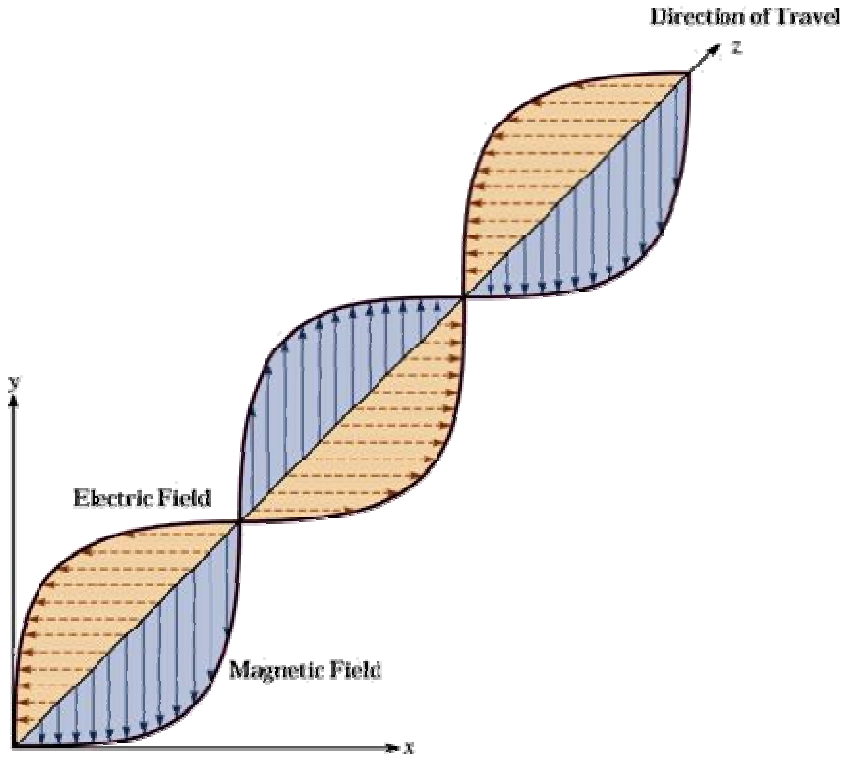
Kuliah ke-3:

Antena dan Propagasi Gelombang Radio

PROGRAM TEKNISI JARDIKNAS

Gelombang Elektromagnetik (e.m.)

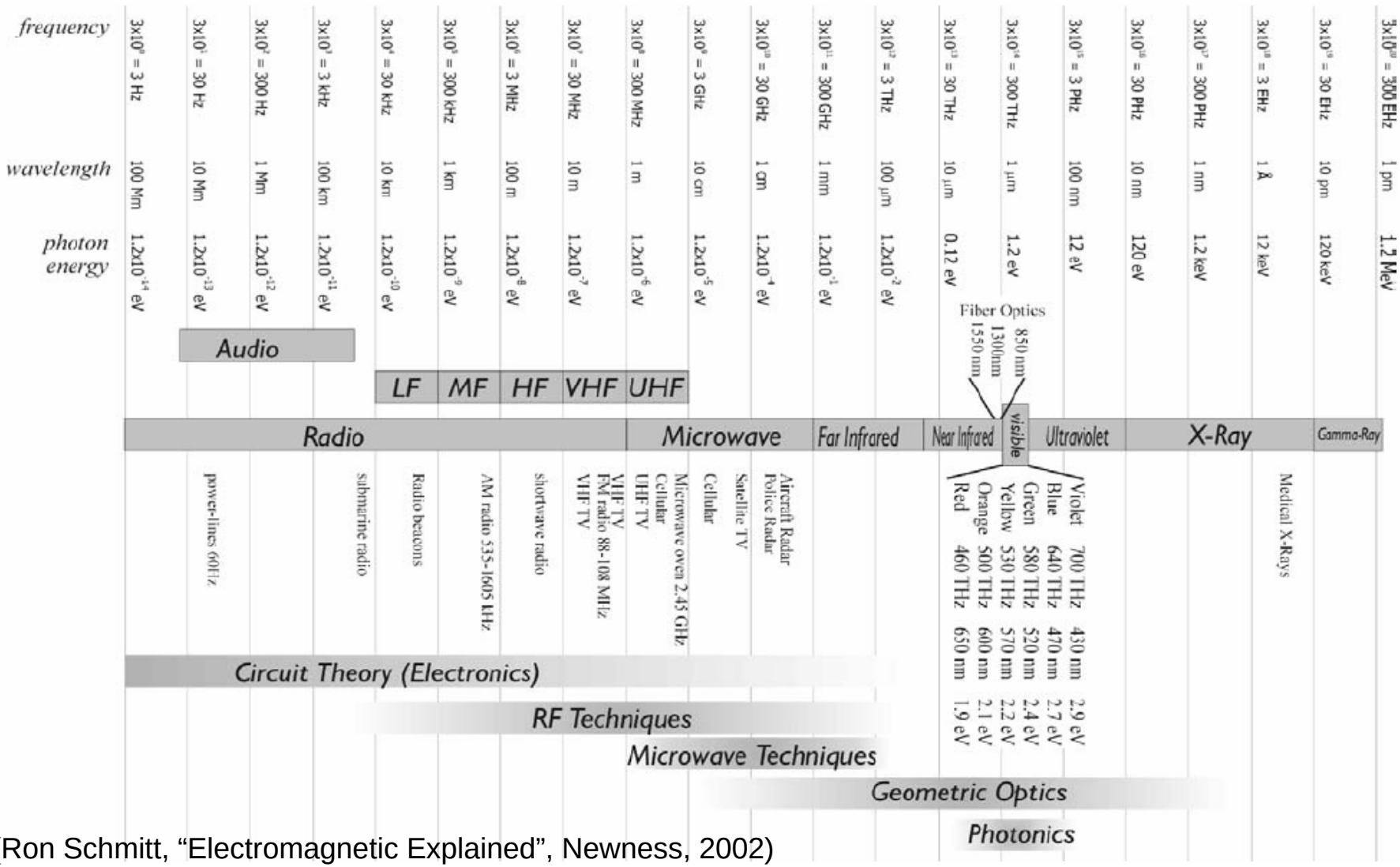
- Gelombang e.m., gelombang yang mempunyai sifat listrik dan magnet bersama-sama.
- Gelombang radio, bagian dari gelombang e.m. pada spektrum frekuensi radio.
- Transmisi gelombang e.m. di ruang adalah sebagai gelombang transversal.
- Gelombang dikarakterisasikan oleh *frekuensi* dan *panjang gelombang*:



$$v = f\lambda$$

v=kecepatan (m/dt), di ruang bebas v=c=3x10^{8}m/dt
f=frekuensi (Hz)
λ=panjang gelombang

Spektrum Frekuensi Gelombang e.m.



(Ron Schmitt, “Electromagnetic Explained”, Newness, 2002)

Penamaan pita frekuensi gelombang radio

Designation	Abbreviation	Frequencies	Free-space Wavelengths
Very Low Frequency	VLF	9 kHz – 30 kHz	33 km – 10 km
Low Frequency	LF	30 kHz – 300 kHz	10 km – 1 km
Medium Frequency	MF	300 kHz – 3 MHz	1 km – 100 m
High Frequency	HF	3 MHz – 30 MHz	100 m – 10 m
Very High Frequency	VHF	30 MHz – 300 MHz	10 m – 1 m
Ultra High Frequency	UHF	300 MHz – 3 GHz	1 m – 100 mm
Super High Frequency	SHF	3 GHz – 30 GHz	100 mm – 10 mm
Extremely High Frequency	EHF	30 GHz – 300 GHz	10 mm – 1 mm

(Olexa, “Implementing 802.11, 802.16, and 802.20 Wireless Networks”, Newness, 2005)

Contoh :

- Sebuah pemancar radio AM dan FM masing-masing bekerja pada 600 kHz dan 90 MHz. Bekerja pada panjang gelombang berapakah kedua pemancar tersebut ?
- Jawab :

$$\lambda_{AM} = \frac{c}{f_{AM}} = \frac{3.10^8}{600.10^3} = 500\,m$$

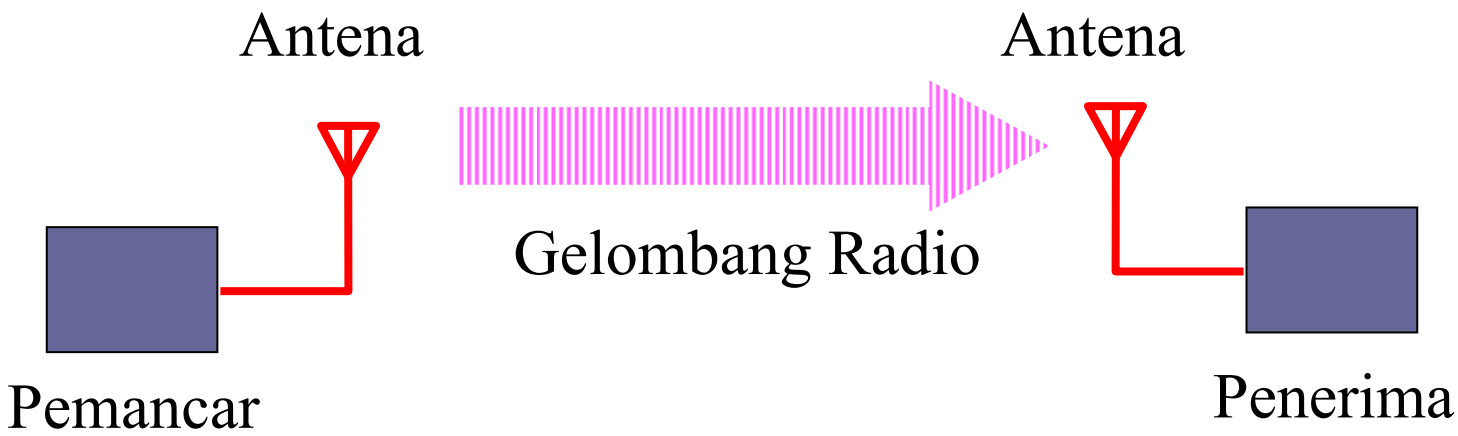
$$\lambda_{FM} = \frac{c}{f_{FM}} = \frac{3.10^8}{90.10^6} = 3{,}33\,m$$

Spektrum Frekuensi ~ ‘Wireless’ Komersial

AM Radio	535-1605 KHz
FM Radio	88-108 MHz
Broadcast TV (Channels 2-6)	54-88 MHz
Broadcast TV (Channels 7-13)	174-216 MHz
Broadcast TV (UHF)	470-806 MHz
3G Broadband Wireless	746-764 MHz, 776-794 MHz
3G Broadband Wireless	1.7-1.85 MHz, 2.5-2.69 MHz
1G and 2G Digital Cellular Phones	806-902 MHz
Personal Communications Service (2G Cell Phones)	1.85-1.99 GHz
Wireless Communications Service	2.305-2.32 GHz, 2.345-2.36 GHz
Satellite Digital Radio	2.32-2.325 GHz
Multichannel Multipoint Distribution Service (MMDS)	2.15-2.68 GHz
Digital Broadcast Satellite (Satellite TV)	12.2-12.7 GHz
Local Multipoint Distribution Service (LMDS)	27.5-29.5 GHz, 31-31.3 GHz
Fixed Wireless Services	38.6-40 GHz

(Andrea Goldsmith, “Wireless Communication”, Stanford University, 2004)

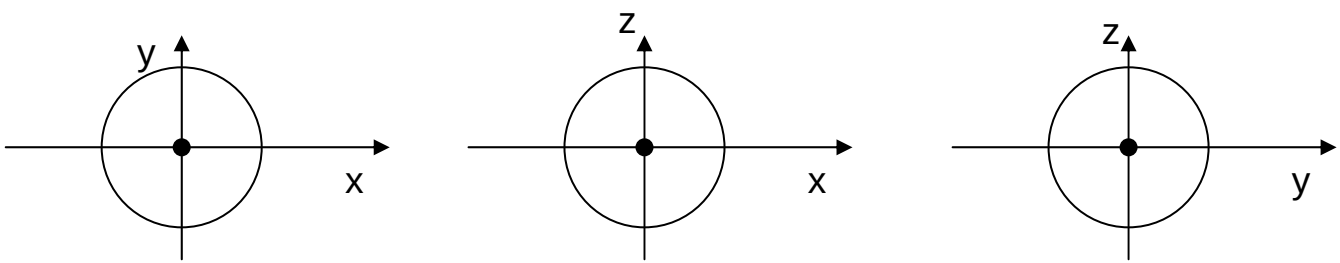
Antena



- Antena, berfungsi sebagai radiator gelombang radio (antena pemancar) dan penerima gelombang radio (antena penerima)
- Antena mempunyai sifat ‘reciprocity’

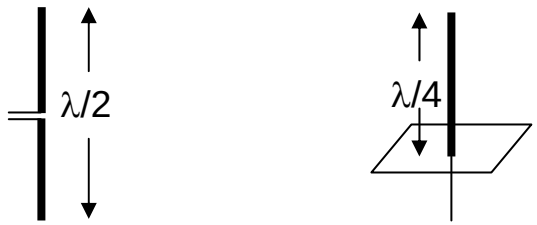
Jenis Antena : Isotropis

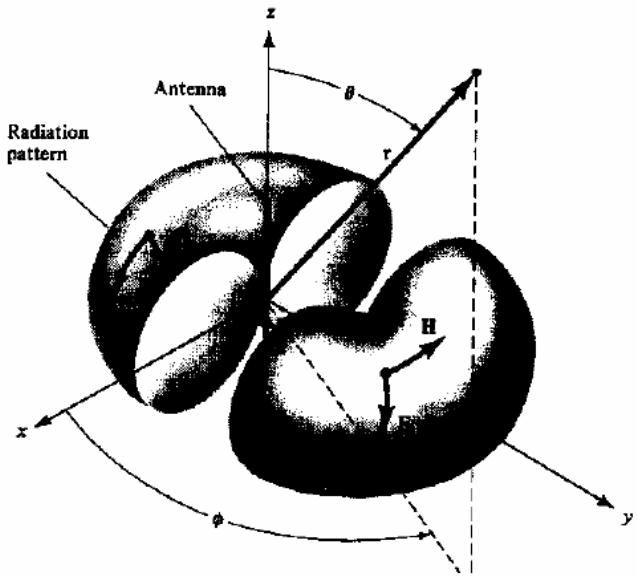
- Antena teoritis sebagai referensi, radiasi serba sama ke segala arah
- Pola radiasi, pola yang menggambarkan kekuatan radiasi antena pada arah horizontal dan/atau vertikal
- Pola radiasi antena isotropis : bola
- Gain, daya maksimum pada main lobe suatu antena nyata dibandingkan dengan daya yang diradiasikan oleh antena isotropis



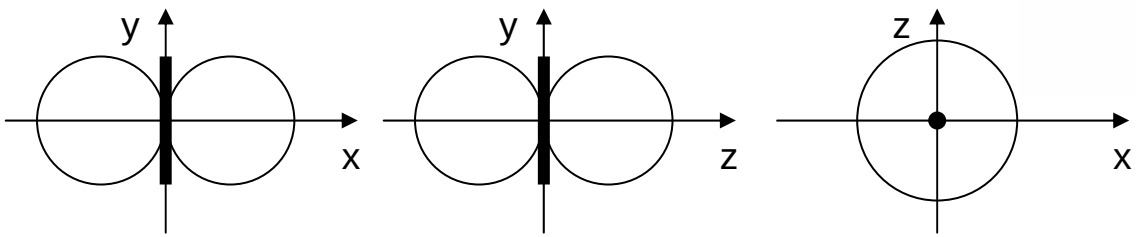
Jenis Antena : dipole, monopole

- Ukuran antena sebanding dengan bagian panjang gelombang, misal dipole $\lambda/2$, monopole $\lambda/4$





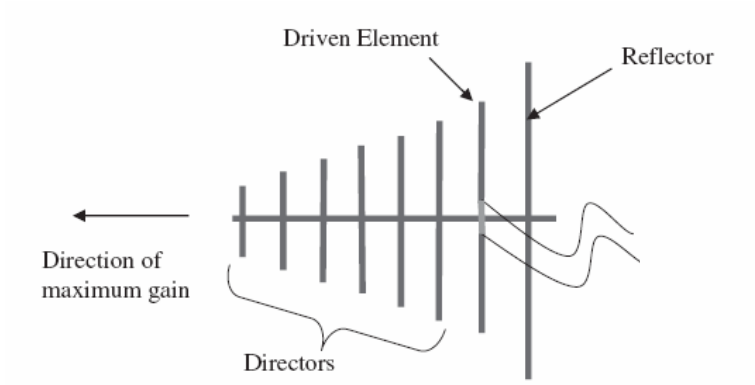
- Pola radiasi : ‘omnidirectional’

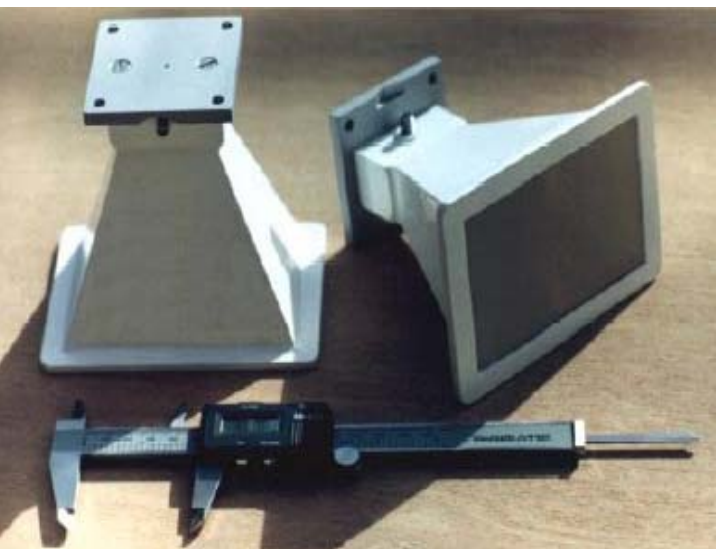


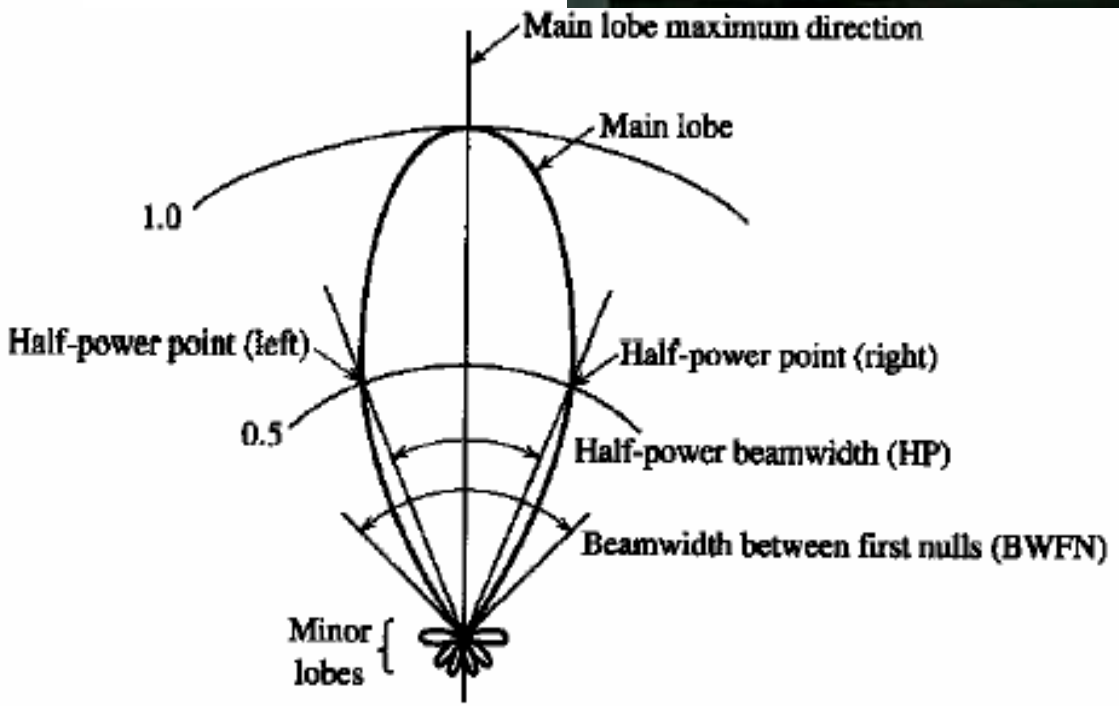
(Balanis, “Antenna Theory and Design”, Wiley,1997)

Jenis antena : ‘directive’

- Yagi, horn, parabola







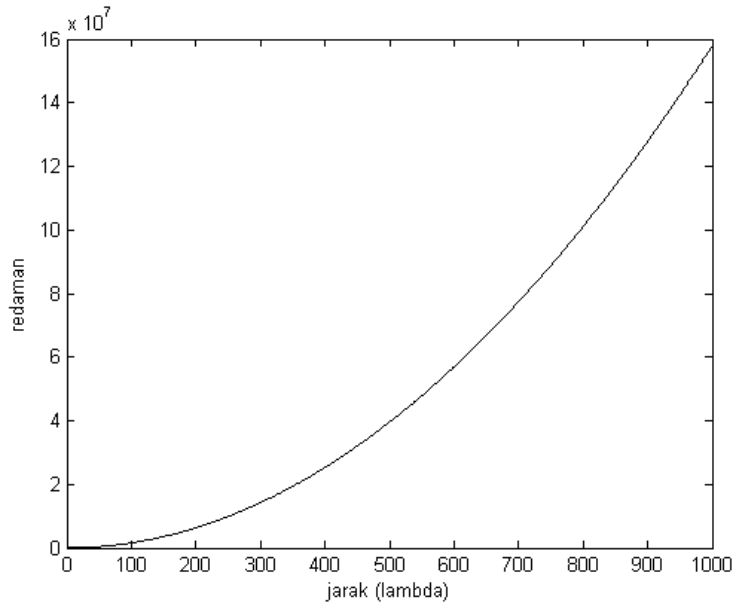
(Balanis, “Antenna Theory and Design”, Wiley,1997)

Propagasi Gelombang Radio

- Di ruang bebas, redaman disebabkan oleh penyebaran energi yang diradiasikan oleh antena isotropis dan diterima oleh antena isotropis

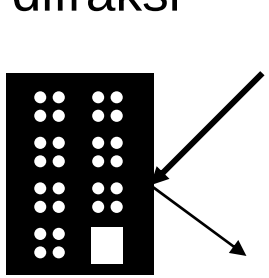
$$P_r = \frac{P_t}{4\pi d^2}\frac{\lambda^2}{4\pi} = P_t\left(\frac{\lambda}{4\pi d}\right)^2$$

$$L_{fs} = \left(\frac{4\pi d}{\lambda}\right)^2$$

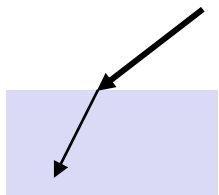


Propagasi Gelombang Radio

- Bila pada sisi pemancar dan penerima digunakan antena dengan gain G_1 dan G_2 :
  Rumus Friis : $$P_r = P_t G_1 G_2 \left[\frac{\lambda}{4\pi d} \right]^2$$
- Di medium sesungguhnya, propagasi gelombang radio dipengaruhi oleh :
  --pantulan
  --pembiasan
  --penghamburan
  --difraksi

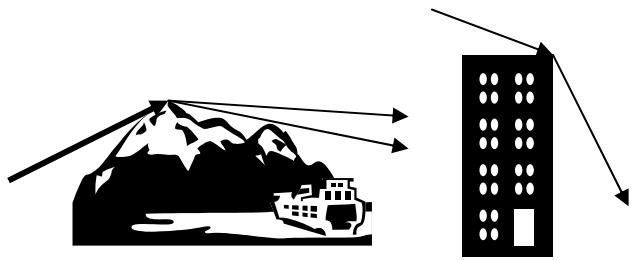


Pantulan



Pembiasan

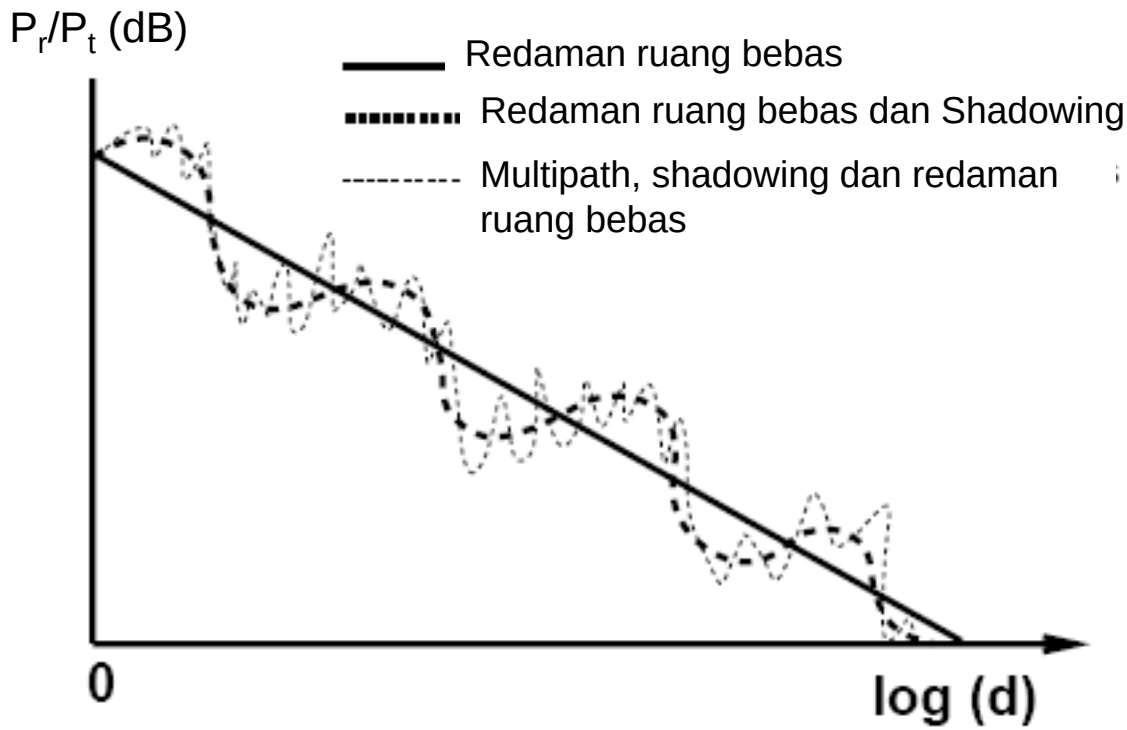
Penghamburan



Difraksi

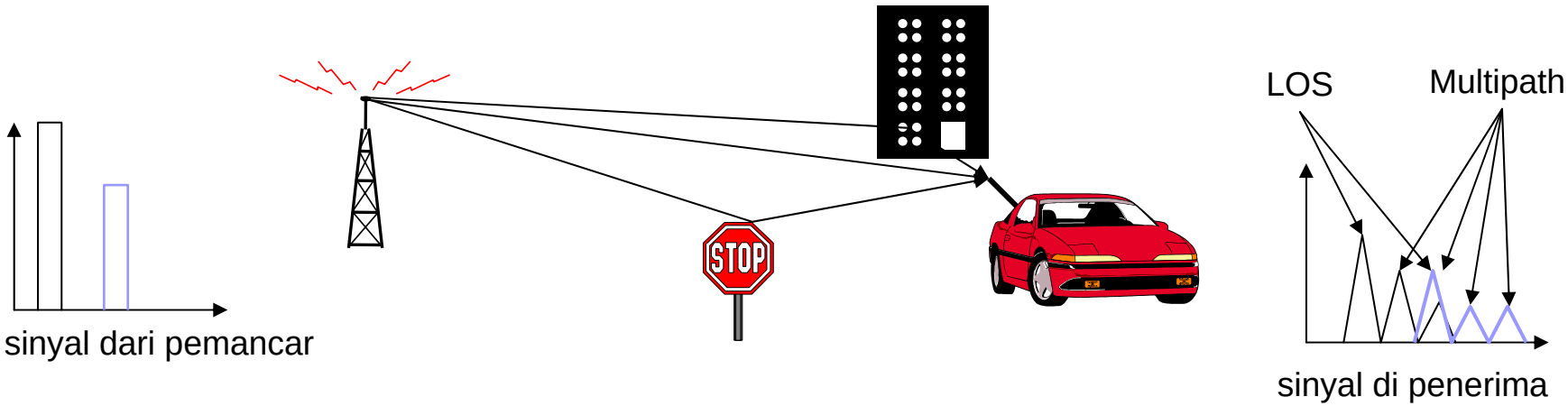
Propagasi Gelombang Radio

- Level sinyal di penerima karena adanya difraksi, hamburan dan pantulan yang menyebabkan shadowing dan lintasan jamak



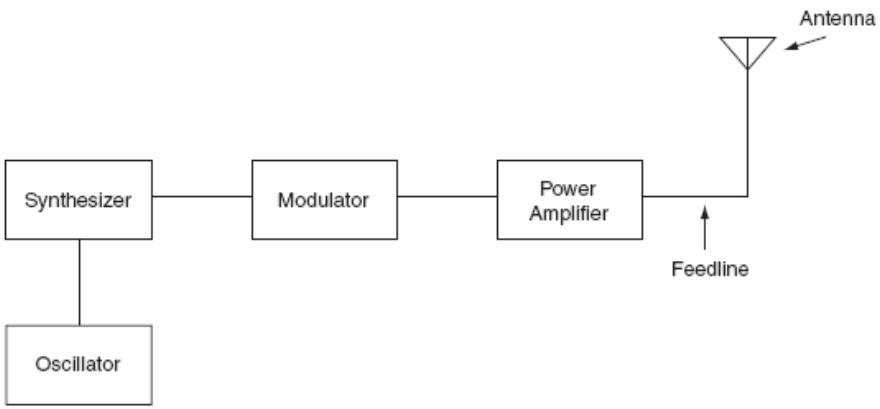
Lintasan Jamak

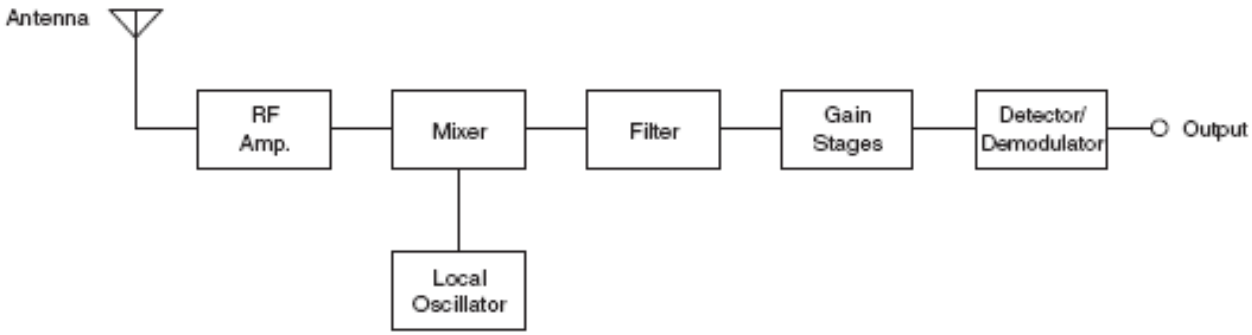
- Gelombang radio dapat melalui beberapa lintasan yang berbeda antara pemancar dan penerima karena terjadinya pantulan, difraksi, dan hamburan.



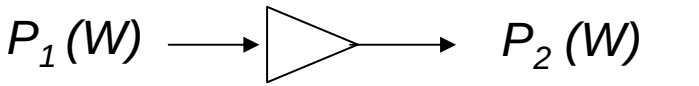
- Dispersi dalam domain waktu, menyebabkan interferensi antar simbol yang berdekatan (Inter Symbol Interference (ISI))
- Sinyal-sinyal datang di penerima dengan fase yang berbeda-beda, menyebabkan distorsi

Diagram Kotak Pemancar, Penerima

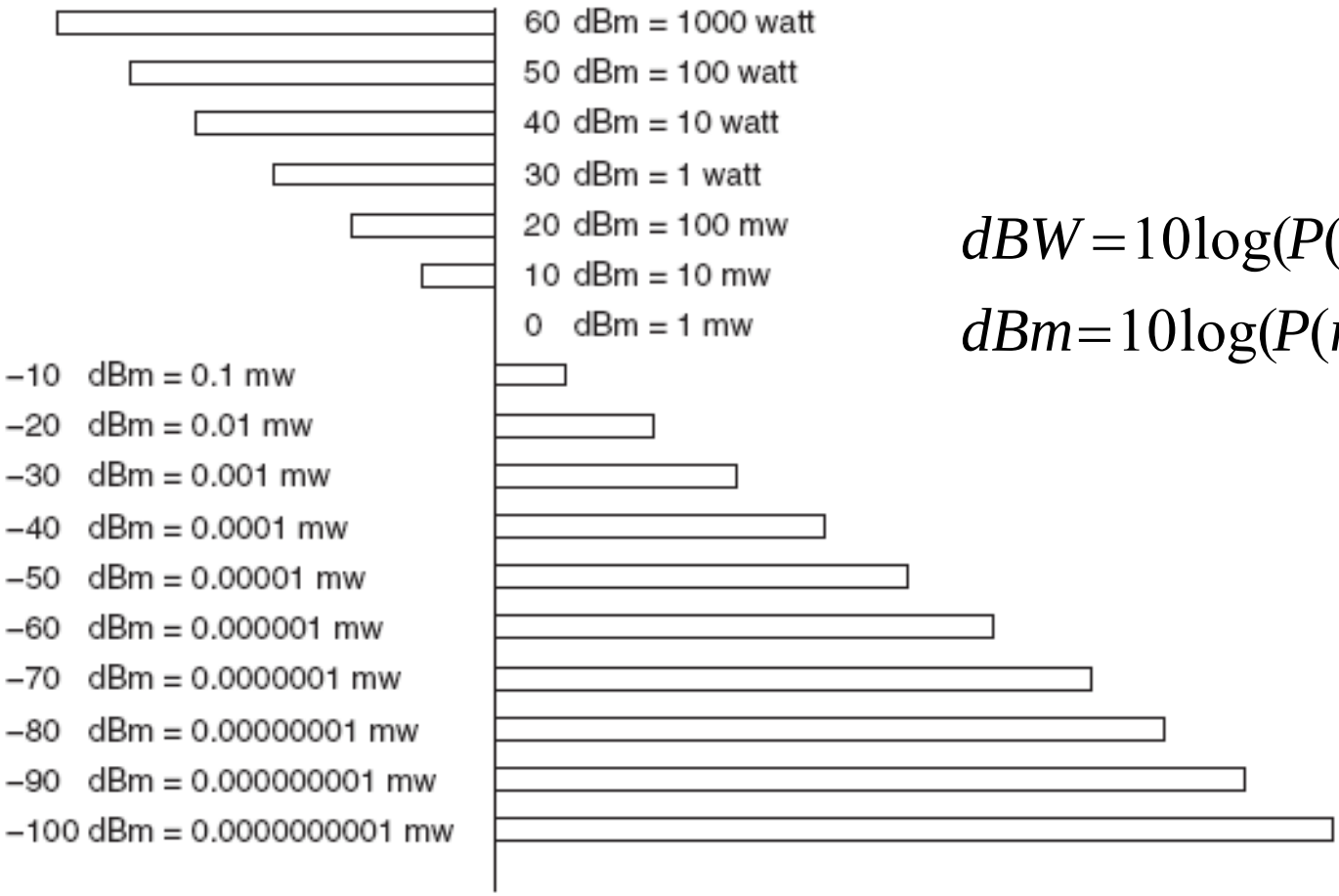




decibell (dB)



$$G = \frac{P_2}{P_1} \qquad G_{dB} = 10\log(P_2 / P_1)$$



$$dBW = 10\log(P(W)/1(W))$$

$$dBm = 10\log(P(mW)/1(mW))$$

Link Budget

$$EIRP_{dB} = P_{t,dBm} + G_{t,dB}$$

$$P_{r,dBm} = EIRP_{dB} - L_{fs,dB} - L_{other,dB} + G_r + FM$$ (FM=fade margin)

Parameter penerima :

- Level sinyal minimum atau sensitivitas penerima (P_{rmin}),
- SNR, dan
- Noise Figure (F) atau temperatur ekivalen noise (T_e)

$$N = kT_0BF$$

$$F = 1 + \frac{T_e}{T_0}$$

Link budget, contoh link point to point dengan redaman hujan, availability link 99,9%

Frequency	38.6 GHz
Wavelength	0.0078 m
Polarization	Vertical
Link Distance	2 km
Tx Power	10.0 dBm
Tx Loss	–1.5 dB
Tx Antenna Gain	32.0 dB
Radome Loss	–2.0 dB
EIRP	**38.5 dBm**
Path Loss (FSL)	–130.2 dB
Tx Pointing Error	–1.0 dB
Rain Loss (0.999)	–15.0 dB
Multipath	–2.0 dB
Atmospheric Loss	–0.2 dB
Total Path Losses	**–148.4 dB**

Radome Loss	–2.0 dB
Rx Antenna Gain	32.0 dB
Polarization Loss	–0.2 dB
Rx Loss	–2.0 dB
Rx Pointing Error	–1.0 dB
Total Rx Gain	**26.8 dB**
RSL	**–83.1 dBm**
Interference margin	–1.0 dB
Rx Noise Figure	7.0 dB
Noise Bandwidth	25.0 MHz
Total Noise Power	**–93.0 dBm**
Signal-to-Noise Ratio	8.9 dB
Threshold	–88.0 dBm
Net margin	**3.9 dBm**