ECE 495 – Electromagnetic Warfare and Survivability

Block 2: RF Electronic Warfare

Lesson 12: Electromagnetic Support

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Where We Left Off

L11 made the case: the listener detects at R^2 while the radar pays R^4. The B-21 hears every radar on the battlefield long before any of them sees it.

Hearing is not understanding. Thousands of pulses per second arrive interleaved, from every direction, on every band.

Today: the box that turns that chaos into a threat display — the RWR.

Lesson Objectives

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

- Distinguish **ES** from **ELINT** by purpose and data depth
- Name the **four functions** of every threat warning system
- Walk the **RWR block diagram** from antenna to cockpit display
- Explain how **pulse parametrics** turn raw intercepts into a threat ID

ES vs ELINT: Same Spectrum, Different Job

- **ES** collects just enough to answer: *what radar, what mode, right now*
- **ELINT** collects everything: full parametric depth, future threats, library building
- ES is bandwidth-bounded by *known* threats; ELINT by *any possible* threat
- ELINT's product becomes the threat library the RWR classifies against

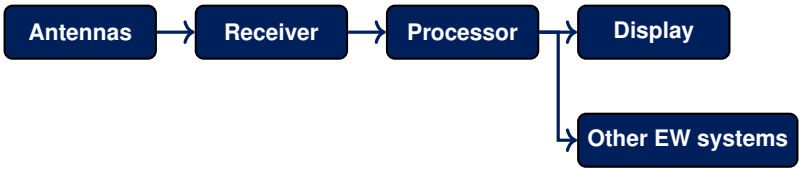
ES fights the fight — ELINT studies the fight.

Four Functions of Every Threat Warning System

Function	What it does	OODA phase
Observe	Monitor the radar bands continuously	Observe
Detect	Recognize a threat signal is present	Orient
Classify	Determine radar type and operating mode	Decide
Alert	Warn aircrew and cue defensive systems	Act

- Same four functions in every threat warning system, RF or IR
- The hard engineering lives in **Classify** — the rest is plumbing and ergonomics

The RWR, End to End



- **Antennas** — typically four, one per quadrant; small, broadband, low gain
- **Receiver** — measures each pulse's parameters
- **Processor** — sorts, classifies, decides what matters
- **Display + cueing** — aircrew scope, plus chaff / jammer / decoy cues

The RWR's Bandwidth Dilemma

The RWR wants to hear *everything*: all bands, all directions, all the time. Physics sends the bill:

$$S_{\min} = kTB \cdot \text{NF} \cdot \text{SNR}_{\text{req}}$$

- Same $S_{\min}$ contract as L8 — but now B spans **tens of GHz**, not MHz
- Every decade of bandwidth costs 10 dB of noise floor
- Saved by the one-way advantage: radar main lobes arrive *loud*

For warning, wide-open and deaf-ish beats narrow and sharp.

Five Ways to Build the Receiver

Type	Sensitivity	Character
Crystal video	Low	Wide coverage, fast, one signal at a time
IFM	Low	Frequency only, up to an octave
Superheterodyne	Med–high	Selects one signal, recovers any modulation
Channelized	Med–high	Multiple simultaneous signals
Digital	Med–high	Wide, fast, flexible — the modern default

- Classic RWRs leaned on crystal video + IFM: cheap, fast, wide
- Modern RWRs digitize wholesale and let the processor do the selecting

Pulse Parametrics: The PDW

Each intercepted pulse becomes a **pulse descriptor word (PDW)**:

- **One pulse:** frequency, pulse width, TOA, AoA, power, polarization, modulation
- **Two pulses:** pulse repetition interval (PRI) — the single most diagnostic number
- **Many pulses:** staggered PRI patterns, carrier modulation, antenna scan rate

Easy and quick measurements run first; if the ID resolves, stop. Scan rate takes longest — it waits for the threat's beam to come around again.

Deinterleave, Then Classify

The receiver hears *one* merged stream of pulses from every emitter in view. The processor must:

1. **Deinterleave** — cluster PDWs by frequency, AoA, and PW into per-emitter buckets
2. **Estimate PRI** — difference the TOAs inside each bucket
3. **Classify** — match (frequency, PRI, PW, scan) against the threat library
4. **Determine mode** — search, track, or launch; PRF jumps betray the handoff

The RWR's first job is sorting, not hearing.

When the RWR Is Blind

The RWR only warns about things that *radiate*:

- **LPI radars** — spread, low-power waveforms below the RWR's detection floor
- **EMCON** — the threat simply doesn't transmit until late
- **Passive seekers** — IR and EO weapons give no RF launch indication
- **Silent terminal phases** — GPS / inertial / home-on-jam guidance leaves the scope quiet until impact

This is why survivability never rides on one sensor — B3 covers the IR half.

Today's Interactive Demo: Sort the Stream

Today's interactive demo.

- Merge three emitters' pulse trains into one TOA stream — the receiver's view
- Deinterleave by measured frequency
- Estimate each cluster's PRI from TOA differences
- Classify against a three-entry threat library — the B1 cast returns

Companion script: `L12_RWRPulseSort.m`

In L13 we add the question the PDW can't fully answer yet: where is it?

Quick Exercise / Type-along: Read the Scope

Your RWR reports four PDW clusters. Call the threat and the mode:

1. 0.5 GHz, PRI 5 ms, wide PW, AoA drifting slowly aft
2. 10 GHz, PRI jumped from 1 ms to 0.1 ms, steady AoA, rising power
3. 3 GHz, PRI 2 ms, beam sweeps past every 6 seconds
4. 10 GHz cluster from Q2 goes silent — power gone, nothing else changes

Wrap-Up

Key ideas:

- ES answers *what and now*; ELINT builds the library it answers from
- Observe, Detect, Classify, Alert — Classify is where the engineering lives
- PDWs + PRI turn an interleaved pulse stream into named threats with modes
- A silent scope is not a safe sky

Next lesson:

- **L13: Angle of arrival** — amplitude comparison and interferometry
- Pre-flight quiz for L13 due before class