THE OBSTACLE AVOIDANCE RADAR

A SAFETY MEAN FOR LOW ALTITUDE FLIGHTS

IN ADVERSE WEATHER CONDITIONS

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ABSTRACT

The use of helicopters at low altitude is increasing. Such operations have always faced the hazard of wires and obstacles hardly visible even in daylight.

Development of helicopter capabilities, at night and in adverse weather, call for a sensor providing the pilot with safe detection and precise localization of obstacles.

THOMSON-CSF has developed ROMEO, an obstacle avoidance radar meeting these requirements. Using millimeter wave technology ROMEO will reduce the risk of low level tactical flights or Emergency Medical Services Operations, particularly in adverse weather conditions.

INTRODUCTION

In its last annual survey of military accidents, the FLIGHT INTERNATIONAL review highlighted the number of night wire-strike accidents supported by combat helicopters in 1989. It was emphasized that the new technology brings the ability to fly nap-of-the-earth profiles at night or in poor visibility, even though technical enhanced vision is still not as good as normal day vision.

However, all helicopters, civilian as well as military ones, are concerned by wire strike accidents, even in day light. In so far as they are fitted with equipment increasing their flight domain, helicopters will take a greater risk facing up to unvisible obstacles.

For several years, THOMSON-CSF has been developing an obstacle avoidance radar for helicopter, based on the millimeter wave technology. The ROMEO radar, as described in this paper, has the capability to detect small obstacles and wires. Thus, this equipment could be a mean to increase the flight safety :

- in all types of low altitude flights
- in all adverse weather conditions
- aboard most of low-flying helicopters.

1. THE NEED

With its ability to fly at low speed, the heliccpter is a wonderful aircraft. The range of missions it can perform is very large and always increasing. Nowadays, every modern army forces use combat helicopters.

In the same time, civilian helicopters are used for off-shore oil rig support duties, Emergency Medical Services, law enforcement and many other types of flight.

But when they can fly slowly, they can fly low. And unfortunately, helicopters are there flying in a volume which is scattered with traps like wires, power lines, bracing wires, antennas, masts and so on. Their domain is widely extended. Our european ccuntries look like a lethal spider's web (Fig. 1). Power lines can be higher than 100 m above ground, particularly in mountainous terrain.

And in fact, even in day light, wires are difficult to see because of their small size. That is why the best way to detect them with eyes is to search pylons. But when wires are seen, they are also difficult to localize and to avoid because of the lack of perspective in looking at a long thin object.

Fig. 2 : Power lines represent a lethal spider's web

Thereby wires and other alike obstacles have caused many accidents. In Vietnam, an alleged sole power line was involved in 14 wire strikes, in a 6 year period, inducing 55 fatalities. Every year, several helicopters are destroyed during wire strike accidents and alas, there will be some others in the future. This is why an obstacle avoidance system might be necessary to improve the helicopter flight safety.

A simple solution could be to fly higher. It is easy to talk about but impossible to do in some types of mission. An other solution could be to put wires in the earth. Large and expensive work. It is also possible to cut them. Some helicopters are already fitted with wire cutters. This system has proven its efficiency but has also shown it was not a fully safe solution because it depends on the helicopter velocity.

Besides this hazard, the modern technology enables helicopters to fly nap-of-the-earth, at night or with a poor visibility. Consequently, the danger caused by wires, unsolved in day light, is more important in adverse weather conditions.

It is therefore necessary to provide crews with an information or warning about obstacles along and around the flight path. Without an obstacle avoidance system, helicopter pilots would have to choose between staying on the airfield when the visibility is insufficient or flying with a high risk degree to hit wires.

2. WHY MILLIMETER WAVES ?

The Radar and Counter-Measure Division of THOMSON-CSF has formerly had a good background knowledge about millimeter wave technology, especially in missile seeker development. This technology has appeared to be able to achieve the obstacle avoidance system requirements :

- Detection and localization of small wires

- 100 % reliability

- all adverse weather conditions

- low weight, low volume, affordable cost

- low workload man-machine interface

Detection and localization of obstacles requires an active sensor to provide distance as well as directional information. At the same time, the system must have a good angular resolution to increase the accuracy of small sized obstacle detection. This can be reached using high frequency radio waves.

However, the propagation characteristics of radio waves have also to be taken into account because these conditions become progressively worse as the frequency increases. But in some "windows", the atmospheric attenuation falls to relatively moderate values. These windows are located around 35, 94, 140 and 220 GHz (Fig. 2).

Rain attenuation depends on the rain rate and remains roughly constant over 70 GHz. It is not the same for fog. That attenuation increases continuously with the frequency (Fig. 3). So, the attenuation caused by a foggy weather is much lower in the millimeter wave band than in the Infra Red one. It is the same with smoke and dust.

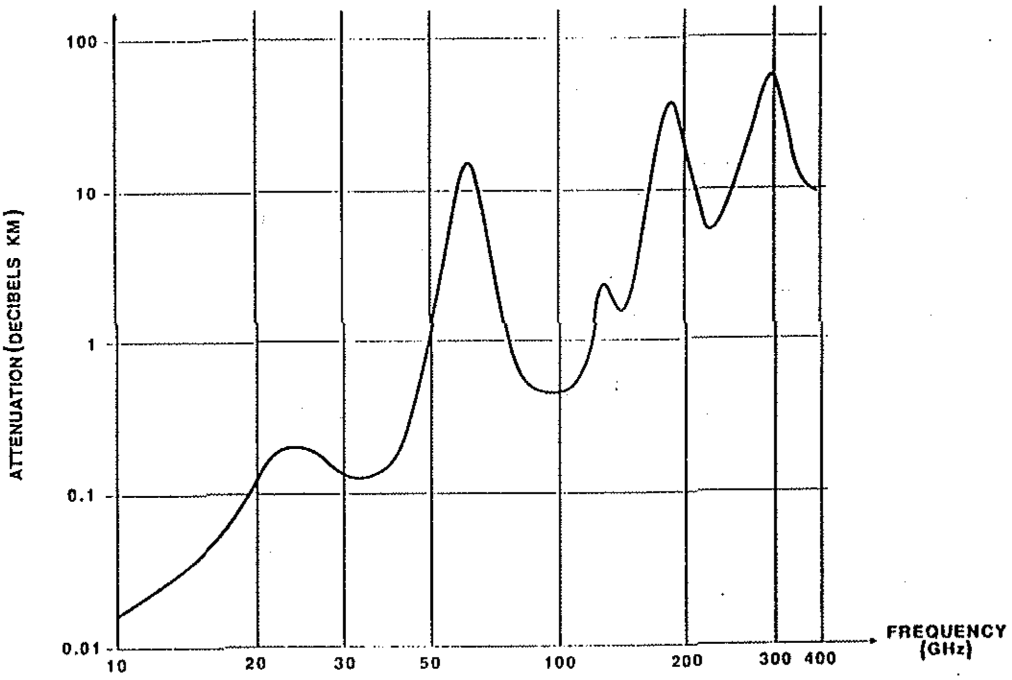

Fig. 2 : Atmospheric attenuation

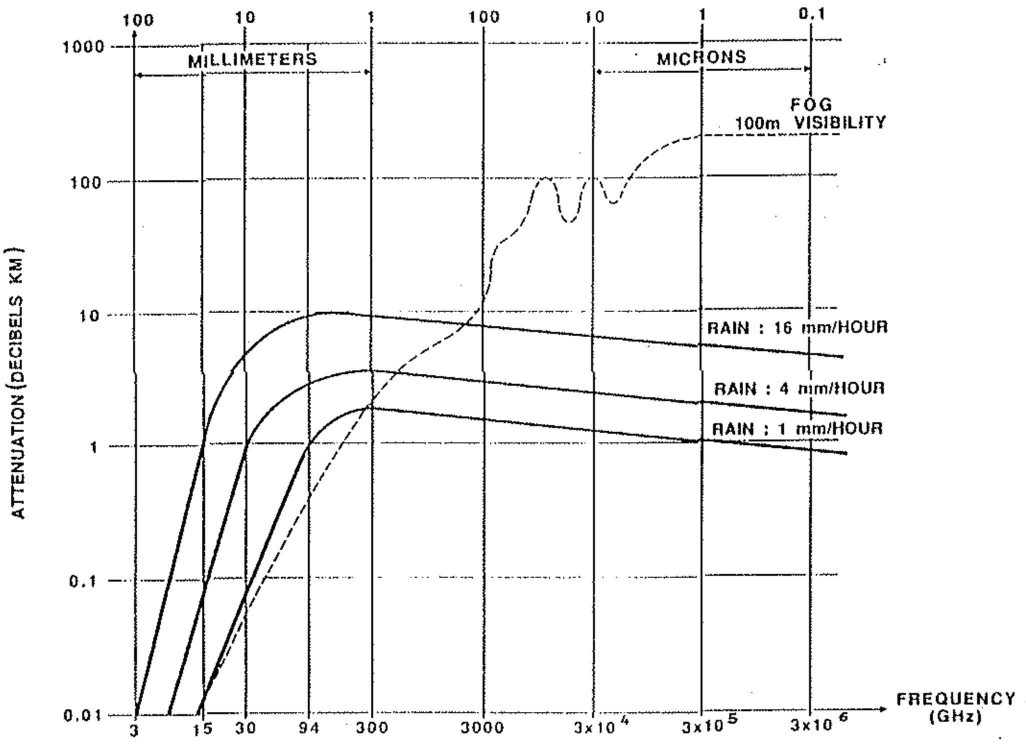

Fig. 3 : Rain and Fog attenuations

For these reasons, THOMSON-CSF judge that 94 GHz is the optimum band where atmospheric attenuation values remain acceptable for the detection range requirements of an obstacle avoidance system over a wide range of weather conditions. Furthermore, this frequency allows the design of a radar with small dimensions and good angular resolution which can be easily installed aboard helicopters. So, the company decided to develop, with its own funds, an obstacle avoidance radar in the 94 GHz band, dubbed ROMEO (Radar à Ondes Millimétriques d'Evitement d'Obstacles, i.e. Obstacle Avoidance Millimeter wave radar).

3. THE ROMEO RADAR

After ground tests with a mock up to validate design predictions, a radar prototype has been designed and built to be flight tested aboard a PUMA helicopter.

The ROMEO radar is made of three sub-assemblies (Fig. 4) :

- a front end assembly, including antenna, transmitter, receiver, and servomechanisms

- a digital processing unit

- a control box

To provide satisfactory data on obstacles along and around the flight path, the antenna must scan a sufficiently large volume in front of the helicopter. As the aperture of this antenna is around 10 m-radians, the scanning speed is optimized to cover the whole volume in a domain of 90° in azimuth and 30° in elevation (Fig. 5). If necessary the scanning domain could be reduced in order to accelerate the renewal time.

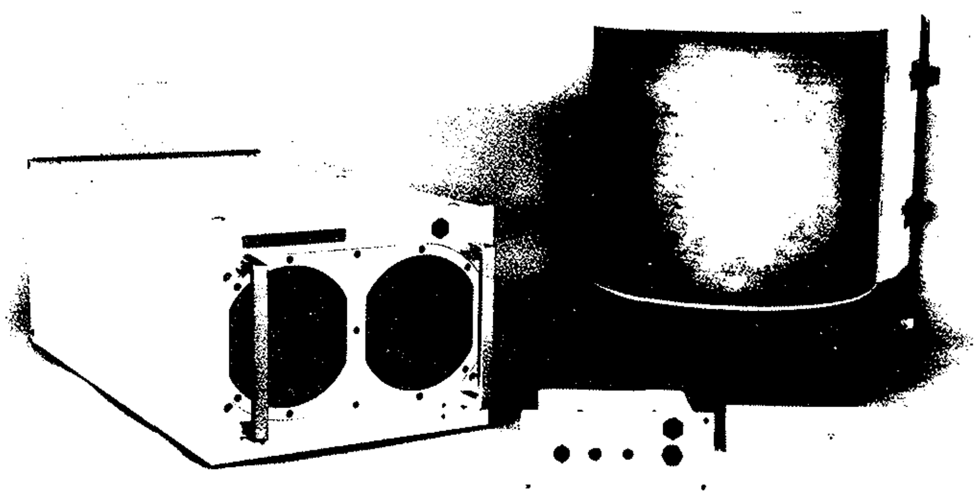

Fig. 4 : ROMEO radar components

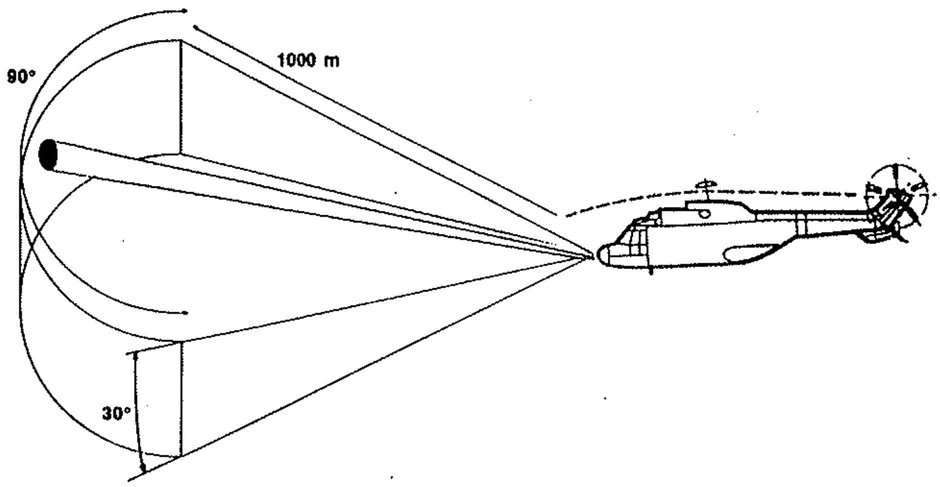

Fig. 5 : Volume scanned by the radar

The transmission is a continuous wave type, with a linearly modulated frequency (sawtooth). Thus, the radar works like a conventional pulsed radar but this technique allows use of a continuous wave solid state source with a very low peak power (less than 1 w).

At the output of a spectrum analyser, the analogue signal is converted to a digital format. Then, the processing unit makes the necessary operations to display on a CRT all the information extracted in the three dimensional volume.

Obstacle echoes are encoded with graduated green colour, according to their distance. Aerial obstacle echoes, identified by the difference of distance with bordering echoes, are encoded with red. The information is displayed to the pilot, either in a photographic display (azimuth and elevation) or in a sector PPI display (azimuth and distance).

Flight tests began in 1987, at the French CEV (Flight Test Center) in Bretigny (Fig. 6). Purposes of these tests were :

- to verify the equipment performance in different weather conditions

- to check the detection capability on wires of different radar Cross Sections (RCS)

- to test several types of display

These tests confirmed the theoretichal computations that had been performed during the design phase. Power lines were detected at distances over 500 meters, depending on their RCS. In the same time, the RCS variation of different types of wires was also evaluated against various azimuth angles of view.

Fig. 6 : ROMEO in flight tests

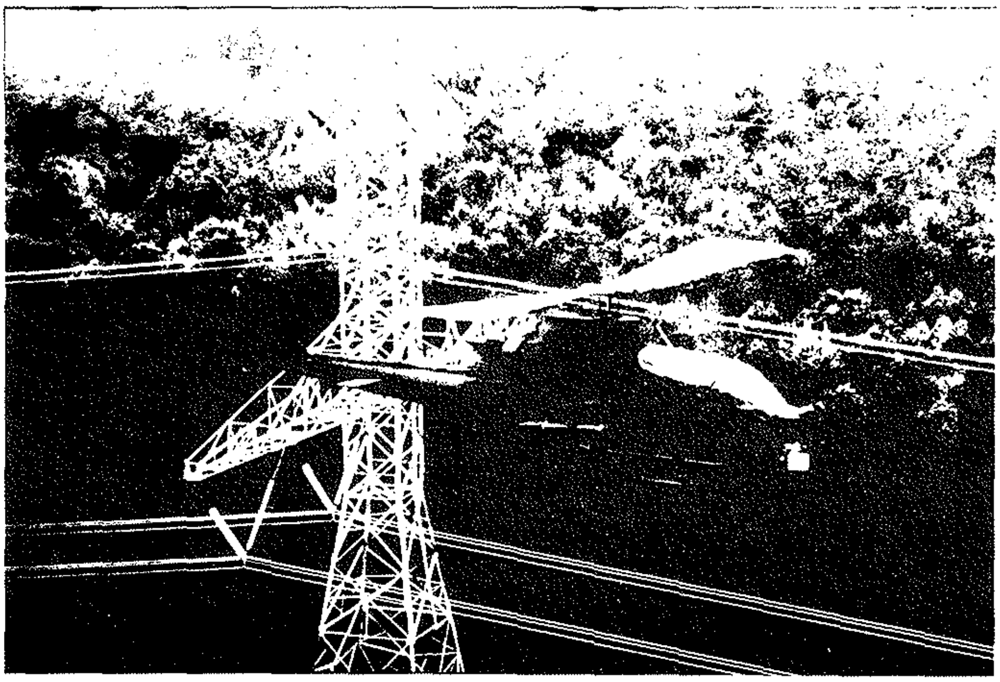

Fig. 7 : ROMEO on a COBRA helicopter

The French flight test programme ended in 1988. In 1989, the radar was also tested by the US Army at Fort Belvoir, as part of the Foreign Weapon Evaluation. ROMEO was installed aboard a COBRA helicopter to demonstrate its detection capability (Fig. 7).

During the former flight tests, the French Army Aviation, ALAT, made a favourable judgement of the prototype and showed its interest for an obstacle avoidance system. It was therefore decided to continue the development of this equipment.

A new designed radar has been ordered and funded by the French Administration : DGA/STTE. More than a demonstrator for sensor capabilities, the new ROMEO will be a real obstacle avoidance system. Several improvements will substantially increase the warning time to be given to the pilot. This will be achieved by different means. The explored volume is to be expanded up to 180° in azimuth while the scanning time will be reduced to 1,5s. Thanks to an energy budget improvement, detection range will be increased. And finally, other functions, such as weather avoidance, ground mapping, will be added.

This up-graded millimeter wave radar will be fully compliant with the operational obstacle avoidance requirements, even in all adverse weather conditions.

4. DESIGNING THE MAN MACHINE INTERFACE

A good obstacle avoidance system must display the information to the crew in an easily available way. This will be another purpose of the new ROMEO radar development. The question is: how to present the right information to the pilot ?

On one hand, the ROMEO radar is able to detect, recognize and localize obstacles and wires in a three dimensional volume, whatever the weather conditions. On the other hand, among his workload, the pilot must receive that information to control the aircraft and avoid the obstacle safely.

This is undoubtedly a difficult and sensitive problem to solve. As in other man-machine interface problems, one is in a realm of subjective judgement, and there are no precedents for this particular application. All solutions must be evaluated. In this research, simulators provide valuable assistance in developing an optimum presentation to pilots.

For instance, the information could be displayed with different means. Firstly, it is mandatory to alert the crew when there is an obstacle on the flight path. This could be done by a warning light and/or an aural warning message. Secondly, the obstacle position is to be displayed to the pilot. This could be achieved by a head down display. The pilot could receive the information with either a photographic or PPI display. But a head up display, NVG with symbology or Helmet mounted display could also present a synthetic information to the pilot.

In an other way, the processing unit could elaborate control instructions to guide the pilot in avoiding the obstacle. These instructions could be displayed on the equipment formerly described. Lastly, these control instructions could be linked to the AFCS, to have a full automatic obstacle avoidance system.

However the man machine interface must take into account the equipment of the aircraft. Head down display, Head up display and Helmet mounted display are not fitted on each helicopter. A less expensive mean to present the information is perhaps to be defined, in order that light or civilian helicopters could be equiped with the obstacle avoidance system.

For this side of the problem, there is no precise requirement. The users' point of view is therefore a main step for this research.

CONCLUSION

Having formerly demonstrated the capability of the millimeter wave technology and the short term feasability of a wire detection system, THOMSON-CSF is now designing and developing an obstacle avoidance system to meet the operational requirements.

Particularly, this system will detect and localize small obstacles like wires either carrying power or "dead", at a range which is compatible with the helicopter flight velocity, and radar performances will be maintained in all adverse weather conditions.

However, the right man-machine interface is still to be defined in order that pilots could operate their aircraft and avoid obstacles with great confidence. This man-machine interface design could never be perfectly achieved but with users' assistance.

So, with this obstacle avoidance system helicopters will have an increased safety level in every low altitude flight, and the capability of ROMEO in all adverse weather conditions will enable to extend the flight domain at night or in poor visibility without further risk.