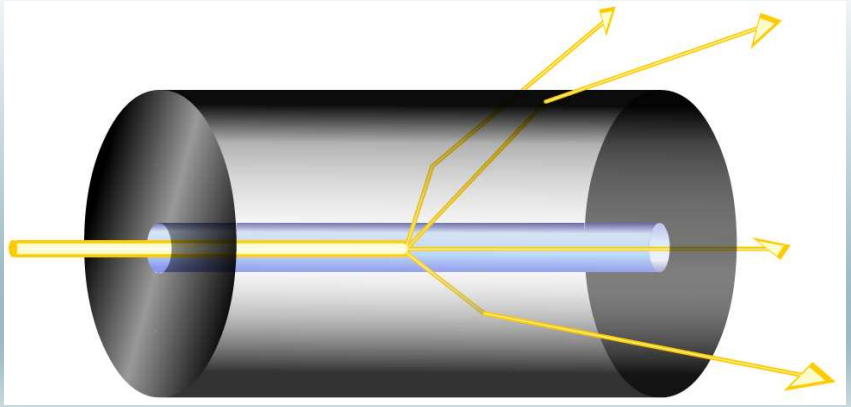
SERAT OPTIK

❖ **Beberapa hal yang dapat menurunkan kualitas Optik :**

1. **Scattering**
2. **Bending**
3. **Splicing**

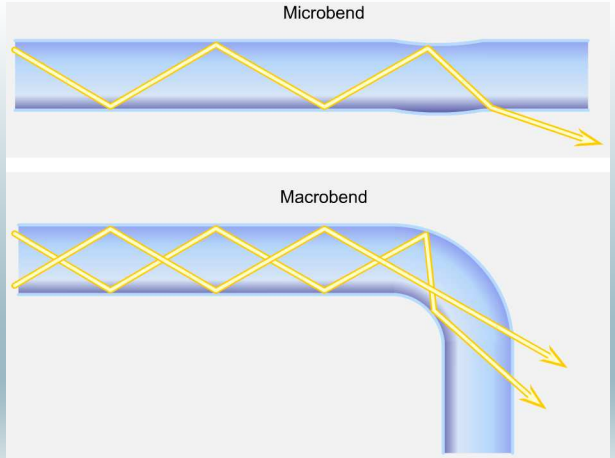
SERAT OPTIK

❖ **SCATTERING**



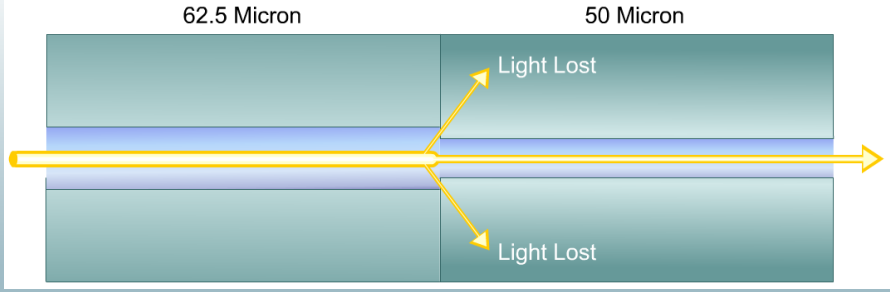
SERAT OPTIK

❖ **BENDING**



SERAT OPTIK

- **SPLICING**



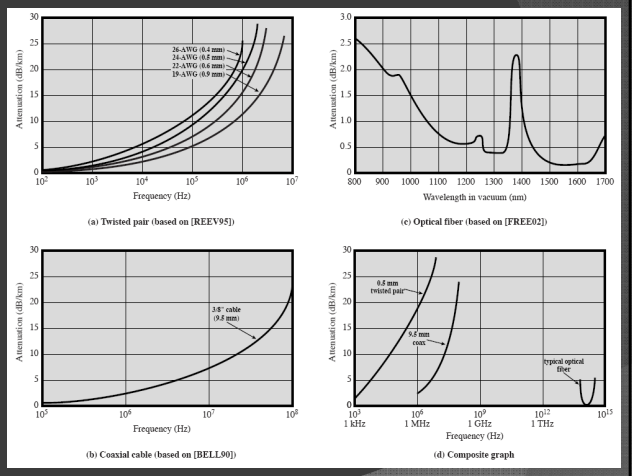
SERAT OPTIK

- **Fiber End Face Finished**

Flat: Finish causes light to be reflected back into the fiber due to a step in the refractive index caused by the glass-air-glass interface.	Flat Finish Air Gap
Angle: Polish connectors cause the reflection to exit the core and dissipate in the cladding.	Angled Finish Angled Surfaces Touch
Physical Contact (PC): Finish minimizes backreflection due to the very small refractive index discontinuity.	Round Finish Physical Contact
Ultra: Polish connector finish uses several grades of polishing film to achieve an untra-smooth surface.	Ultra-fine Round Finish Physical Contact

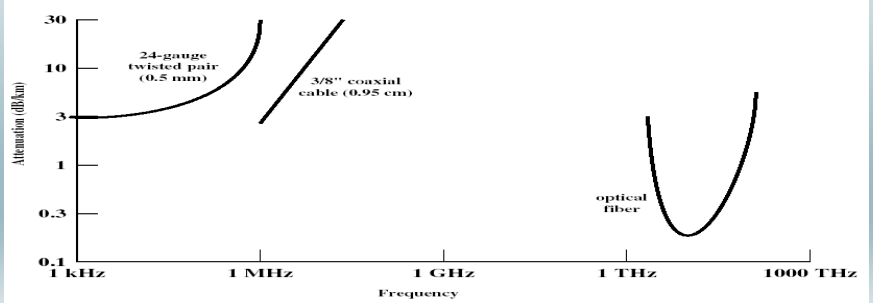
REDAMAN

- Kabel koaksial memiliki karakteristik frekuensi yang superior terhadap twisted pair, sehingga laju data lebih tinggi



REDAMAN

- Bentuk kurva redaman serat optik menunjukkan frekuensi kerja optimumnya, di mana nilai dispersi dan redaman minimum
- Faktor yang berkontribusi besar terhadap redaman serat optik adalah penyerapan dan hamburan (scattering)



WIRELESS

❖ **Transmisi Wireless :**

1. Pengiriman dan penerimaan sinyal dilakukan dengan antena
2. Frekuensi
   - ✓ Gelombang mikro: 2 - 40 GHz
   - ✓ Radio broadcast: 30 MHz - 1 GHz
   - ✓ Infra merah: 3.10^{11} – 2.10^{14} Hz
3. Gelombang mikro terestrial
   - ✓ Antena microwave yang umum adalah piringan parabola
   - ✓ Diameter parabola 3 m
   - ✓ Jarak maksimum $d = 7{,}14\sqrt{Kh}$

WIRELESS

❖ **Transmisi Wireless :**

Frequency band	Name	Analog data		Digital data		Principal applications
		Modulation	Bandwidth	Modulation	Data rate	
30–300 kHz	LF (low frequency)	Generally not practical		ASK, FSK, MSK	0.1 to 100 bps	Navigation
300–3000 kHz	MF (medium frequency)	AM	To 4 kHz	ASK, FSK, MSK	10 to 1000 bps	Commercial AM radio
3–30 MHz	HF (high frequency)	AM, SSB	To 4 kHz	ASK, FSK, MSK	10 to 3000 bps	Shortwave radio
30–300 MHz	VHF (very high frequency)	AM, SSB; FM	5 kHz to 5 MHz	FSK, PSK	To 100 kbps	VHF television, FM radio
300–3000 MHz	UHF (ultra high frequency)	FM, SSB	To 20 MHz	PSK	To 10 Mbps	UHF television, Terrestrial microwave
3–30 GHz	SHF (super high frequency)	FM	To 500 MHz	PSK	To 100 Mbps	Terrestrial microwave, Satellite microwave
30–300 GHz	EHF (extremely high frequency)	FM	To 1 GHz	PSK	To 750 Mbps	Experimental short point-to-point

WIRELESS

- **ANTENA**

  → Didefinisikan sebagai konduktor listrik atau sistem konduktor yang digunakan untuk meradiasikan energi elektromagnetik atau untuk mengumpulkan energi

  - Hubungan antara penguatan antena dan luas efe

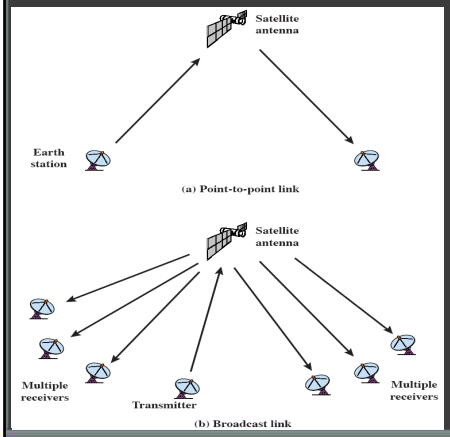
WIRELESS

- **TERESTRIAL :**
  1. Rugi-rugi transmisi microwave → $L = 10\log\left(\frac{4\pi d}{\lambda}\right)^2$ dB
  2. Frekuensi operasi 2-40 GHz
  3. Jarak repeater atau amplifier 10-100 km
  4. Efek curah hujan sangat besar pada frekuensi >10 GHz
  5. Band 4-6 GHz untuk telekomunikasi jarak jauh
  6. Band 12 GHz untuk komponen TV kabel,
  7. Band 22 GHz untuk point to point antar gedung

Band (GHz)	Bandwidth (MHz)	Data Rate (Mbps)
2	7	12
6	30	90
11	40	135
18	220	274

WIRELESS

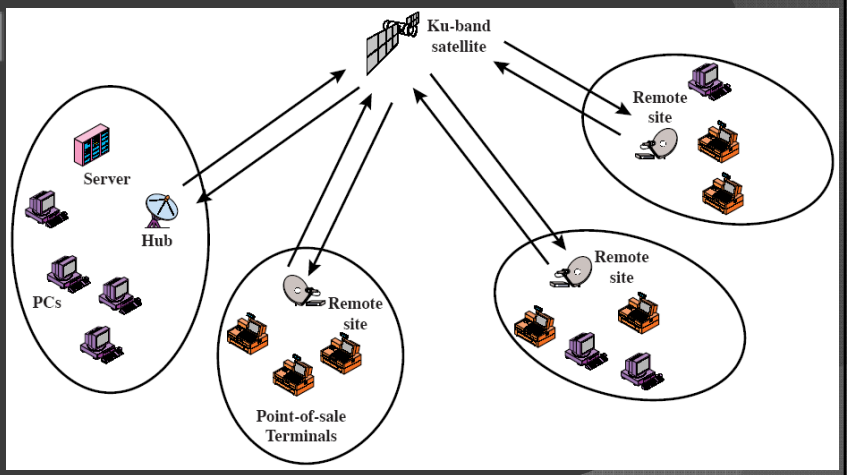
❖ SATELITE



- ❖ Gelombang mikro satelit
  - Mirip stasiun relay gelombang mikro untuk jarak sangat jauh
  - Ketinggian stasioner 35.784 km
  - Untuk menghindari interferensi: jarak 4^{o} pada 4/6 GHz, jarak 3^{o} pada 12/14 GHz
- ❖ Aplikasi penting:
  - Distribusi televisi
  - Transmisi telepon jarak jauh
  - Jaringan bisnis privat

WIRELESS

VSAT



WIRELESS

❖ Perambatan Wireless

Band	Frequency Range	Free-Space Wavelength Range	Propagation Characteristics	Typical Use
ELF (extremely low frequency)	30 to 300 Hz	10,000 to 1000 km	GW	Power line frequencies; used by some home control systems.
VF (voice frequency)	300 to 3000 Hz	1000 to 100 km	GW	Used by the telephone system for analog subscriber lines.
VLF (very low frequency)	3 to 30 kHz	100 to 10 km	GW; low attenuation day and night; high atmospheric noise level	Long-range navigation; submarine communication
LF (low frequency)	30 to 300 kHz	10 to 1 km	GW; slightly less reliable than VLF; absorption in daytime	Long-range navigation; marine communication radio beacons
MF (medium frequency)	300 to 3000 kHz	1,000 to 100 m	GW and night SW; attenuation low at night, high in day; atmospheric noise	Maritime radio; direction finding; AM broadcasting
HF (high frequency)	3 to 30 MHz	100 to 10 m	SW; quality varies with time of day, season, and frequency.	Amateur radio; international broadcasting, military communication; long-distance aircraft and ship communication
VHF (very high frequency)	30 to 300 MHz	10 to 1 m	LOS; scattering because of temperature inversion; cosmic noise	VHF television; FM broadcast and two-way radio, AM aircraft communication; aircraft navigational aids
UHF (ultra high frequency)	300 to 3000 MHz	100 to 10 cm	LOS; cosmic noise	UHF television; cellular telephone; radar; microwave links; personal communications systems
SHF (super high frequency)	3 to 30 GHz	10 to 1 cm	LOS; rainfall attenuation above 10 GHz; atmospheric attenuation due to oxygen and water vapor	Satellite communication; radar; terrestrial microwave links; wireless local loop
EHF (extremely high frequency)	30 to 300 GHz	10 to 1 mm	LOS; atmospheric attenuation due to oxygen and water vapor	Experimental; wireless local loop
Infrared	300 GHz to 400 THz	1 mm to 770 nm	LOS	Infrared LANs; consumer electronic applications
Visible light	400 THz to 900 THz	770 nm to 330 nm	LOS	Optical communication

WIRELESS

❖ Mode Perambatan Wireless

- ❖ Sinyal yang diradiasikan dari antena berjalan melalui salah satu dari rute: gelombang tanah, gelombang langit, atau saluran bebas pandang (LOS)
- ❖ Efek gelombang tanah ditemukan pada frekuensi kurang dari 2 MHz

- ❖ Gelombang langit dapat berjalan melalui sejumlah hop, memantul antara ionosfir dan permukaan bumi
- ❖ Di atas 30 MHz, komunikasi harus secara line of sight
- ❖ Dalam ruang hampa, gelombang elektromagnetik (cahaya atau radio) memiliki kecepatan $3x10^8$ m/s

WIRELESS

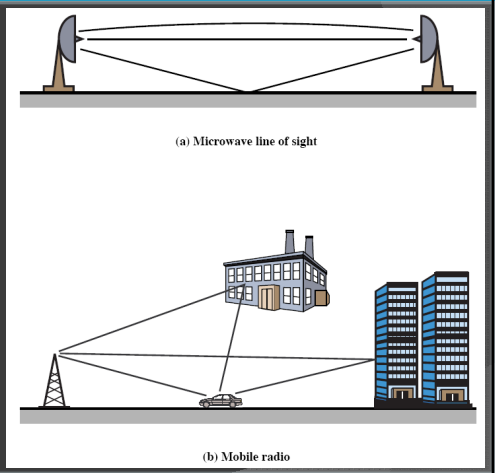
❖ **Perambatan Bebas Pandang**

1. Untuk komunikasi satelit, sinyal di atas 30 MHz tidak dipantulkan oleh ionosfir, oleh karena itu sinyal dapat dikirimkan antara stasiun bumi dan satelit
2. Kondisi tanpa penghalang
   - ✓ LOS optik dapat dinyatakan sebagai $d = 3{,}57\sqrt{h}$
   - ✓ LOS radio efektif $d = 3{,}57\sqrt{(Kh)}$

WIRELESS

❖ **Lintasan Jamak**

- ❖ Pada kasus telepon bergerak, terdapat banyak sekali penghalang
- ❖ Ada perbedaan tipe interferensi multipath pada komunikasi gelombang mikro terestrial (fixed) dan komunikasi bergerak



(a) Microwave line of sight

(b) Mobile radio

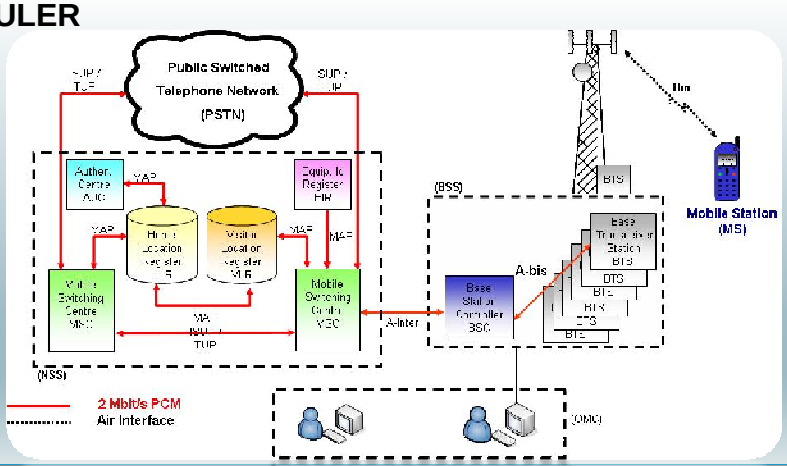
WIRELESS

❖ **Bluetooth (802.15)**

BLUETOOTH

WIRELESS

❖ **SELULER**



WIRELESS

❖ **802.11 (WiFi)**

Wireless Standard	802.11b	802.11a	802.11g
Popularity	Widely adopted. Readily available everywhere.	New technology.	New technology with rapid growth expected.
Speed	11 Mbps — Up to 11Mbps (note: cable modem service typically averages no more than 4 to 5Mbps).	54 Mbps — Up to 54Mbps (5X greater than 802.11b).	54 Mbps — Up to 54Mbps (5X greater than 802.11b).
Relative Cost	Inexpensive.	Relatively more expensive.	Relatively inexpensive.
Frequency	2.4 GHz — More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.	5 GHz — Uncrowded 5GHz band can coexist with 2.4 GHz networks without interference.	2.4 GHz — More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.
Range	100-150 — Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.	25-75 — Shorter range than 802.11b & 802.11g. Typically 25 to 75 feet indoors.	100-150 — Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.
Public Access	The number of public "hotspots" is growing rapidly, allowing wireless connectivity in many airports, hotels, college campuses, public areas, and restaurants.	None at this time.	Compatible with current 802.11b hotspots (at 11Mbps). Also, it is expected that most 802.11b hotspots will quickly convert to 802.11g.
Compatibility	OK 802.11b — Widest adoption.	OK 802.11a — Incompatible with 802.11b or 802.11g.	OK 802.11b 802.11g — Interoperates with 802.11b networks (at 11Mpbs). Incompatible with 802.11a.

WIRELESS

❖ **802.16 (WiMAX)**