Link budget

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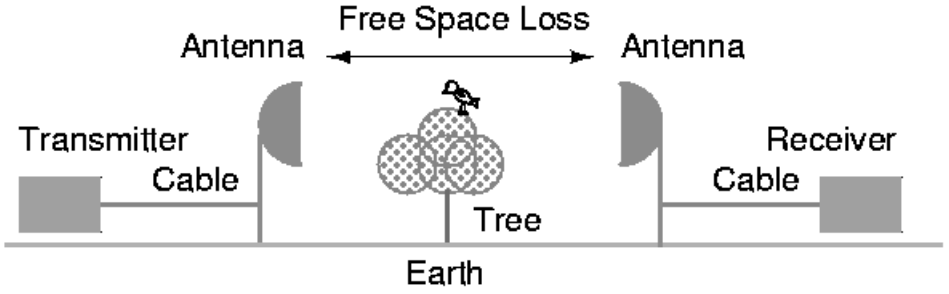
Elements of a radio link

- **Effective transmit power:** transmit power [dBm] - (cable + connector) loss [dB] + amplifier gain [dB] + antenna gain [dBi]
- **Propagation loss [dB]:** Free space loss [dB]
- **Effective receiving sensibility:** antenna gain[dBi] + amplifier gain [dB] - cable loss [dB] - receiver sensitivity [dBm]



The elements one by one

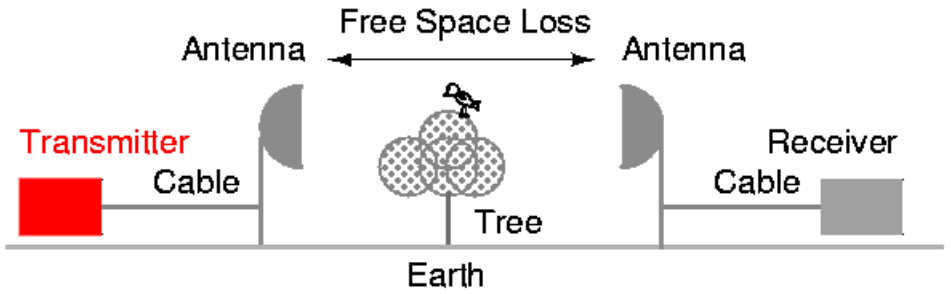
- Complete radio link calculation is simply a sum of all contributions, as long as all values are in dBs
- All positive values are gain
- All negative values are losses

Terms

- Link Budget / Power Budget / System gain
- System operating margin
- SNR: Signal-to-Noise ratio
- EIRP: Effective Isotropic Radiated Power

Transmit power

- what comes out of the radio unit
- depends on legal limits and thus on country/region
- check vendor's tech specifications
- typical in 802.11b:
  15 ... 20 dBm (30 ... 100 mW)



Transmit Power

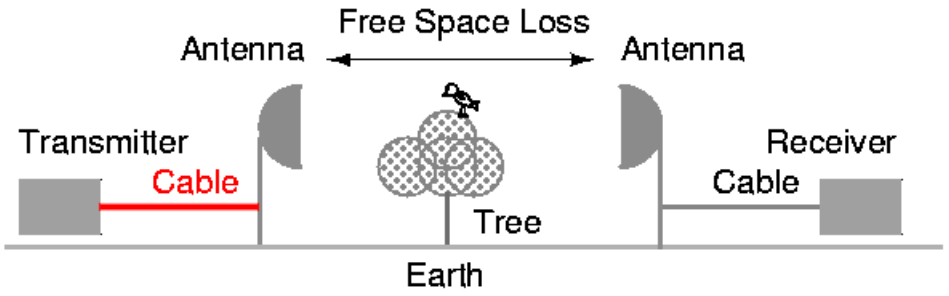
- Example from a 802.11a/b card:

  Output Power:

  802.11b: 18 dBm (65 mW) peak power
  802.11a: 20 dBm (100 mW) peak power

Cable loss

- Rule: Antenna cable should be as short as possible
- Typical loss values range from
  1 dB/m down to < 0.1 dB/m
- Frequency dependent
- Check datasheets (and verify)

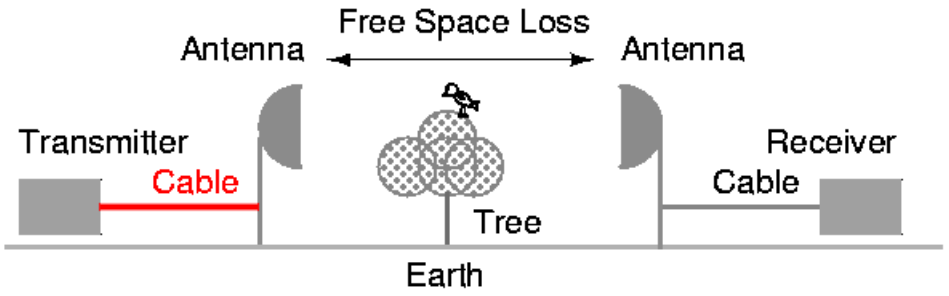


Cable loss: typical values

Antenna Type	**loss [dB/100m]**	
RG 58	ca. 80-100	“thin black”
RG213	ca. 50	“big black”
LMR-200	50	
LMR-400	22	
Aircom plus	22	
LMR-600	14	
1/2” Flexline	12	
7/8” Flexline	6.6	

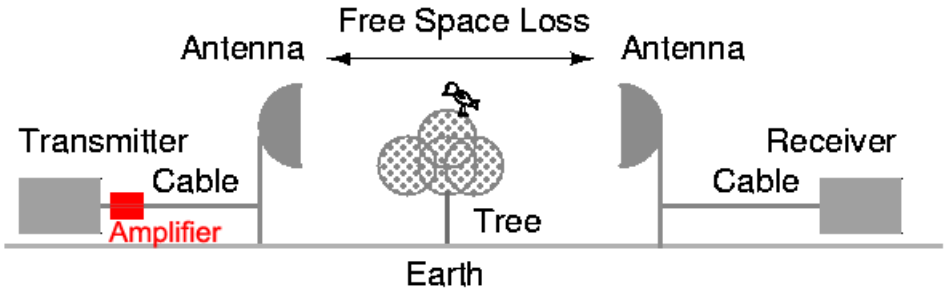
Cable loss – connectors

- Allow at least – 0.25 dB (loss) for each connector in your cabling
- Check data sheets for loss at your frequency
- Lightning arrestors (circa 1 dB)



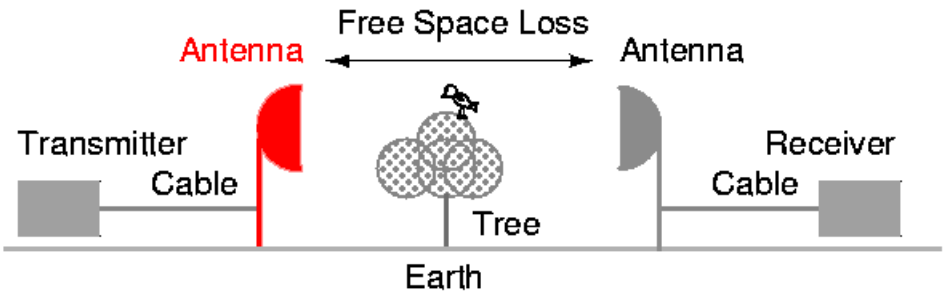
Amplifiers

- optionally, amplifiers might be used
- high quality amplifiers are expensive
- amplifiers may change frequency characteristics (broadening) and add noise
- intelligently optimized antennas and high receive sensitivity are better than brute force amplification
- consider legal limits



Antenna – TX

- Antenna gains range:
  2 dBi (simple integrated antennas)
  5 dBi (standard omnidirectionals)
  up to
  25-30 dBi (paraboles)
- verify that you really get nominal gain
  (tilt losses, polarization losses, etc)



Free Space Loss

- Proportional to the square of the distance and also proportional to the square of the radio frequency
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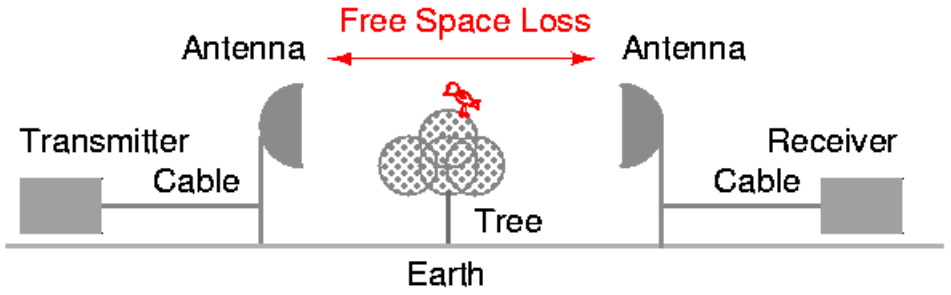
  FSL [dB]= C + 20 * Log(D) + 20 * Log(F)

  D distance, and F frequency [MHz].
  The constant C is 36.6 if D is in miles, and 32.5 if D is in kilometers.



Free Space Propagation: Fresnel zones

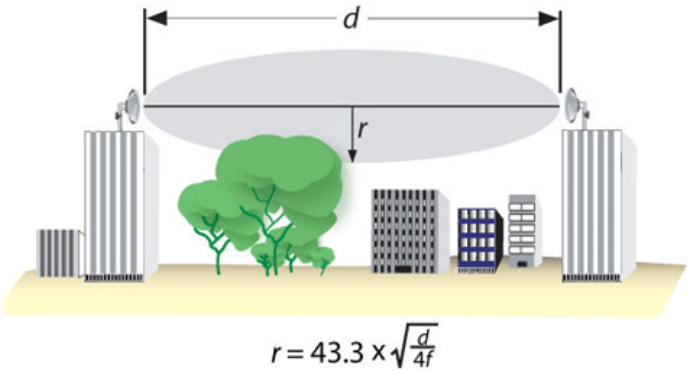
- r = 17.33 sqrt(d1*d2/f*d) radius for first zone [m]

  d1, d2 distances from obstacle to link end points,
  d link distance [km], f [GHz]

- if d1 = d2 (= obstacle in the middle)

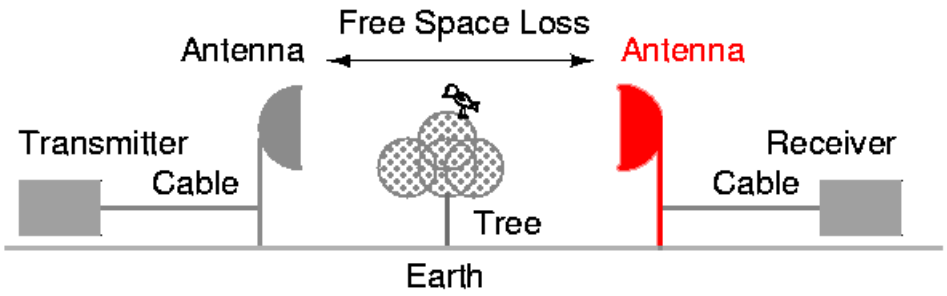
  r = 17.33 sqrt (d / 4*f)

- r (60%) = 10.4. (d / 4*f)



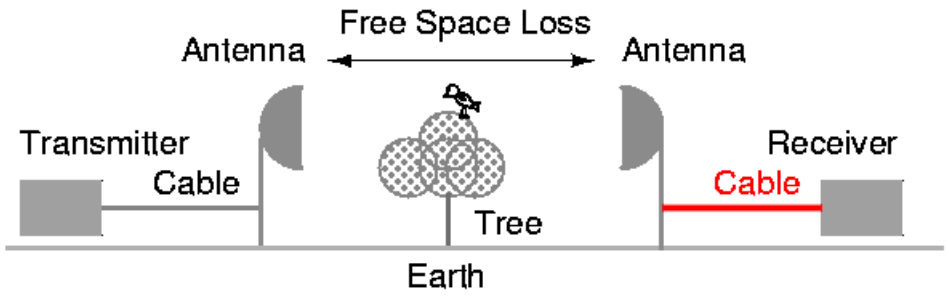
Antenna – RX

- Same as Antenna – TX



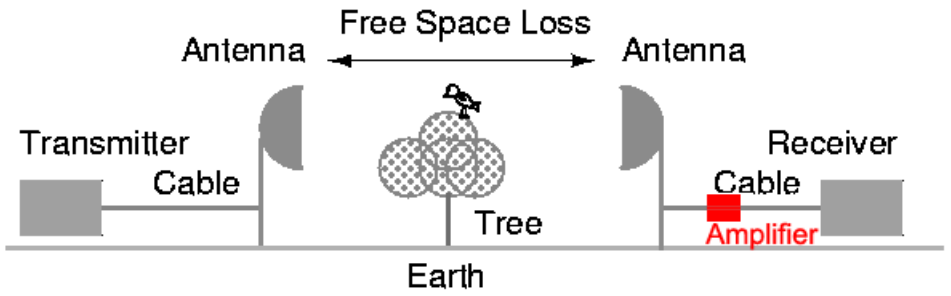
Cable on receive side

- same as on transmit side



Amplifiers on receive side

- same as on transmit side
- again, not a suggested method



Receive sensitivity

- Typical values are circa -85 dBm for maximum data rate
- Example: Orinoco cards PCMCIA Silver/Gold
  11Mbps => -82 dBm ; 5.5Mbps => -87 dBm;
  2Mbps=> -91 dBm; 1Mbps=> -94 dBm.
- Example: Senao 802.11b card
  11 Mbps => -89dBm; 5.5 Mbps =>-91dBm
  2 Mbps => -93dBm; 1 Mbps => -95dBm
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Complete link budget – ex. 1

- Transmit output + 015 dBm
- Cable + Connectors - 003 dB
- Antenna TX + 024 dBi
- FSL (50 km / 31.1 miles at 2.4 Ghz) - 134 dB
- Antenna RX + 024 dBi
- Cable + Connectors - 003 dB
- Receive Sensitivity - 085 dBm (subtract!)

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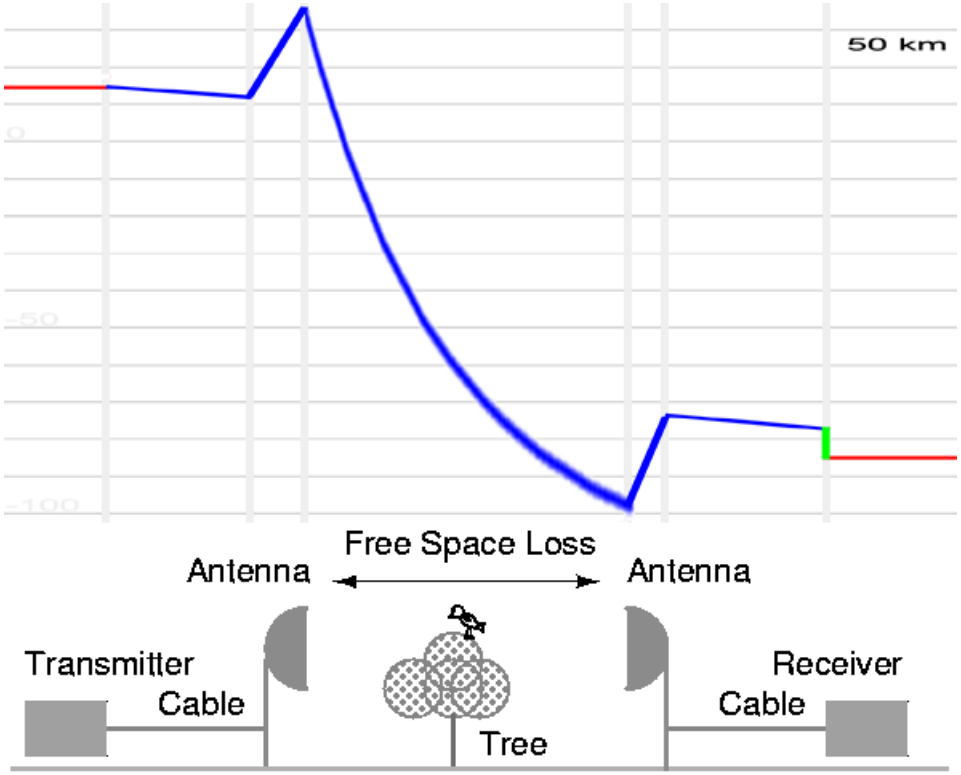
- **TOTAL** **+ 008 dB margin**

Complete link budget – ex. 1



Complete link budget – ex. 2

- Transmit output + 018 dBm
- Cable + Connectors - 005 dB (low quality cabling)
- Antenna TX + 005 dBi (an omni)
- FSL (1 km / 0.622 miles at 2.4 Ghz) - 100 dB
- Antenna RX + 008 dBi (patch antenna
- Cable + Connectors - 005 dB (bad again :)
- Receive Sensitivity - 092 dBm (subtract!)

- **TOTAL** **+ 13 dB margin**

Complete link budget – ex. 2