# CERTIFICATION

This thesis titled "Study and Performance Analysis of Radar Cross Section for F-117A Night Hawk Stealth Aircraft" is submitted by the group as under mentioned has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical, Electronic and Communication Engineering on December 2017.

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## DECLARATION

This is to certify that, the work presented in this thesis is the outcome of the investigation carried out by the following students under the supervision of Gp Capt Dr. Mohammad Hossam-E-Haider, PhD, BAF, Head of the Department, Department of Electrical, Electronic and Communication Engineering (EECE), Military Institute of Science and Technology (MIST).

It has also declared that neither of this paper nor any part therefore has been submitted anywhere else for the award of any degree, diploma or other qualifications.

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# ABSTRACT

Radio Detection and Ranging (RADAR) is a technology with which immense practical consequences can be measured and detected at high accuracy. Using radar, Air travel is thousands of times safer than travel by road, astronomers can map the contours of far-off planets, physicians can show images of internal organs, meteorologists can measure weather change in distant places on Earth. Due to its reasonable larger practical applications, the bi-static radar cross section of F117 Nighthawk Stealth Aircraft is the main focus of our thesis.

The main goal of this thesis is to carry out a detail study of the Radar Cross Section with an aim to find out its performance under changing radar transmitter's frequency variation, aspect angle configurations. In this regard, various radar parameters were swept and the best outcome was identified. Thereafter, the significant effect of radar frequency and aspect angle on F117 Nighthawk in its RCS were studied with a small introduction to complex target RCS. The significance of operating frequency and aspect angle on radar detection range has also been illustrated.

An elaborate and exhaustive effort is taken to examine various antenna parameters to suggest the best possible radar configuration for better target detectability. In this regard, various correlated mathematical equations were taken into consideration, those were simulated using COMSOL Multiphysics to provide relevant plots for study and analysis. The extensive use of this toll has made the thesis extremely interesting with valuable results drawing important conclusions about the behavior of radar under changing conditions.

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## Chapter 04

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# List of Symbols

| | |
|---|---|
| $f_r$ | Pulse Repetition Frequency (PRF) |
| T | Pulse Repetition Interval (PRI) |
| $\boldsymbol{\tau}$ | Pulse width |
| $d_t$ | Radar Transmitting Duty Cycle |
| $P_{avr}$ | Radar Average Transmitted Power |
| $P_T$ | Transmitted Power |
| $R_u$ | Maximum unambiguous range |
| c | Velocity of light |
| $R_{min}$ | Radar Minimum Range |
| $R_{max}$ | Radar Maximum Range |
| M | Number of gates |
| $\Delta R$ | Width of gates |
| B | Radar Bandwidth |
| $f_D$ | Doppler Frequency |
| $f_T$ | Transmitted Frequency |
| $V_T$ | Target Velocity |
| $V_R$ | Radar velocity |
| R | Radius of the Sphere |
| $S_t$ | Power Density |
| $\theta$ | Principle Plane Angle of X-axis |
| $\varphi$ | Principle Plane Angle of Y-axis |
| $G_t$ | Gain of Transmitting Antenna |
| $\sigma$ | Radar Cross Section |
| $S_r$ | Power Density of Echo Signal |
| $A_e$ | Aperture |
| $\lambda$ | Operating Wavelength |
| G | Gain |
| $P_{min}$ | Minimum Signal Power |

| | |
|---|---|
| $N_i$ | Input Noise Power |
| $T_e$ | Receiver Effective Noise Temperature |
| k | Boltzman Constant |
| $F$ | Noise Figure |
| $S_i$ | Input Signal Power |
| $S_o$ | Output Signal Power |
| $N_o$ | Output Noise Power |
| L | Radar Losses |
| $P_{Dr}$ | Total power delivered to the signal processor by the receiving antenna |
| $P_t$ | Peak transmitted power |
| $G_t$ | Gain of transmitting antenna |
| $G_r$ | Gain of receiving antenna |
| $R_t$ | Range from transmitter |
| $R_r$ | Range from receiver |
| $L_t$ | Transmitter losses |
| $L_r$ | Receiver losses |
| $L_p$ | Medium propagation loss. |
| $\beta$ | Bi-static Angle |
| $\sigma_\beta$ | Bistatic Radar Cross Section |
| $d_r$ | Receiving Duty Factor |
| $n_p$ | Number of Coherent Pulses |
| $T_i$ | Time on target |
| $d$ | Duty Factor |
| $T_{sc}$ | Time needed for radar to search a volume defined by solid angle Ω |
| Ω | Solid Angle |
| $E^{scat}$ | Scattered Electric Field |
| $E^{inc}$ | Incident Electric Field |
| $P_s$ | Scattered Power Density |
| $P_i$ | Incident Power Density |
| $H^{scat}$ | Scattered Magnetic Field |
| $H^{inc}$ | Incident Magnetic Field |

| | |
|---|---|
| $\sigma_{ref}$ | Reference RCS Value |
| $\sigma_{m^2}$ | RCS per $m^2$ |
| $\sigma_{dBsm}$ | RCS per square meter in dB |
| $\sigma_T$ | Total Target Scattered RCS |
| W | Total Scattered Power |
| $\theta_i$ | Incident Wave Propagation Direction in X-axis |
| $\varphi_i$ | Incident Wave Propagation Direction in Y-axis |
| $\theta_s$ | Scattered Wave Propagation Direction in X-axis |
| $\varphi_s$ | Scattered Wave Propagation Direction in Y-axis |
| $\psi$ | Green's function |
| $k$ | Wave number |
| $\hat{\boldsymbol{s}}$ | Unit vector aligned along the scattering direction, |
| $\boldsymbol{n}$ | Unit normal to the surface, |
| J | Electric current density |
| M | Magnetic current density |
| $\rho$ | Electric charge density |
| $\rho^*$ | Magnetic charge density |
| $\in$ | Permittivity |
| $\mu$ | Permeability |
| $\psi_0$ | Far Field Green's function |
| $s$ | Unit vector aligned along the scattering direction |
| $i$ | Unit vector along the direction of incidence |
| $r$ | Position vector from the local origin to the surface patch dS |
| $Z_0$ | Impedance of free space |
| $Y_0$ | Admittance of free space |
| $J_n$ | First order Bessel's function |
| r | Radius of cylinder |
| h | Height |
| $P_{Rcv}^{scat}$ | Power scattered by target and received by radar |

| | |
|---|---|
| $P_0^{Xmt}$ | Power from the transmitter |
| $\lambda$ | Wavelength of radiation |
| $R_0$ | Distance from focus to reflector |
| $G_F$ | Gain of feed |
| $E_b$ | Backscattered electric field |
| $\mu_o$ | Permeability of free space |
| $\mu_r$ | Relative permeability |
| $\epsilon_o$ | Permittivity of free space |
| $\epsilon_r$ | Relative permittivity |
| $\omega$ | Angular frequency |
| $n$ | Number of waves |

# List of Abbreviations

| | |
|---|---|
| A/D | Analog to Digital |
| AI | Airborne Intercept |
| AIAA | American Institute of Aeronautics and Astronautics |
| AFB | Air Force Base |
| API | Application Programming Interface |
| AWACS | Airborne Warning and Control System |
| CAD | Computer Aided Design |
| COMSOL | COMputer SOLution |
| CW | Continuous Wave |
| dB | Decibel |
| FC | Fire Control |
| IDE | Integrated Development Environment |
| IEEE | Institute of Electrical and Electronic Engineering |
| IPP | Inter Pulse Period |
| LO | Low Observability |
| LOS | Line of Sight |
| PDE | Partial Differential Equation |
| PEC | Perfect Electrical Conductor |
| PML | Perfectly Matched Layer |
| PO | Physical Optics |
| PRF | Pulse Radar Frequency |
| PRI | Pulse Repetition Interval |
| RADAR | Radio Detection and Ranging |
| RAM | Radar Absorbing Material |
| RCS | Radar Cross Section |
| RF | Radio Frequency |
| SNR | Signal to Noise Ratio |
| TT | Target Tracking |