SCIENCES

Waves, Field Directors – Pierre-Noël Favennec, Frédérique de Fornel

Electromagnetism, Subject Head – Pierre-Noël Favennec

Electromagnetic Waves 1

Maxwell's Equations, Wave Propagation

Coordinated by
Pierre-Noël Favennec

Color Section

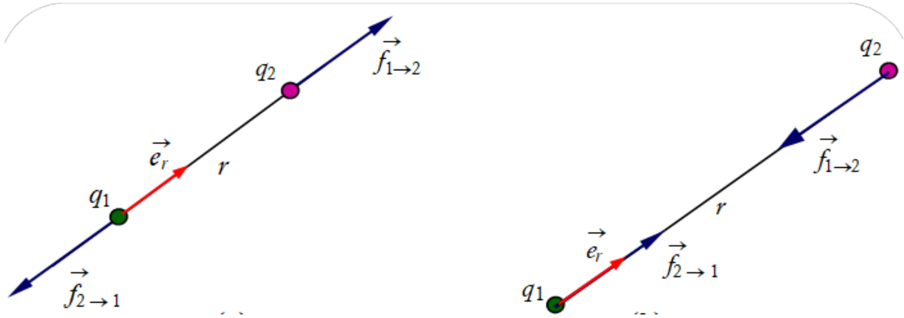

Figure 1.1. *Coulomb forces between two point and fixed charges q_1 and q_2*

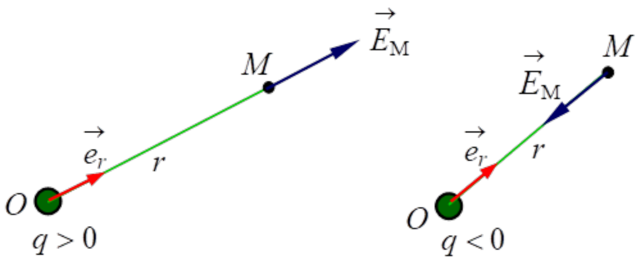

Figure 1.2. *Electrostatic field $\vec{E}_M$ created by a fixed point charge q*

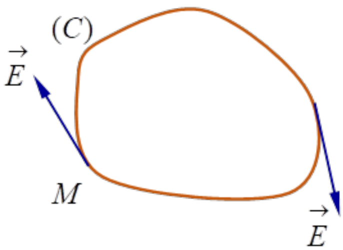

Figure 1.3. *Circulation of the electrostatic field about a closed contour (C)*

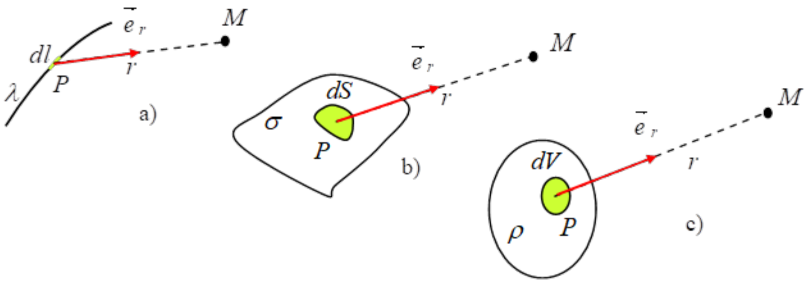

Figure 1.4. *Continuous charge distributions*

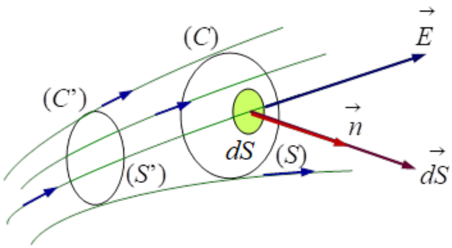

Figure 1.5. *Electrostatic field lines*

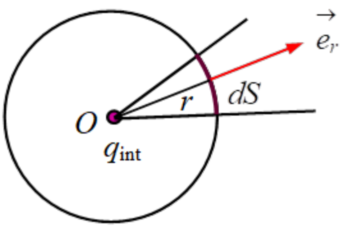

Figure 1.6. *Charge q_{int} at the center O of a sphere with radius r*

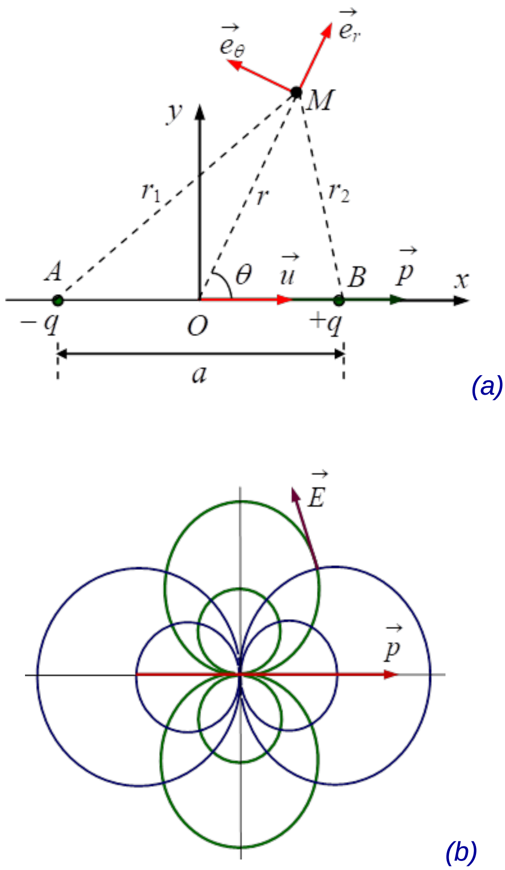

Figure 1.7. *a) Electrostatic dipole; b) field lines (in green) and equipotential surfaces (in blue) of an electrostatic dipole*

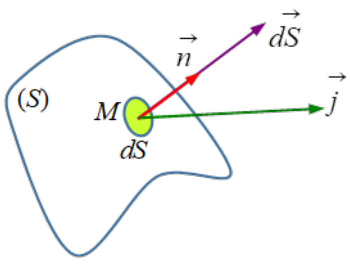

Figure 1.8. *Current density vector at point M*

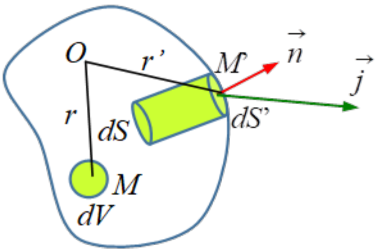

Figure 1.9. *Current density vector at point M'*

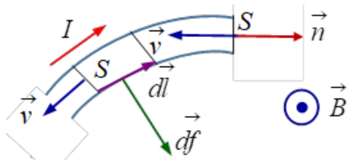

Figure 1.10. *Portion of a conductor with section s, traversed by a current with intensity I*

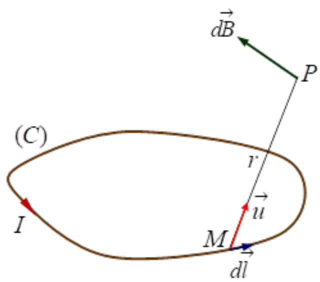

Figure 1.11. *Magnetic field* $\vec{dB}$ *created by an element with a length* $\vec{dl}$ *of a circuit (C)*

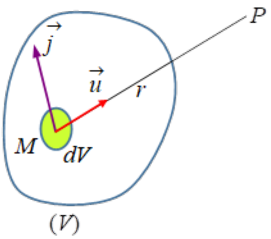

Figure 1.12. *Current distribution within volume V*

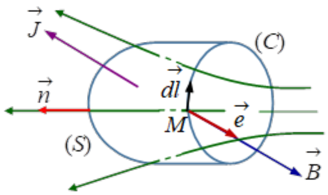

Figure 1.13. *Circulation of a magnetic field on a contour (C)*

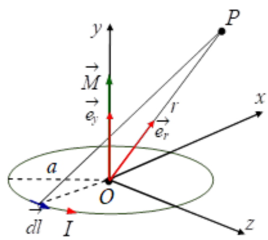

Figure 1.14. *Magnetic dipole composed of a circular coil with magnetic moment M*

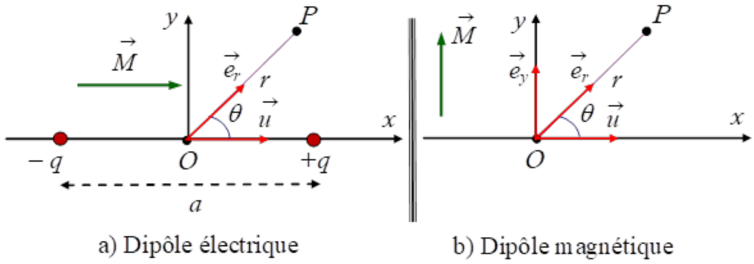

Figure 1.15. *Analogy a) electric dipole; b) magnetic dipole*

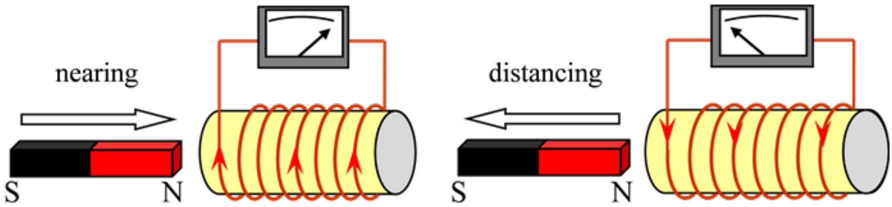

Figure 1.16. *a) Magnet far from the coil axis: an electric current occurs; b) magnet close to the axis of the current: an electric current occurs*

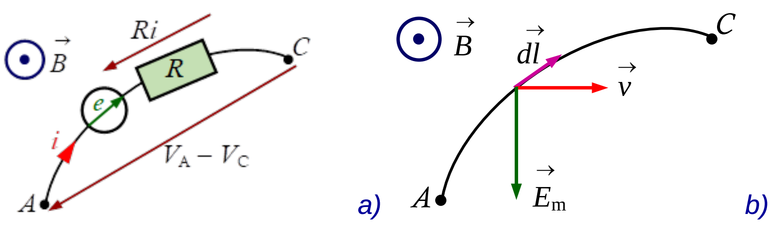

Figure 1.17. *a) Portion AC of a conductor in motion in a magnetic field; b) electric circuit equivalent to conductor A*

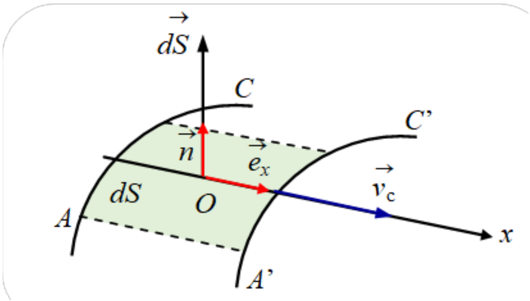

Figure 1.18. *Area swept by a section AC of the filiform conductor in motion*

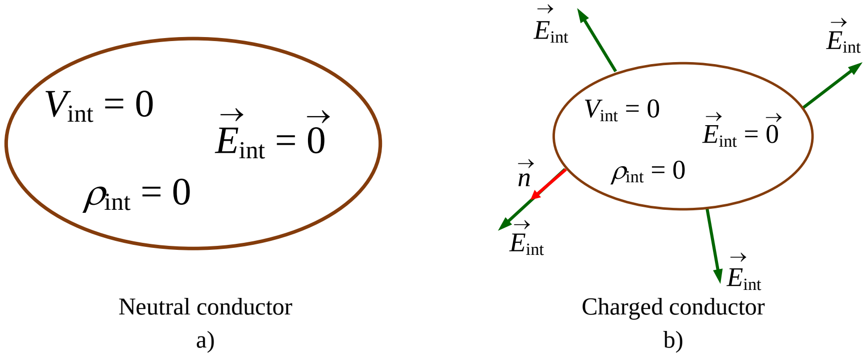

Figure 1.19. *Conductors in equilibrium*

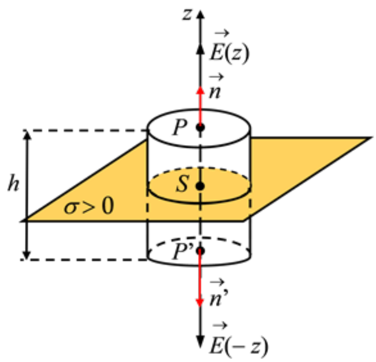

Figure 1.20. *Electrostatic field surrounding a flat charged surface*

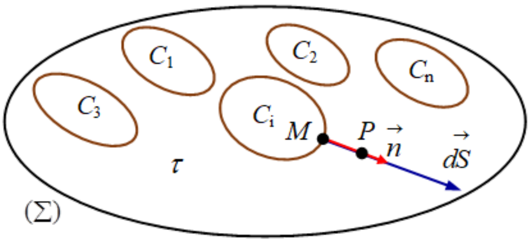

Figure 1.21. *Conductors in equilibrium*

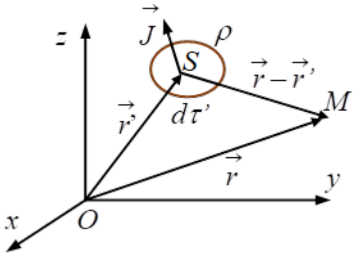

Figure 1.22. *Sources (S) of charges and currents*

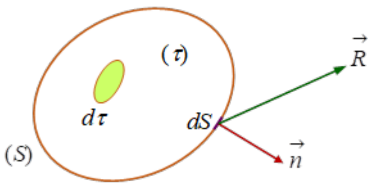

Figure 1.23. *Surface S surrounding volume V containing charge carriers*

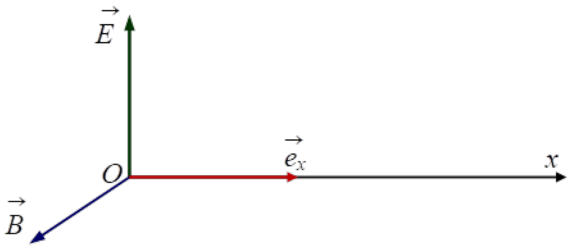

Figure 1.24. *Electric and magnetic fields perpendicular and orthogonal to the propagation direction of the progressive plane wave*

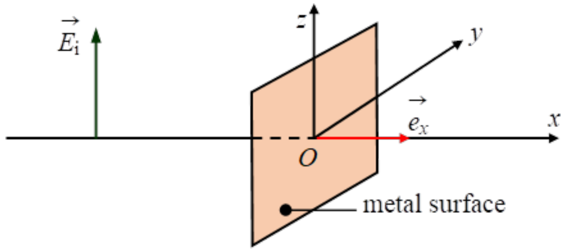

Figure 1.25. *Perfect metal arranged vertically on the propagation axis of a monochromatic progressive plane wave*

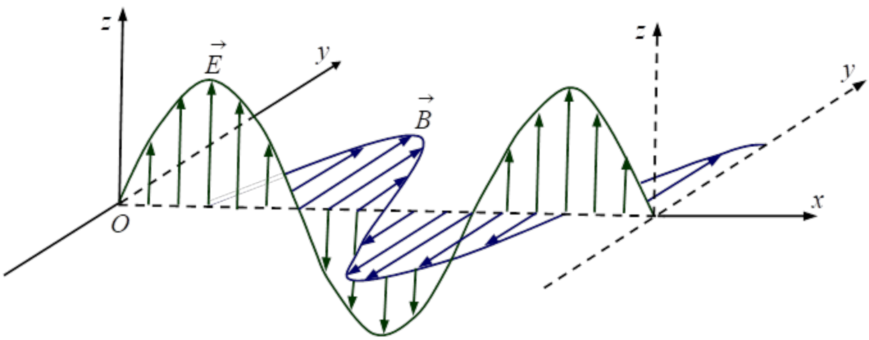

Figure 1.26. *Structure of an electromagnetic stationary wave*

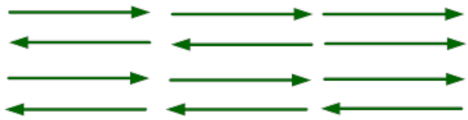

Figure 1.27. *Most likely arrangement of dipole moments of the most stable polar molecules*

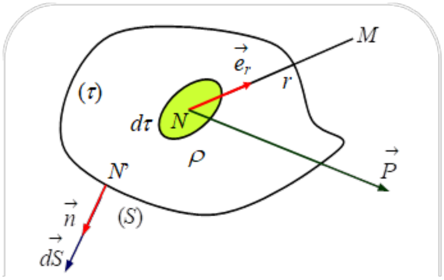

Figure 1.28. *Dielectric medium with volume τ*

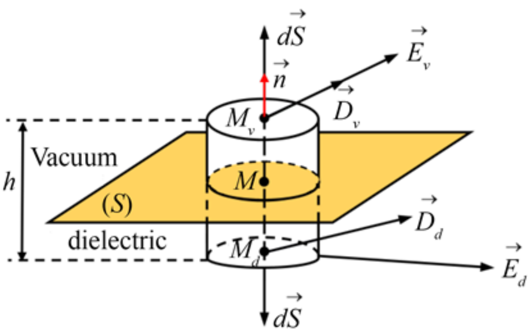

Figure 1.29. *Refraction of the electric displacement vector across a vacuum-dielectric surface of separation*

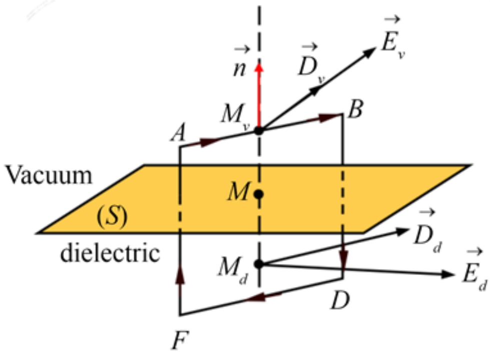

Figure 1.30. *Circulation of the electric field along an ABDF circuit overlapping a vacuum-dielectric surface of separation*

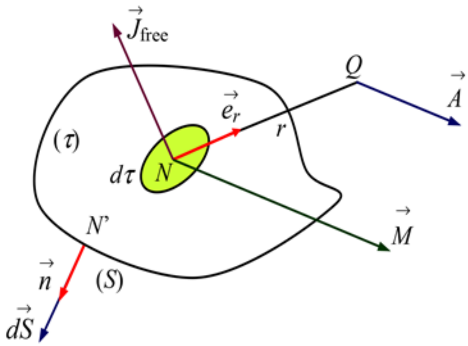

Figure 1.31. *Magnetic medium with volume τ*

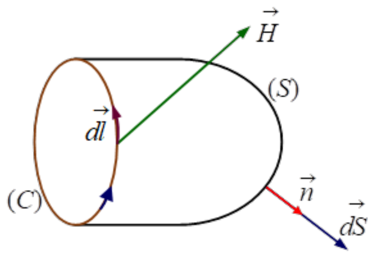

Figure 1.32. *Circulation of the excitation magnetic vector on a closed contour (C)*

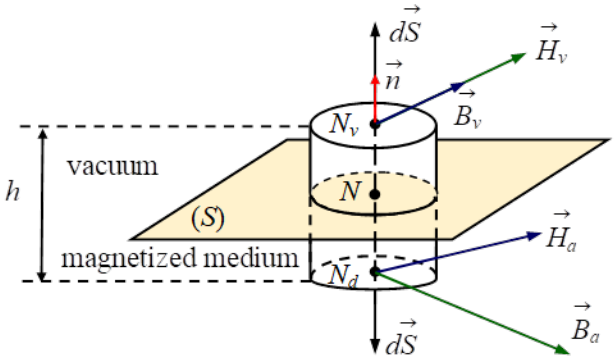

Figure 1.33. *Refraction of the magnetic field crossing a vacuum-magnetic medium surface of separation*

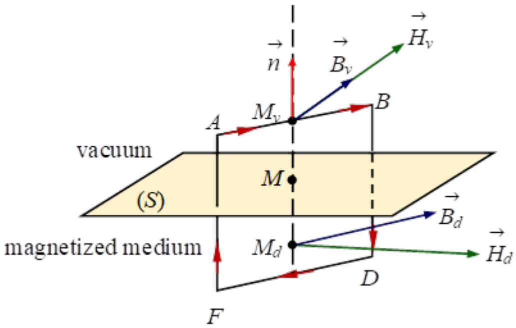

Figure 1.34. *Circulation of the magnetic field along an ABDF circuit overlapping a vacuum-magnetic medium surface of separation*

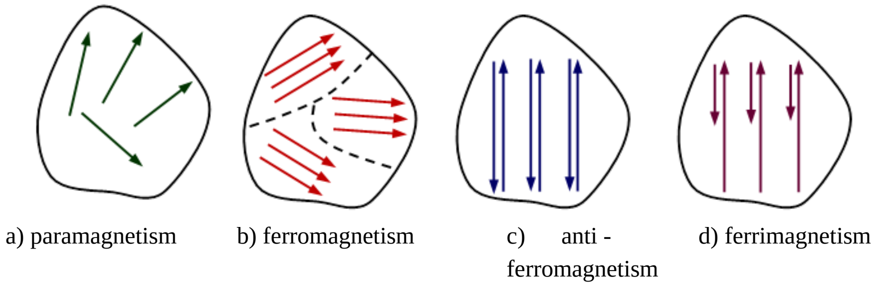

Figure 1.35. *Illustration of the different types of magnetism: a) magnetic moments distributed irregularly; b) magnetic moments aligned in a Weiss domain (10 μm to 1 m); c) antiparallel magnetic moments with equal intensities; d) antiparallel magnetic moments with different intensities*

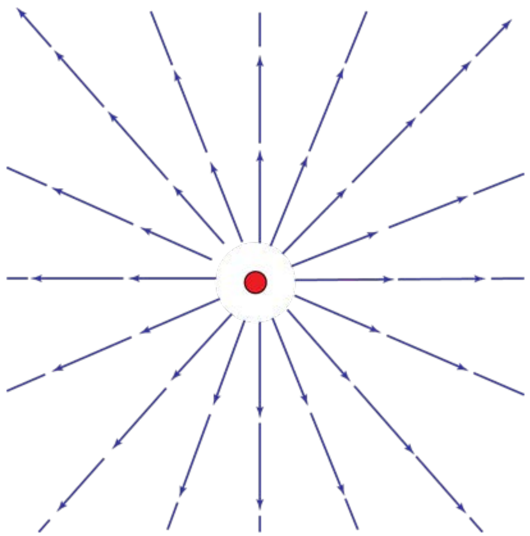

Figure 2.1. *Configuration of field lines of the electric field*

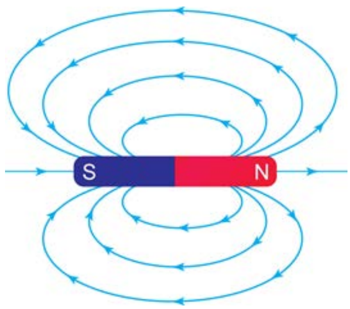

Figure 2.2. *Configuration of magnetic field lines*

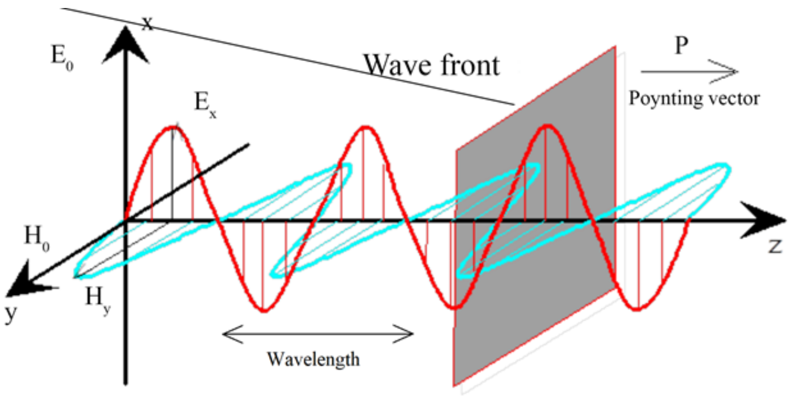

Figure 2.3. *Diagram depicting the propagation of an electromagnetic wave*

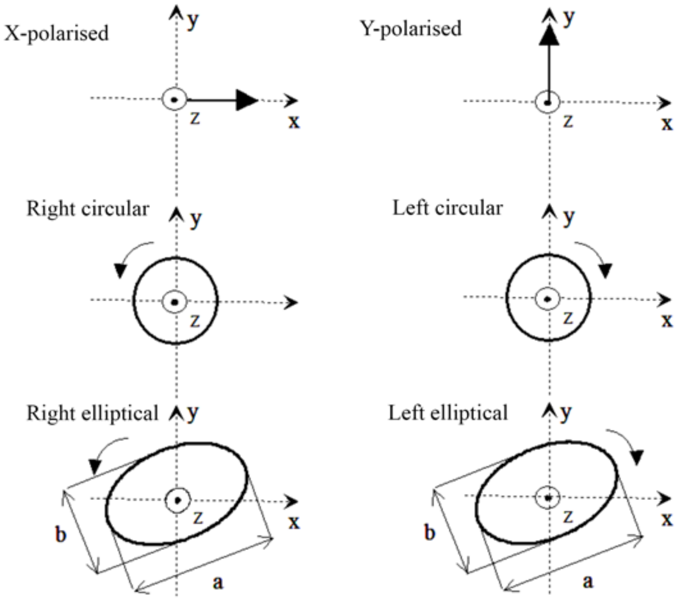

Figure 2.4. *The different polarization states for a wave propagating in direction z*

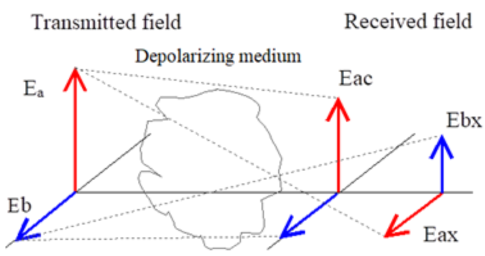

Figure 2.5. *Schematic of transpolarization*

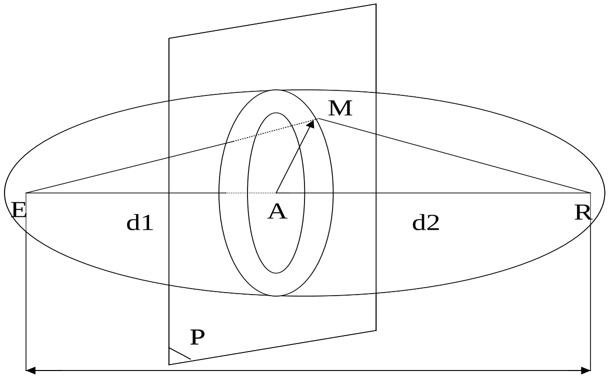

Figure 2.6. *Schematic representation of Fresnel zones*

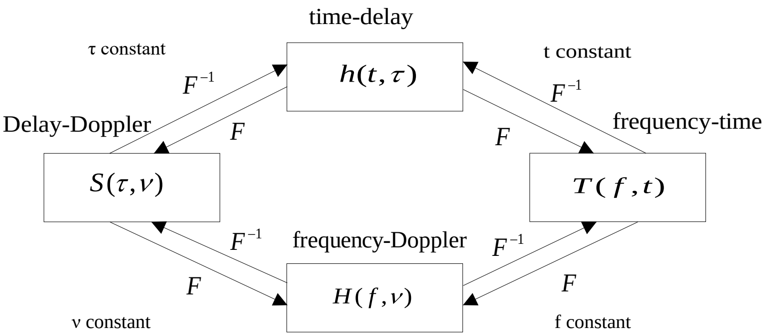

Figure 2.7. *Representation of the different Fourier transforms on impulse response*

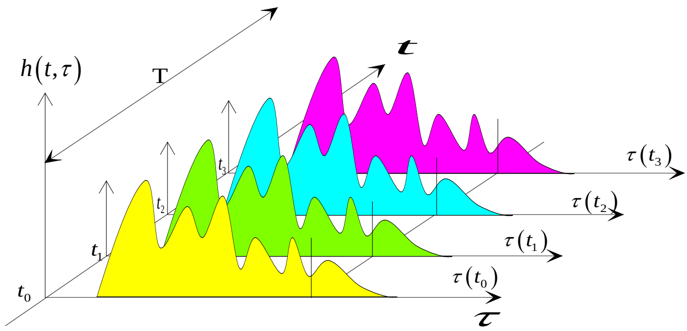

Figure 2.8. *Representation of the temporal evolution of the propagation channel impulse response*

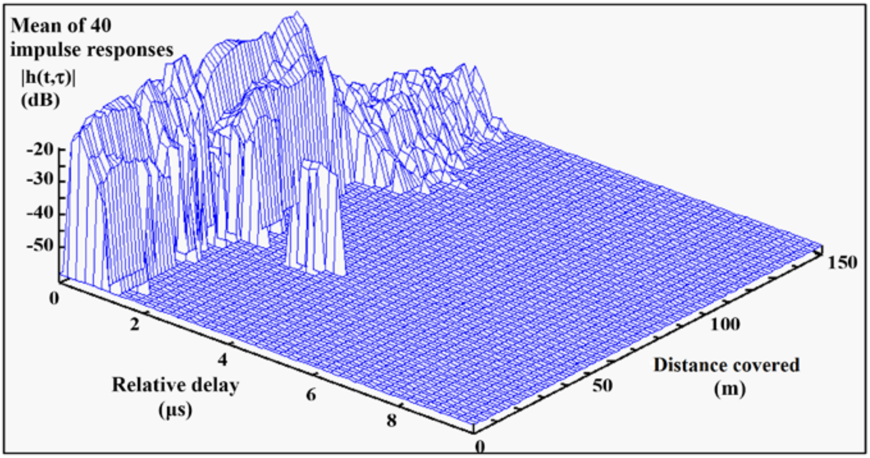

Figure 2.9. *Evolution of the impulse response: turning a street corner in the microcellular environment (Paris, 900 MHz, FTR&D sounder)*

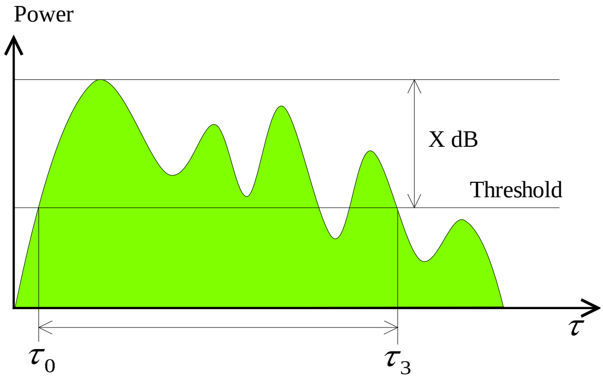

Figure 2.10. *Example of a power delay profile; highlighted by the delay interval at X dB*

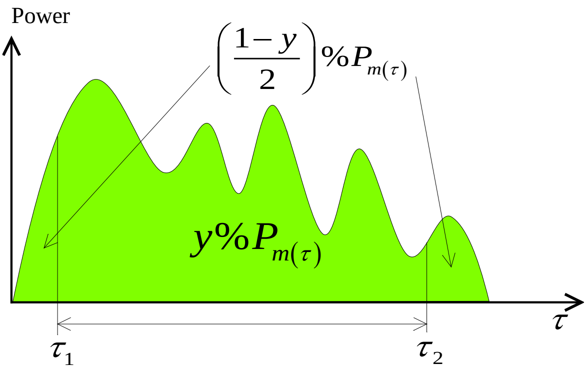

Figure 2.11. *Example of a power delay profile; highlighted by the delay window at y%*

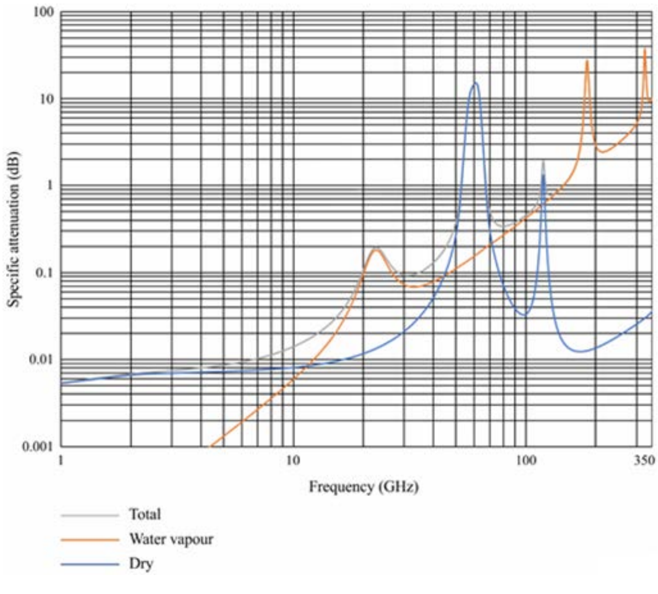

Figure 2.12. *Specific attenuation (dB/km) due to atmospheric gases (O_2 and H_2O) and total (ITU-R P.676)*

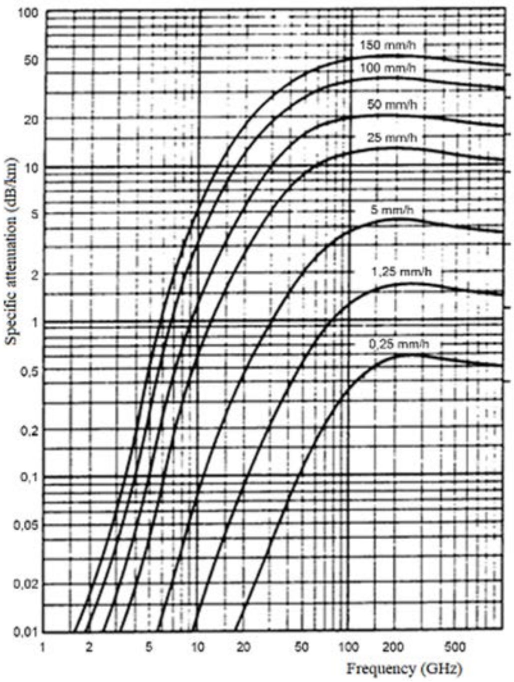

Figure 2.13. *Specific attenuation (dB/km) due to rain as a function of the frequency (ITU-R P.837)*

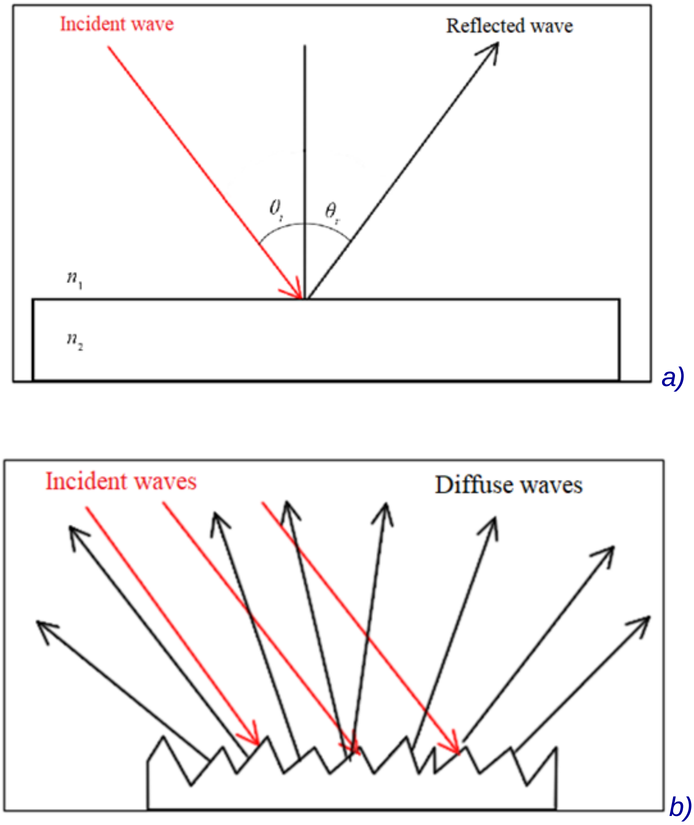

Figure 2.14. *a) representation of specular reflection; b) representation of diffuse reflection*

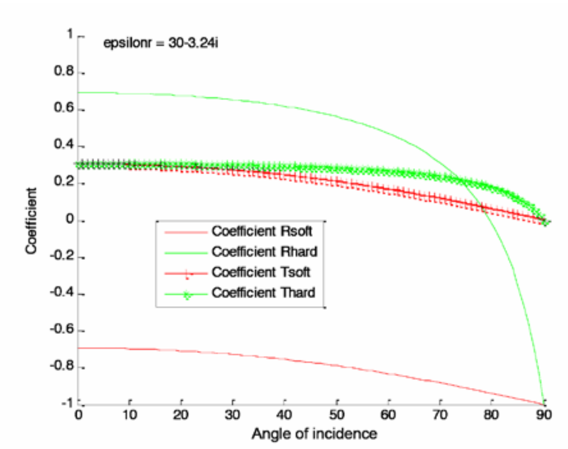

Figure 2.15a. *Example of the variation of the real part of reflection and transmission coefficients of wet soil at 1 GHz in vertical (hard) and horizontal (soft) polarizations*

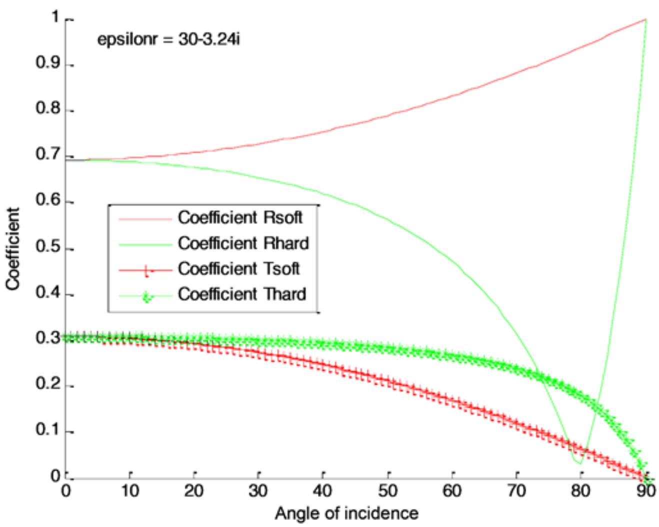

Figure 2.15b. *Example of the variation of the modulus of the reflection and transmission coefficients of wet soil at 1 GHz in vertical (hard) and horizontal (soft) polarizations*

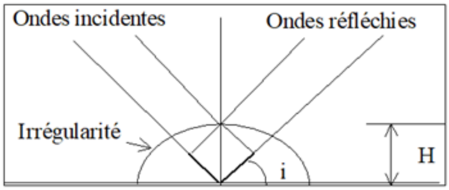

Figure 2.16. *Difference in path created by a surface irregularity with height H*

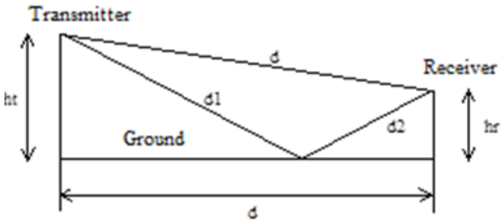

Figure 2.17. *Two-line model*

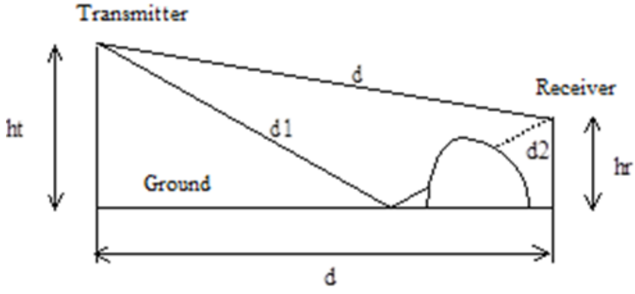

Figure 2.18. *Diagram showing the blocking of the reflected ray with an obstacle*

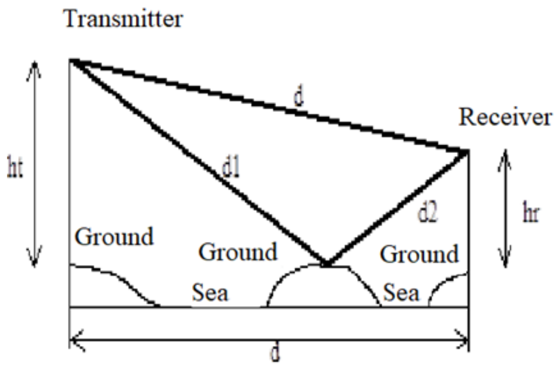

Figure 2.19. *Diagram showing the path reflected on an island to limit the effect of the reflected path on a maritime link*

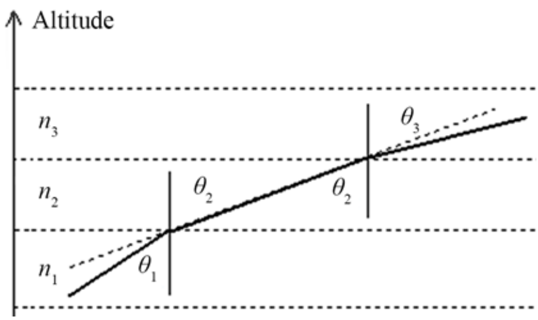

Figure 2.20. *Geometries associated with Descartes law*

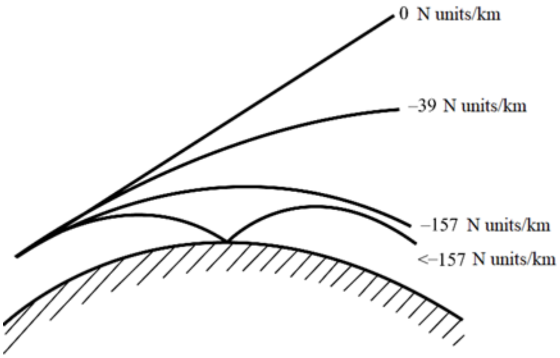

Figure 2.21. *Paths of radioelectric waves as a function of refractivity gradient*

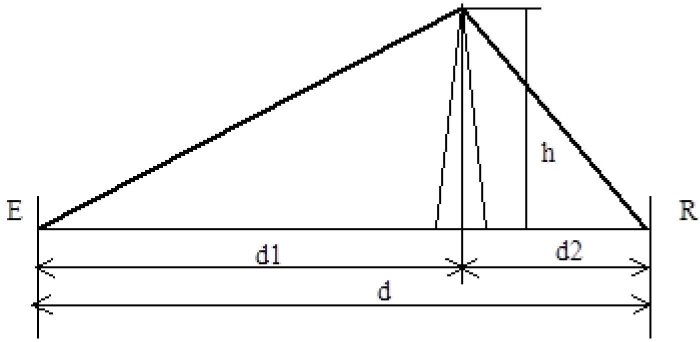

Figure 2.22. *Representation of a sharp diffracting edge*

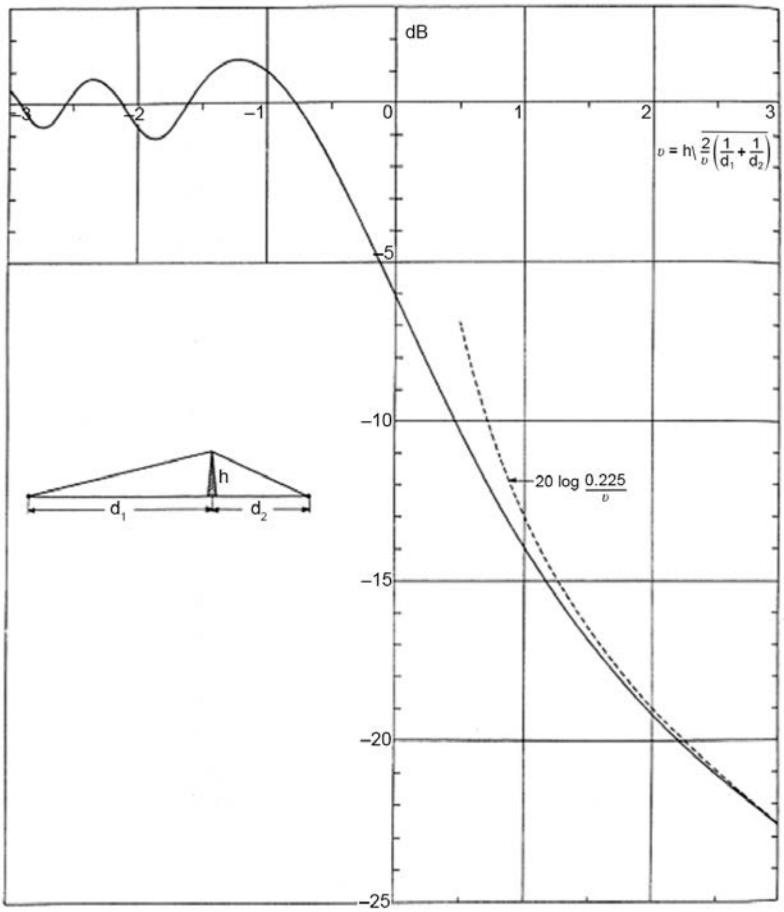

Figure 2.23. *Attenuation due to diffraction off an edge*

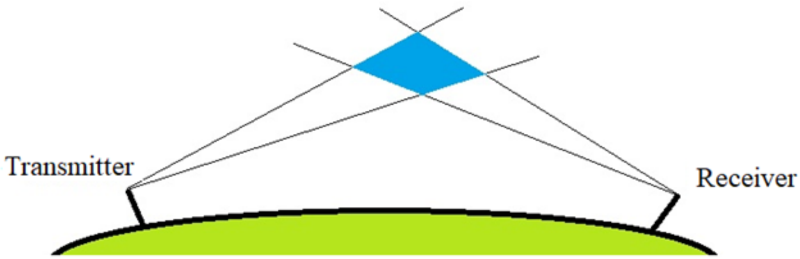

Figure 2.24. *Propagation of an electromagnetic wave by tropospheric scattering*

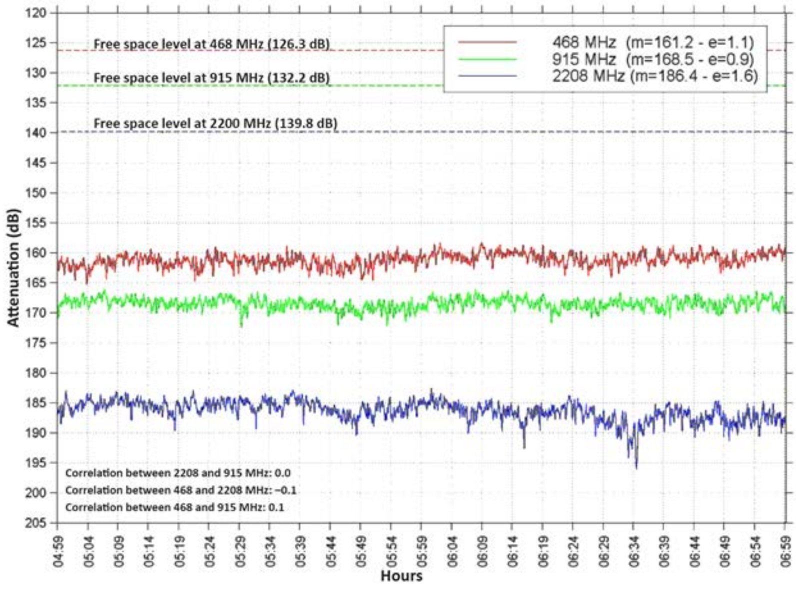

Figure 2.25. *Example of variation in the radioelectric field due to tropospheric scattering*

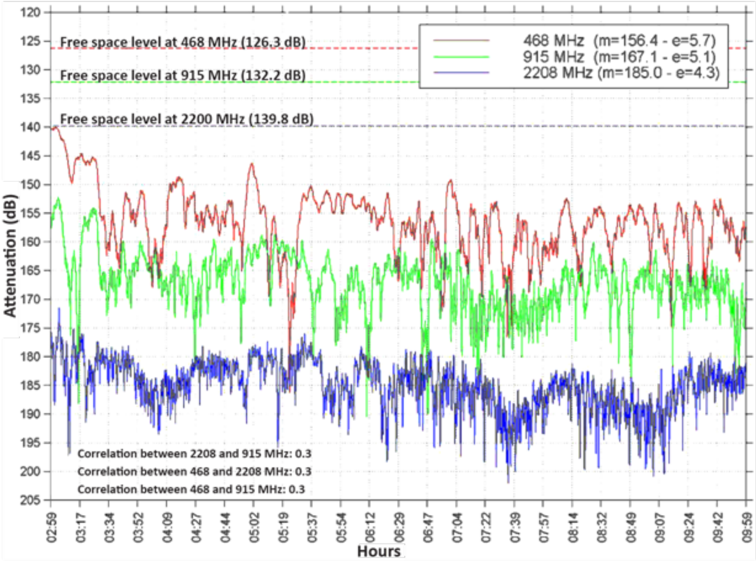

Figure 2.26. *Example of variation in the radioelectric field due to reflection on layers of the atmosphere*

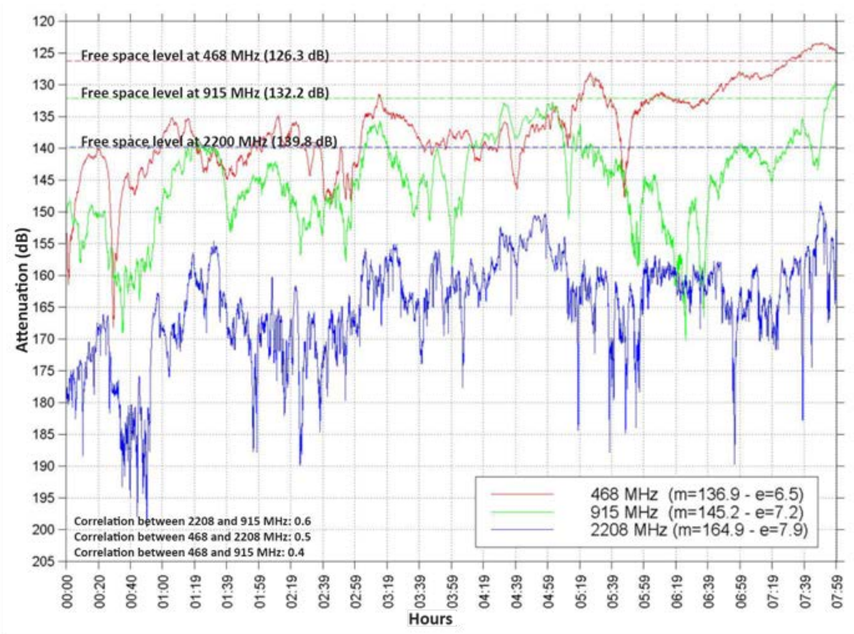

Figure 2.27. *Example of variation in radioelectric field due to the presence of ducts*

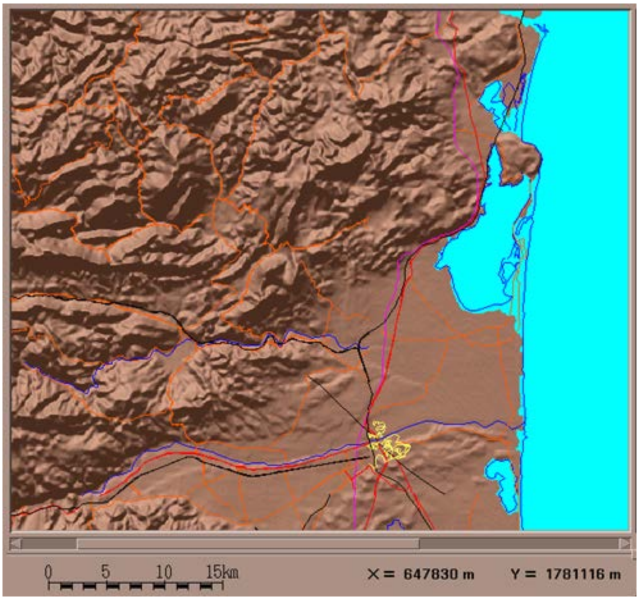

Figure 2.28. *Map of the topography (relief) in the Perpignan region, France*

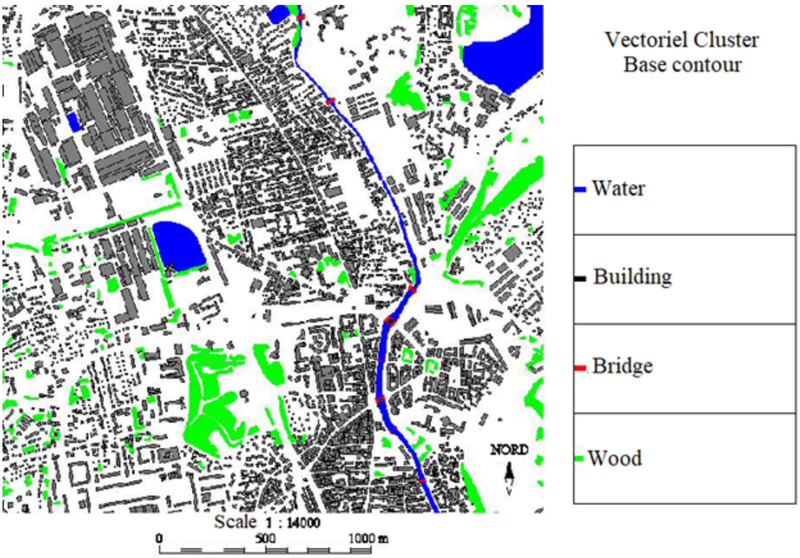

Figure 2.29. *Map of the topography (relief) in the Belfort region, France*

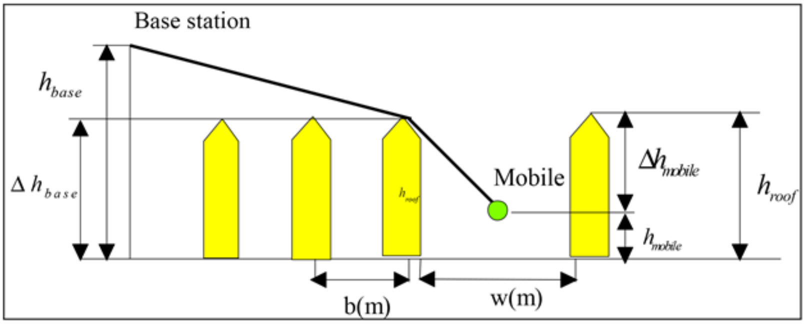

Figure 2.30. *Schematic representation of the "transmitter-receiver" profile*

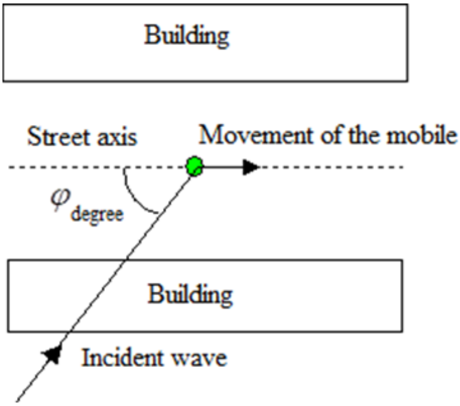

Figure 2.31. *Definition of the angle between the street axis and the direction of the incidence angle*

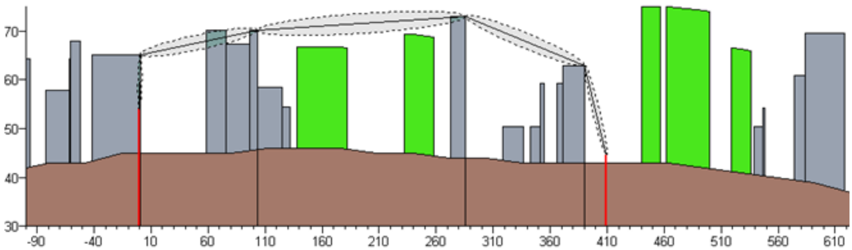

Figure 2.32. *Example of a "transceiver" profile*

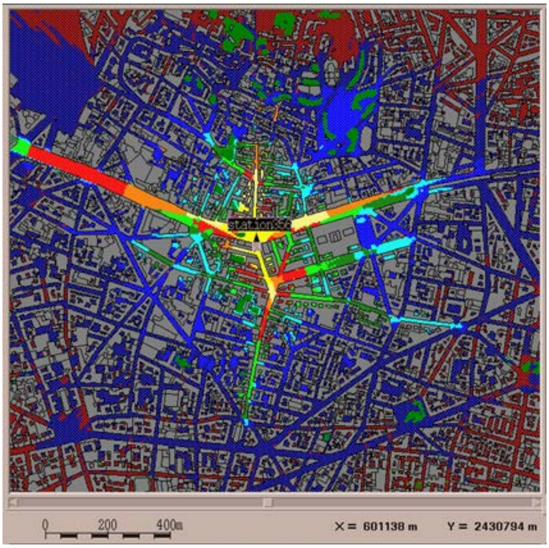

Figure 2.33. *Example of urban coverage*

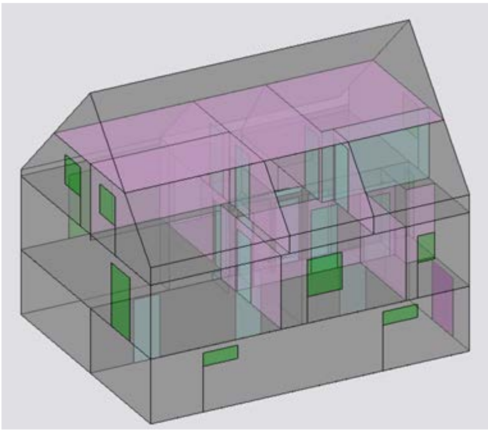

Figure 2.34. *Example of a representation of a residential environment*

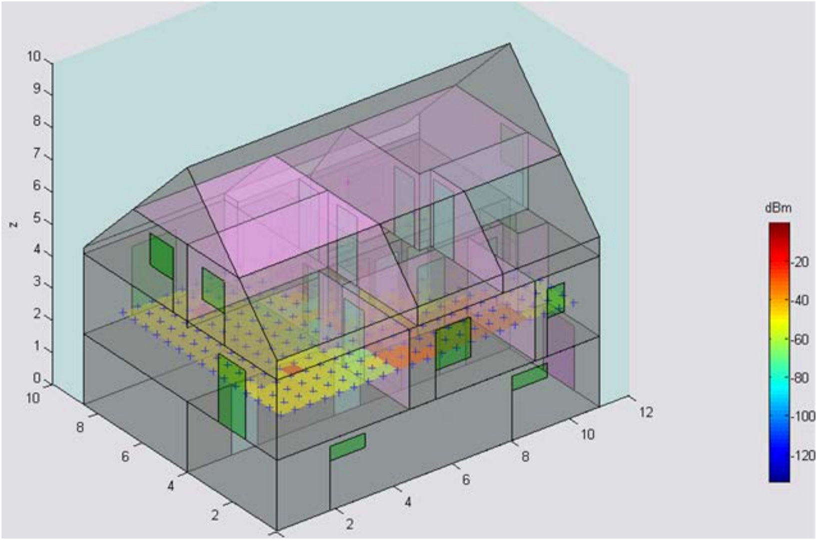

Figure 2.35. *Example of radioelectric coverage in a residential environment*

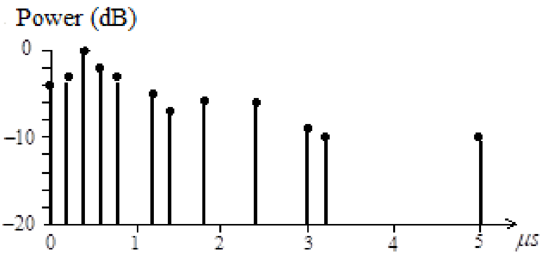

Figure 2.36. *Schematic representation of a GSM TU channel with 12 paths*

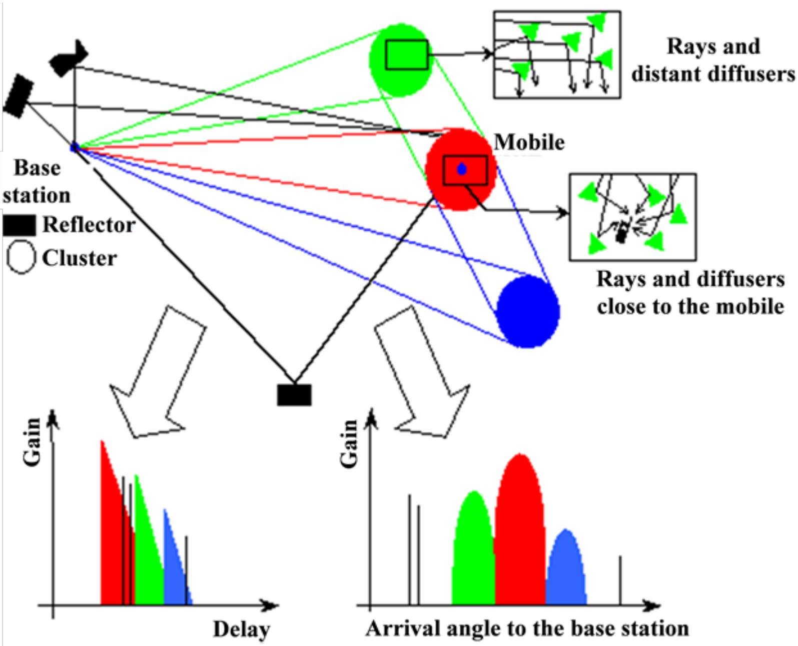

Figure 2.37. *Relations between the position of reflectors and diffusers in the propagation environment; shape of the power time profile*

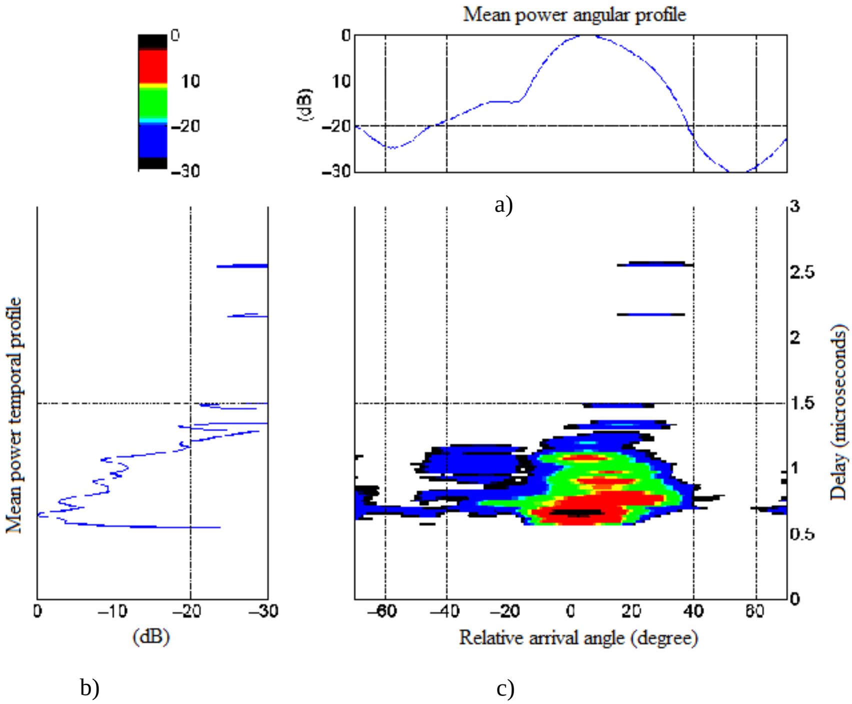

Figure 2.38. *Spatiotemporal representation of the impulse response: a) angular power profile, b) temporal power profile, c) mean spatio-temporal power distribution, the origin of the angles corresponds to the pointing axis of the antenna at the base station*

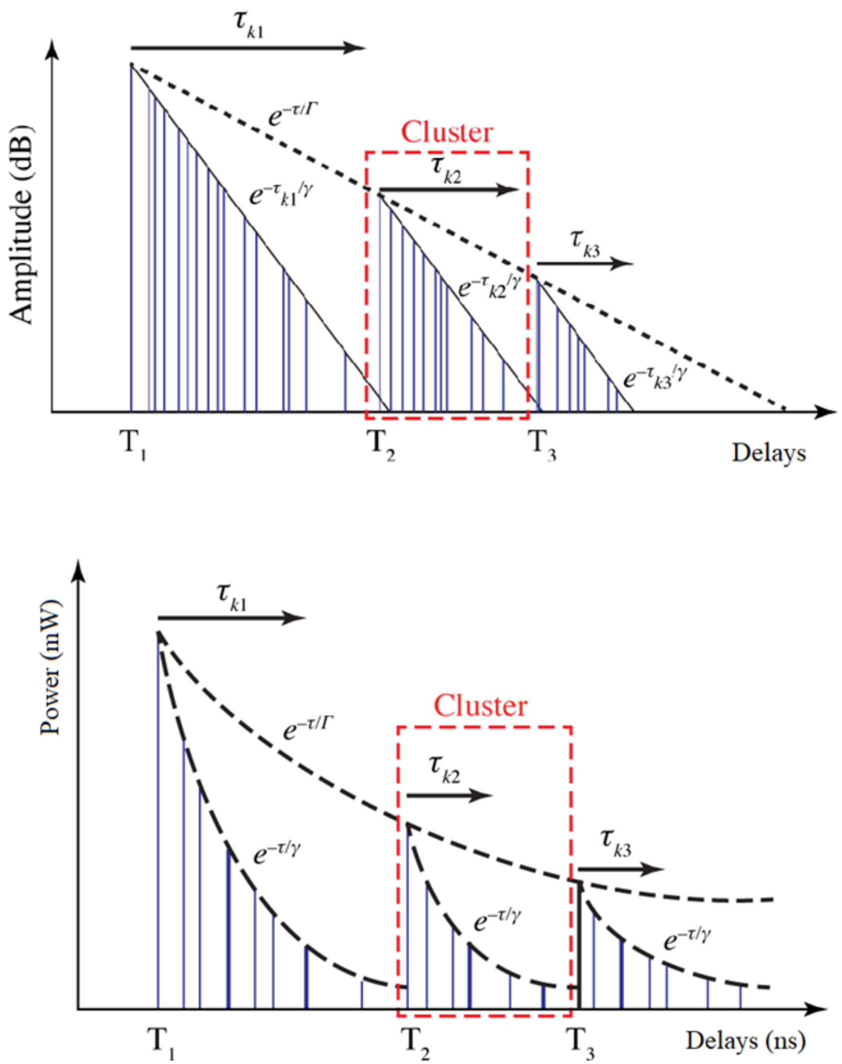

Figure 2.39. *Power profile according to Saleh and Valenzuela formalism*

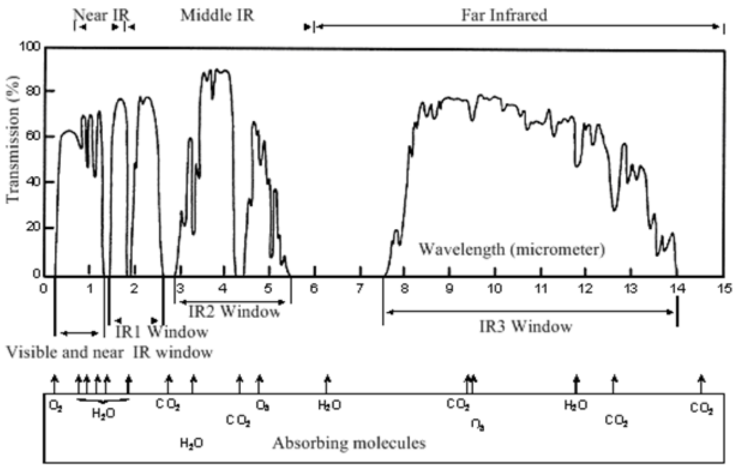

Figure 2.40. *Transmittance of the atmosphere due to molecular absorption*

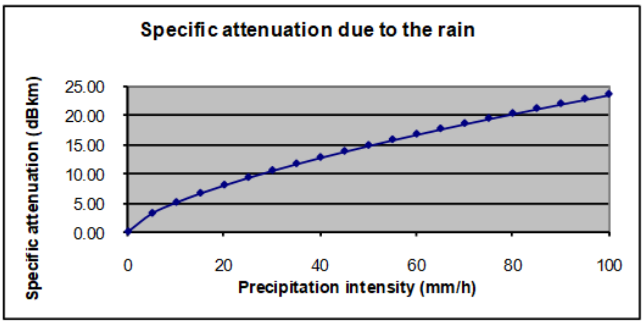

Figure 2.41. *Specific attenuation (dB/km) due to rain in the optical and infrared range*

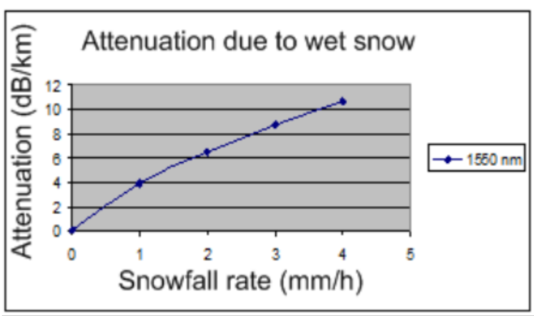

Figure 2.42. *Wet snow: attenuation as a function of precipitation rate at 1,550 nm*

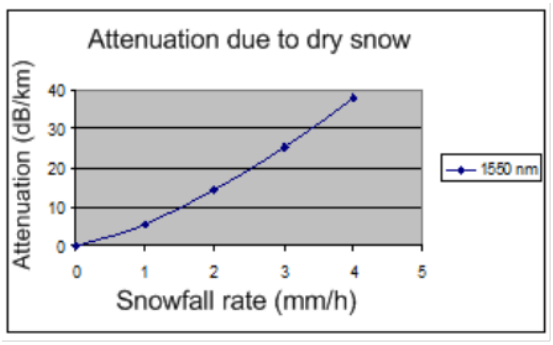

Figure 2.43. *Dry snow: attenuation as a function of precipitation rate at 1,550 nm*

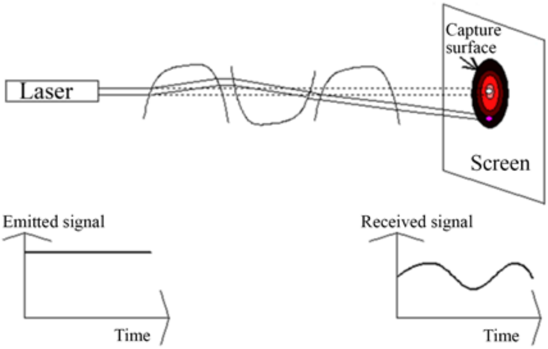

Figure 2.44. *Deviation of the laser beam under the influence of turbulence cells greater than the beam diameter (deviation of the beam)*

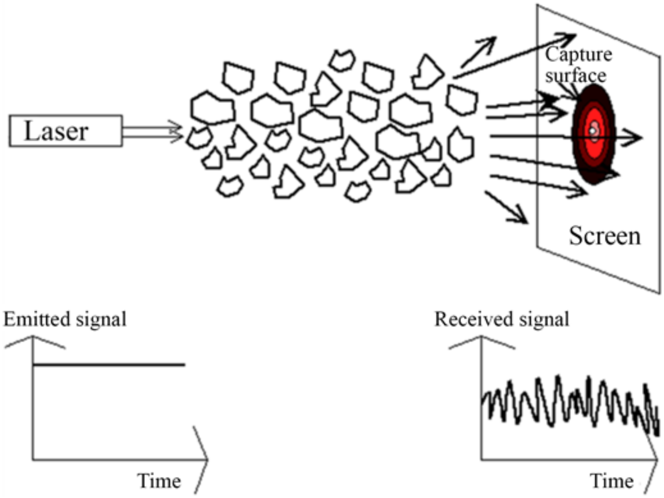

Figure 2.45. *Deviation of the laser beam under the influence of turbulence cells smaller than the beam diameter (beam enlargement)*

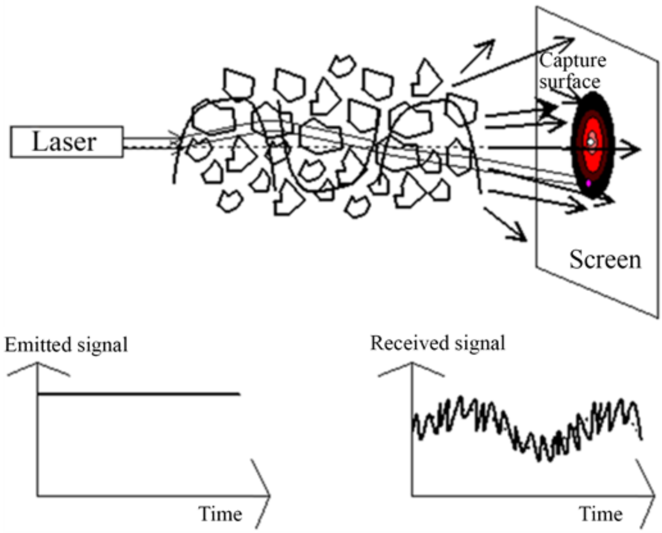

Figure 2.46. *Effects of different heterogeneities and different sizes on the propagation of a laser beam (scintillations)*

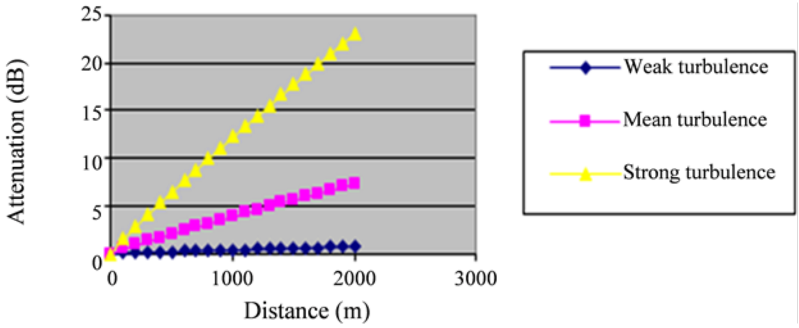

Figure 2.47. *Variation in attenuation linked to the scintillation as a function of distance for different types of turbulence at 1.55 micron*

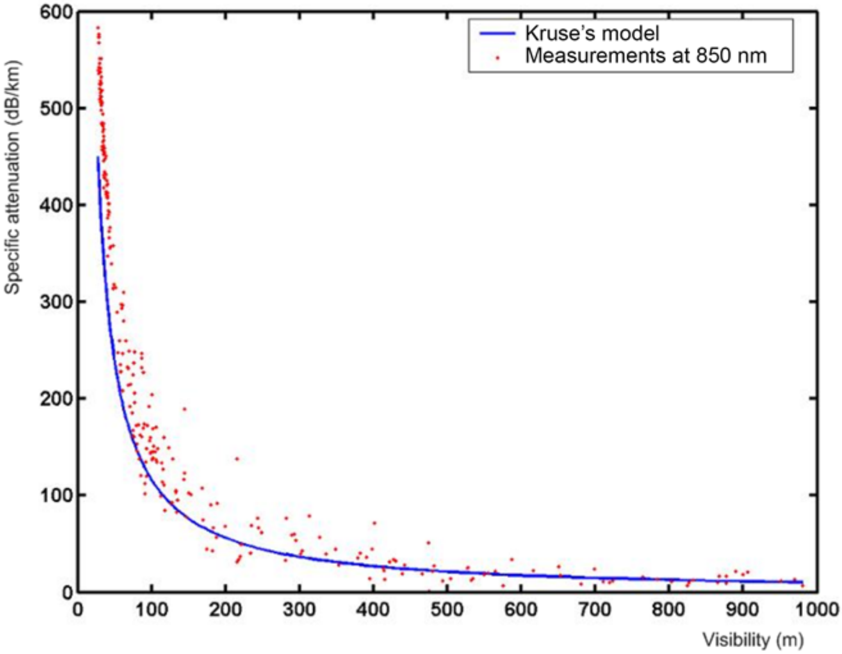

Figure 2.48a. *Variation in specific attenuation at 850 nm as a function of visibility (comparison with the Kruse's model)*

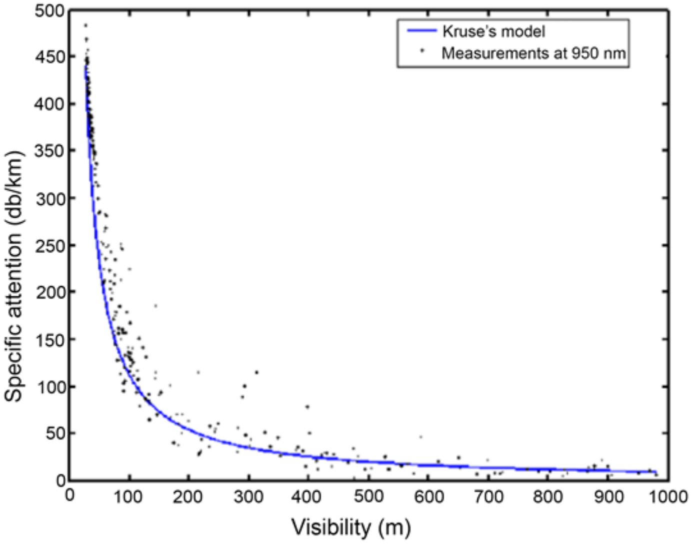

Figure 2.48b. *Variation in specific attenuation at 950 nm as a function of visibility (comparison with the Kruse's model)*

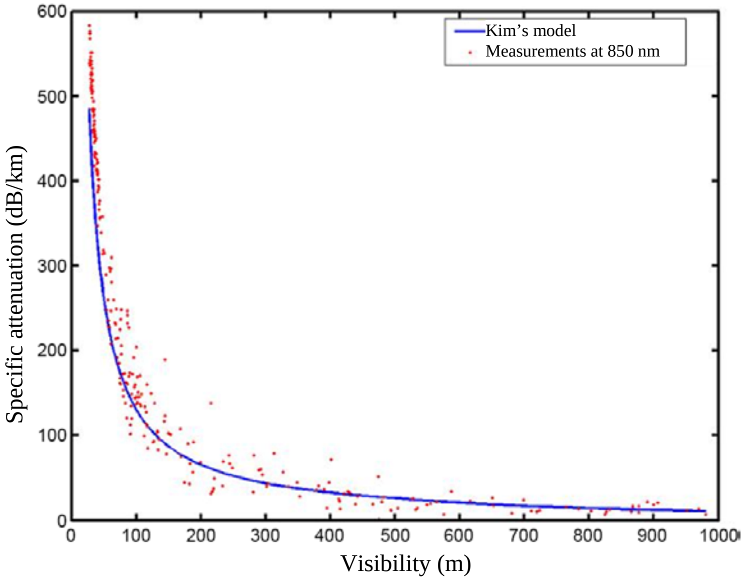

Figure 2.49a. *Variation in specific attenuation at 850 nm as a function of visibility (comparison with Kim's model)*

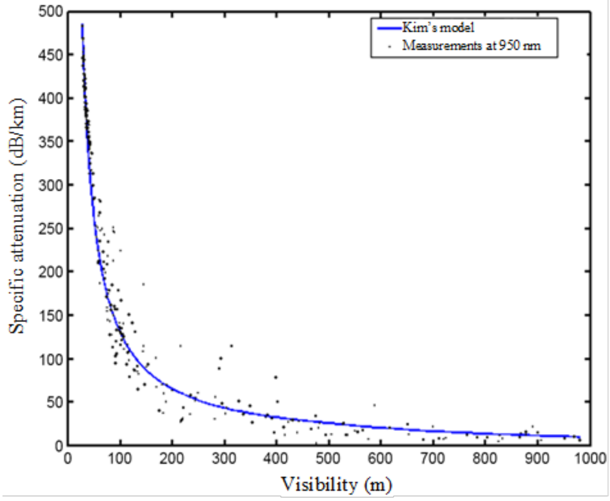

Figure 2.49b. *Variation in specific attenuation at 950 nm as a function of visibility (comparison with Kim's model)*

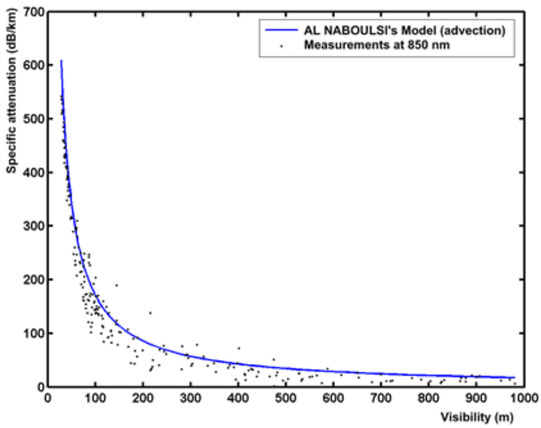

Figure 2.50. *Variation in specific attenuation at 850 nm as a function of visibility (comparison with the Al Naboulsi advection model)*

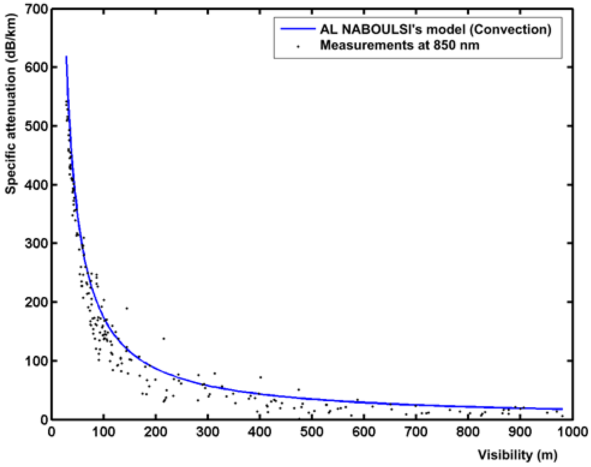

Figure 2.51. *Variation in specific attenuation at 850 nm as a function of visibility (comparison with the Al Naboulsi convection model)*

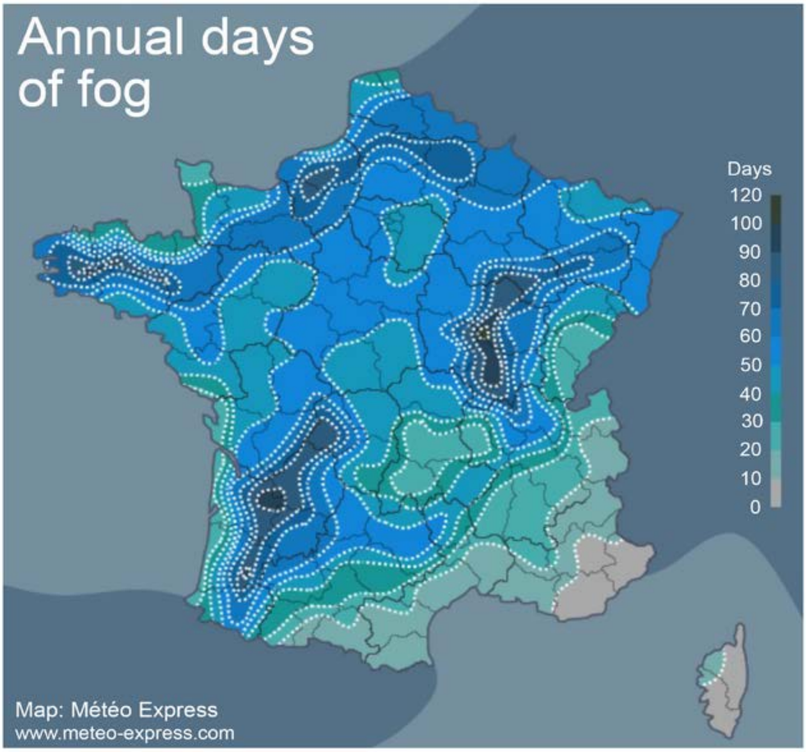

Figure 2.52. *Number of days a year in France with fog (visibility less than 1 km)*

Figure 2.53. *Sandstorm (source: Wikipedia)*

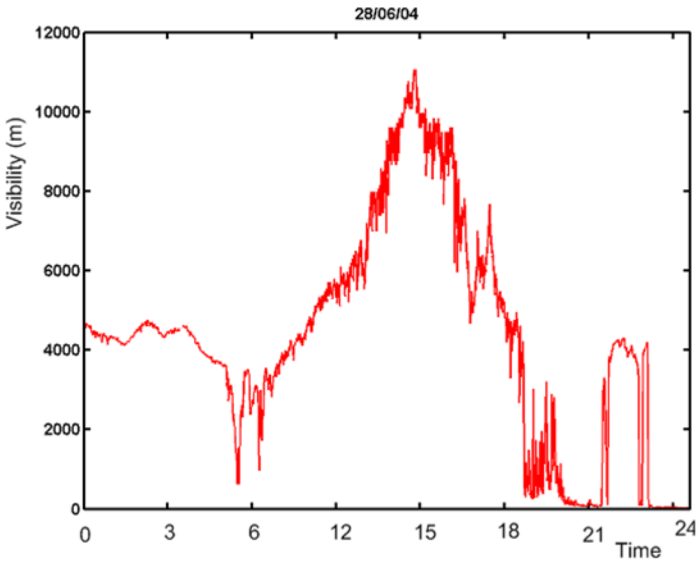

Figure 2.54. *Variations in the MOR observed at the Turbie site on June 28, 2004*

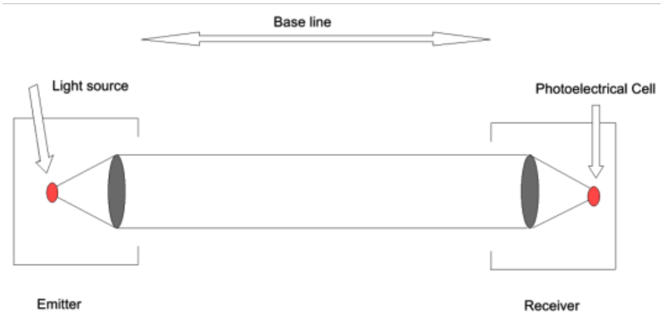

Figure 2.55. *Direct beam transmissometer*

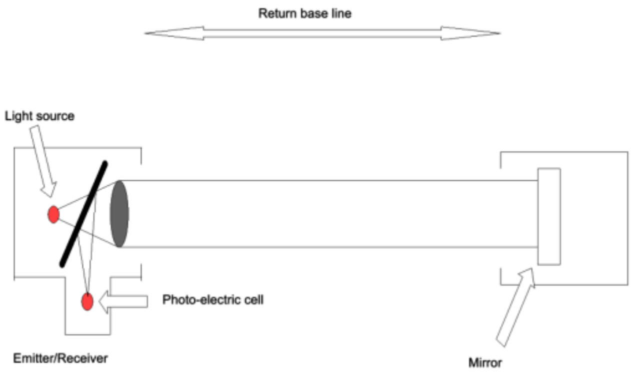

Figure 2.56. *Reflected beam transmissometer*

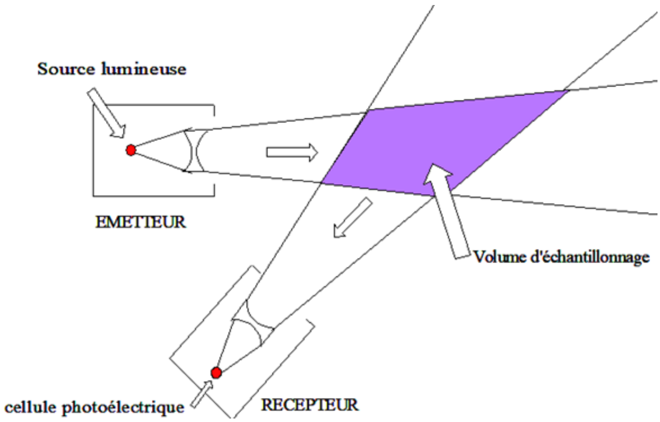

Figure 2.57. *Diagram showing the measurement of visibility by backscatter*

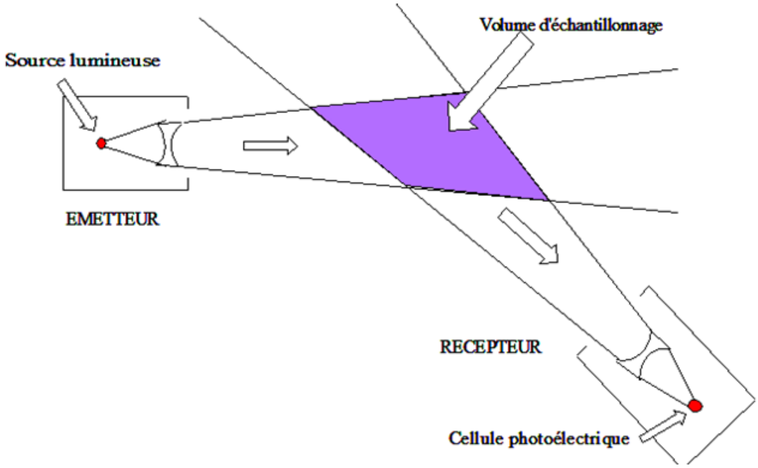

Figure 2.58. *Diagram showing the measurement of visibility by forward scatter*