TUTORIAL 3 (9h-12h)

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Design fundamentals for infrared systems

Key words: thermal radiation, atmospheric propagation, IR optics and detectors, signal to noise ratio, NETD, MRTD, detection, imaging.

Electro-optical systems fulfill an increasing number of applications in both civilian and military domains. This course deals more particularly with the design ofinfrared equipmentsintended for use in defense, aeronautics, or space. Nowadays, they are being used in most areas of defense, such as: surveillance, target detection, recognition or identification, missile guidance, …

This course comprises two parts:

The first part defines the main optical constituents of an infrared system: infrared scene, atmosphere, optics, detector. It follows the optical signal throughout the front part of the system, starting bythe infrared scene being observed, the basic properties of thermal radiation and its specifications in terms of radiometric (geometric and spectral) quantities.
Then, the main IR properties ofthe atmosphere, i.e. absorption and scattering, are described along with the resulting attenuation of useful signal and emission of stray light. Typical results of atmospheric spectral transmission obtained from Modtran software are shown in order to illustrate the influence of meteorological conditions upon the performances of IR systems operating inside the classical atmospheric windows (Short, middle, long wave IR bandwidths).
Third element of the infraredassembly, the lens is the optical antenna that collects input radiation; its main specifications, such as transmittance, aperture, focal length, resolution, field of view are being rapidly defined.
The detector is the last component to be described: it converts the optical signal from the lens into electrical, for processing. Among the two families of IR detectors (quantum and thermal), the emphasis is put here on quantum detectors, which are of better electro-optical performance: quantum efficiency, responsivity and noise equivalent power are defined.

The second part of the course deals with some basic rules in infrared system design:
At first, the output signal from IR detector is evaluated for a few typical configurations, according to the application at hand (detection or imaging device), usually based upon blackbody equivalent temperatures of backgrounds and targets. This modeling leads to the definition of the NETD, or difference in temperature resulting in unit SNR. Actual signal to noise ratio may then be deduced, which is the starting point for computing probability of detection and false alarm rate in the case of automatic IR detection systems, along with corresponding range equations. Particular case must be taken in order to maximize SNR, either through optical methods (thin film coatings) or matched filtering techniques.
In the case of more complex systems (man in the loop systems), for visual recognition or identification of targets onto a monitor, the performance of the system is not only specified by its thermal sensitivity, but also by its angular resolution. Typical criteria are recalled, as well as the

definition of a system's MRTD (minimum resolvable temperature difference), from which the designer will compute recognition, or identification ranges.

Intended audience:
This course is intended for research and development engineers and scientists who are involved in the design of infrared systems, and also for users of such systems who feel the need for a better understanding of the inside working parameters and specifications.

Jean-Louis MEYZONNETTE

J.L. Meyzonnette graduated in optics from the Institut d'Optique (Orsay, France) in 1968, and got a PhD from the Institute of Optics (Rochester, USA) in 1975. From 1975 upto 1990, he worked in research and development at the Optronics department of Thomson-CSF (now Thales Optronics SA), designing and in the field testing IR and laser equipments for defense applications. In 1990, he joined the Institut d'Optique as a professor, where he has been teaching optical radiometry and the design of electro-optical systems, at the master's level as well as in continuing education courses.