



ECE 495 – Electromagnetic Warfare and Survivability

Block 2: RF Electronic Warfare Lesson 11: From Radar to EW

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Block 1 put you in the threat's seat: you can now compute exactly how an IADS sees the B-21, aspect by aspect, band by band.

Block 2 flips the seat. Same physics, opposite agenda.

Today: what EW actually is, the three pillars in doctrine terms, the asymmetry the whole discipline rests on, and where B2 goes from here.

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

- Map each term of the radar range equation to the **EW lever** that attacks it
- State the roles of **ES**, **EP**, and **EA** with doctrinally correct examples
- Explain the **one-way vs two-way** detection asymmetry and why it favors the listener
- Navigate the **Block 2 roadmap** from ES through EA to Project 2

The Range Equation Is a Target List



$$R_{\max} = \left[\frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 S_{\min}} \right]^{1/4}$$

Every factor is something we can attack or defend:

- σ — shrink it by design: LO shaping and RAM (EP)
- $S_{\min}$ — raise their effective noise floor: jamming (EA)
- G_t, G_r — enter through the side lobes they can't help having (EA)
- P_t, λ, PRF — every emission leaks intent: collect it (ES)

B1 taught you the equation. B2 teaches you to fight it.

Situational awareness EW — sense the spectrum to support targeting, warning, and intelligence.

- **On-board:** radar warning receivers (RWR), EO/IR warning sensors
- **Off-board:** SIGINT / ELINT / COMINT national assets
- Exploits the threat's one unavoidable weakness: *a radar must radiate to work*
- Feeds everything else — EA needs cueing, routes need threat locations

Legacy term: ESM. Modern Joint term: Electromagnetic Support.

Defensive EW — protect our own use of the spectrum, against both enemy attack and friendly interference.

- **LPI** waveforms — spread the energy so the listener's job gets hard
- **Agility** — frequency and polarization hopping outrun the jammer's set-on
- **Side-lobe cancellation** — close the back doors into the receiver
- **Hardening and LO** — survive the disturbance, deny the detection

Legacy term: ECCM. Modern Joint term: Electromagnetic Protect.

Electromagnetic Attack (EA)



Offensive EW — deny, degrade, or deceive the enemy's use of the spectrum.

- **Noise jamming** — self-protect and stand-off; brute-force the $S_{\min}$ term
- **Deception** — DRFM false targets; lie to the tracker instead of shouting at it
- **Expendables** — chaff and flares; give the seeker something better to love
- **NAVWAR** — counter-PNT; the spectrum includes GPS

Legacy terms: ECM, and confusingly, "EW." Modern Joint term: Electromagnetic Attack.

The radar needs its energy to make a *round trip*. The RWR only needs to hear it *arrive*.

- Radar detection: power falls as $1/R^4$ — two-way
- RWR intercept: power falls as $1/R^2$ — one-way
- Same transmitter, same instant: the listener wins by orders of magnitude
- In practice the RWR's limit is the horizon, not its sensitivity

The radar pays R^4 to see you. You pay R^2 to hear it.

The Endless Cycle: Measure, Counter, Counter-Counter



- **Action** — radar innovates: pulse-Doppler, frequency agility, LPI
- **Reaction** — countermeasures answer: noise jammers, chaff, DRFM deception, LO
- **Counter-reaction** — ECCM closes the loop: hopping, side-lobe cancellation, adaptive processing, multistatic radar

No move is permanent — every technique in B2 has a counter.

EW is decided as much by speed of adaptation as by hardware.

- **ES (L12–L14):** RWR architecture, angle of arrival, triangulation and fusion
- **EP (L15–L16):** LPI radar, agility, side-lobe cancellation, spread spectrum for comms
- **EA (L17–L18):** jamming taxonomy, J/S and burn-through, DRFM deception, decoys
- **Project 2 (L19–L20):** B-21 RWR AoA characterization — design, fit, defend

Same rhythm as B1: HW2 and Quiz 2 land with the Project 2 presentations at L20.

Quick Exercise / Type-along: Pick the Lever



For each desired effect, name the pillar (ES / EP / EA) and the range-equation term it works through:

1. Make the TTR's screen bloom with noise during the ingress
2. Locate the SA-21's acquisition radar from 200 km away without transmitting
3. Keep the B-21's own radar usable while the enemy jams the band
4. Convince the tracker the B-21 is 2 km left of where it actually is

Today's interactive demo.

- Reuse the B1 threat classes: EW, ACQ, TTR
- Compute each radar's two-way $R_{\max}$ against the B-21 (B1 review)
- Compute the RWR's one-way intercept range against each radar
- Compare the two — and find which limit actually binds the RWR

Companion script: L11_OneWayVsTwoWay.m

In L12 we open up the box that does the hearing: the RWR.

Key ideas:

- The range equation is a target list — every term is an EW lever
- ES senses, EP defends, EA attacks; ES feeds the other two
- One-way beats two-way: the listener detects at R^2 while the radar pays R^4
- Every move has a counter — B2 is a tour of the move-countermove tree

Next lesson:

- **L12: Electromagnetic Support** — the RWR, inside and out
- Pre-flight quiz for L12 due before class