4th year Communication

كلية الهندسة بشبرا

Shoubra faculty of Engineering

BENHA UNIVERSITY

Advanced Electronic Systems

Part 2

Lecture 1

- Satellite System Link Models
- Satellite System parameters

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Part 2 Schedule

Week No.	Topic
1	Comm. Satellite System Models and Parameters
2	▪ Link design equations ▪ GPS
3	Communication satellite services

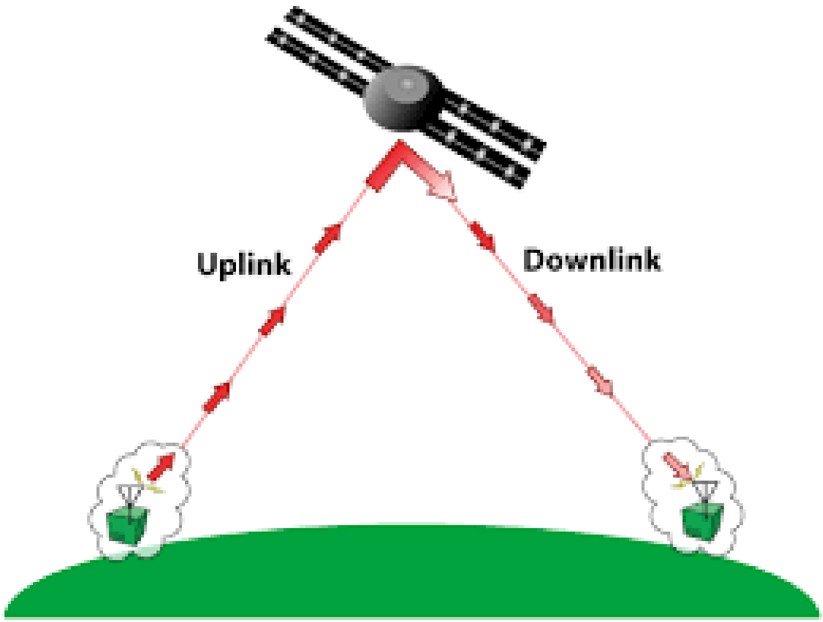
References

- Wayne Tomasi – “Advanced Electronic Communications Systems”- 6th edition
- L.Frenzel – “Principles of electronic communication systems”- 4th edition
- Maini, Anil K., and Varsha Agrawal. ‘Satellite technology: principles and applications’. John Wiley & Sons, 3rd Edition, 2014.

Satellite System Link Models

Communication satellite system

- A communication satellite system consists of three basic sections:
  - Uplink: link from transmitter ES to Satellite transponder
  - A satellite transponder: Microwave repeater
  - Downlink: Link from Satellite transponder to receiver ES



Communication satellite system (cont'd)

- The common carrier frequencies used for communication satellite are the 6/4-GHz (C-band) and 14/12-GHz (Ku-band) bands.
- The first number is the uplink frequency, and the second number is the downlink frequency.
- Different uplink/downlink frequencies are used to prevent ringaround (interference bet. uplink and downlink)

- Higher frequencies are subjected to higher losses through atmosphere, so uplink needs more transmitted power.

Satellite System Link Models

1- Uplink Model

- The primary component within the uplink section of a satellite system is the earth station transmitter.

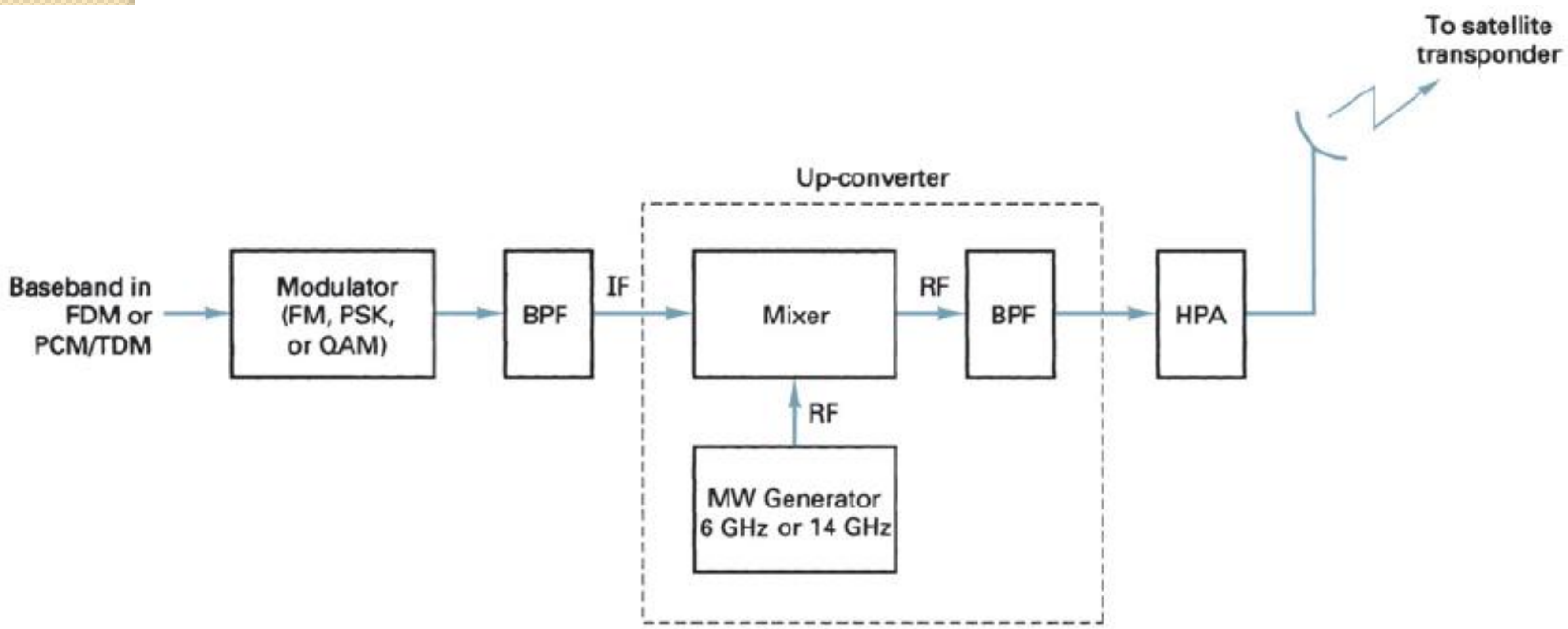


Fig. Satellite uplink model (Block diag. of ES transmitter).

1- Uplink Model (Cont'd)

- IF modulator: Converts the input baseband signal to modulated IF signal.
- BPF: band pass filter. Limits the required band.
- Microwave up-converter (mixer and BPF): converts the IF to an appropriate RF carrier frequency.
- The high power amplifier (HPA): provides adequate gain and output power to propagate the signal to the satellite transponder.

2- Transponder Model

- An input BPF limits the total noise applied to the LNA.
- The output of the LNA is fed to a frequency translator which converts the high-band uplink frequency to the low-band downlink frequency.
- The low-level power amplifier amplifies the RF signal for transmission through the downlink to ES.

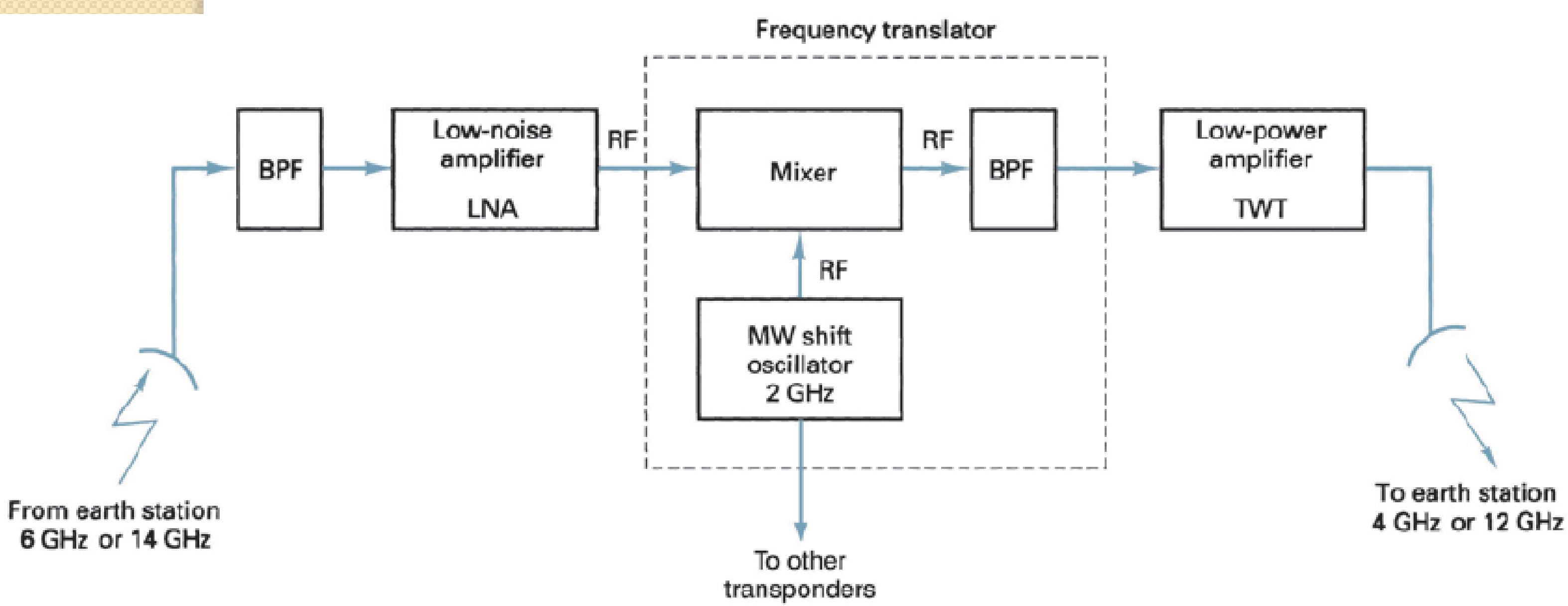


Fig. Satellite Transponder.

3- Downlink Model

- The primary component within the Downlink section of a satellite system is the earth station receiver.

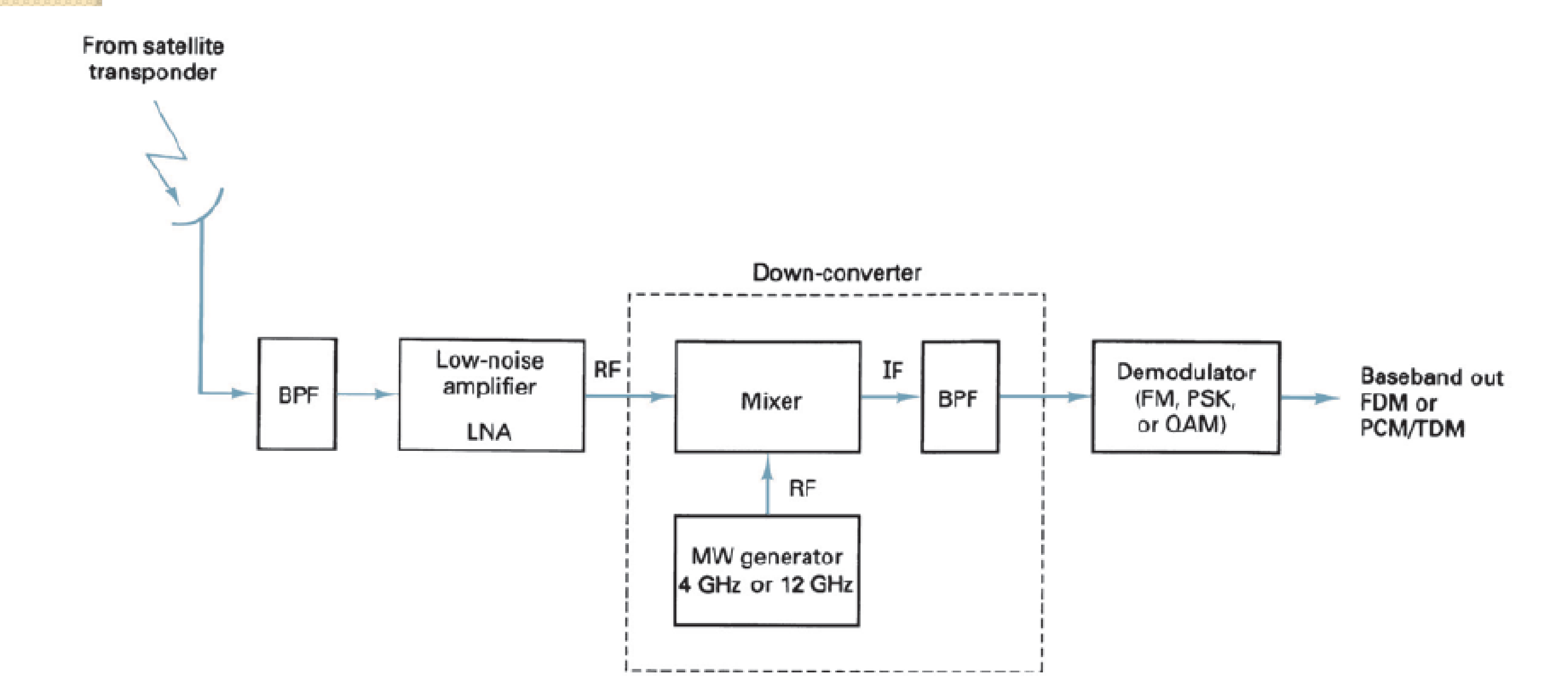


Fig. Satellite downlink model (Block diag. of ES receiver).

3- Downlink Model (cont'd)

- BPF: limits the input noise power to the LNA.
- The LNA is a highly sensitive, low-noise amplifier device.
- The RF-to-IF down-converter (Mixer + BPF): converts the received RF signal to an IF frequency
- IF Demodulator: demodulates the IF-modulated signal to the baseband signal

Cross Links

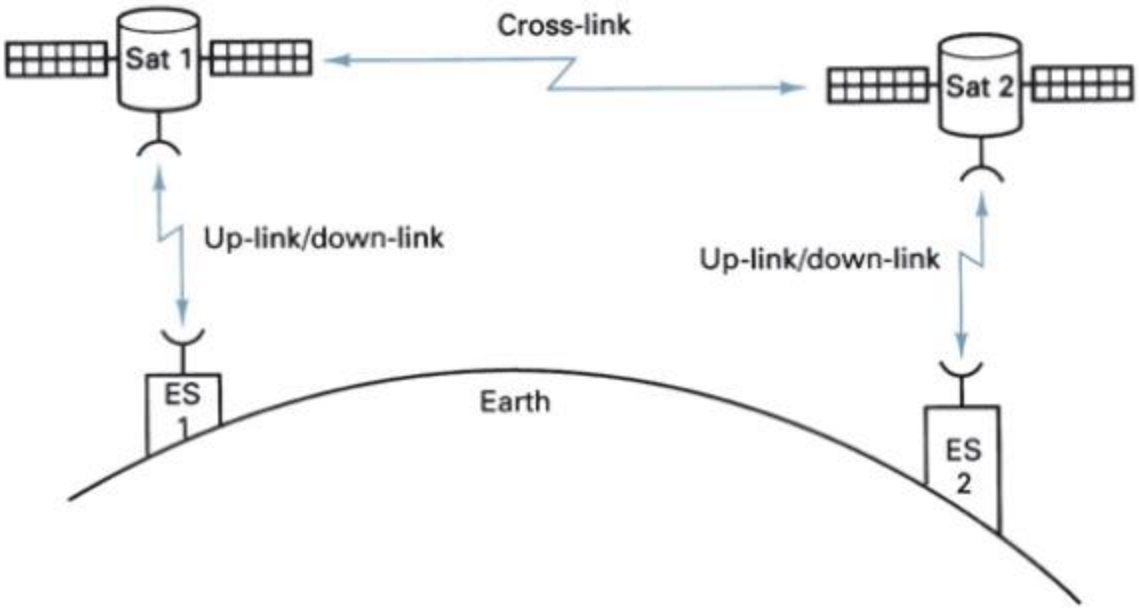


Fig. Intersatellite link

- Some applications need communication between satellites. This is done using satellite cross-links or intersatellite links (ISLs).

- A disadvantage of using an ISL is that both the transmitter and the receiver are space bound. Consequently, both the transmitter's output power and the receiver's input sensitivity are limited.

Satellite System Parameters

Satellite System Parameters

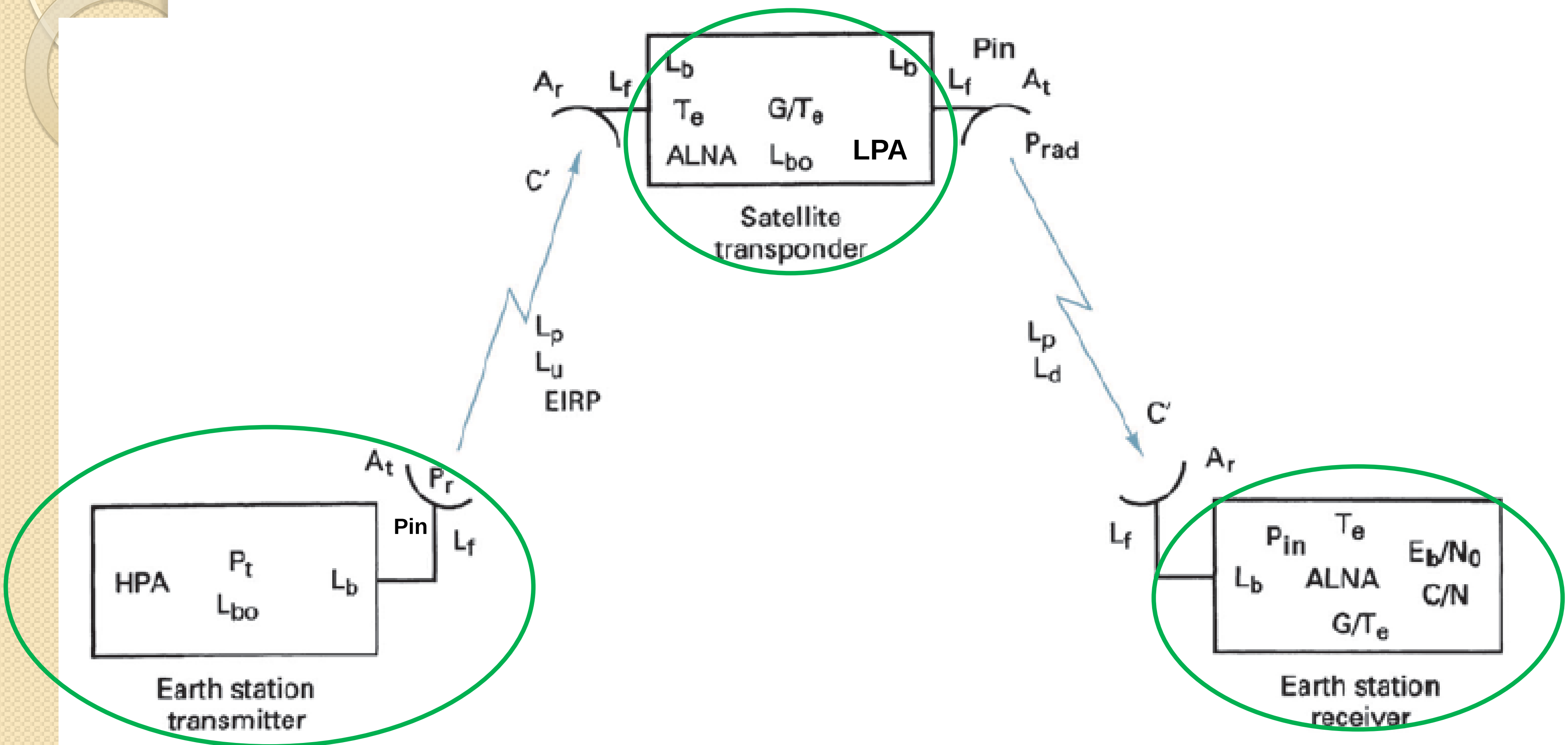


Fig. Overall satellite system showing the gains and losses incurred in satellite system

Back-off Loss (L_{bo})

- Power amplifiers are nonlinear devices; their gain (output/input power) is dependent on input signal level.
- It can be seen from figure that, at the nonlinear region, as the input power is changed by 4 dB, the output power is changed by only 2 dB (this means power compression)

The amount the output level backed off from rated levels is equivalent to a loss called backoff loss (L_{bo}).

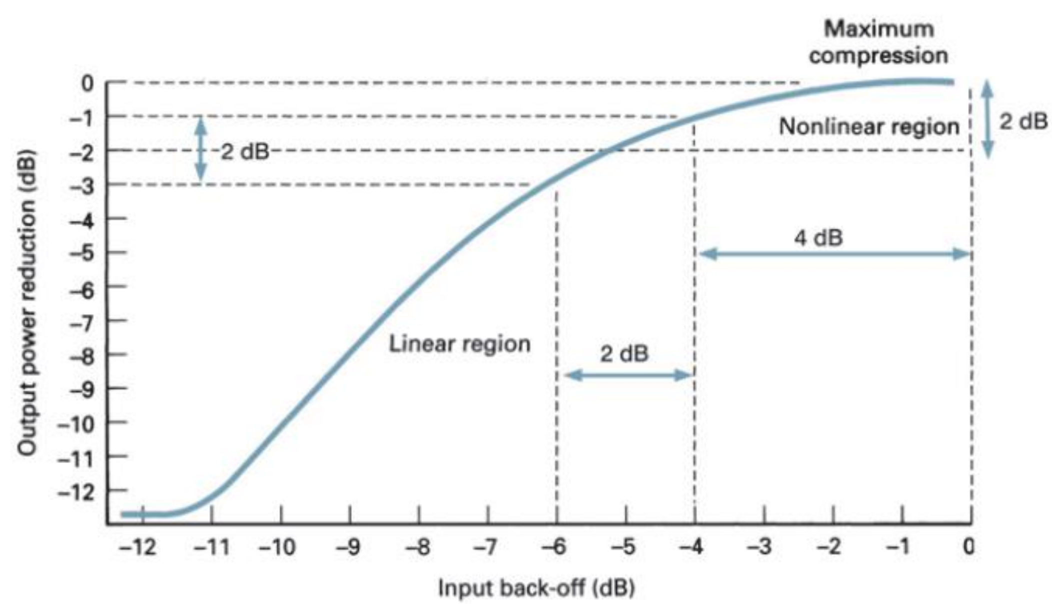
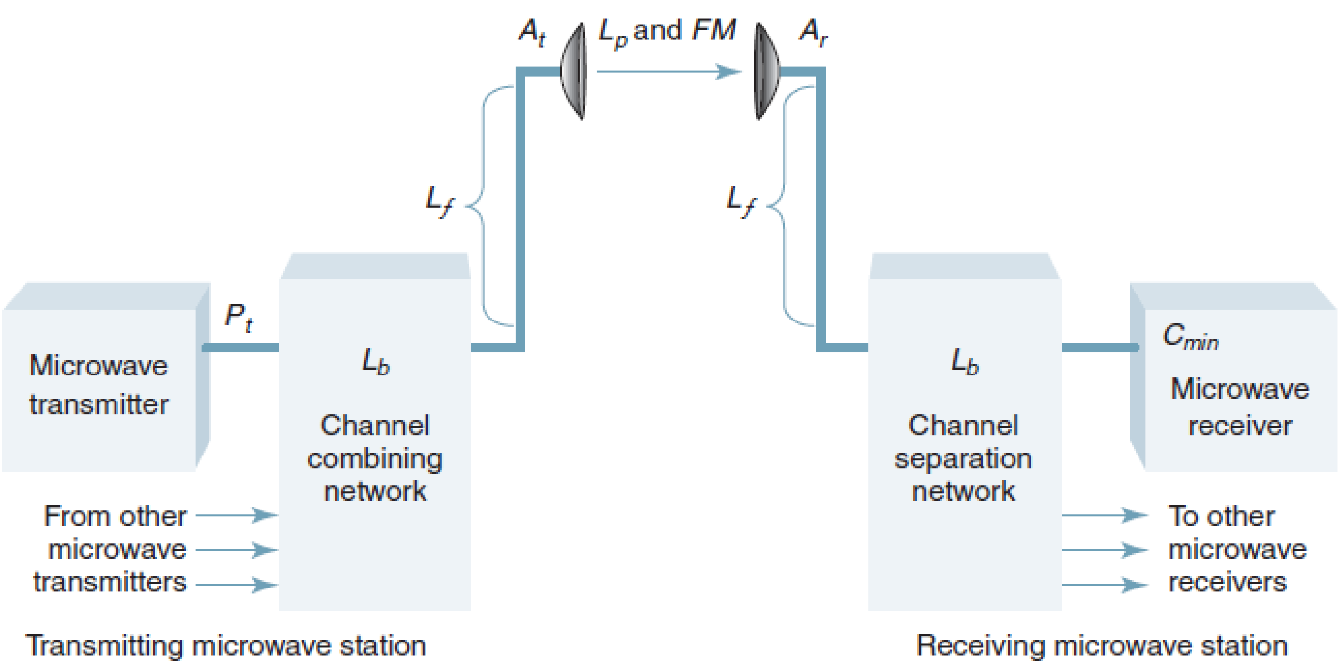


Fig: HPA input/output characteristic curve

Branching (L_b) and Feeding (L_f) Losses

- Branching Loss: Due to branching effect when multiple transmitters' signals are combined to be transmitted through single channel. Similar effect occurs at the receiver when separating them again.

- Feeding Loss: Loss in the transmission line that connected to the antenna.



Transmit Power and Bit Energy

Transmit power:

- To operate as efficiently as possible, a power amplifier should be operated as close as possible to saturation. The saturated output power is designated $P_{o(sat)}$ or simply P_t.

- Most modern satellite systems use either PSK or QAM rather than conventional FM. Also, the input baseband is generally a PCM-encoded. So, several bits may be encoded in a single transmit signaling element. Consequently, a parameter more meaningful than carrier power is energy per bit (E_b).

Transmit Power and Bit Energy (cont'd)

- Energy per bit (E_b) is the energy contained in one bit.

$$E_{\mathrm{b}} = P_{\mathrm{t}} T_{\mathrm{b}} = \frac{P_{\mathrm{t}}}{f_{\mathrm{b}}} \left(\frac{\mathrm{J/s}}{\mathrm{bit/s}} = \mathrm{J/bit}\right)$$

E_{b}: Energy of a single bit (joules per bit)

P_{t}: Total output power of HPA (watts or joules per second)

T_{b}: Time of a single bit (seconds)

f_{b}: Bit-rate (bps)

Transmit Power and Bit Energy (cont'd)

Example:

For a total transmit power (P_t) of 1000 W, determine the energy per bit (E_b) for a transmission rate of 50 Mbps.

Answer:

$$E_b = \frac{P_t}{f_b} = \frac{1000 \text{ J/s}}{50 \times 10^6 \text{ bps}} = 20 \text{ μJ/bit}$$

Expressed in dB with 1 Joule as the reference:

$$E_b = 10 \log (20 \times 10^{-6}) = -47 \text{ dBJ}$$

Effective Isotropic Radiated Power (EIRP)

- EIRP is defined as an equivalent transmit power of antenna.

$$\mathrm{EIRP} = P_{\mathrm{in}} A_{\mathrm{t}}$$

EIRP: effective isotropic radiated power (watts)

P_{in}: antenna input power (watts)

A_{t}: transmit antenna gain (unitless ratio)

Expressed as log: $\mathrm{EIRP}_{(\mathrm{dBW})} = P_{\mathrm{in(dBW)}} + A_{\mathrm{t(dB)}}$

$$P_{\mathrm{in(dBW)}} = P_{\mathrm{t(dBW)}} - L_{\mathrm{bo(dB)}} - L_{\mathrm{fb(dB)}}$$

$$\mathrm{EIRP}_{(\mathrm{dBW})} = P_{\mathrm{t(dBW)}} - L_{\mathrm{bo(dB)}} - L_{\mathrm{fb(dB)}} + A_{\mathrm{t(dB)}}$$

$L_{\mathrm{b}o}$: Back-off loss of HPA (dB)

L_{fb}: Total branching and feeder loss (dB)

Effective Isotropic Radiated Power (EIRP)

Example:

For an earth station transmitter with P_t of 40 dBW (10,000 W), a back-off loss of 3 dB, a total branching and feeder loss of 3 dB, and a transmit antenna gain of 40 dB, determine the EIRP.

Answer:

$$\mathrm{EIRP}_{(\mathrm{dBW})} = P_{\mathrm{t(dBW)}} - L_{\mathrm{bo(dB)}} - L_{\mathrm{fb(dB)}} + A_{\mathrm{t(dB)}}$$

$$\mathrm{EIRP} = 40\ \mathrm{dBW} - 3\ \mathrm{dB} - 3\ \mathrm{dB} + 40\ \mathrm{dB} = 74\ \mathrm{dBW}$$

Noise Density (N_0)

- Noise density (N_0) is the noise power normalized to a 1-Hz bandwidth, or the noise power present in a 1-Hz bandwidth.

$$N_0 = \frac{N}{B}$$

N : Total noise power (watts), B: Bandwidth (Hz)

$$N = KT_eB$$

K : Boltzmann's constant (1.38×10^{-23} J/Kelvin)

T_e: Equivalent noise Temp. (kelvin)

$$N_0 = \frac{KT_eB}{B} = KT_e$$

Noise Density (N_0) (cont'd)

Example:

For an equivalent noise bandwidth of 10 MHz and a total noise power of 0.0276 pW, determine the noise density and equivalent noise temperature.

Answer:

Noise density:

$$N_0 = \frac{N}{B} = \frac{0.0276 \times 10^{-12}}{10 \times 10^{6}} = 2.76 \times 10^{-21}\ \mathrm{W/Hz}$$

Expressed in log: $N_0 = 10 \log(2.76 \times 10^{-21}) = -205.6\ \mathrm{dBW/Hz}$

Equivalent Noise Temp.:

$$T_e = \frac{N_0}{K} = \frac{2.76 \times 10^{-21}\ \mathrm{W/Hz}}{1.38 \times 10^{-23}\ \mathrm{J/K}} = 200\ \mathrm{K}$$

Carrier-to-Noise density Ratio (C/N_0)

- Carrier power-to-noise density ratio (at receiver)

$$\frac{C}{N_0} = \frac{C}{KT_e}$$

Expressed as log:

$$\frac{C}{N_0}(\mathrm{dB}) = C_{(\mathrm{dBW})} - N_{0(\mathrm{dBW})}$$

Energy of Bit-to-Noise density Ratio (E_b/N_0)

$$\frac{E_b}{N_0} = \frac{C/f_b}{N/B}$$

$$= \frac{CB}{Nf_b} = \frac{C}{N} \times \frac{B}{f_b}$$

Expressed as log:

$$\frac{E_b}{N_0}(\mathrm{dB}) = \frac{C}{N}(\mathrm{dB}) + \frac{B}{f_b}(\mathrm{dB})$$

- E_b/N_0 is independent of bandwidth and modulation scheme, so it is a convenient method for comparing the probability of error performance of two digital radio systems.
- This is in contrary to C/N, that is affected by BW and modulation.

Energy of Bit-to-Noise density Ratio (E_b/N_0)

Example:

Determine E_b/N_0 when the receiver input carrier power is -100 dBW, the receiver input noise Temp. is 290 K, and the transmission rate is 60-Mbps.

Answer:

$$\frac{E_b}{N_0} = \frac{C/f_b}{N_0}$$

$$N_0 = K\,T_e = 1.38 \times 10^{-23} \times 290 = 4 \times 10^{-21}\ \mathrm{W/Hz}$$

Expressed in log: $N_0 = 10\log(4 \times 10^{-21}) = -203.98\ \mathrm{dBW/Hz}$

$$\frac{E_b}{N_0}(dB) = C_{(\mathrm{dBW})} - f_{b(\mathrm{dB})} - N_{0(\mathrm{dBW/Hz})}$$

$$= -100 - 10\log(60 \times 10^{6}) + 203.98 = 26.2\ \mathrm{dB}$$

Gain-to-Equivalent Noise Temp. Ratio (G/T_e)

- $\boldsymbol{G/T_e}$ is used to represent the quality of a satellite transponder receiver or ES receiver.

$$\frac{G}{T_e}(\mathrm{dBK}^{-1}) = G - 10\log\,(T_e)$$

$$T_e = T_a + T_r$$

G: Receive antenna gain (dB)

T_e: system equivalent noise temperature (degrees Kelvin)

T_a: Antenna temperature (degrees Kelvin)

T_r: Receiver effective input noise temperature (degrees Kelvin)

Gain-to-Equivalent Noise Temp. Ratio (G/T_e)

Example:

For an earth station receiver with an equivalent noise temperature of 250 K and a receive antenna gain of 60 dB, determine G/T_e.

Answer:

$$\frac{G}{T_e}(\mathrm{dBK^{-1}}) = G - 10\log\,(T_e)$$

$$= 60\ \mathrm{dB} - 10\log\,(250)$$

$$= 36\ \mathrm{dBK^{-1}}$$

Satellite System Parameters Summary

Parameter	Formula
Energy per bit (E_b) (at Transmitter ES)	$E_\mathrm{b} = P_\mathrm{t} T_\mathrm{b} = \frac{P_\mathrm{t}}{f_\mathrm{b}}$
Effective isotropic radiated power (EIRP)	$\mathrm{EIRP} = P_\mathrm{in} A_\mathrm{t}$
Noise density (N_0)	$N_0 = \frac{N}{B} = KT_e$
Carrier to noise density ratio ($\frac{C}{N_0}$) (at Receiver transponder or ES)	$\frac{C}{N_0} = \frac{C}{KT_e}$
Energy of bit-to Noise density ratio ($\frac{E_b}{N_0}$) (at Receiver transponder or ES)	$\frac{E_b}{N_0} = \frac{C/f_b}{N/B} = \frac{C}{N} \times \frac{B}{f_b}$

Thanks for attention