Proceedings of ISAP2007, Niigata, Japan

1E5-3

RCS COMPUTATION OF AIRCRAFT AND HELICOPTER ROTATING BLADES

P. POULIGUEN, J.F. DAMIENS
DGA - Centre d'Electronique de L'ARmement (CELAR)
35170 Bruz, FRANCE
Tel: 33 (2) 99 42 96 34 fax: 33 (2) 99 42 90 94
Philippe.pouliguen@dga.defense.gouv.fr
Jean-françois.damiens@dga.defense.gouv.fr

1 INTRODUCTION

Radar Cross Section (RCS) of helicopter rotors and aircraft propellers have been the subject of numerous theoretical and experimental studies [1-4] in the last years. This research arises from the characteristics of helicopter and aircraft radar signatures that facilitate their identification. Indeed, RCS of these kinds of targets may be separated into a fuselage component at the incident wave frequency and harmonics arising from the amplitude and phase modulations of the scattered signal. These harmonics are functions of the blade number, their angular rotational frequency and also of their buckling during flight configurations. A high frequency model, based on Physical Theory of Diffraction (PTD), has been developed to calculate the time-dependent RCS of such targets [4]. The problem is treated using the quasi-stationary approach [1] and a realistic blade cinematic. Then, the spectral responses are analyzed through "time - Frequency" maps. The influence of the blades buckling, versus flight configuration, is particularly analyzed.

2 RCS CALCULATION PRINCIPLE

Figure 1 shows the general geometry of the radar scattering by two propeller engines, composed of 6 blade helix of diameter 3.93m, which rotate with an angular velocity Ω=984 tr/mn. Figure 2 shows the general geometry of the radar scattering by helicopter main and tail rotors. The main rotor, composed of 4 blades, has a diameter equal to 15.50m which rotates with an angular velocity Ω=250 tr/mn. The tail rotor, composed of 5 blades, has a diameter equal to 3m which rotates with an angular velocity Ω=1200 tr/mn. The time-dependent RCS is calculated thanks to the quasi-stationary approach [1], since the rotating velocity is much less than the velocity of light and the angular frequency of rotation is very small compared to the angular frequency of the radar wave. At each instant, the coordinates of each node of the engines meshing are calculated via a flight cinematic model and the electromagnetic fields scattered by the rotating blades are calculated by assuming the blades frozen in their tracks. The EM scattered fields are calculated thanks to the Physical Optics (PO) and the Method of Equivalent Currents (MEC). This has already been described in

ISBN: 978-4-88552-223-9 C3055©IEICE

[4]. For great bistatic angles, RCS is calculated by applying the Babinet principle.

Helix diameter = 3.93m
Rotating speed = 984 tr/mn
Aircraft speed = 169 m/s

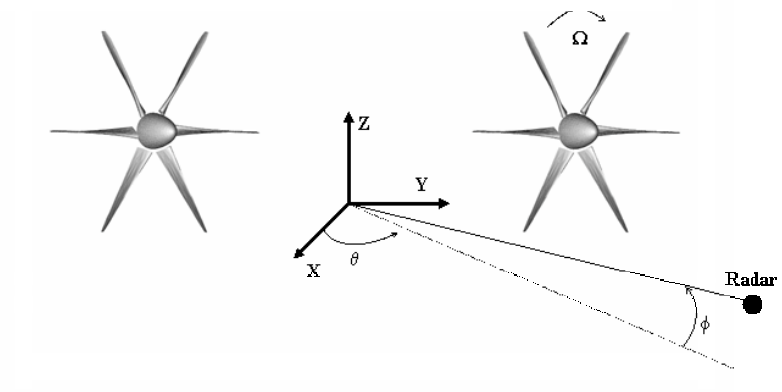


Figure 1: EM scattering by 2 propellers

Main rotor *diameter = 15.50m*
Rotating speed = 250 tr/mn

Tail rotor *diameter= 3m*
Rotating speed = 1200 tr/mn

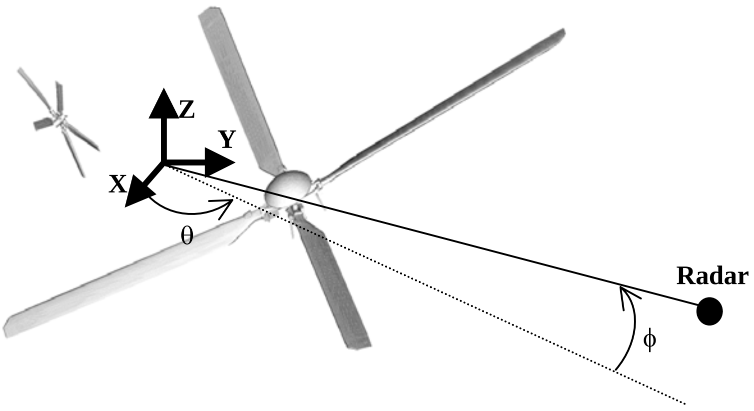


Figure 2: EM scattering by helicopter main and tail rotors

Figure 3 shows “time-dependent” monostatic RCS diagrams of the two propeller engines, at 10 GHz, for site null and azimuth angle equal to 45°. The diagrams are plotted on a rotation period, for two distinct flight configurations “ascent (in red) and descent (in blue)”. These diagrams present 6 peaks corresponding to the specular reflection on each blade. These peaks are shifted according to the flight configuration.

Figure 4 shows “time-dependent” monostatic RCS diagrams of helicopter rotors, at 6 GHz, for site and azimuth nulls. The diagrams are plotted on a rotation period of the main rotor, for a forward translation flight configuration (figure 4a) and for an auto rotation flight (figure 4b)”.

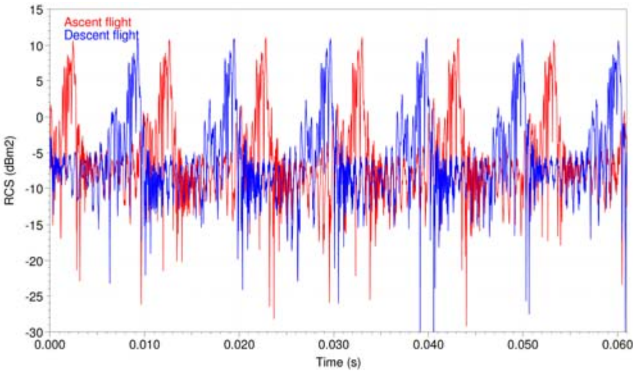
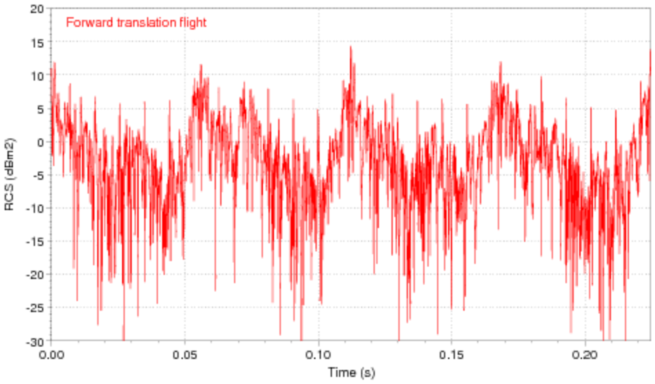
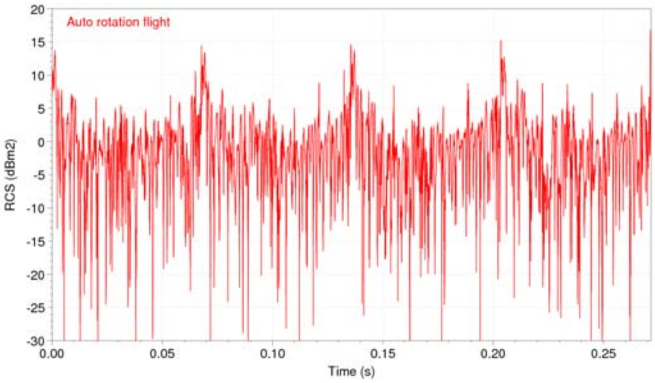


Figure 3: RCS of the two propeller engines at 10 GHz, site null, azimuth 45°, ascent flight (in red) and descent flight (in blue)



a) forward translation flight

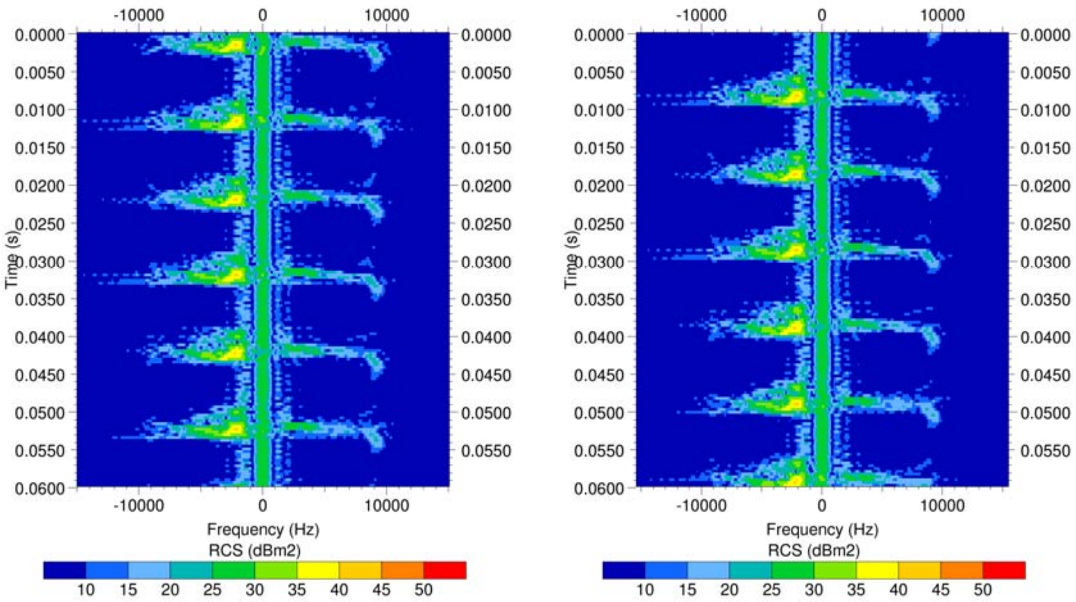


b) auto rotation flight

Figure 4: RCS of the helicopter rotors versus time at 6 GHz

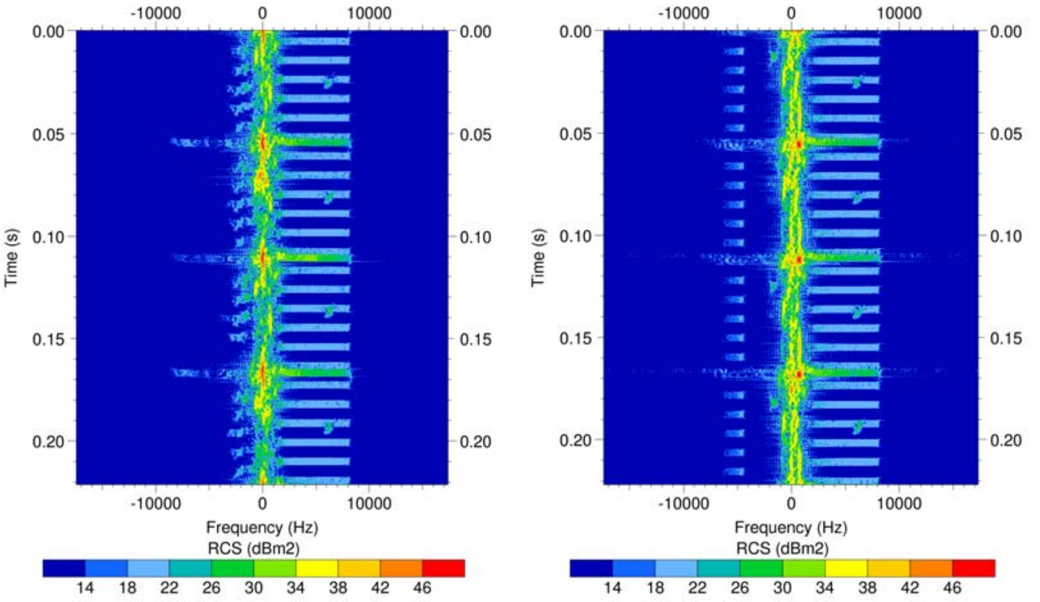
3 SPECTRAL ANALYSIS

Spectral signatures are analyzed through "time - Frequency" maps, which are calculated by segmenting the time domain data into sliding windows of N points and transforming them into the frequency domain [3]. These representations allow isolating each engine component (flashes of incoming and outgoing blades, blade extremities, hub…) in function of its position in time and frequency. Figure 5 shows such maps, calculated from the time-dependent RCS of the two propeller engines given in figure 3, with N=64 FFT points and a shift of 20 temporal samples between two windows. Figure 6 shows “time frequency” maps calculated from the time-dependent RCS of helicopter rotors plotted in figure 4.



a) Ascent flight b) Descent flight

Figure 5: "time - Frequency" maps of the two propeller engines at 10 GHz



a) forward translation flight b) auto rotation flight

Figure 5: "time - Frequency" maps of the two rotors at 6 GHz

4 REFERENCES

[1] J. Van Bladel, "Electromagnetic Fields in the Presence of Rotating Bodies", Proceeding of the IEEE, Vol. 64, No. 3, pp. 301-318, Mar. 1976.

[2] S.S. Bor, T.L. Yang, S.Y. Yang, "Radar Cross-Sectional Spectra of Rotating Multiple Skew-Plated Metal Fan Blades by Physical Optics / Physical Theory of Diffraction, Equivalent Currents Approximation", J. Appl. phys. Vol. 31, pp. 1549-1554, Part 1, No. 5A, May 1992.

[3] J. Pentalone, "Doppler and MTI Radar Cross-Section Simulation, Measurement, and Analysis of Rotating Bodies and Bodies in Motion", Conference paper, NIST, Boulder, Co., USA, pp. 2-43 to 2-46, 1992.

[4] P. Pouliguen, L. Lucas, F. Muller, S. Quete and C. Terret, "Calculation and Analysis of Electromagnetic Scattering by Helicopter Rotating Blades", IEEE Transactions on Antennas and Propagation, Vol. 50, No 10, pp. 1396-1408, October 2002.