An Introduction to RF and IR Stealth Technology

May 25, 2006

R. S. Myong

Aerospace Computational Modeling Laboratory
(http://acml.gsnu.ac.kr, myong@gsnu.ac.kr)

Dept. of Mechanical and Aerospace Engineering
Gyeongsang National University
South Korea
Talk I Outline (Today)

• History of stealth and status
• Aircraft combat survivability
  survivability and susceptibility
  radar and IR system fundamentals
  anti stealth and future weapon system
• Modeling and simulation of RF and IR stealth
  ECM and trade-off
• Stealth discipline in aircraft design
• RF stealth concepts
  EM scattering mechanism and RCS
  RCS prediction method and measurement
  RAM
  RCS reduction and RAS
• IR stealth concepts
• Summary
Talk II Outline (June 22, 2006)

• Basic EM theory
• Role of CEM (computational electromagnetics)
  aircraft design
  RAM development
• RCS prediction method
  component buildup method
  high-frequency approximation
  moment method and fast solvers, FEM, and hybrid method
  time-domain FVM
  limitation, optimization, and current status of CEM research
• RAM
  principle, design parameters, software
• IR signature assessment
  prediction code
• Measurement and validation
• Summary
Definition of Stealth

• Definition of stealth
  The act of moving, proceeding, or acting in a *covert* way
  The ability to *blend* in with the background
  Reducing the aircraft signatures and observables, thus providing the aircraft with the capability of evading the enemy’s air defence

• Aircraft signatures
  Active
    *radar* : airframe, engine inlet, weapons, radome, canopy
  Passive
    *infrared* : engine casing, airframe, exhaust plume, sun glint
    *acoustic* : engine parts, engine exhaust, airframe
    *visual* : airframe, engine exhaust and glow, canopy glint
    *misc.* : navigation radar, communication, countermeasures
Present Status (Domestic)

- Domestic activities
  ADD (1999-2002), navy application, universities

Numerical Formulation of Two-dimensional Electromagnetic Scattering Problems - based on the Conservation Form

by

Rhoshin Myong

Aerospace Engineering
The University of Michigan

Advisor: Professor P.L. Roe

Sept. 7, 92
**Present Status (Foreign: JSF)**

**Joint Strike Fighter’s stealthy treatment**
- No sheet material, minimal use of RAM
- Minimal use of tape, robotic application
- Minimal use of “butter”—short cure materials form in-place gaskets
- CAD/CAM tools and modern manufacturing
- Maintain high level of tolerances

**Joint Strike Fighter’s stealthy design**
- RF signature control to minimize susceptibility
- EO/IR technology to maximize survivability
- Covert lighting technology to minimize susceptibility to optical/night vision systems
- Control of electronic and acoustic emissions
Present Status (Foreign: Saab’s Filur UAV)

- **Technology gap**: “It’s been a quarter of a century since we developed the B-2, and the basic tenets of how U.S. goes about designing a LO airplane have been known for at least 20 years. But when you look at foreign systems designed to stealth principles, they’re still not even remotely close to what we did. … So, the U.S. still needs to protect those things that really make a difference,” A. F. Myers, Northrop then-vice president, 2006

- **Driving factors**
  - Effectiveness: precision weapon
  - Technology: modeling, RAM, avionics, navigation
  - Diverse applications: sea, land
Aircraft Combat Survivability (ACS)

• It is about the **effectiveness** of military aircraft contending with an enemy.

• **ACS**: The capability of an aircraft to **avoid (susceptibility)** or **withstand (vulnerability)** a **man-made** hostile environment (enemy air defenses or terrorist weapons).

\[ \text{Survivability} = 1 - \text{Susceptibility} \times \text{Vulnerability} \]

• **Assessment**:
  1) establishing the requirements for survivability,
  2) selecting and designing the specific survivability enhancement features that will meet the requirements,
  3) supporting the evaluation that the final product meets the requirements, and
  4) providing survivability and vulnerability data to mission and campaign models.

• The U. S. military basic survivability requirements given in MIL-HDBK-2069
Flow of Assessment and Susceptibility Reduction Concepts

Mission-Threat Analysis

Susceptibility Assessment

Vulnerability Assessment

Survivability Assessment
One-on-One Mission Campaign

Trade Studies

Aircraft Design

Aircraft Description

Noise jamming & deceiving
Radar (ALQ–xxx)
IR (ALQ–xxx)

Threat warning
RWR (ALR–xxx)
MAWS (AAR–xxx)

Threat suppression
Air-to-air missiles
Antiradiation missiles
Guns

Signature reduction
Radar (shaping, materials)
IR (propulsion, airframe)
Visual (paint, glint)
Aural (propulsion)

Expendables
Dispenser (ALE–xx) with Chaff (RR–xxx)
Flares (MJU–xx)
Towed decoy (ALE–xx)

Weapons and tactics, flight performance, and crew training and proficiency
Radar System Fundamentals

- **Radar (Radio Detection And Ranging):**
  transmitter, antennas, and receiver
  monostatic, bistatic, and multistatic radars
- **Band: 100 MHz ~ 20 GHz**
  surveillance and detection (VHF, UHF, S), SAM (C, X), onboard (K)
IR Fundamentals

- **Infrared radiation**
  seeker dome, optical components, and detector (thermal or photon)
- **Wavelength: 0.7 ~ 1000 micron**
  continuum radiator (solid; grey bodies)
  line radiator (gas): water vapor (1.4, 1.9, 2.7, 3.2, 5.5, 7.5 micron), carbon dioxide (2.7, 4.3, 14, 16 micron)
Anti Stealth and Future Technology

- Bistatic radar and radar net
- Multirole electronically scanned radar (200 mile, X-band)
- UWB (ultra-wide band) pulse radar: effective in RAM and ECM
- Passive radar
- Multi-spectral IR detector
- Direct (high power microwave) weapon system: striking communication networks, need of optical communication
RCS Characteristics and Scattering Mechanisms

RCS: frequency, polarization, incident angle, observing angle, geometry, material properties
Radar Absorbing Materials (RAM)

- **Broadband (attenuating) RAM**
  - Small change in impedance
  - Absorbing lossy layered material (impedance, freq., thickness, angle of incidence)
- **Resonant (interference) RAM**

### Summary of Graded Deposit Absorbers

From the Design Parameters (wish-list)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Graded Deposit Absorbers</th>
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<tbody>
<tr>
<td>Frequency</td>
<td>Good</td>
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<tr>
<td>Reflection Loss</td>
<td>Good</td>
</tr>
<tr>
<td>Polarsation (x2)</td>
<td>Good</td>
</tr>
<tr>
<td>Angle of incidence</td>
<td>Good</td>
</tr>
<tr>
<td>Weight</td>
<td>Low</td>
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<tr>
<td>Thickness</td>
<td>Medium</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Fragile</td>
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<tr>
<td>Environment</td>
<td>Benign</td>
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RCS Reduction Concepts

• **Shaping**: Reducing the scattering of incident wave back, effective against monostatic radars
  
  - Adapting a compact, smooth blend external geometry (flying wing-body concept)
  - Adapting a faceted configuration (but, aerodynamics penalty)
  - Buried engines located over the upper surfaces, a screen placed over the air intake, appropriate shaping of the intake lips and inlet ducts
  - Eliminating cockpit transparencies
  - Clean external geometry without protuberances (weapons) and gaps
  - Highly swept leading edges with rounded wing tips
  - Avoid flat and re-entrant surfaces, having a V-shaped tail
  - Use of composites that have impedance comparable to that of air
  - Design any internal structure reducing reflections in a given direction
  - Special treatment of radome

• **RAM**: Attenuating and interference, 20 dB reduction over 2-18 GHz band (optical regime), not effective against UWB radar
IR Signature Reduction

• Concepts
  Reduce the temperature of the hot parts and the exhaust
  Reduce the surface emissivity of the hot parts
  Reduce or mask the observable surface radiating area

• Techniques
  Propulsion source:
  - engine with available coolant air source
  - cooled shields or turn that block the view from an IR observer
  - coating with IR absorbent materials
  - reducing the gas temperature near the exhaust system by using a cooler surrounding airstream or by putting the plume in a cross flow or by using two-dimensional nozzle

  Airframe source:
  - difficult in dealing with aerodynamic heating (M>2)
  - insulation or judicious placements of hot components
  - nearly flat transparent surface, IR absorbing paint for sun glint
  - optimised coating of different emissivity for localized bright spots (stagnation region like leading edges)
Summary

• **Stealth technology is**
  Evolving
  Multi-disciplinary, team-oriented
  Politics and money driving

• **In the stealth business, one needs to**
  Decide level of stealth considering factors ACS, cost, time, maintainability, and technology trend
  Develop core capability: S/W development branch of M/S, RCS and IR, H/W (RAM, test facility)
  Run the demonstration program in initial development