Satellite Communication

Overview

- Design of the Satellite Links
- Link Budget and their Interpretation
- Multiple Access Systems
- Frequency Band Trade-Offs

Design of the Satellite Link

- The satellite link is probably the most basic in microwave communications since a line-of-sight path typically exists between the Earth and space.
- This means that an imaginary line extending between the transmitting or receiving Earth station and the satellite antenna passes only through the atmosphere and not ground obstacles.
- Such a link is governed by free-space propagation with only limited variation with respect to time due to various constituents of the atmosphere.

Design of the Satellite Link

- Free-space attenuation is determined by the inverse square law, which states that the power received is inversely proportional to the square of the distance.
- The same law applies to the amount of light that reaches our eyes from a distant point source such as an automobile headlight or star.
- There are, however, a number of additional effects that produce a significant amount of degradation and time variation.
- These include rain, terrain effects such as absorption by trees and walls, and some less-obvious impairment produced by unstable conditions of the air and ionosphere.

Design of the Satellite Link

- It is the job of the communication engineer to identify all of the significant contributions to performance and make sure that they are properly taken into account.
- The required factors include the performance of the satellite itself, the configuration and performance of the uplink and downlink Earth stations, and the impact of the propagation medium in the frequency band of interest.

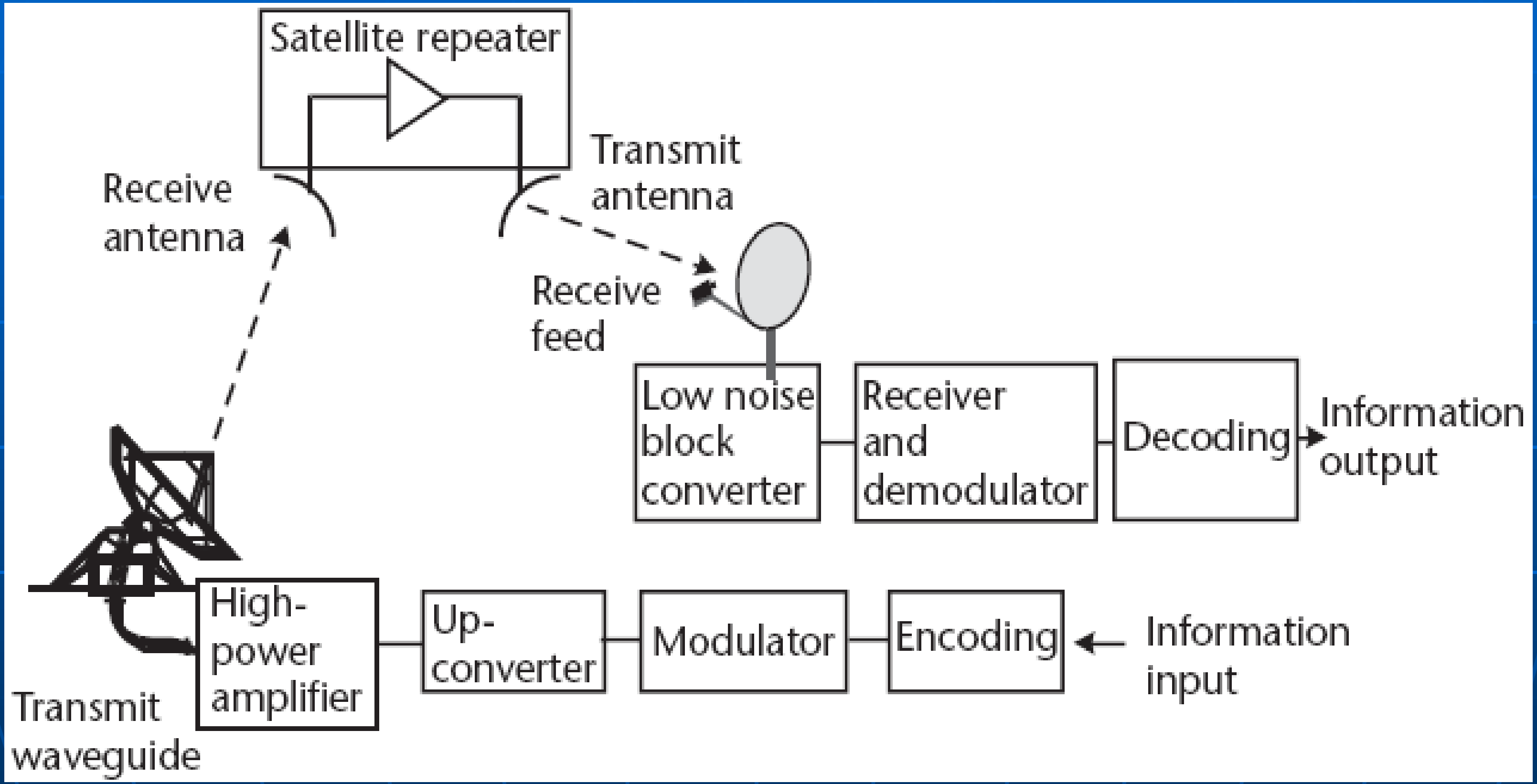
Design of the Satellite Link

- Also important is the efficient transfer of user information across the relevant interfaces at the Earth stations, involving such issues as the precise nature of this information, data protocol, timing, and the telecommunications interface standards that apply to the service.
- A proper engineering methodology guarantees that the application will go into operation as planned, meeting its objectives for quality and reliability.

Design of the Satellite Link

- The RF carrier in any microwave communications link begins at the transmitting electronics and propagates from the transmitting antenna through the medium of free space and absorptive atmosphere to the receiving antenna, where it is recovered by the receiving electronics.
- The carrier is modulated by a baseband signal that transfers information for the particular application.
- The first step in designing the microwave link is to identify the overall requirements and the critical components that determine performance.
- For this purpose, we use the basic arrangement of the link shown in Figure.

Design of the Satellite Link



- Figure 2.1: Critical Elements of the Satellite Link

Design of the Satellite Link

- The example shows a large hub type Earth station in the uplink and a small VSAT in the downlink; the satellite is represented by a simple frequency translating type repeater (e.g., a bent pipe).
- Most geostationary satellites employ bent-pipe repeaters since these allow the widest range of services and communication techniques.

Design of the Satellite Link

- Bidirectional (duplex) communication occurs with a separate transmission from each Earth station.
- Due to the analog nature of the radio frequency link, each element contributes a gain or loss to the link and may add noise and interference as well.

Design of the Satellite Link

- The result in the overall performance is presented in terms of the ratio of carrier power to noise (the carrier-to-noise ratio, C/N) and, ultimately, information quality (bit error rate, video impairment, or audio fidelity).
- Done properly, this analysis can predict if the link will work with satisfactory quality based on the specifications of the ground and space components.
- Any uncertainty can be covered by providing an appropriate amount of link margin, which is over and above the C/N needed to deal with propagation effects and nonlinearity in the Earth stations and satellite repeater.

Link Budget and their Interpretation

- The link between the satellite and Earth station is governed by the basic microwave radio link equation:

$$p_r = \frac{p_t g_t g_r c^2}{(4\pi)^2 R^2 f^2}$$

- where p_r is the power received by the receiving antenna;
  p_t is the power applied to the transmitting antenna;
  g_t is the gain of the transmitting antenna;
  g_r is the gain of the receiving antenna;
  c is the speed of light (i.e., approximately 300×10^6 m/s);
  R is the range (path length) in meters; and
  f is the frequency in hertz.

Link Budget and their Interpretation

- Almost all link calculations are performed after converting from products and ratios to decibels.
- The same formula, when converted into decibels, has the form of a power balance.

$$P_r = P_t + G_t + G_r - 20\log(f \cdot R) + 147.6$$

Link Budget and their Interpretation

- The received power in this formula is measured in decibel relative to 1W, which is stated as dBW.
- The last two terms represent the free-space path loss (A_0) between the Earth station and the satellite.
- If we assume that the frequency is 1 GHz and that the distance is simply the altitude of a GEO satellite (e.g., 35,778 km), then the path loss equals 183.5 dB; that is,

$$P_r = P_t + G_t + G_r - 183.5$$

- for f = 1000000000 Hz and R = 35,788,000 m.

Link Budget and their Interpretation

- We can correct the path loss for other frequencies and path lengths using the formula:

$$A_0 = 183.5 + 20\log(f) + 20\log(R/35788)$$

- where A_0 is the free-space path loss in decibels, f is the frequency in gigahertz, and R is the path length in kilometers.
- The term on the right can be expressed in terms of the elevation angle from the Earth station toward the satellite,

Link Budget and their Interpretation

- The term on the right can be expressed in terms of the elevation angle from the Earth station toward the satellite. i.e.

$$R = 42643.7\sqrt{1 - 0.295577 \times (\cos\phi \cos\delta)}$$

- where φ is the latitude and δ is the longitude of the Earth station minus that of the satellite (e.g., the relative longitude).

Link Budget and their Interpretation

- Substituting for *R in Ao* we obtain the correction term in decibels to account for the actual path length.
- This is referred to as the slant range adjustment and is a function of the elevation angle, θ as shown in Figure 2.3.

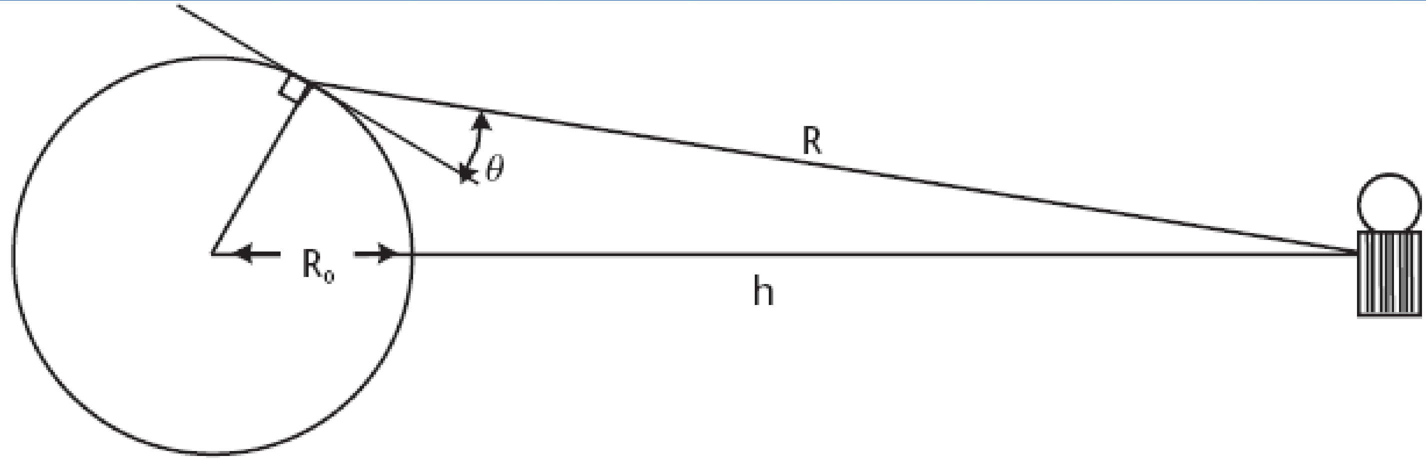


Figure 2.2 Definition of the slant range distance, R, between the Earth station and the GEO satellite. The Earth station elevation angle, θ, is with respect to the local horizon.

Link Budget and their Interpretation

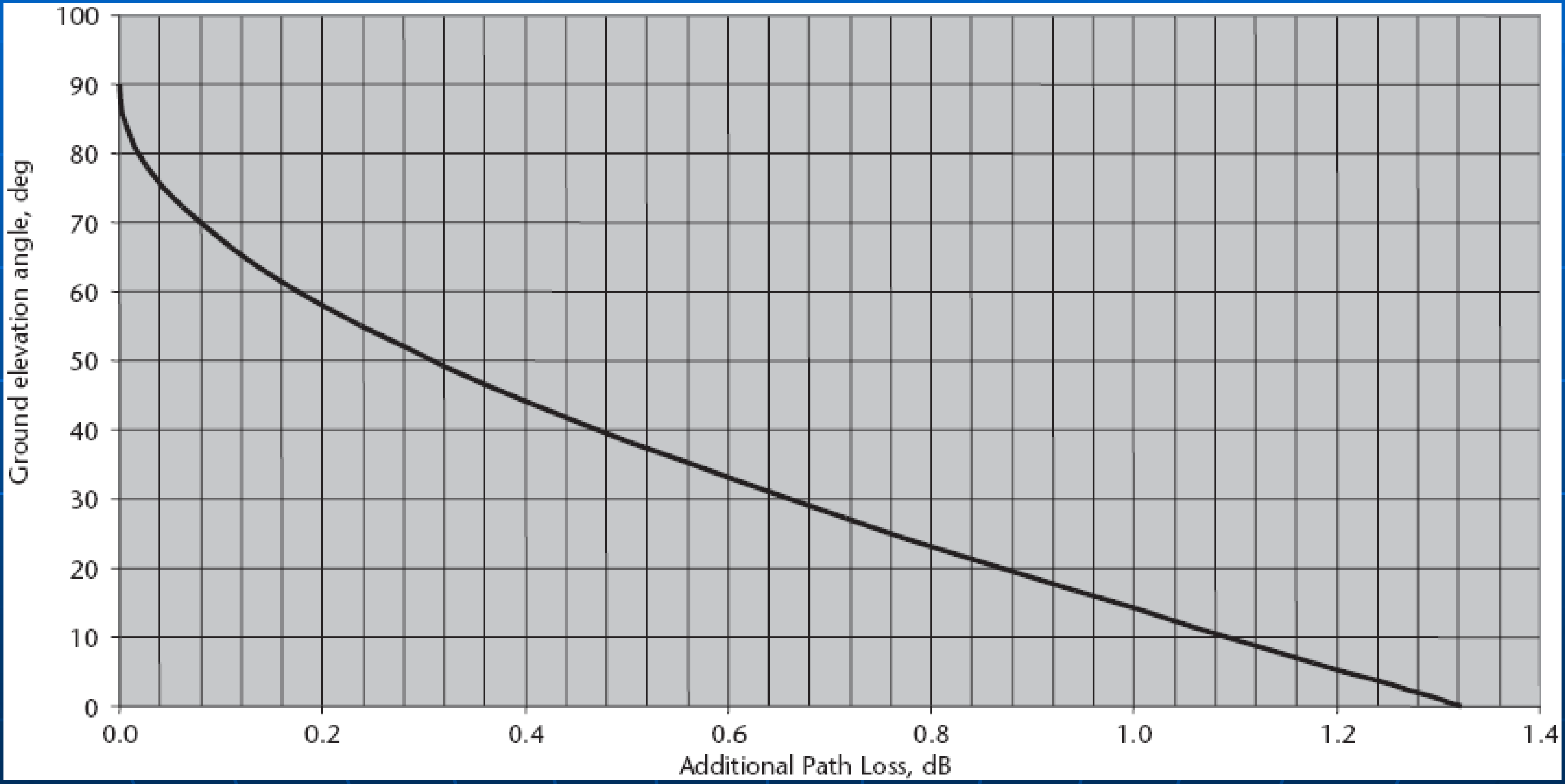


Figure 2.3: Additional path loss due to slant range, versus ground elevation angle.

Atmospheric Effects on Link Budget and their Interpretation

A general quantitative review of ionospheric effects is provided in table below:

Table 2.2 Estimated Maximum Ionospheric Effects in the United States for One-Way Paths at an Elevation Angle of About 30°

Effect	*100 MHz*	*300 MHz*	*1 GHz*	*3 GHz*	*10 GHz*
Faraday rotation*	30 rotations	3.3 rotations	108°	12°	1.1°
Excess time delay	25 ms	2.8 ms	0.25 ms	28 ns	2.5 ns
Absorption (polar)	5 dB	1.1 dB	0.05 dB	0.006 dB	0.0005 dB
Absorption (mid Lat)	<1 dB	0.1 dB	<0.01 dB	<0.001 dB	<0.0001 dB
Dispersion	0.4 ps/Hz	0.015 ps/Hs	0.0004 ps/Hz	0.000015 ps/Hz	0.0000004 ps/Hz

*Rotation of angle of linear polarization.

Atmospheric Effects on Link Budget and their Interpretation

- Ionospheric effects include effects of:
  - Faraday rotation,
  - time delay,
  - refraction, and
  - dispersion.
- It is clear from the data that ionospheric effects are not significant at frequencies of 10 GHz and above,
- but must be considered at L-, S-, and C-bands (L being the worst).