HETERODYNE TECHNIQUES IN THE I.R. BANDWIDTH FOR LASER OBSTACLE DETECTION

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ABSTRACT

In order to accomplish some tactical requirements a helicopter has to fly in a way to minimize the probability of detection: the most common technique is to fly as close to the ground as possible. This type of flight is hazardous due to both natural and human obstacles.
The techniques to detect low altitude obstacles are briefly reviewed in this report. Furthermore the results of studies on a Coherent Monostatic Laser Radar System at a 10.6 μm wavelenght is presented. We used experimental data for the atmospheric turbulence strength to achieve the detection probability as a function of distance for fixed false alarm probabilities values.

INTRODUCTION

The safety systems to avoid small obstacles (such as overhead wires) can be subdivided into the following categories:

- Mechanical Systems "Wire Cut" type
- Millimetric Waves Systems
- Electro-optical Systems

While the Mechanical Systems reduce damage to the aircraft, both the Millimetric Wave and Electro-optical Systems prevent the impact by alerting the pilot at a safe distance.
Millimetric Wave Systems have the ability to operate in poor visibility conditions, where aereosols, smokes, and, most of all, water are present in the atmosphere: they are virtually insensitive to the presence of these elements in the atmosphere. They have, on the other hand, the inconvenience of a poor resolution due to their wavelenghts: these are, indeed, of the same order of magnitude of the transversal dimension of the target.

It is possible to subdivide Electro-optical Systems into Coherent Detection Systems and Incoherent Detection Systems. Incoherent Detection Systems work with an illuminator (usually a laser beam) and the detection by Array Sensors (FLIR, Gated Image Amplifiers, Etc.) . Coherent Detection Systems work basically on the Heterodyne Detection principle. This kind of detection, very typical of Radar Detection, used at shorter wavelenghts, is usually called LADAR, or more specifically, Monostatic or Bistatic Coherent Optical Radar. They are called monostatic or bistatic depending on whether the output and the input beams share the outer opitcs or not.
As a part of a program, that will lead to the setting up of a prototype of a Monostatic Coherent Optical Radar at a wavelength of 10.6 μm, currently in progress at Agusta SpA- Unita' di Roma-, we did some reliability and operational studies. It is possible to obtain some useful information regarding the Signal to Noise Ratio required to achieve the proper Probability of Detection, for a fixed value of False Alarm Probability, as a function of the distance between the aircraft and the obstacle.
In this paper we will discuss the system response in some different operating conditions. It is possible to have some remarks on the preliminary specifications that should be stressed in the set up of the prototype.

DEFINITION OF SOME FUNDAMENTAL PARAMETERS

CNR = Carrier to Noise Ratio: quantity defined as:

$$\frac{\langle |y(t)|^2 \rangle}{\langle |n(t)|^2 \rangle}$$

Where n(t) is the Heterodyne Detector Shot Noise, y(t) is the contribution, at the detector, of the echo signal from the target.
The Carrier to Noise Ratio is a quantity that is a function of the emitted power of the Antenna-Beam , of the Target Cross Section, of a factor that takes into account the atmospheric speckle, and the Shot Noise Power of the Local Oscillator. In Figure (1) the CNR is shown as a function of the distance from the transmitter to the target, having different values of Atmospheric Absorption as a parameter.

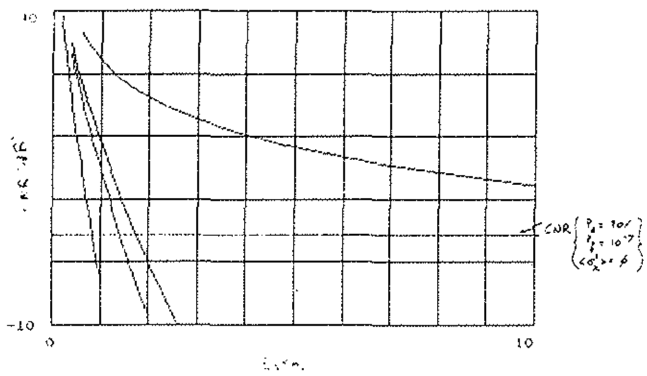

Figure (1): Carrier to Noise Ratio vs distance from the target to the transmitter, Atmospheric Absorption values (dB/Km) as parameters.

$\langle\sigma^2_\chi\rangle$ = Log-Amplitude Turbulence Variance. This quantity is a function of the Atmospheric Turbulence Variance Profile along the Laser propagation path. In Figures (2,3) $\langle\sigma^2_\chi\rangle$ is shown in day and night propagation cases, as a function of CNR, having the height from the ground as a parameter.

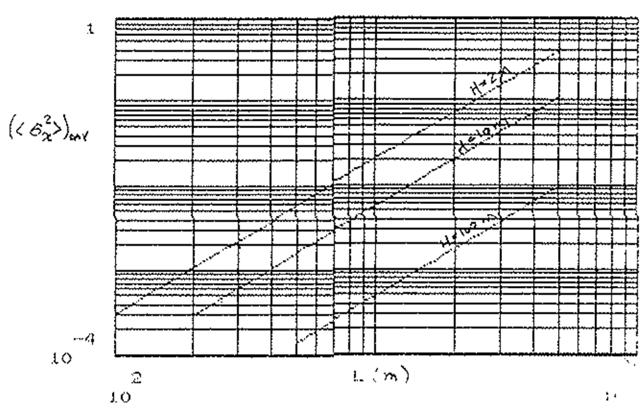

Figure (2) : $\langle\sigma^2_\chi\rangle$ vs Carrier to Noise Ratio (Day Case).

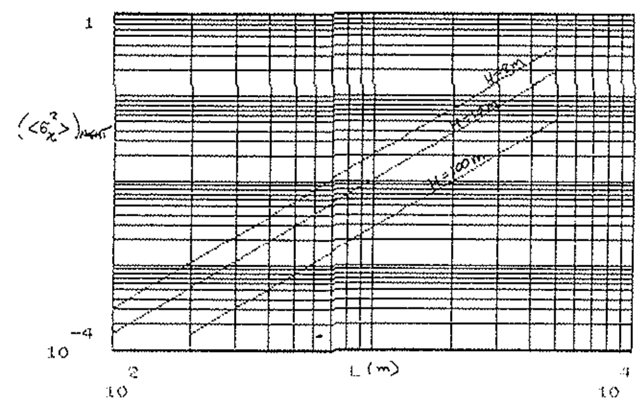

Figure (3): $\langle\sigma^2_\chi\rangle$ vs Carrier to Noise Ratio (Night Case).

P_F = Probability of False Alarm occurrence from the System. This is due to the exceeding of the detection threshold from the noise only.

P_D = Actual Probability of Detection of the target. In Figure (4) the quantity P_D is shown as a function of CNR, having the Log-Variance Turbulence of the tansmitting medium as a parameter.

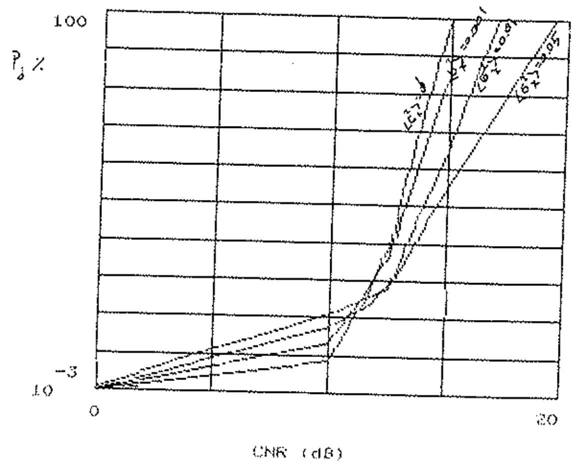

Figure (4): Probability of Detection vs Carrier to Noise Ratio, Log-Variance Turbulence as parameter.

In figure (5) the quantity CNR, needed to attain an actual Probability of Detection of 90%, with a False Alarm Probability of 10^{-7}, is shown as a function of the distance from the detector to target; the two curves refer to a variation profile of Log-Amplitude Variance $\langle\sigma^2_\chi\rangle$ typical for day and night ; the height from the ground is taken, in both cases, as 10 meters.

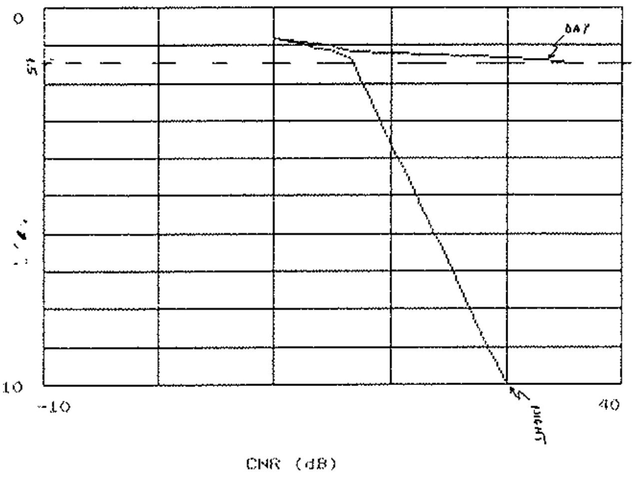

Figure (5): Carrier to Noise Ratio vs Target- Detector Range(P_d= 90%, P_F = 10^{-7})Night and Day Cases.

OPERATIVE MARGIN FOR THE SYSTEM

We shall consider the values, quoted in Table (1) valid for a typical Monostatic Coherent Optical Radar. It should be noted that those values are quoted as an exemple and they are not the design values for the Agusta Project.

Figure (1) shows , as a straight line, the CNR required for a Detection Probability of 10^{-7} in the Free Space (no turbulence at all).
We shall suppose in the following that the system has to be operative in the range from 0 to 1.5 Km.
The difference between the CNR, needed to have a 90% Detection Probability and a False Alarm Probability of 10^{-7} in the Free Space and the CNR corresponding to a null Attenuating Factor (β= 0 dB/Km) is the Operative Margin in the Free Space. From Figure (1) we note that the Margin is 18 dB. From the same Figure we notice that we have actually the same margin between the 0 dB/Km curve and the 2 dB/Km curve.

From the data we have from some Authors (Ref. (1,2)) the probability that the Atmospheric Attenuation is lower than 2 dB/Km is 70% in Summer and 55% in Winter.

We shall consider in the following example the Atmospheric Turbulence also. If we take the typical values for day turbulence we shall have an Operative Margin of 17 dB (see Figure (5)). We have the same

Table (1)

P_T.....Mean Power........................	1 W
η......Detector quantum efficiency........................	0.5
d......Diameter of the Receiver.........	5 cm
Γ......Transmittance efficiency of the Optical System..............	0.1
K_1.....Attenuating Factor due to speckle.................	0.5

margin between the 0 dB/Km attenuation curve and the 1.5 dB/Km attenuation curve (see Figure (1)). The probability of having an Atmospheric Attenuation less than 1.5 dB/Km is 45% in winter and 25% in summer (Ref. (1,2)).

From this very simple example it is easy to see how, even in the case of normal Atmospheric Turbulence, the laser beam propagation in the atmosphere has a relevent impact on System Performance. This means that the designer is obliged to overstimate the Operative Margin of the System in order to cover a wide range of operative scenarios.

REFERENCES

(1) J.W. Strohbehn (Ed.) "Laser Beam Propagation In The Atmosphere" (Springer Verlag 1978 N.Y.).

(2) J.L. Spencer "Long Term Statistics Of Atmospheric Turbulence Near Ground" Report RADC-TR-78-182 Rome Air Development Center (Aug. 1978).