# ECE 495 – Electromagnetic Warfare and Survivability

## Block 3: IR EW and Signature Management
## Lesson 27: RAM, Polarization, and EMCON

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# Where We Left Off

L26 handed out the verdicts: **shape** what you can, **mask** the cavities, **manage** the seams — and left the edges and antennas to be **treated**.

Today we pay those debts. *How do materials absorb what shaping could not redirect — and what is left to hide after that?*

The answer to the second question is uncomfortable: the loudest thing on a stealth aircraft is its **own transmitter**.

# Lesson Objectives

By the end of this lesson, you will be able to:

- Explain how **RAM** attacks the reflectivity knob $\Gamma$ and where it goes on an airframe
- Use **quarter-wave cancellation** to size a resonant absorber and its notch
- Describe how **polarization** betrays edges and wires, and the design response
- Argue **EMCON** from the intercept asymmetry: one-way $1/R^2$ beats two-way $1/R^4$

# RAM: Buying Down $\Gamma$

Shaping chose where energy *goes*; RAM decides how much *survives the trip*:

- In L25's rule, RAM attacks $\Gamma$ — convert the wave to heat instead of echo
- It goes where shaping ran out: **edges**, inlet lips, seams, and cavity throats
- Absorbers trade **bandwidth, thickness, and weight** — you may pick two
- RAM finishes the budget: shaping bought the orders of magnitude, RAM buys the stubborn last dBs

## The Resonant Trick: Quarter-Wave Cancellation

Put a resistive sheet a quarter wavelength above the metal skin:

$$d = \frac{\lambda_0}{4} \quad \Longrightarrow \quad \text{front and rear reflections return } 180^\circ \text{ apart — and cancel}$$

- At the design frequency the echo **nulls**: the wave is eaten by the sheet
- Off frequency, the phase geometry breaks and the echo **comes back**
- The catch is in the formula: $d$ is fixed, so the null lives at *one* $\lambda_0$
- At 10 GHz, $d$ = 7.5 mm; at 1 GHz, 75 mm — low-band RAM gets thick fast

**A resonant absorber is a promise kept at exactly one frequency.**

## The Broadband Problem

The threat does not transmit at your design frequency as a courtesy:

- An IADS spans **VHF to Ku** — a single notch defends one band and betrays the rest
- **Layered** (Jaumann) absorbers stack graded sheets: wider notch, more thickness
- **Magnetic** RAM (iron-loaded coatings) absorbs broadband and thin — but heavy
- **Structural** RAM builds the absorber into the skins and edge wedges themselves
- Every choice re-runs L26's budget: dBs per pound, per inch, per maintenance hour

# Polarization: the Tell in the Echo

The echo carries **orientation** information — and edges talk too much:

- Long conductors scatter strongest in the polarization **parallel** to them
- Corners **flip** circular polarization — radars use that to reject rain and flag corners
- A polarization-diverse radar can hunt LO features the co-pol channel misses
- Design response: no long straight conductors, orient and serrate discontinuities — planform alignment's quiet cousin

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# The Signature You Choose to Radiate

After shaping, masking, and RAM, one **megawatt-class** contributor remains:

- The fire-control radar, the datalinks, the altimeter — every emission is a beacon with your name on it
- B2's ES lesson returns: their receivers are patient, passive, and everywhere
- No coating absorbs a wave you chose to transmit
- So the last LO discipline is **emissions control**: radiate seldom, radiate smart

# The Asymmetry: Why the Listener Wins

The physics is rigged in the receiver's favor:

RWR hears you: $\dfrac{1}{R^2}$ You hear your echo: $\dfrac{\sigma}{R^4}$

- Your signal reaches the enemy RWR **one way**; your echo pays the round trip *and* their small $\sigma$
- Result: they detect your radar far beyond where your radar detects them
- **LPI** fights back — manage power, hop frequencies, spread the waveform thin
- Or refuse the duel: stay passive, let the **IRST** (L23) and offboard cues do the finding

**Whoever transmits first, telegraphs first.**

# Where This Is Headed: Every Other Signature

The RF story is told. But the aircraft is still **seen, heard, and felt**:

- **Visual**: contrails, glint, and paint schemes — the oldest sensor is the human eye
- **Acoustic**: engines and airflow announce low-altitude penetrators
- **EO/IR**: L22's five components never left — they fuse with everything above
- L28 closes the loop: **multi-spectral fusion**, and the rule that you are only as quiet as your *loudest* band

# Quick Exercise / Type-along: Pick the Fix

For each finding, name the **L27 tool** — resonant RAM, magnetic/structural RAM, polarization discipline, or EMCON — and its cost. Call it out.

1. A seam glows at exactly the seeker band, and only there
2. An early-warning radar at VHF sees the aircraft it cannot see at X-band
3. A cross-pol radar channel flags the aircraft's straight wing-root fairing
4. Mission planners want the fire-control radar searching all the way to the target

# Today's Interactive Demo: the Quarter-Wave Notch

Today's interactive demo.

- Model a **Salisbury screen**: resistive sheet, air gap $d$, metal ground plane
- Sweep 2–18 GHz and plot the **reflection** in dB — find the null
- Measure the $-10$ **dB bandwidth**: how much spectrum does one notch defend?
- Double the thickness and watch the null move — *what did the extra depth buy, and what did it cost?*

*Companion script:* `L27_QuarterWaveRAM.m`

*In L28: the signatures that are not RF at all — and fusing every band into one picture.*

# Wrap-Up

Key ideas:

- **RAM** attacks $\Gamma$: quarter-wave resonant notches, layered and magnetic for bandwidth, structural for edges
- $d = \lambda_0/4$ is a one-frequency promise — broadband absorption costs thickness and weight
- **Polarization** betrays straight edges and corners; discipline the geometry
- **EMCON**: one-way $1/R^2$ beats two-way $\sigma/R^4$ — radiate seldom and smart, or go passive
- Materials and discipline buy the last dBs that shaping (L26) left on the table

Next lesson:

- **L28: Acoustic, Visual, and EO Signatures** — multi-spectral fusion closes the story
- Pre-flight quiz for L28 due before class