RCS Reduction (Chapter 7)

EC4630 Radar and Laser Cross Section

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RCS Reduction and Control

- True LO must be a design consideration from the start
- Four basic RCS reduction approaches:
 - 1. Shaping
 - o Orientation and curvature of surfaces
 - o Alignment of edges
 - o Shielding of cavities and ducts
 - 2. Materials selection
 - o Composites and RAM
 - o Metamaterials and other artificial materials
 - 3. Passive cancellation
 - Parasitic elements and loading
 - o Movable or fixed
 - 4. Active cancellation
 - Signals generated to cancel the threat radar's target "skin return"
- Treatments can be applied to existing designs to reduce RCS
 - Apply surface coatings and edge treatments
 - Reshape intakes and engine ducts
 - Upgrade antennas and sensors

"Fifth Generation" Fighters

Examples are the F-35 and F-22. LO features of the F-22*:

An integrated airframe design, advanced materials and an axisymmetric nozzle maximize the F-35's stealth features. A quick look at the aircraft reveals an **adherence to fundamental shaping principles** of a stealthy design. The leading and trailing edges of the wing and tail have identical sweep angles (a design technique called planform alignment). The fuselage and canopy have sloping sides. The canopy seam and bay doors are sawtoothed. The vertical tails are canted. The engine face is deeply hidden by a serpentine inlet duct. The inlet itself has no boundary layer diverter channel, the space between the duct and the fuselage, to reflect radar energy. And, of course, weapons can be carried internally. Each internal bay contains two hardpoints onto which a wide variety of bombs and missiles can be attached.

According to November 2005 reports, the US Air Force states that the F-22 has the lowest RCS of any manned aircraft in the USAF inventory, with a **frontal RCS of 0.0001~0.0002 sqm**, marble sized in frontal aspect. According to these reports, the F-35 is said to have an RCS equal to a metal golf ball, about 0.0015 sqm, which is about 5 to 10 times greater than the minimal frontal RCS of F/A-22. The F-35 has a lower RCS than the F-117 and is comparable to the B-2, which was half that of the older F-117. Other reports claim that the F-35 is said to have an smaller RCS headon than the F-22, but from all other angles the F-35 RCS is greater. By comparison, the RCS of the Mig-29 is about 5m2.

Much has been improved between the design of the F-22 and the F-35. The F-35 doors for landing gear and equipment, as well as control surface, all have straight lines. The F-35 does not require "saw tooth" openings to divert RF energy. One reason the openings on the F-35 are straight lines is reported to be embedded electrical wires near the edges which interfere with RF signals. The F-35 RAM is thicker, more durable, less expensive and, being manufactured to tighter tolerances compared to that of the F-22. The tighter tolerances means less radar signal can penetrate openings and reflect back to its source. The newer RAM is more effective against lower frequency radars, and maintenance should cost about a tenth that of the F-22 or B-2. Some forms of RAM have electrical plates or layers within the layers of carbon composites.

*From: http://www.globalsecurity.org/military/systems/aircraft/f-35-design.htm

Shaping Considerations

- Surface orientation:
 - Make sure surface normals do not point in high priority threat directions
 - Specular component is frequency independent, but scattering lobe widths decrease with increasing frequency



Principal Plane RCS

- Principal planes (i.e., cuts with the highest sidelobes) are perpendicular to edges
- Example shown: square versus diamond with the same surface area
- Application: straight wing versus swept wing design



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Sidelobe Envelopes

PO RCS of plates of constant width (b = 10 m) versus length a ($\phi = 0^{\circ}$ cut)



For PO:

- Specular peak increases as A^2
- Sidelobe levels roughly the same at mid-angles
- Wide angle RCS primarily determined by width *b* (if no traveling wave or edge diffraction included)

Retro-directive Reflectors

Avoid corner reflectors (dihedral and trihedral reflectors)



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Surface Orientation Examples





SWATH (Small waterplane area twin hull)

Tumblehome hull

Edge Serration and Alignment

The maximum intensity of the diffracted lobe from an edge (in the Keller cone direction) increases with edge length.



• Serrations break up edges to reduce lobe intensities

 Edges are generally aligned so that their lobes occur in low priority region

Edge Scattering

Leading edge scattering is dominated by TE polarization. Trailing edge by TM polarization. Example shown: 5λ plate with wave incident perpendicular to edge, 70 degrees from normal incidence (green arrow is \vec{E} ; red arrow is \hat{k}_i)

TE Polarization ($\vec{E} \parallel edge$)



TM Polarization ($\vec{E} \perp edge$)



Edge Serration

Serrations are applied to both edges. Example using a rectangular plate is shown.



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Edge Serration Application

- Application to an airfoil
- Serrations on the SR-71 (SR-71 is not a good example of a LO aircraft)







Current Discontinuities

Gaps in conductivity lead to edge diffraction. A seam can look continuous, but there may not be good conduction between the two sides. Example shown: wire with a break.



Traveling Wave Edge Treatments

• Resistive film edge treatment for traveling wave



Passive Cancellation



- Approach: add a secondary scatterer and adjust it so its scattered field cancels that of the bare target
- Only effective over a narrow range of angles and frequency bandwidth
- Only practical for canceling low RCS levels
- Examples: parasitic elements and lumped loads

Passive Cancellation

These structures can be viewed as passive cancelation



Active Cancellation

The concept is similar to passive cancellation, but the use of an active circuit increases the range of cancellation:

- Frequency range
- Spatial angles
- RCS cancellation dynamic range

Drawing: example of cancellation elements for parallel and perpendicular RCS components



Extremely complex and difficult to achieve in practice, especially at high frequencies

- RF circuitry required
- Antennas for reception and retransmission
- Processing speed and CPU

Next level of complexity is deception

• Impart "misinformation" in the cancellation signal to induce range, velocity, and angle errors in the threat radar

Active Cancellation Circuits



Passive circuit with limited cancellation dynamic range

Active circuit with improved cancellation dynamic range