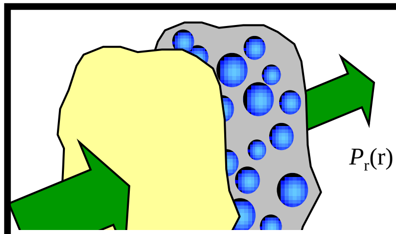
Radio front end

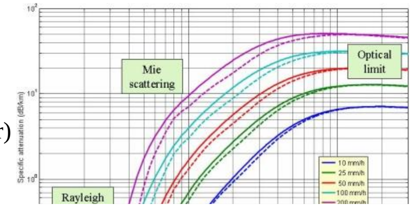
Between the antenna and the base band

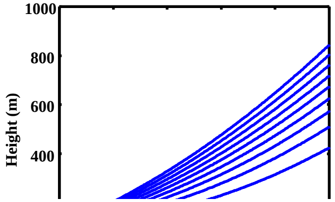
- Antenna
- Filter
- Amplifier
- Up-conversion and down-conversion
- Duplex unit

Radio transmission: wave propagation, antennas, radio front end

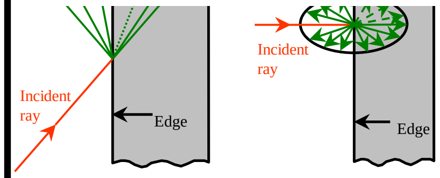
Transmitter/Receiver

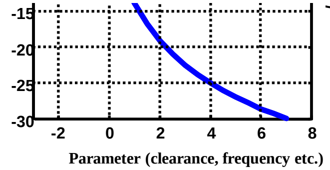


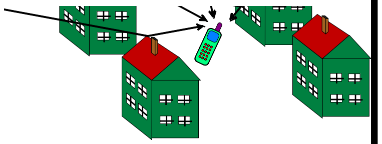




Radiowaves through a medium between the transmitter and receiver antennas, filters, amplifiers, mixers, coding and decoding.

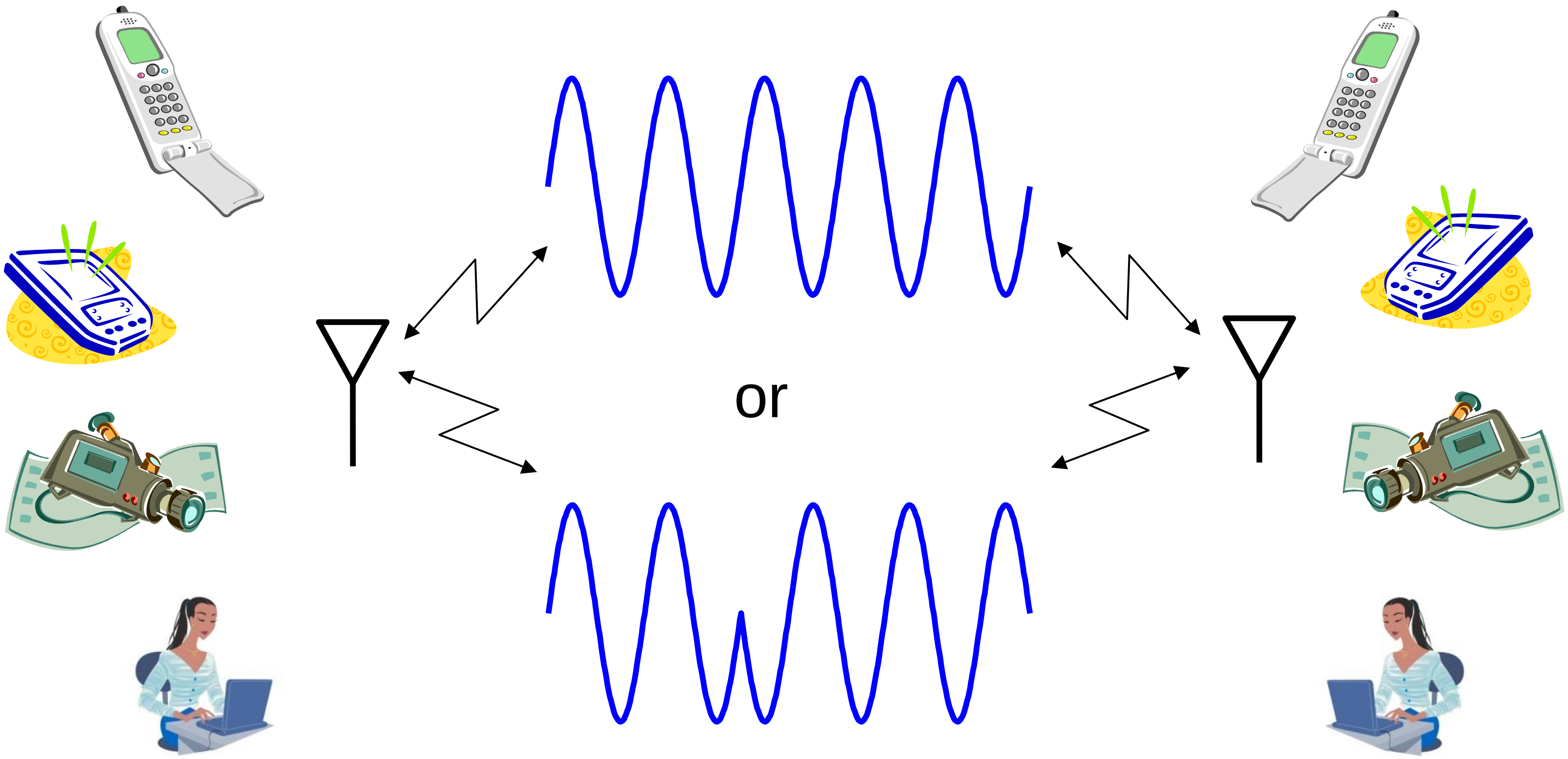




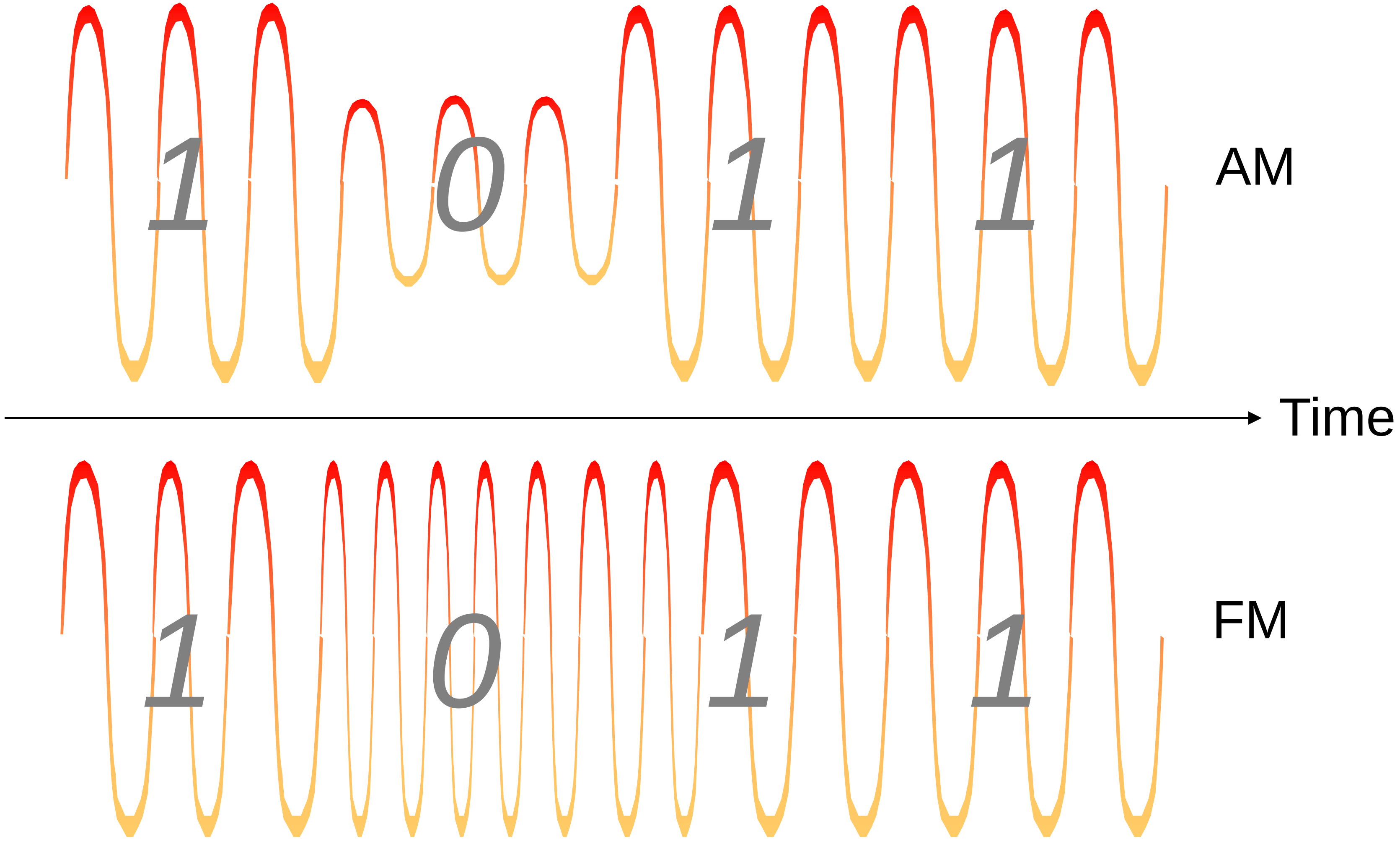


Receiver/Transmitter

Data through the transmission medium



Radio frequency and modulation



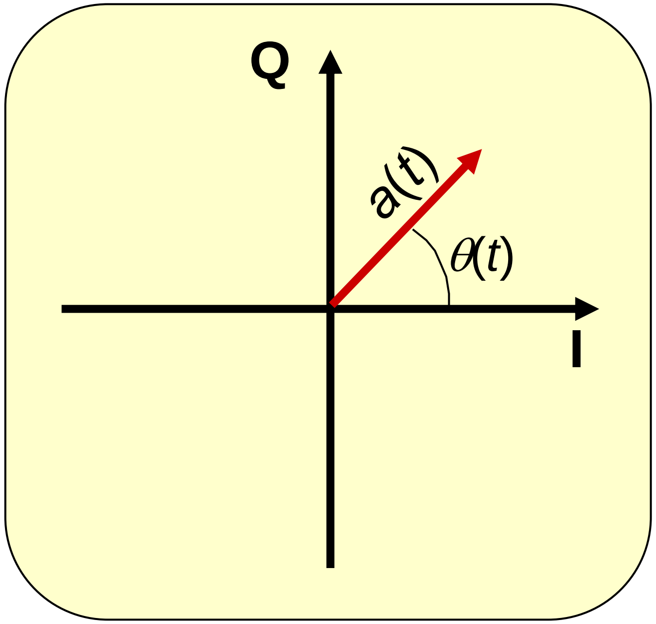
Signal representation

The signal *s* has amplitude *a*, phase θ, and carrier frequency f_c

$$s(t) = a(t)\cos[2\pi f_c t + \theta(t)]$$
$$= a(t)\cos\theta(t)\cos 2\pi f_c t - a(t)\sin\theta(t)\sin 2\pi f_c t$$
$$= x(t)\cos 2\pi f_c t - y(t)\sin 2\pi f_c t$$

x* and *y*, called the quadrature components of *s

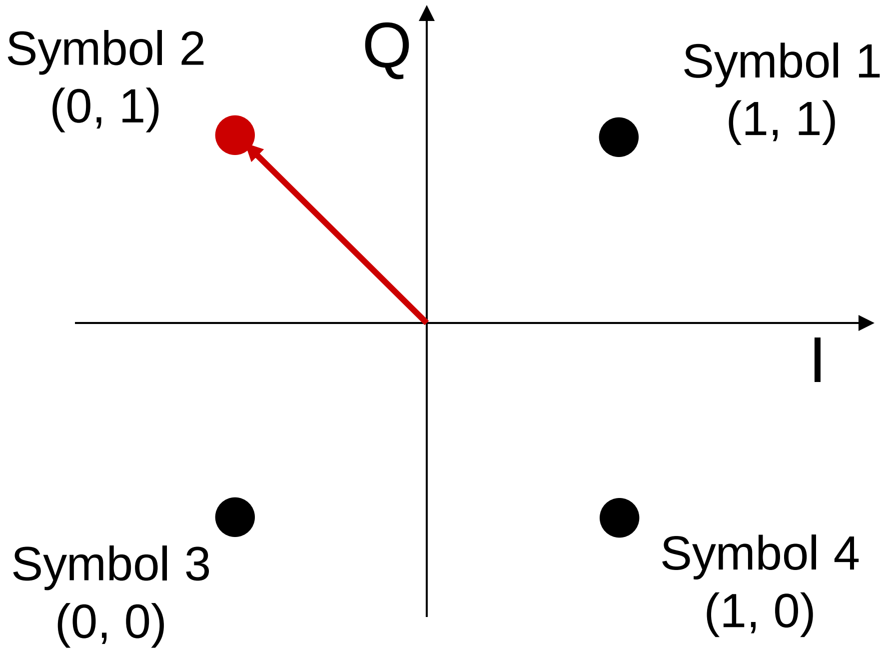
$$x(t) = a(t)\cos\theta(t)$$
$$y(t) = a(t)\sin\theta(t)$$



Complex signal *u* where the real part is *s*

$$u(t) = a(t)e^{j\theta(t)} = x(t) + jy(t)$$
$$s(t) = \mathrm{Re}\left[u(t)e^{j2\pi f_c t}\right]$$

Quadrature phase modulation (QPSK)



Digital information

2 ***symbols*** (red and blue)

Transmitter

Receiver

1 0 0 1 0 0 1 1

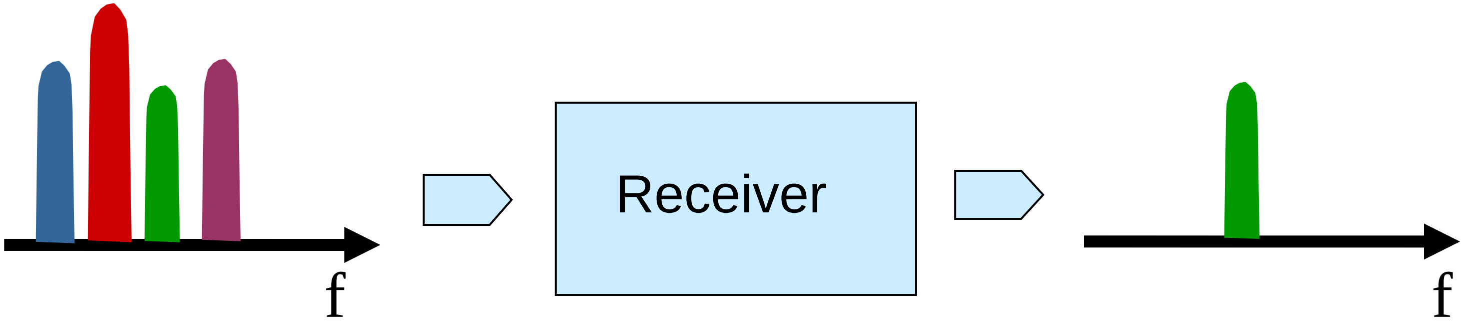
4 ***symbols*** (red, green, blue, and pink)

Transmitter

Receiver

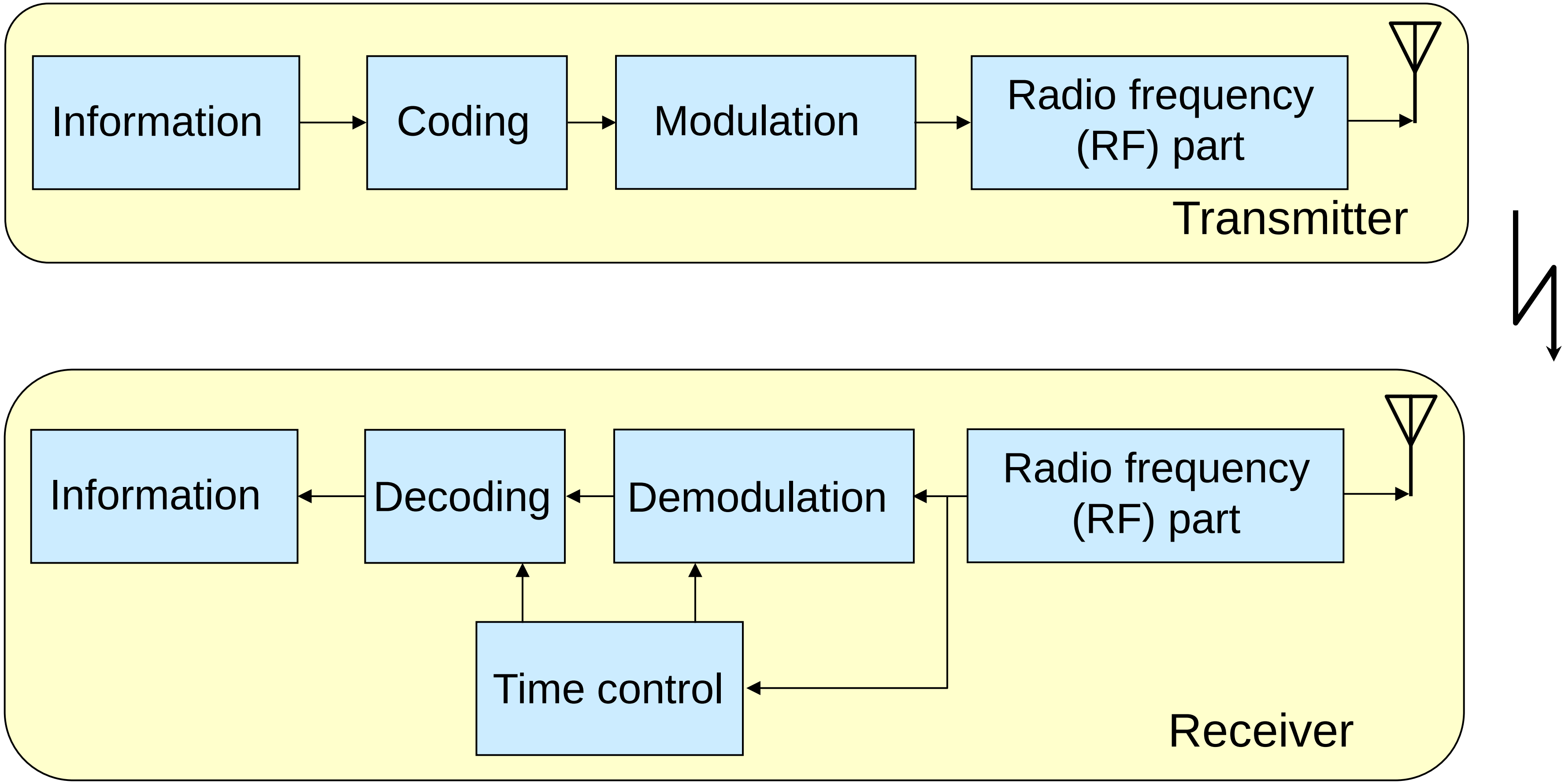
1 1 1 0 0 0 0 0 0 1 1 1 1 0 1 0

Radio receiver front end

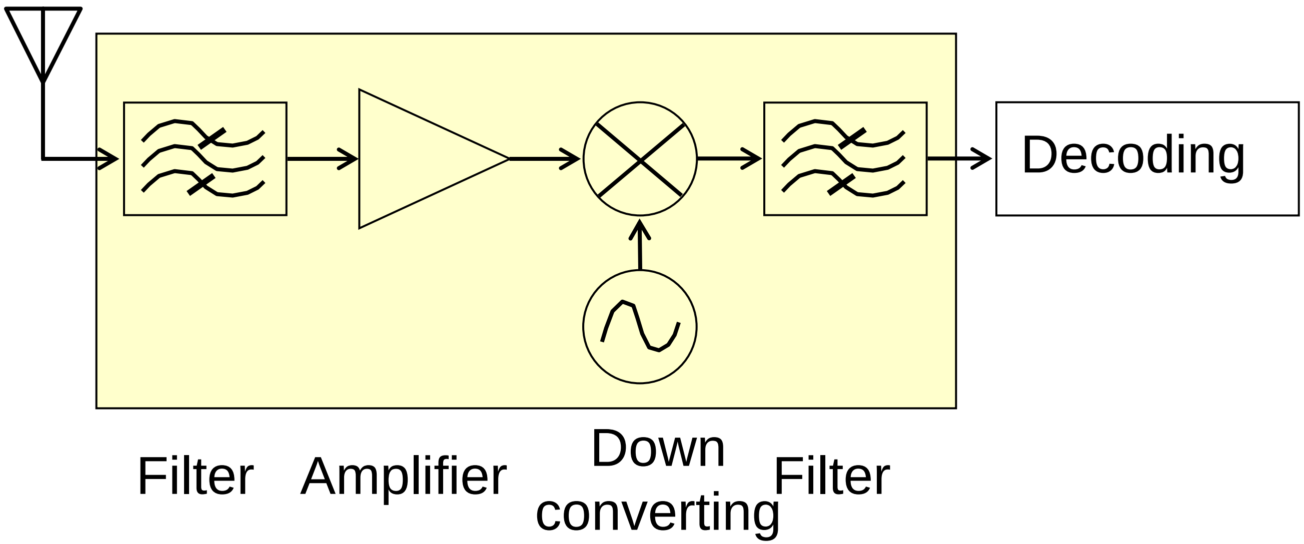


The receiver chooses the wanted channel among all including interferers

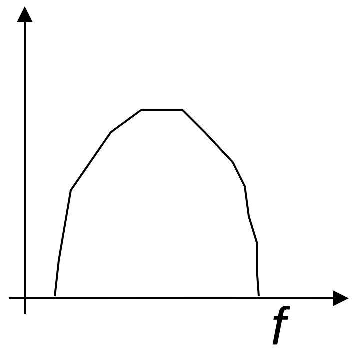
Radio system block diagram

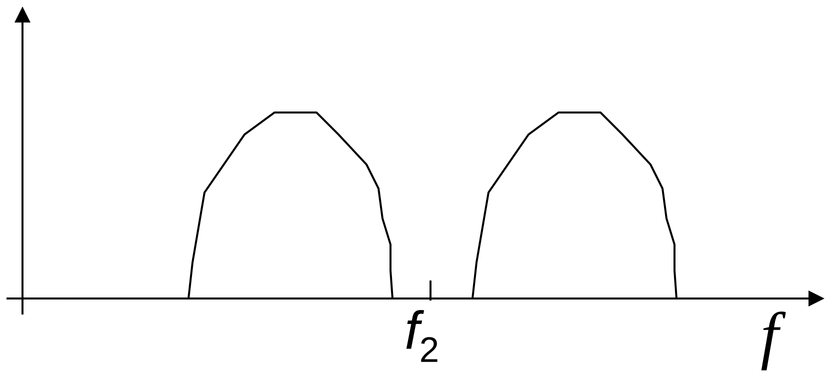


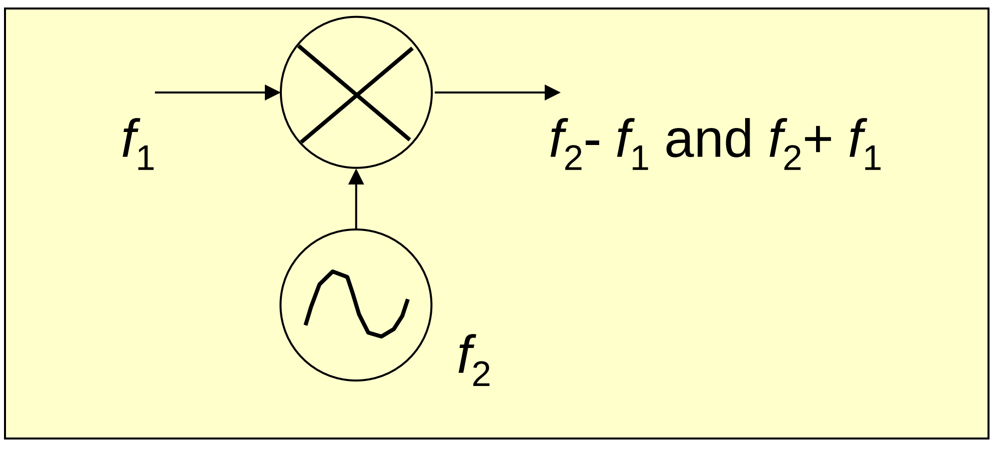
RF part, receiver



Frequency conversion

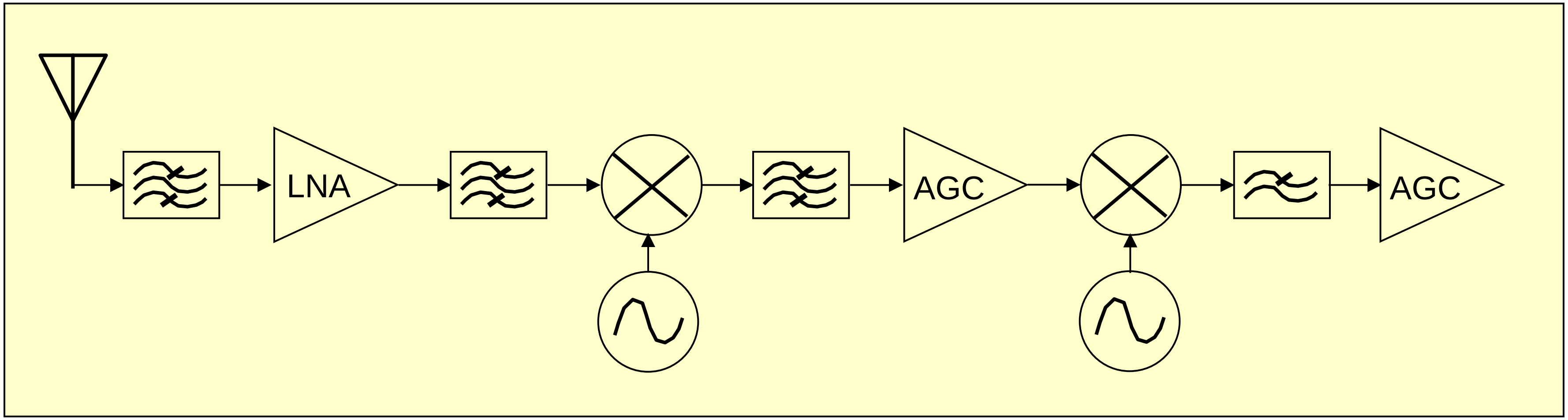






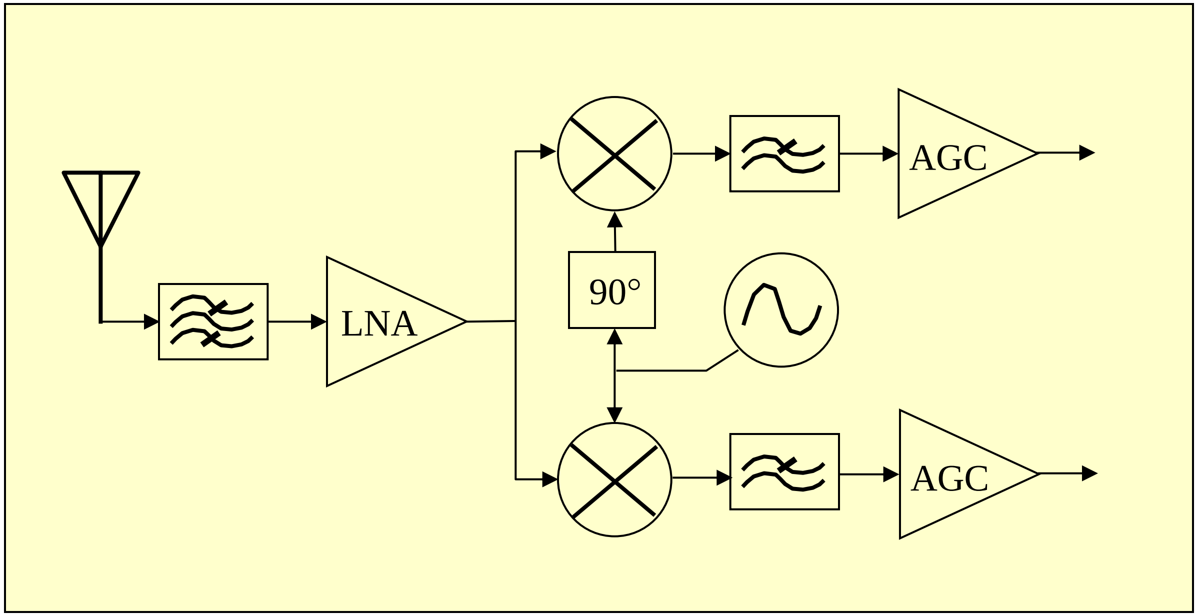
$$\cos(\omega_1 t)\cdot\cos(\omega_2 t)=\cos((\omega_1+\omega_2)t)+\cos((\omega_1-\omega_2)t)$$

Super heterodyne receiver



Used in a radio receiver to obtain high gain, and to be able to use intermediate frequency filters at fixed frequencies and standardised equipment at fixed bands, i.e., 950-2050 MHz for satellite. Originally developed to solve a tuning problem for direct conversion radio. Two intermediate frequency steps, as shown above, are easier to make.

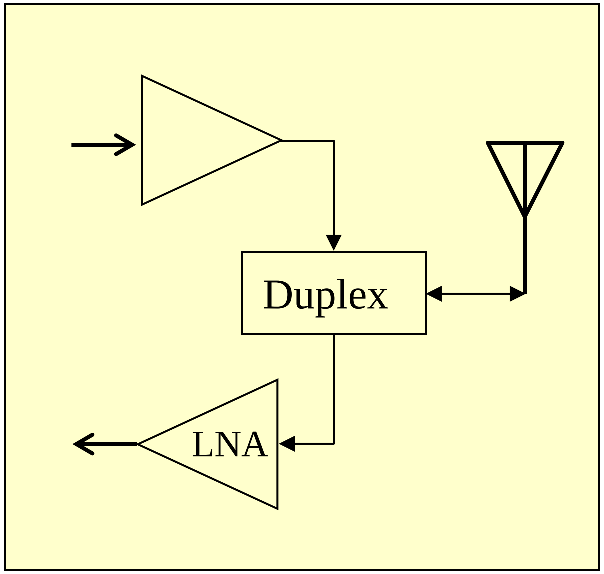
Direct conversion



Direct conversion radio is attractive because it needs fewer components.
Here shown direct conversion to quadrature components.

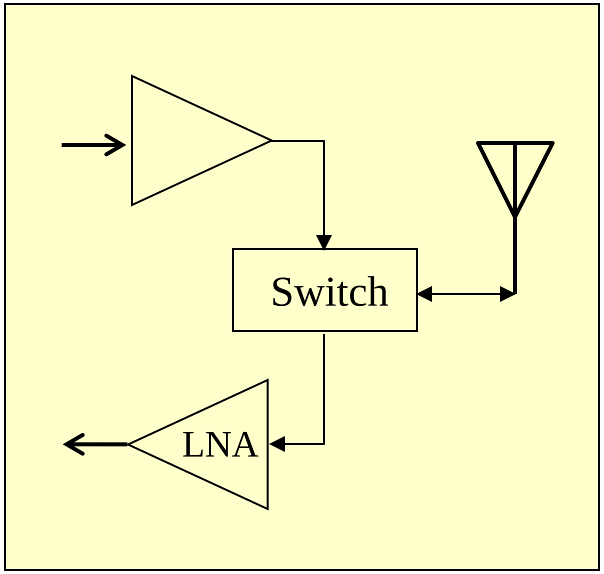
Duplex unit or switch

FDD



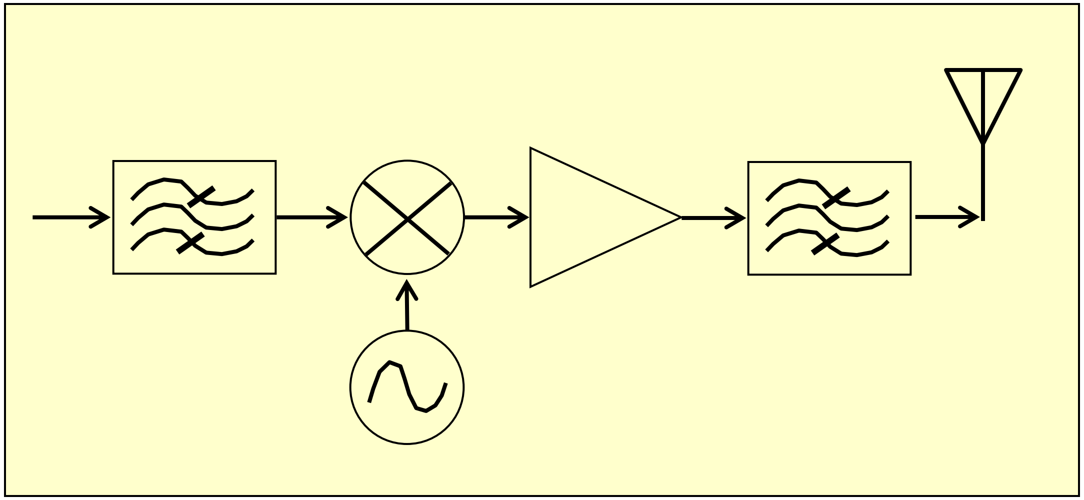
Duplex unit or circulator for frequency division duplex where the traffic flows simultaneously in both directions but in different frequency bands

TDD

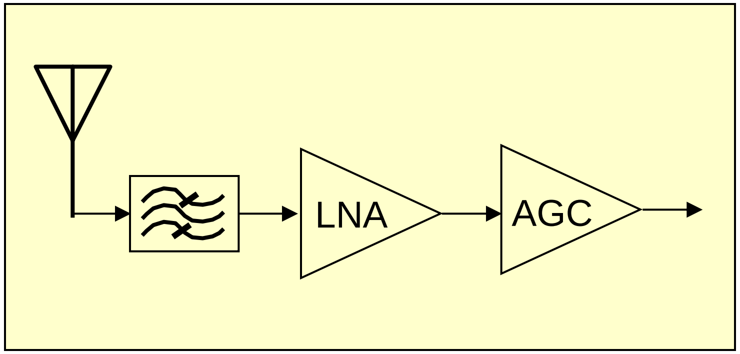


Switch for time division duplex where the traffic flows just in one direction per time unit, but change direction for the next time slot

Radio frequency parts for the transmitter



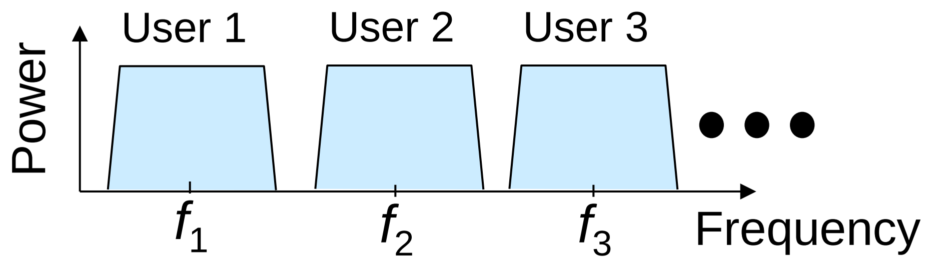
Tuned receiver



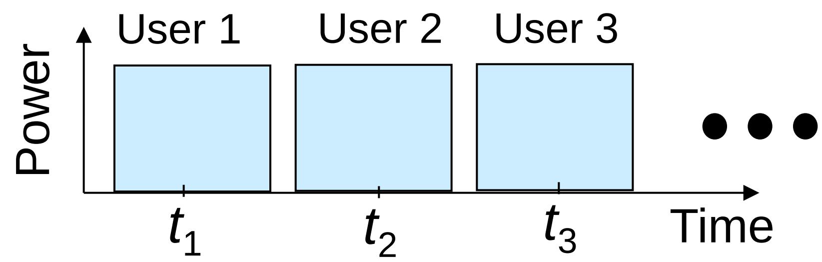
Fewer components and an interesting option for the future for digital configurable radios for several bands and systems where the signals can be digitised close to the radio frequency.

Multiple access techniques

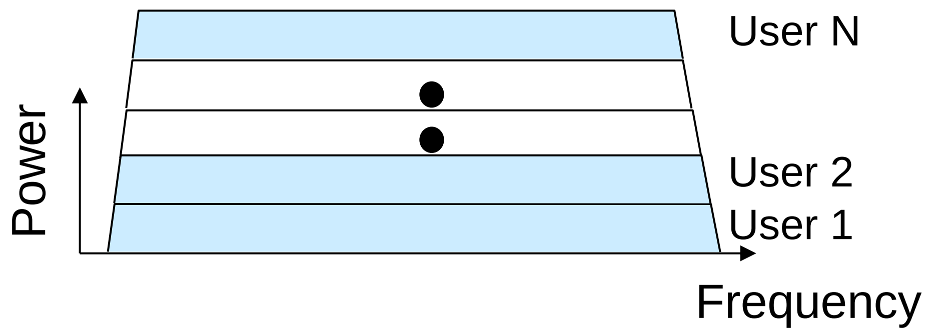
FDMA



TDMA



CDMA



Bandwidth and capacity

The maximum capacity C (bit/s) in bandwidth B (Hz) for a signal of power S (W) and N (W) noise in the channel is (Shannon, 1948):

$C = B \log2 (1 + S/N)$

Example:

Assume 5 MHz bandwidth. If the signal to noise ratio (S/N) is 20 dB Shannon predicts maximum capacity to 33 Mbit/s.

Typical radio functions

- Handle bit, base band signal forming and pass band processing
- The transmitter: information source, code, encryption, channel coding, modulation, digital/analogue transformation, and RF part
- The receiver, analogue/digital transformation, demodulation, detection, decryption, source decoding, and information receiver
- The transmitter radio frequency part includes up conversion, filter, amplifier before the antenna
- The receiver RF part includes amplifier and down conversion after the antenna
- The antenna may well be common for the transmitter and receiver and there will be a duplex unit in the case frequency division duplex is used

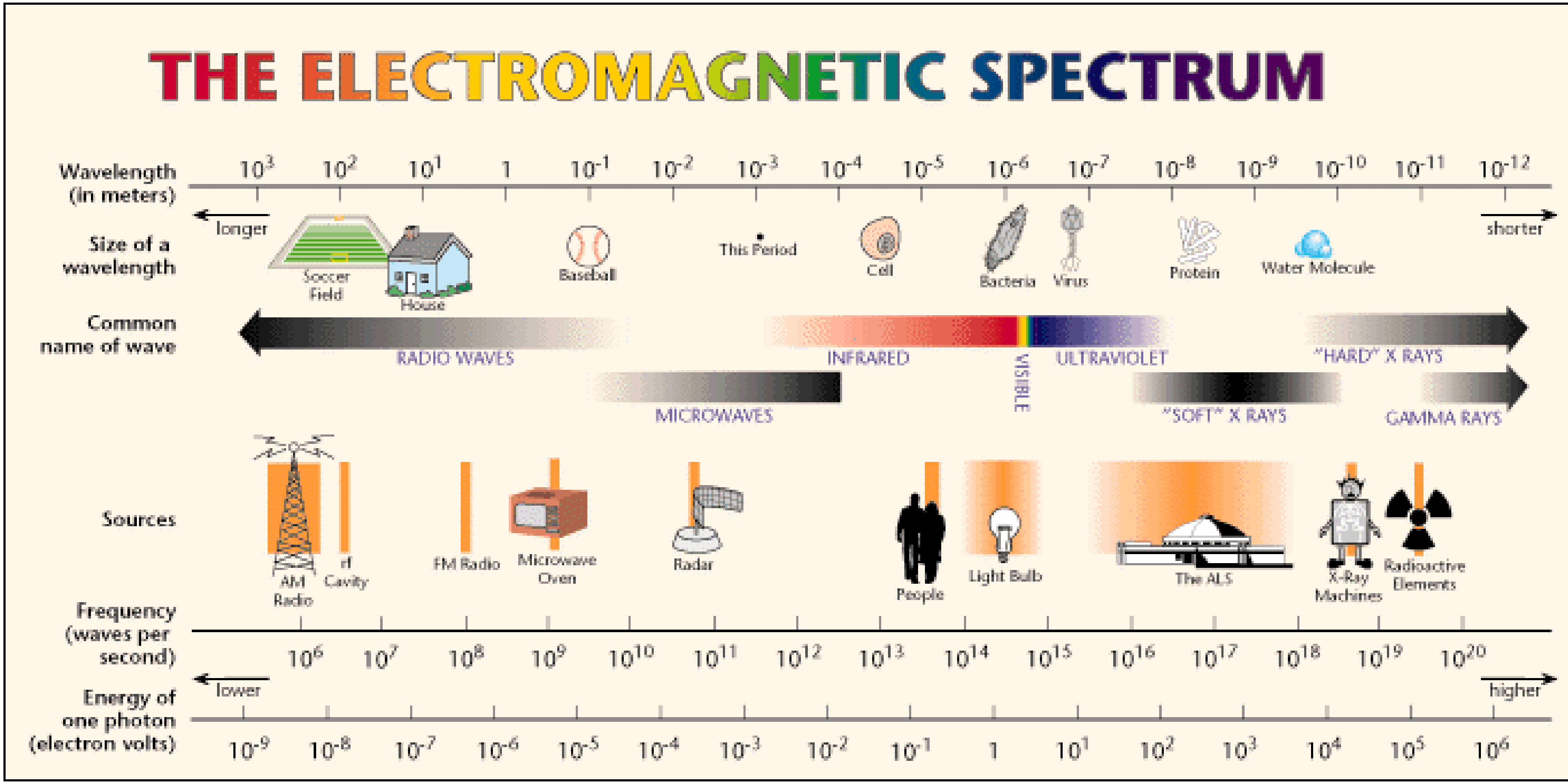
Conclusion

- Short radio front end introduction
- Base band signals and radio frequency
- Components such as amplifier, filter, and converters
- Access methods including duplex unit or switch

Free space optics (FSO)

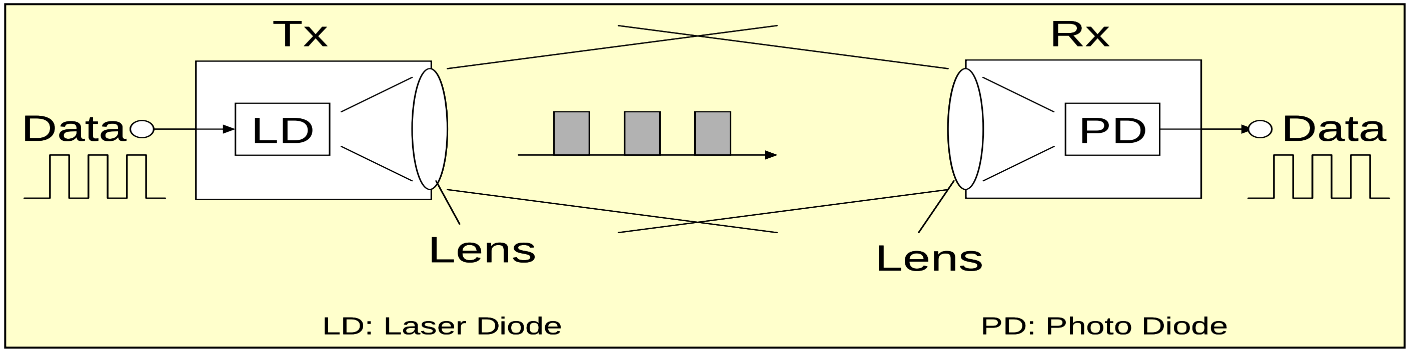
- Free space optics (FSO) is optical communication over the air using laser (light amplification by stimulated emission of radiation) technology
- Can offer wireless gigabit capacity
- May use visible light, but usually infrared wavelengths
- Has been talked about for a while, but not so much used apparently

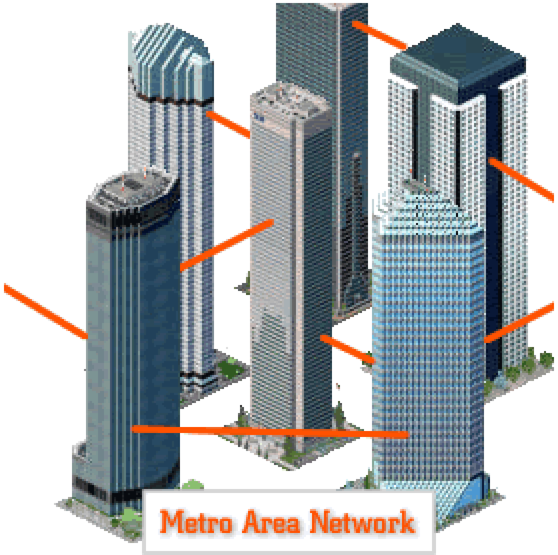
Electromagnetic spectrum



Source: www.rfsafe.com/research/rf_radiation/what_is_rf/emf_spectrum.htm

Free space optics (FSO)

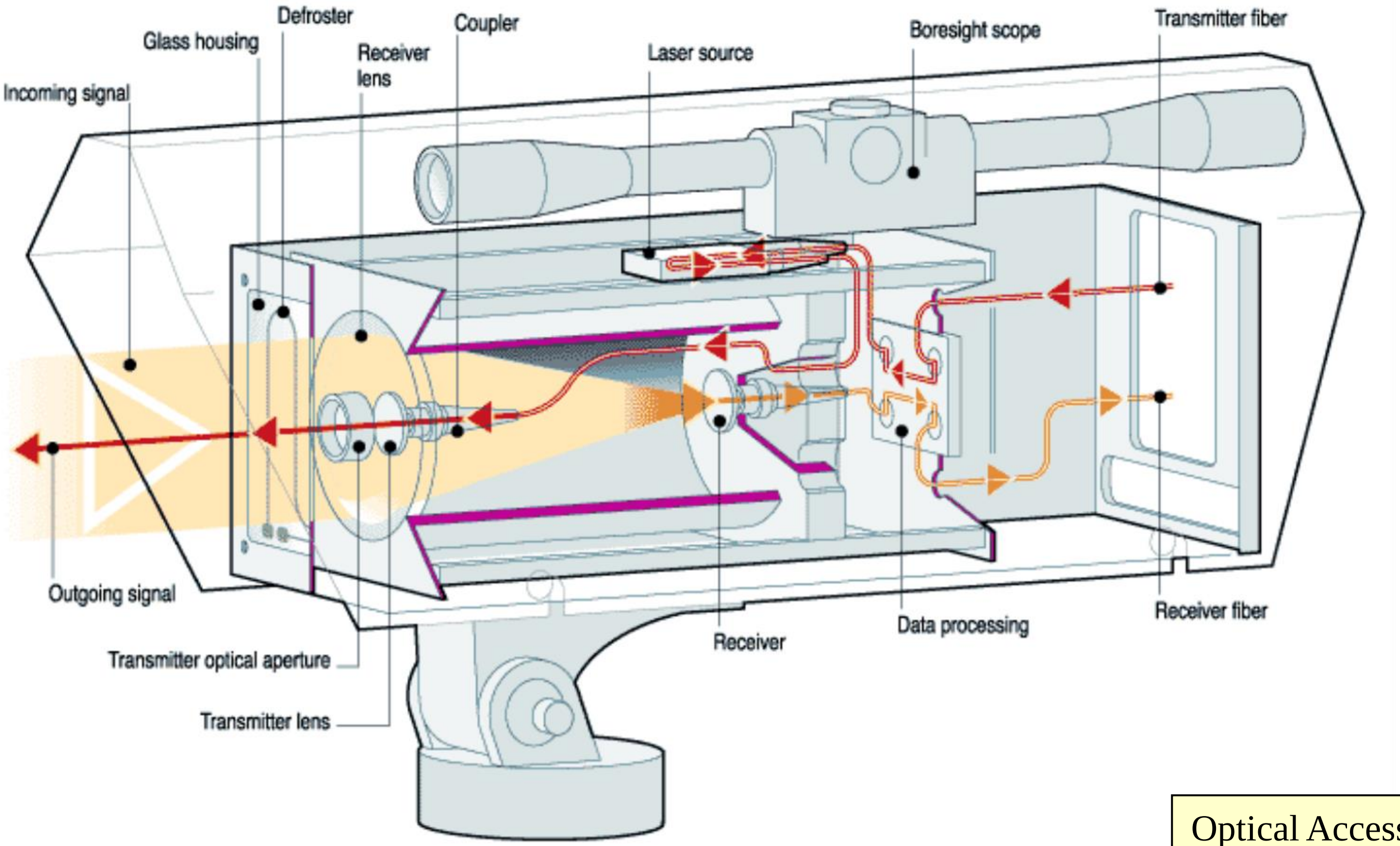




Powered by SONAbeam - a leading FSO Solution

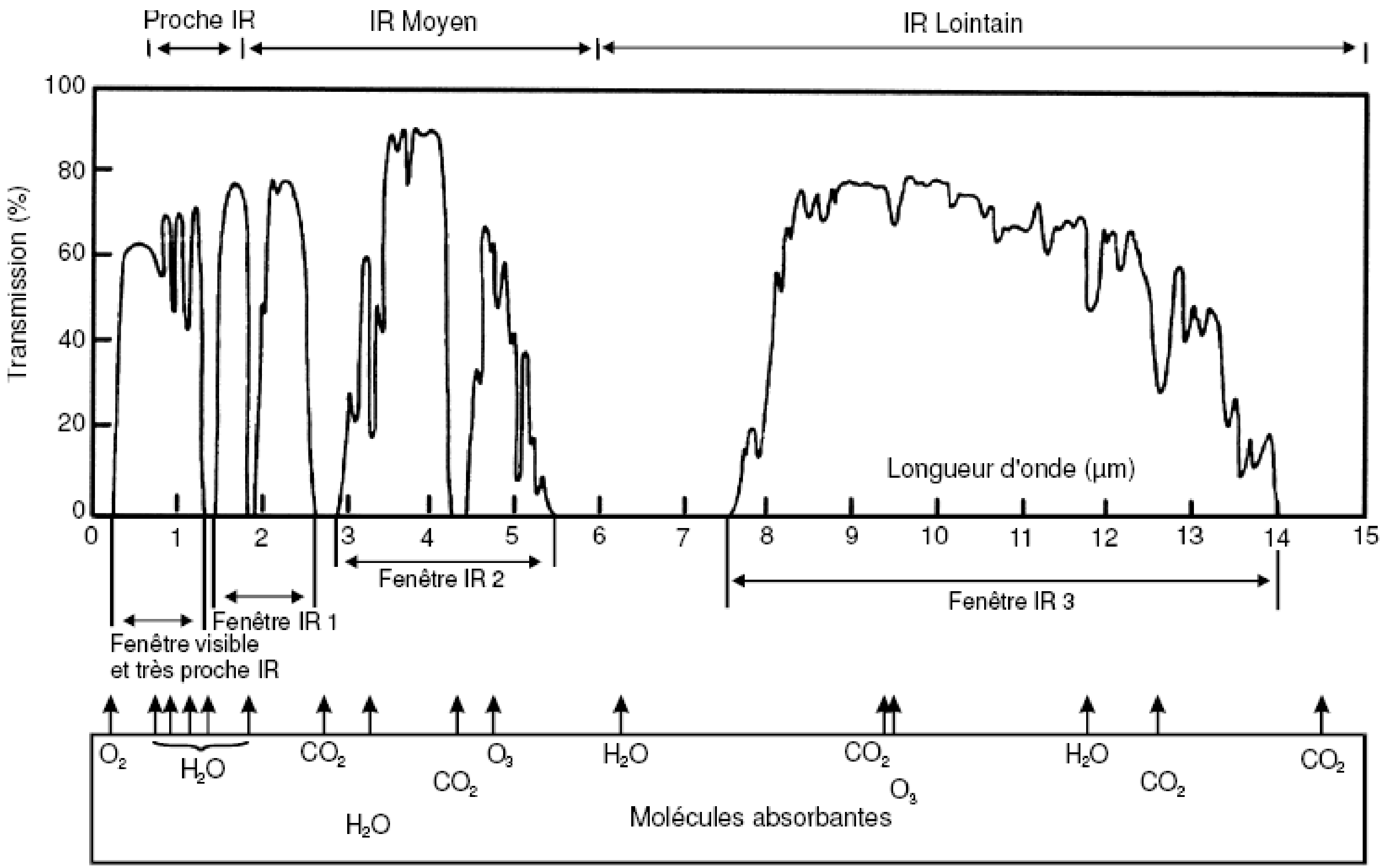
The PAVLight Linkhead (Outdoor Unit)

FSO terminal

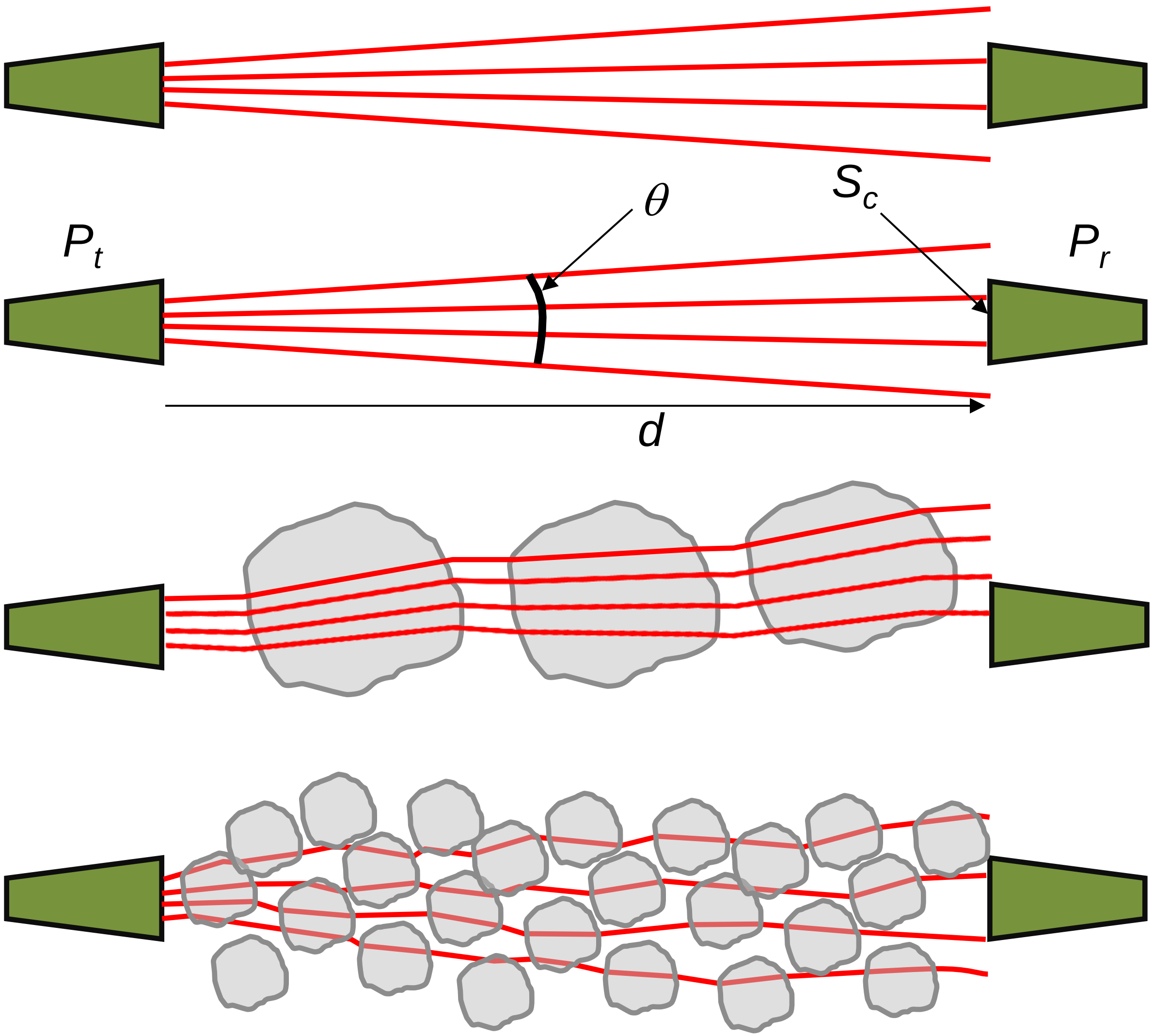


Optical Access, San Diego, US

Clear air atmospheric transmittance (through 1800 m)



FSO in clear air with increasing turbulence



Scattering

	Rayleigh Scattering	Mie Scattering	Non-selective or Geometrical scattering
Type of scatter	Air molecules Haze	Haze Fog Aerosol	Fog Rain Snow Hail

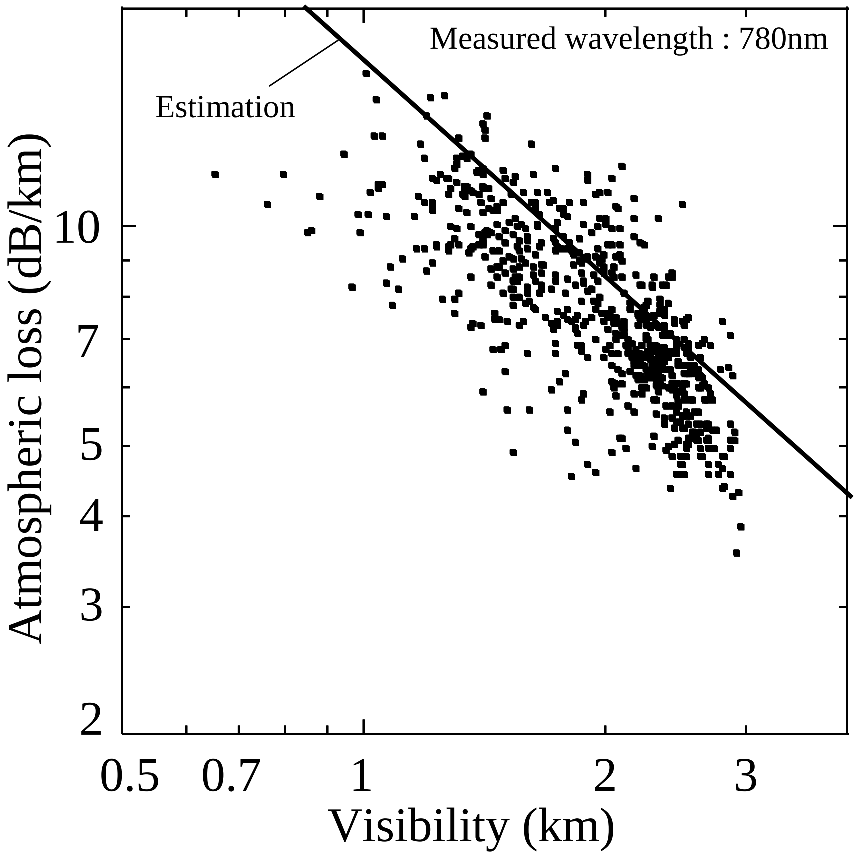
Fog attenuation

The specific attenuation γ (dB/km) is

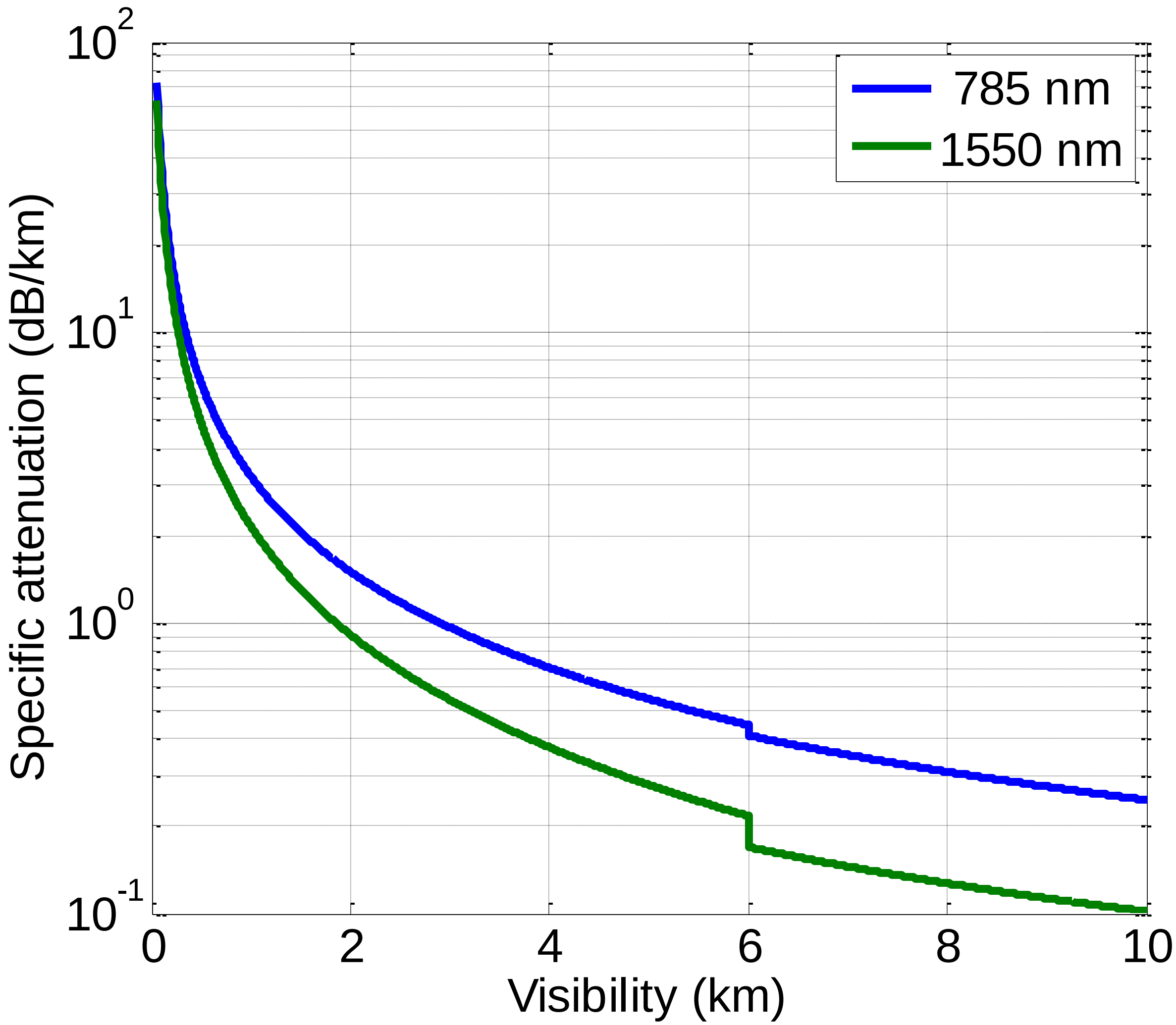
$$\gamma_{fog}(\lambda) = \frac{3.91}{V}\left(\frac{\lambda}{550nm}\right)^{-q}$$

where V (km) is the visibility, λ (nm) the wavelength, and

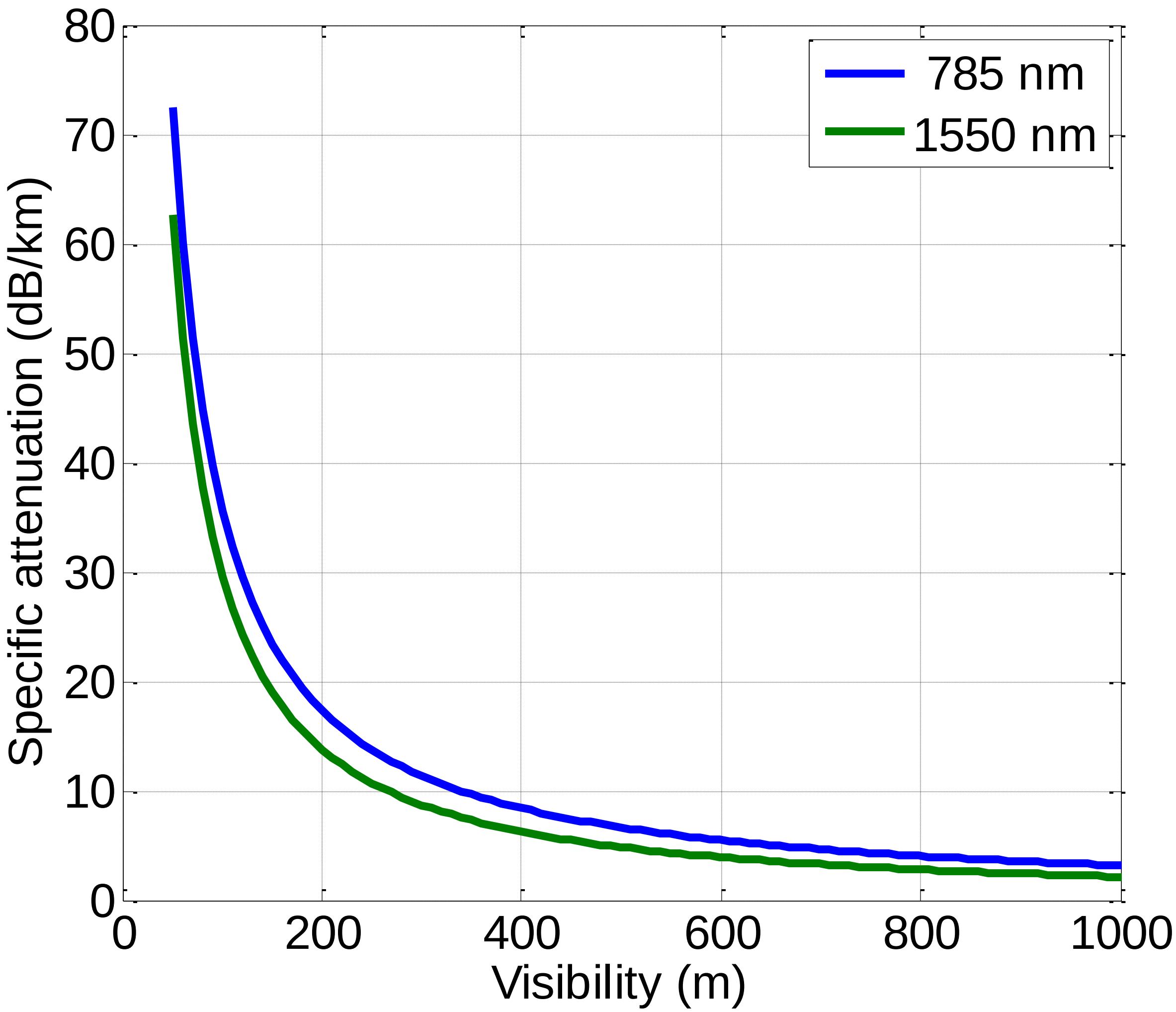
$$q = \begin{cases} 1.6, & V > 50 \\ 1.3, & 6 \le V \le 50 \\ 0.58V^{1/3}, & V < 6 \end{cases}$$



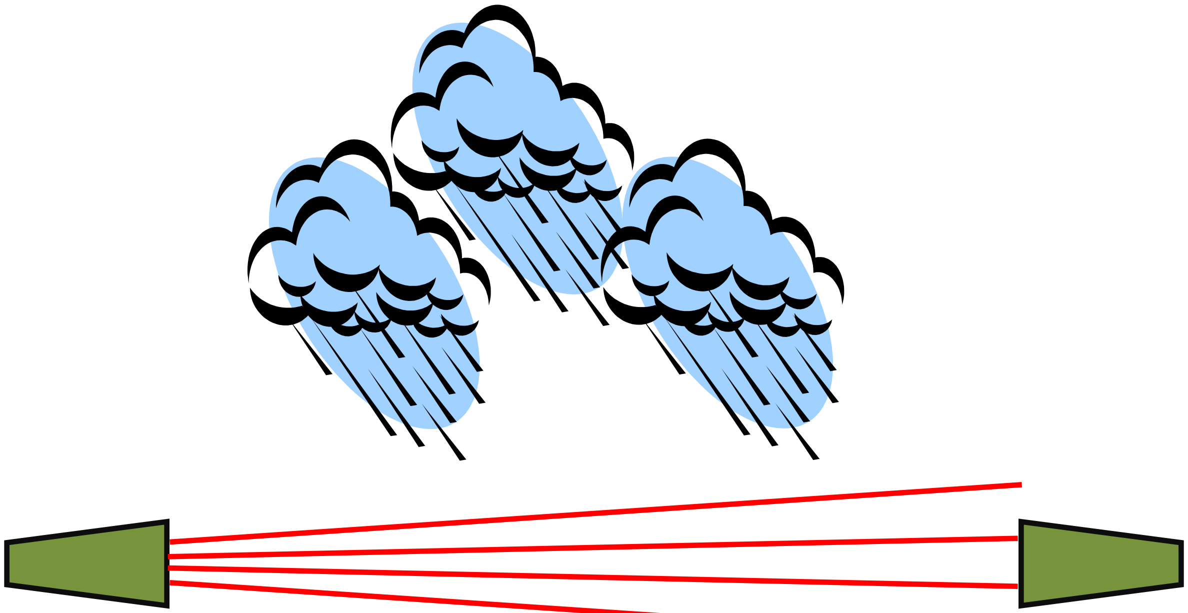
FSO links: Specific attenuation due to fog



FSO links: Specific attenuation due to fog



FSO in rain



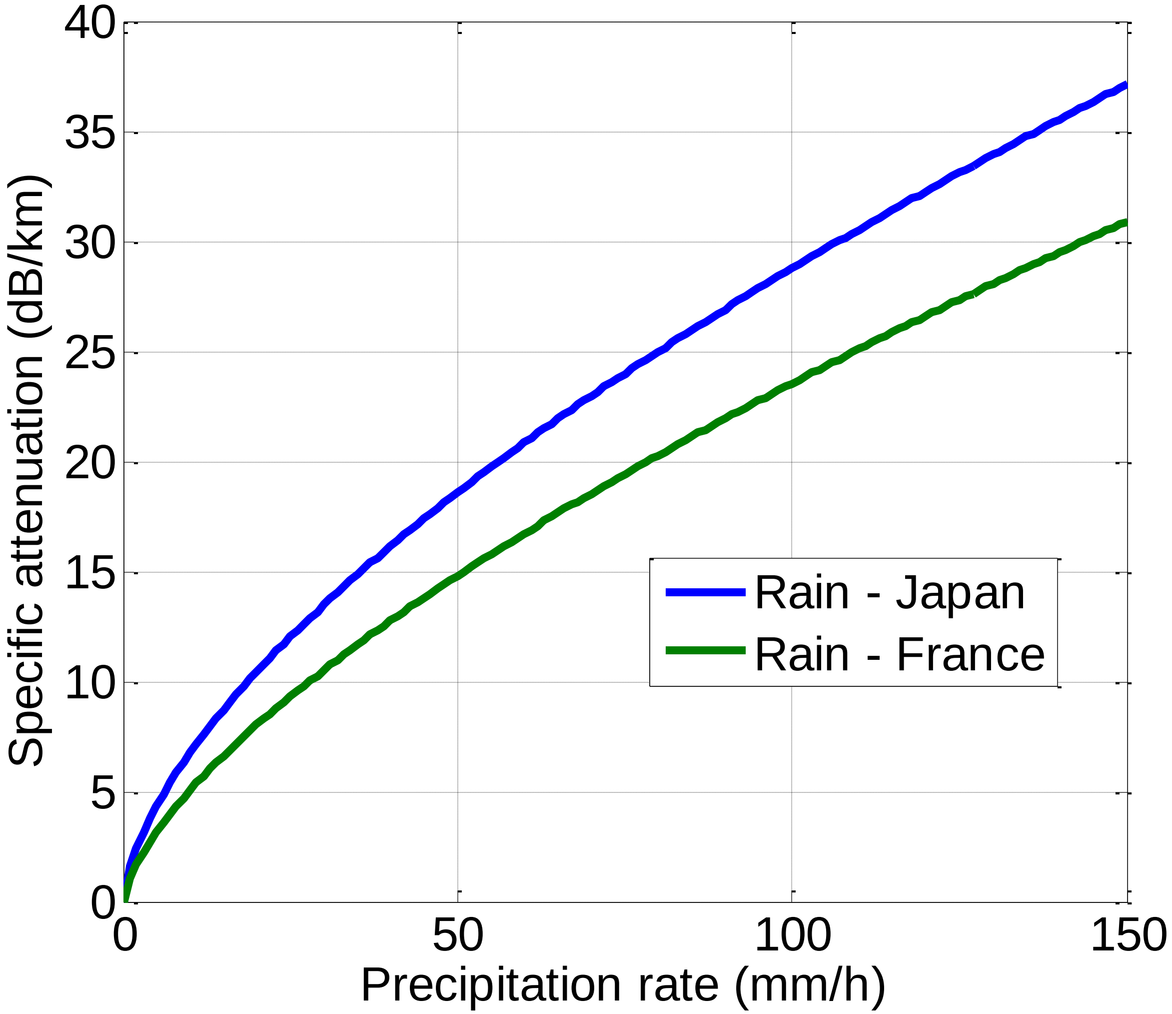
Rain and snow attenuation

Specific attenuation (dB/km) $\gamma = \alpha R^{\beta}$

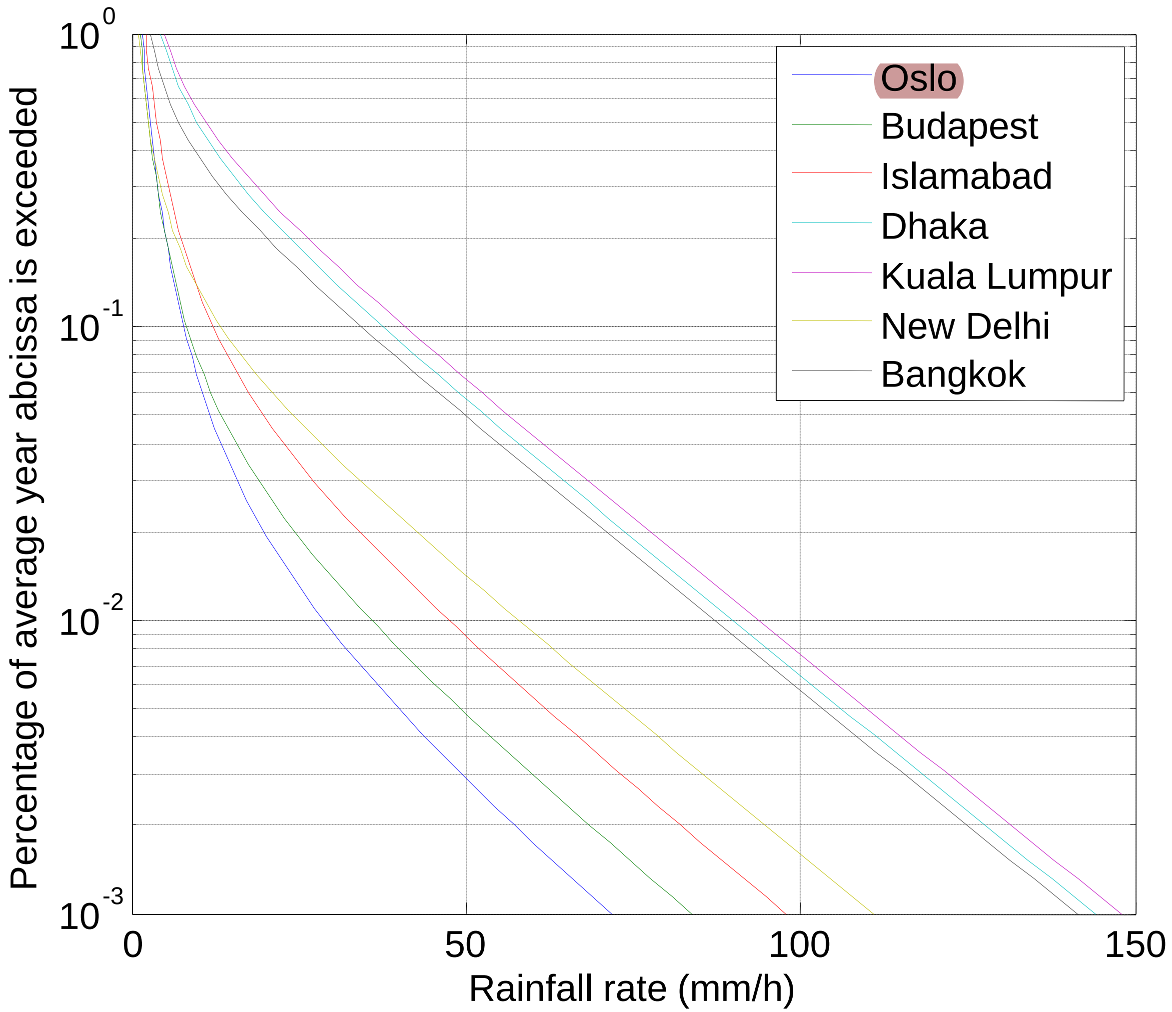
where *R* is the precipitation rate (mm/h), and α and β from the table below. Here *l* (nm) is the wavelength.

Location	α	β
Japan, rain	1.58	0.63
France, rain	1.076	0.67
Wet Snow	$0.000102\lambda + 3.79$	0.72
Dry Snow	$0.0000542\lambda + 5.50$	1.38

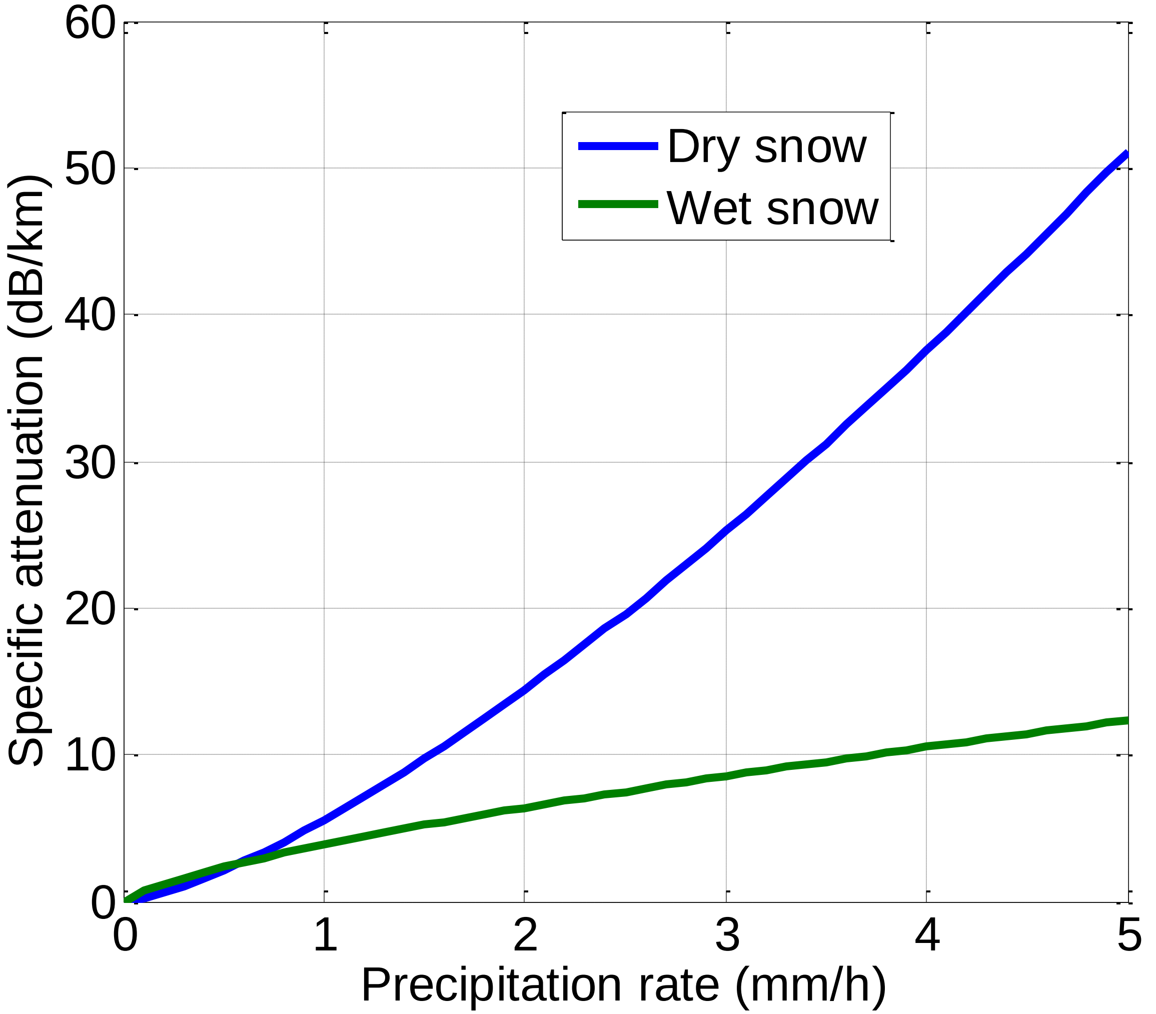
FSO links: Specific attenuation due to rain



Rainfall rate some cities



FSO links: Specific attenuation due to snow



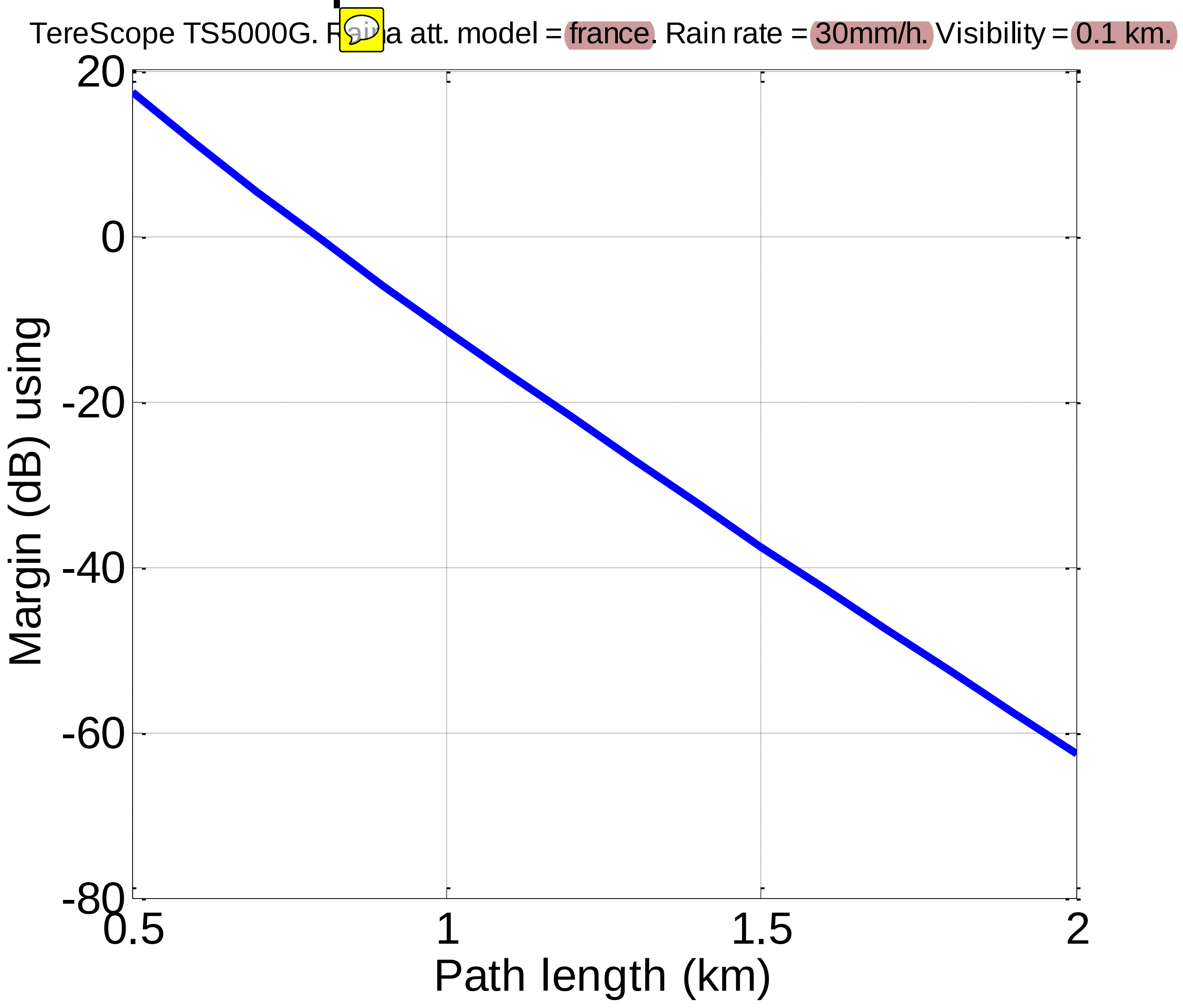
FSO Link budget

The link margin *M* (dB) is

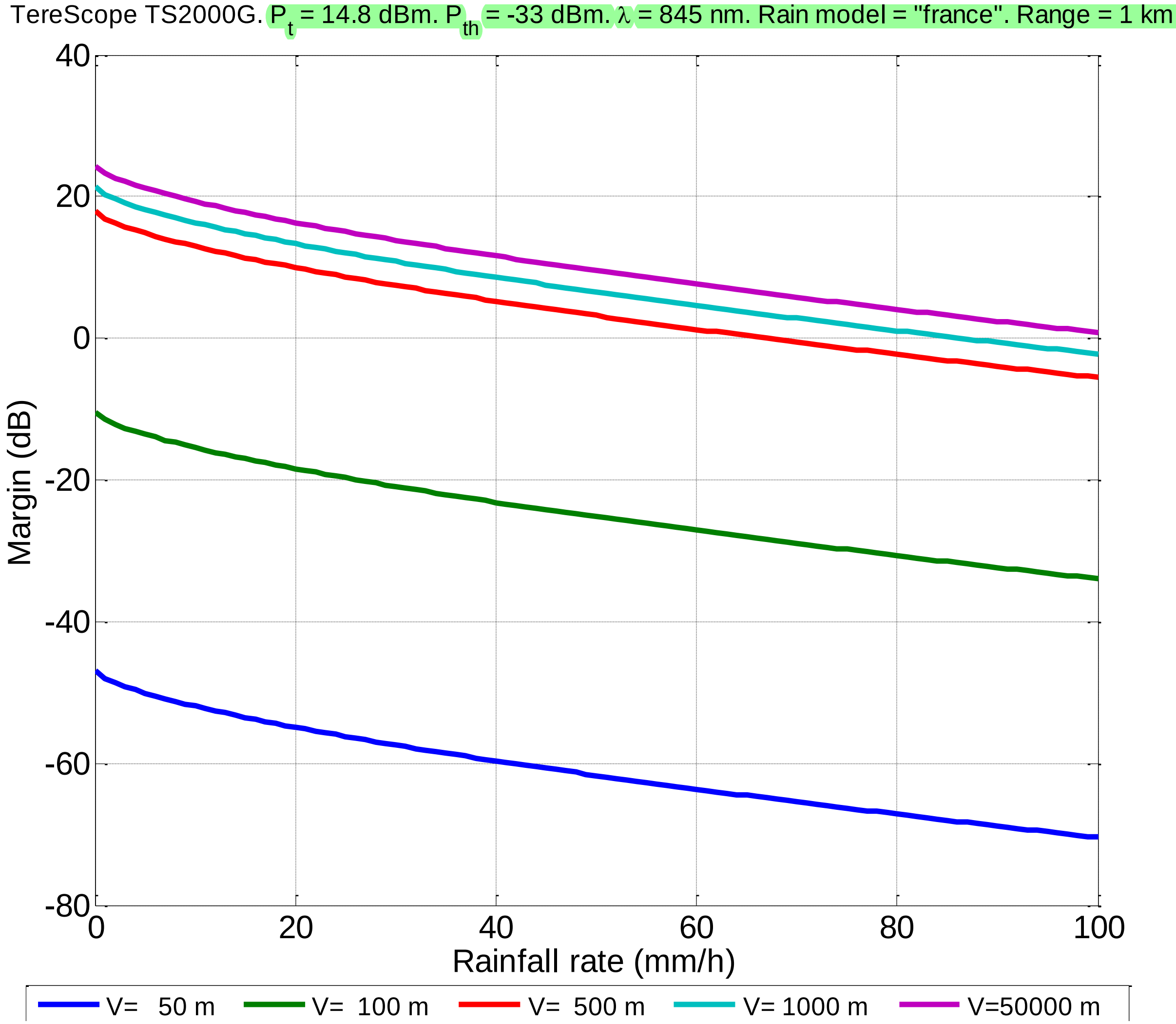
$$\boldsymbol{M = P - S - A_g - A_a - A_{sc} - A_s \;\; (dB)}$$

- *P* (dBm) is the total power of the emitter
- *S* (dBm) is the sensitivity of the receiver which depends on the bandwidth (data rate)
- A_g (dB) is the link geometrical attenuation due to transmit beam spreading with increasing range
- A_a (dB) is the atmospheric attenuation due to absorption and scattering
- A_{sc} scintillation (dB) is the attenuation due to atmospheric turbulence
- A_s (dB) all other system depending loss (mis-pointing loss, receiver optical loss, beam wander loss, ambient light attenuation (solar radiation))

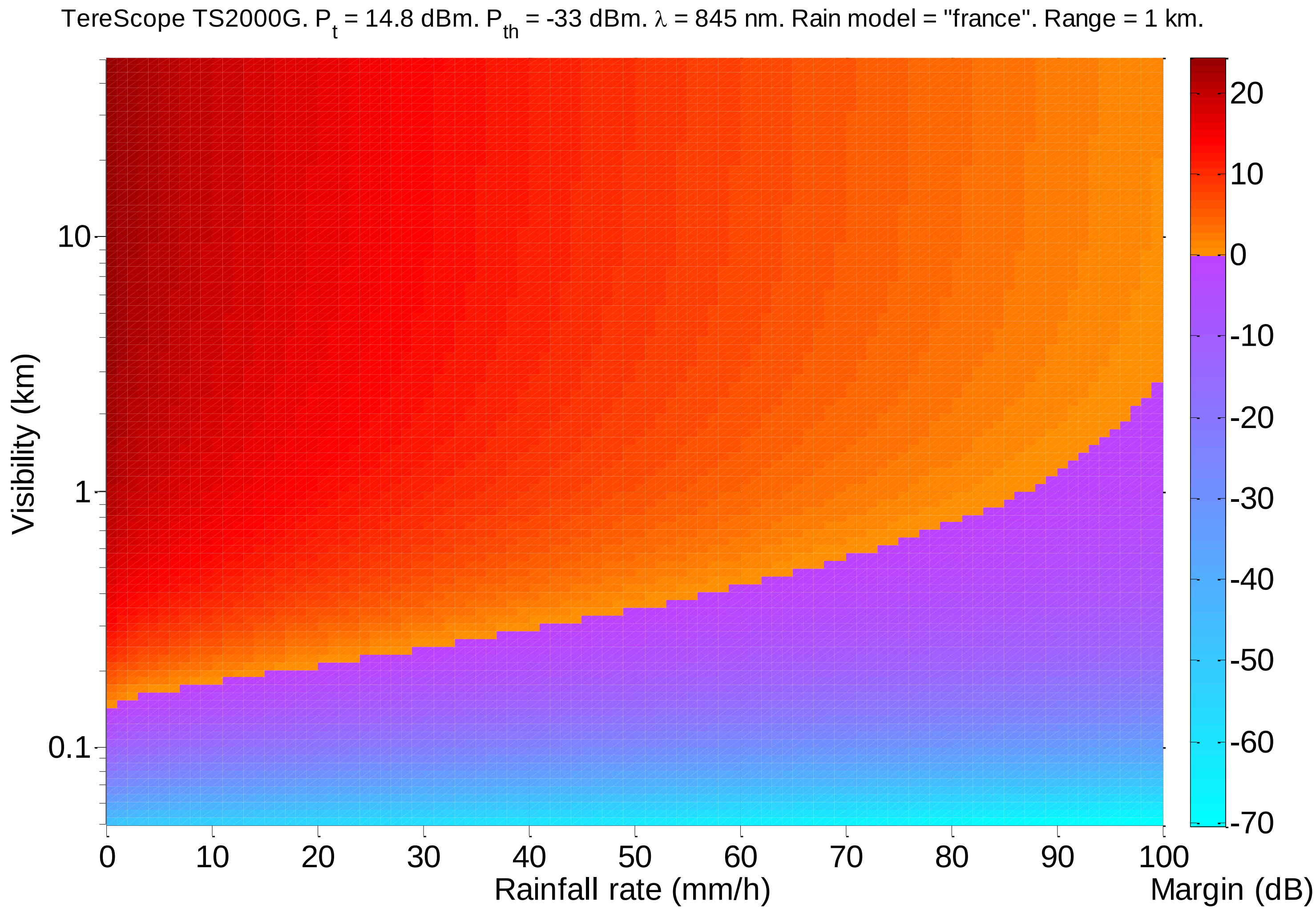
FSO links: Specific attenuation due to fog



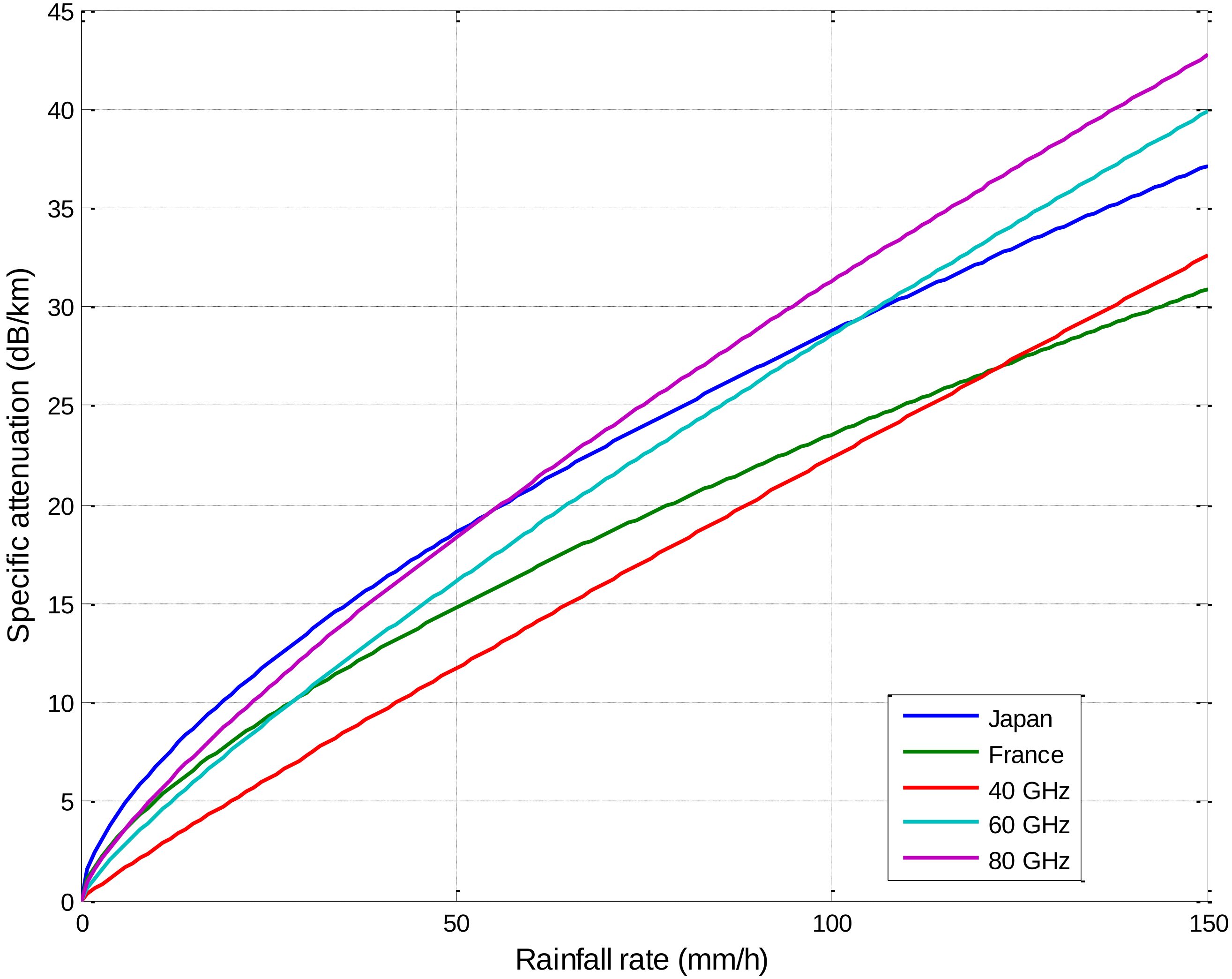
FSO link margin versus rain rate and visibility



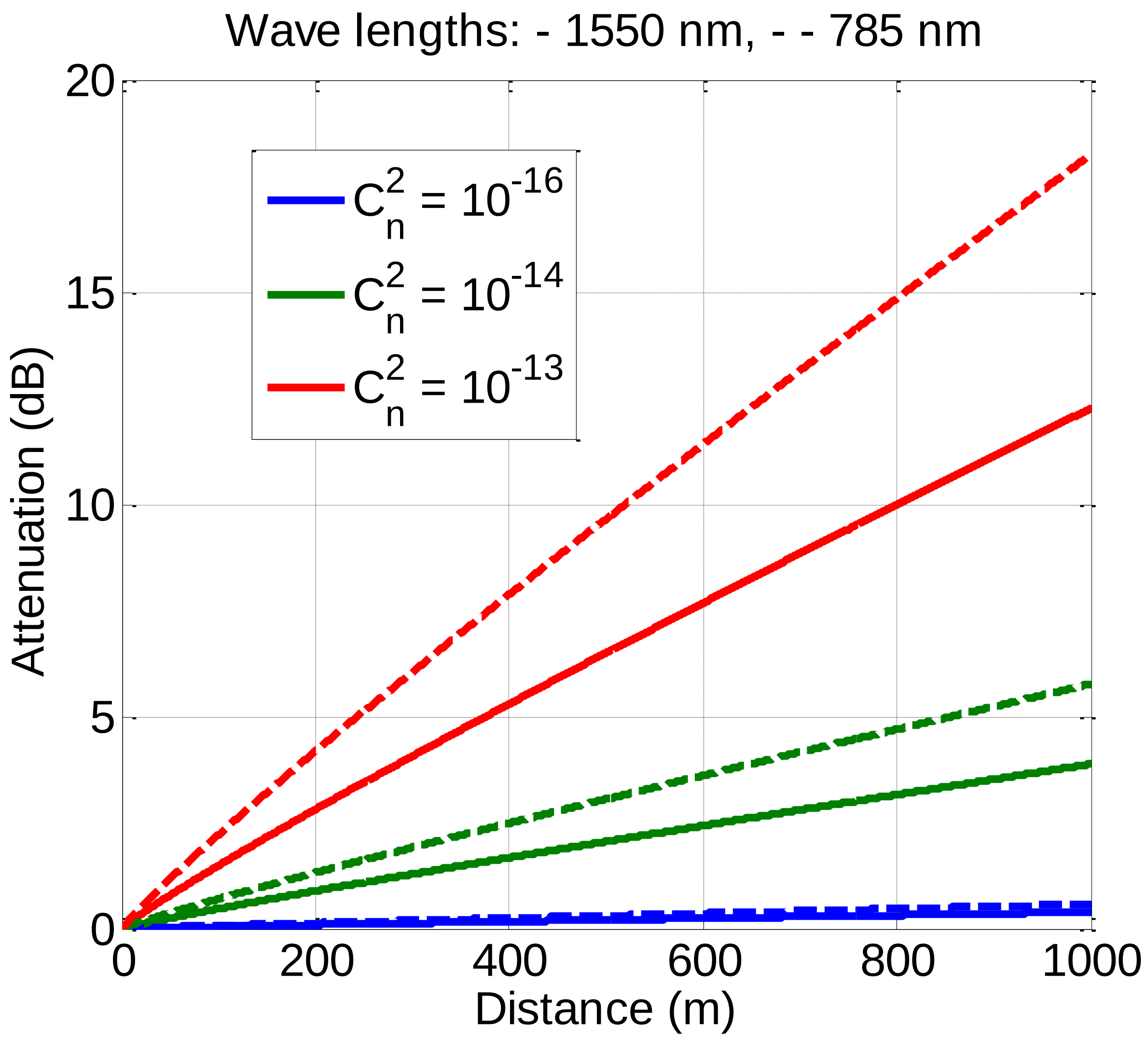
FSO link margin versus rain rate and fog



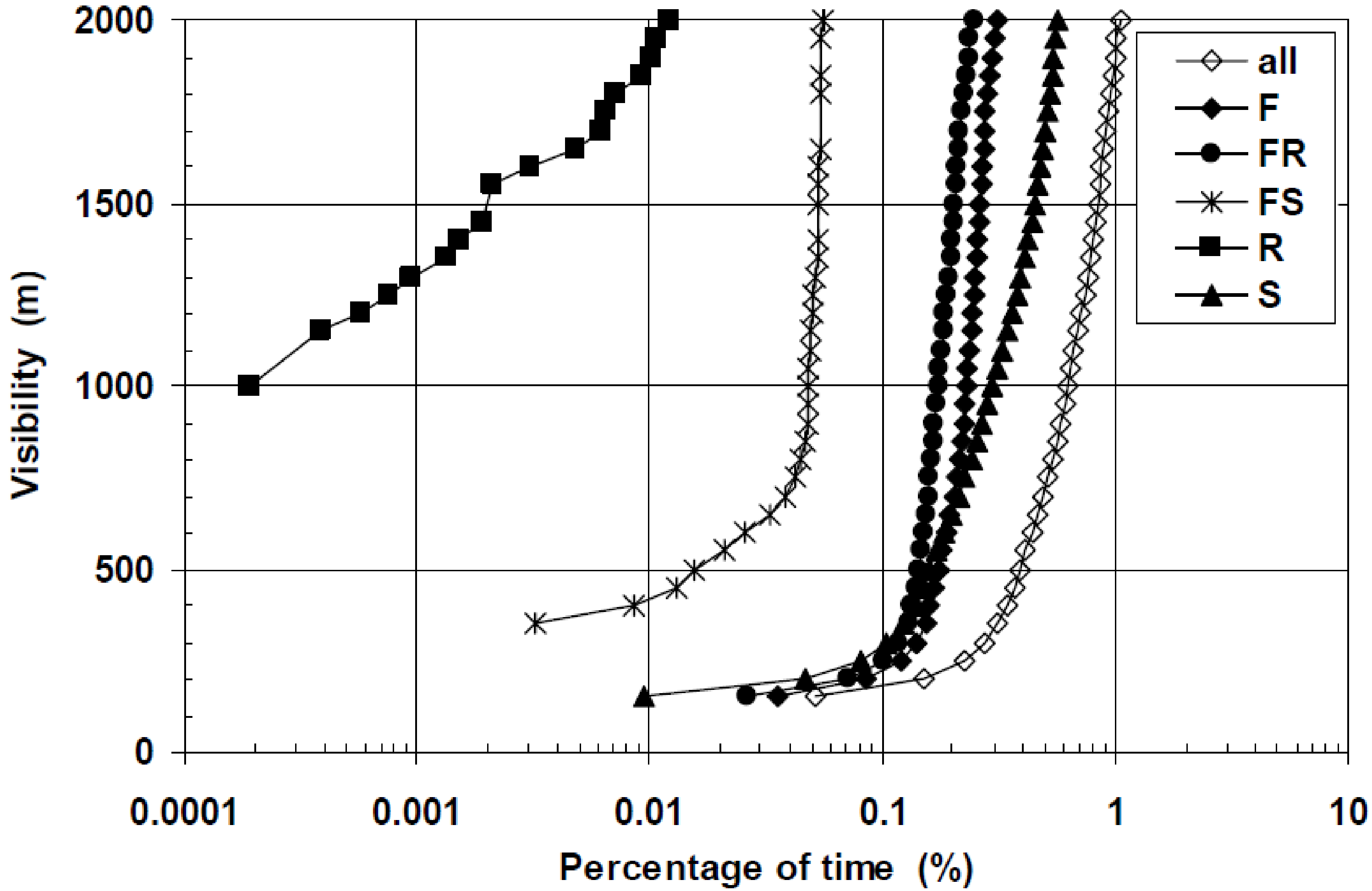
Diversity combining FSO and millimetrewave



Scintillation

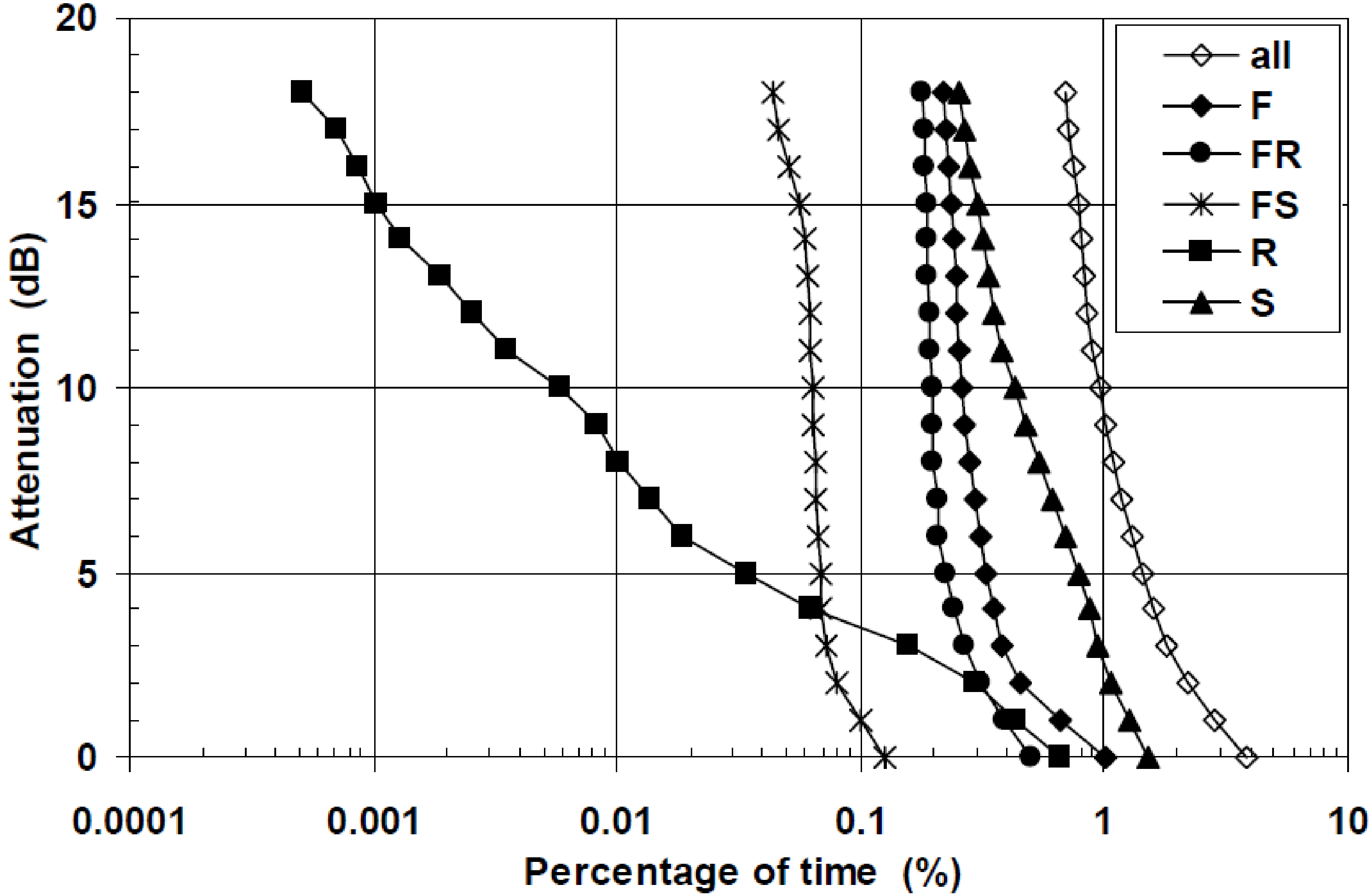


Visibility in Prague



KVICERA V., GRABNER M., FISER O. Visibility and Attenuation Due to Hydrometeors at 850 nm Measured on an 850 m Path. In Proc. of the Sixth International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP08), July 23-25, 2008, Graz, Austria, pp. 270-272. ISBN 978-1-4244-1875-6.

Attenuation in Prague for a 850 nm system over 850 m



KVICERA V., GRABNER M., FISER O. Visibility and Attenuation Due to Hydrometeors at 850 nm Measured on an 850 m Path. In Proc. of the Sixth International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP08), July 23-25, 2008, Graz, Austria, pp. 270-272. ISBN 978-1-4244-1875-6.

Conclusion

- Free space optics commercially available high capacity communications systems
- Provides quick links for example suitable for short distances between corporate company buildings
- May work well under periods with rain
- Problematic under periods with fog resulting in very high attenuation