CORAC Aéronautique Environnement Recherche — DASSAULT AVIATION — AIRBUS HELICOPTERS

ONERA THE FRENCH AEROSPACE LAB — THALES — OKTAL-SE Synthetic Environment

IKKY PROJECT MILLIMETRIC WAVE RADAR FOR ENHANCED FLIGHT VISION SYSTEM 31.8-33.4GHz

FSMP WG/6 – 8-15 february 2018

What is EFVS ?

- EFVS is a system composed of a head-up display (HUD) and an imaging sensor
- The image from the sensor is displayed to the pilot with superposed navigation and guidance information
- It enables lower decision heights and reduced runway visual range…
- and thus provides increased accessibility to the airport in low visibility conditions, especially to little and mid-size ones unequipped with CATII/III ILS

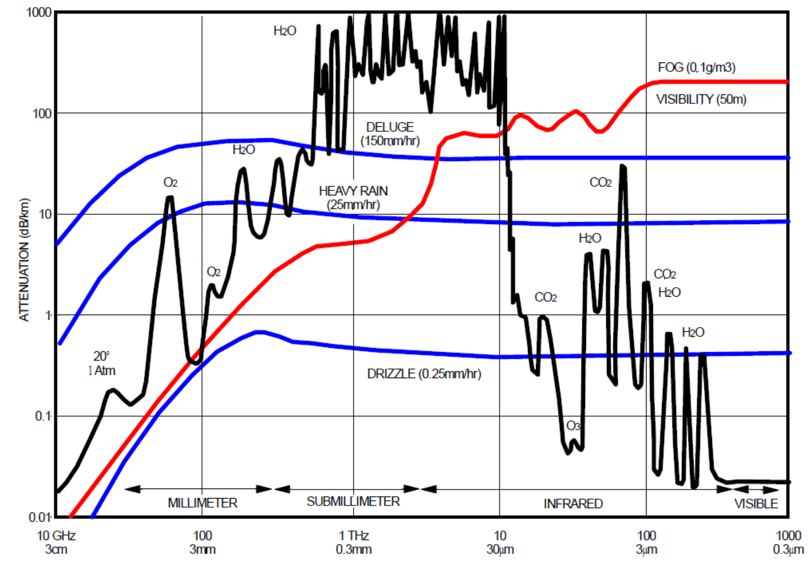
In 2017, *Falconeye* EFVS has been certified by EASA and FAA for use on Falcon 2000 and Falcon 8X.

What are the benefits of radar technology for EFVS ?

- In some bad weather conditions (low clouds, fog, …) current Infrared/Electro-Optical technology offers limited operational benefit because of weak atmosphere penetration.
- radar technology gives operational credit in those bad weather conditions.

Ka band for RADAR EFVS

- Ka band is the best compromise between range/atmosphere penetration and angular resolution.



- For technical and technological reasons, Ka band allows the development of affordable antenna arrays with no mechanical gimbals, which make it easier to integrate on an aircraft

What is FAA's position ?

- About EFVS in general :

*« On December 13, 2016, the Federal Aviation Administration (FAA) published a final rule to permit operators to use an **Enhanced Flight Vision System** in lieu of natural vision to continue descending from 100 feet above the touchdown zone elevation to the runway and to land on certain straight-in instrument approach procedures under instrument flight rules. »*

Federal Register / Vol. 82, No. 25

- About radar technology for EFVS in particular :

*«Current enhanced flight vision systems use infrared-based (IR-based) sensors. While IR-based sensors provide the required enhanced flight visibility in certain visibility-limiting conditions, they currently do not provide the enhanced flight visibility required by the operating rules for EFVS to support operations in lower visibility ranges. Industry is developing other sensor technologies, **such as millimeter wave radar**, that are not limited in the same ways that IR-based sensors are limited. These efforts are still developmental, but show promise.»*

NPRM Federal Register / Vol. 78, No. 112 / Tuesday, June 11, 2013

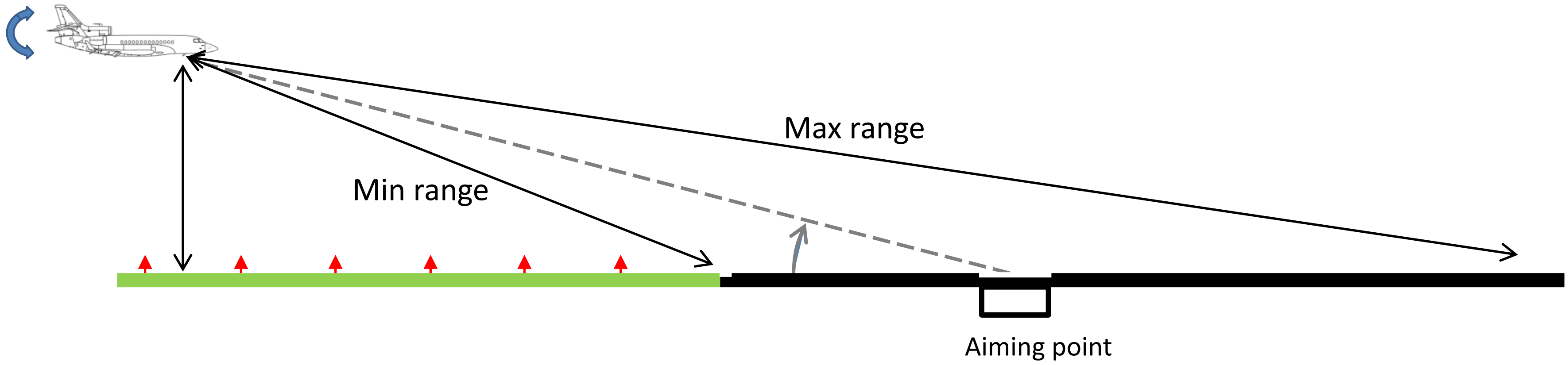
What is being studied in the IKKY project ?

- Operational need specification
- Radar specification
- Integration constraints
- Ground reflectivity on airports
- Radar definition and integration study
- Radar measurements with a mock up
- Simulation
- Sharing studies with other services

Operational need specification

The operational need has been specified in terms of :

- Radar image caracteristcs good enough for the pilot to indentify the runway :
  - Size : min and max range, azimuth and elevation angular coverage
  - Range and angular resolution
  - Signal to noise ratio and contrast
- Image rate
- Heavy weather conditions (fog, clouds, rain, snow)



Radar Specification

The radar has been specified to respond to operational need in terms of :

- Peak power
- Wave form
- Instantaneous antenna coverage
- Scanning rate
- Antenna size

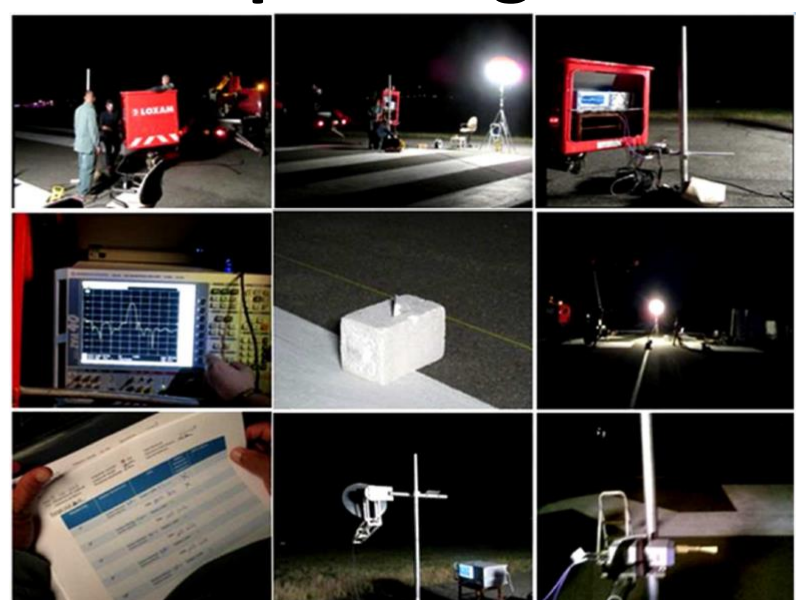
Integration constraints

- Different potential locations for the radar on the aircraft have been studied.
- Corresponding constraints in terms of size, shape, weight and scanning technology have been taken into account for the radar design.

Ground reflectivity

Radar ground reflectivity measurements at very low grazing angle have been carried out at LFCL, on the runway and on the grass, in dry and wet conditions.

→ **Measured contrast is sharp enough**



Radar definition and integration study

- Various radar solutions have been considered and compared in term of :
  - Performance
  - Integration complexity
  - Cost
- Results of the study are :

→ Radar architecture detailed design

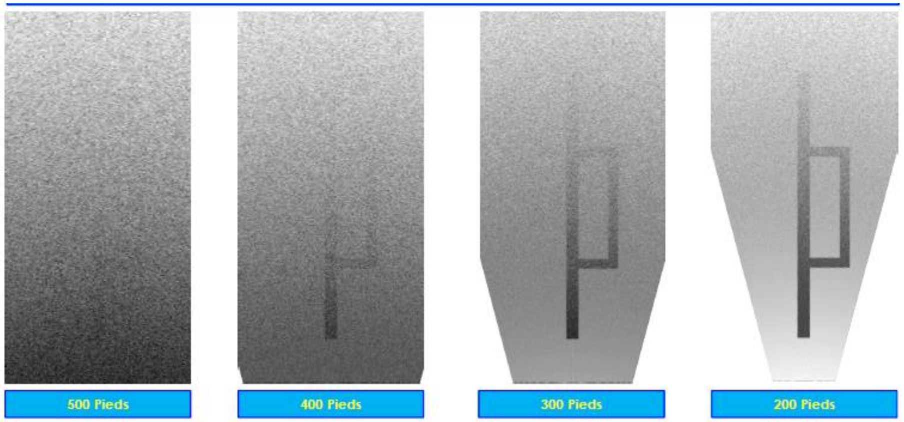
→ Interface definition :

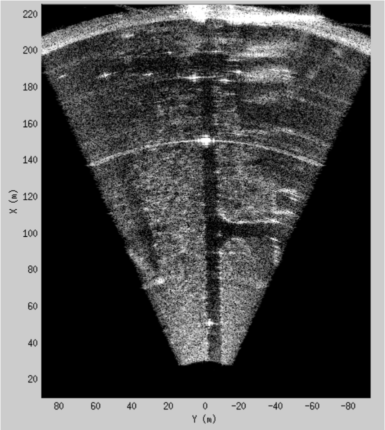
  - Mechanical
  - Electric Power supply
  - Functional

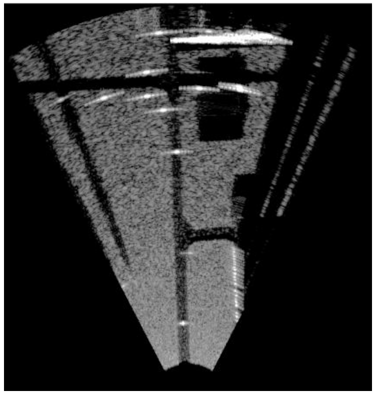
→ Aircraft CAD model with integrated radar

Radar measurements and simulation

- Radar imagery with a mock up have been carried out
- Sharp models of the radar and of the environment are under development
- Environment model is compared to real measures



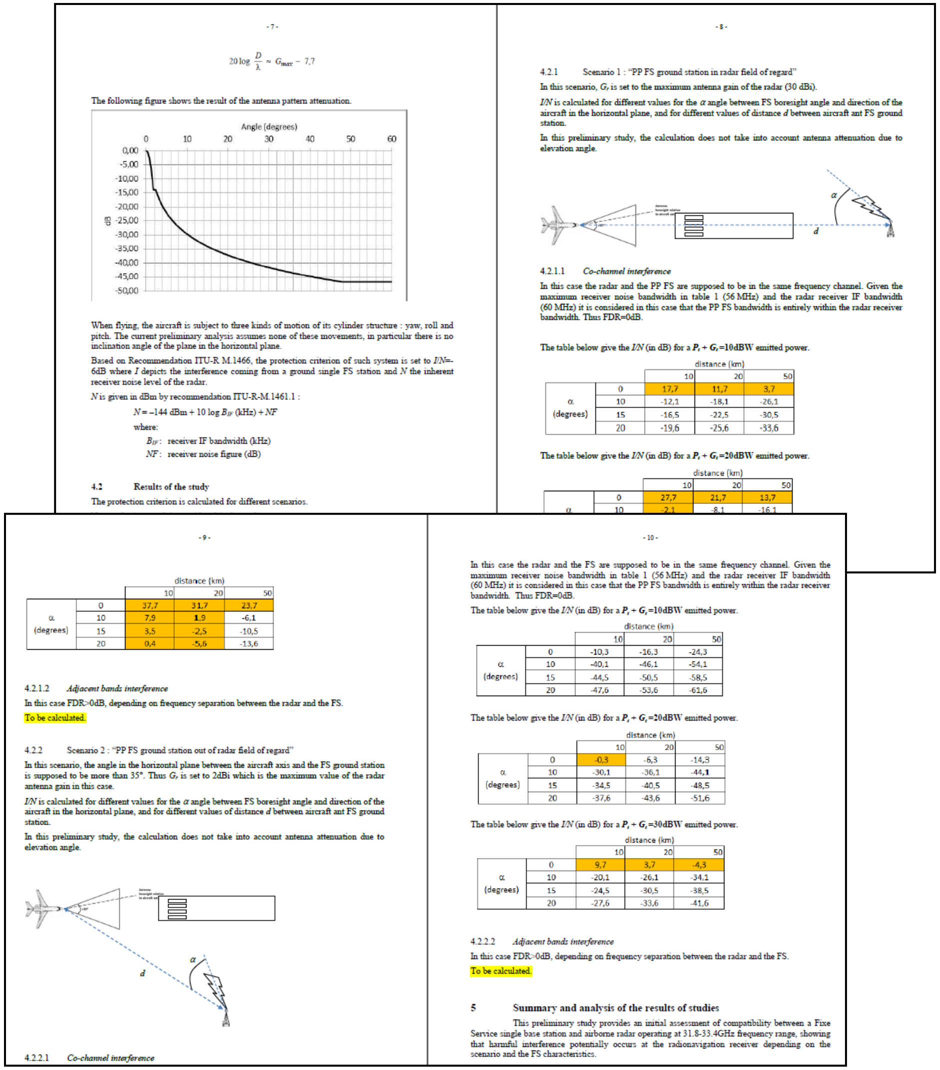




- Models will help to confirm that radar design is consistent with pilot need in various conditions

Sharing Studies with Fix Service

Sharing studies are being conducted and provide an first assessment of compatibility between a Fixe Service single base station and airborne radar operating at 31.8-33.4GHz frequency range.



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$$20 \log \frac{D}{\lambda} \approx G_{max} - 7{,}7$$

The following figure shows the result of the antenna pattern attenuation.

When flying, the aircraft is subject to three kinds of motion of its cylinder structure : yaw, roll and pitch. The current preliminary analysis assumes none of these movements, in particular there is no inclination angle of the plane in the horizontal plane.

Based on Recommendation ITU-R M.1466, the protection criterion of such system is set to I/N=-6dB where I depicts the interference coming from a ground single FS station and N the inherent receiver noise level of the radar.

N is given in dBm by recommendation ITU-R-M.1461.1 :

$$N = -144 \text{ dBm} + 10 \log B_{IF} \text{ (kHz)} + NF$$

where:

B_{IF}: receiver IF bandwidth (kHz)

NF: receiver noise figure (dB)

4.2 Results of the study

The protection criterion is calculated for different scenarios.

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4.2.1 Scenario 1 : "PP FS ground station in radar field of regard"

In this scenario, G_r is set to the maximum antenna gain of the radar (30 dBi).

I/N is calculated for different values for the α angle between FS boresight angle and direction of the aircraft in the horizontal plane, and for different values of distance d between aircraft ant FS ground station.

In this preliminary study, the calculation does not take into account antenna attenuation due to elevation angle.

4.2.1.1 *Co-channel interference*

In this case the radar and the PP FS are supposed to be in the same frequency channel. Given the maximum receiver noise bandwidth in table 1 (56 MHz) and the radar receiver IF bandwidth (60 MHz) it is considered in this case that the PP FS bandwidth is entirely within the radar receiver bandwidth. Thus FDR=0dB.

The table below give the I/N (in dB) for a $P_t + G_t$=10dBW emitted power.

		distance (km)		
		10	20	50
α (degrees)	0	17,7	11,7	3,7
	10	-12,1	-18,1	-26,1
	15	-16,5	-22,5	-30,5
	20	-19,6	-25,6	-33,6

The table below give the I/N (in dB) for a $P_t + G_t$=20dBW emitted power.

		distance (km)		
		10	20	50
α	0	27,7	21,7	13,7
	10	-2,1	-8,1	-16,1

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		distance (km)		
		10	20	50
α (degrees)	0	37,7	31,7	23,7
	10	7,9	1,9	-6,1
	15	3,5	-2,5	-10,5
	20	0,4	-5,6	-13,6

4.2.1.2 *Adjacent bands interference*

In this case FDR>0dB, depending on frequency separation between the radar and the FS.

To be calculated.

4.2.2 Scenario 2 : "PP FS ground station out of radar field of regard"

In this scenario, the angle in the horizontal plane between the aircraft axis and the FS ground station is supposed to be more than 35°. Thus G_r is set to 2dBi which is the maximum value of the radar antenna gain in this case.

I/N is calculated for different values for the α angle between FS boresight angle and direction of the aircraft in the horizontal plane, and for different values of distance d between aircraft ant FS ground station.

In this preliminary study, the calculation does not take into account antenna attenuation due to elevation angle.

4.2.2.1 *Co-channel interference*

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In this case the radar and the FS are supposed to be in the same frequency channel. Given the maximum receiver noise bandwidth in table 1 (56 MHz) and the radar receiver IF bandwidth (60 MHz) it is considered in this case that the PP FS bandwidth is entirely within the radar receiver bandwidth. Thus FDR=0dB.

The table below give the I/N (in dB) for a $P_t + G_t$=10dBW emitted power.

		distance (km)		
		10	20	50
α (degrees)	0	-10,3	-16,3	-24,3
	10	-40,1	-46,1	-54,1
	15	-44,5	-50,5	-58,5
	20	-47,6	-53,6	-61,6

The table below give the I/N (in dB) for a $P_t + G_t$=20dBW emitted power.

		distance (km)		
		10	20	50
α (degrees)	0	-0,3	-6,3	-14,3
	10	-30,1	-36,1	-44,1
	15	-34,5	-40,5	-48,5
	20	-37,6	-43,6	-51,6

The table below give the I/N (in dB) for a $P_t + G_t$=30dBW emitted power.

		distance (km)		
		10	20	50
α (degrees)	0	9,7	3,7	-4,3
	10	-20,1	-26,1	-34,1
	15	-24,5	-30,5	-38,5
	20	-27,6	-33,6	-41,6

4.2.2.2 *Adjacent bands interference*

In this case FDR>0dB, depending on frequency separation between the radar and the FS.

To be calculated.

5 Summary and analysis of the results of studies

This preliminary study provides an initial assessment of compatibility between a Fixe Service single base station and airborne radar operating at 31.8-33.4GHz frequency range, showing that harmful interference potentially occurs at the radionavigation receiver depending on the scenario and the FS characteristics.

Sharing Studies with Fix Service

Preliminary conclusions of the studies show that harmful interference potentially occurs at the radionavigation receiver.

→ **separation rules based on :**

- **minimum distance between runway and Fix Service ground station,**
- **maximum Fix Service emitted power in the vicinity of an airport,**
- **Fix Service antenna side lobe attenuation,**
- **frequency separation**

have to be established.

What is the next step ?

- Development and integration of an airborne demonstrator according to the defined radar design
- Carrying out of flight trials in various approach and weather conditions.
- To carry on sharing studies with Fix Service