Introduction to Radar Warning Receivers

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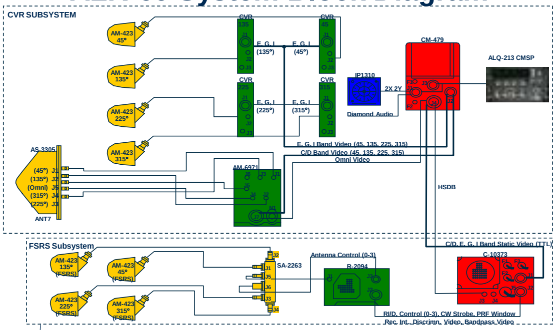
What is a Radar Warning Receiver?

- A Radar Warning Receiver (RWR) is a *passive* EW system that does the following:
  - Detects RF signals transmitted by radar systems
  - Identifies the signal by radar type
  - Manages detected signals
  - Generates visual and audio cues to pilot
  - Manages interfaces to other systems

What the Pilot Sees

ALR-69 System Block Diagram



ALR-69 System

What the Pilot Sees

(Very) Brief History of RWR

- RWRs have been around for about 40 years.
  - First-generation RWRs were used by the US Air Force during the Vietnam War in response to Russian radar-guided SAMs deployed in North Vietnam.
- The Israelis suffered heavy losses to radar-directed AAA and SAMs during the 1973 Yom Kippur War.

Example USAF RWR Installations

RWR Type	Aircraft
ALR-56C	F-15
ALR-56M	F-16, C-130, B-1
ALR-69	B-52, A-10, C-130, F-16, C-130
ALR-94	F-22
APR-39	C-130, V-22

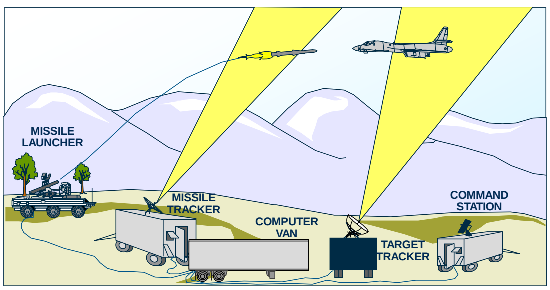
How Does an RWR Work?

- Hardware handles detection
  - Hardware detects radar pulses and converts pulse parameters to digital format
  - Major hardware components: antennas, RF cables, receiver, signal processor, user I/O devices
- Software handles identification and aircrew interface
  - Software processes digital data to determine what type of radar system is illuminating the aircraft and then provides aircrew cues
  - Major software components: operational flight program and mission data file

Why Do You Need an RWR?

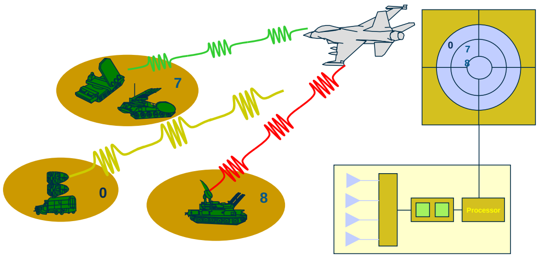
- The enemy is out there!
- The enemy has air defense systems that are very dependent on radar and RF-guided weapons.
  - They have surface-to-air-missiles (SAMs), anti-aircraft artillery (AAA), and air-to-air missiles that are cued/targeted/guided by RF signals.
- When an enemy radar points at a USAF aircraft, we can detect that signal and warn the aircrew of the presence of that weapon system.

Typical Air Defense System Encounter



SA-2 Surface to Air Missile

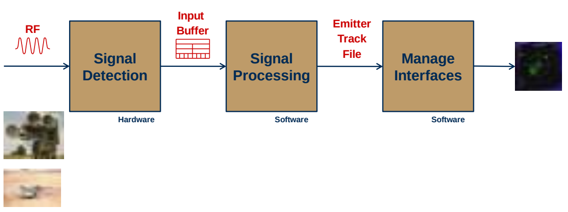
RWR Operational Concept



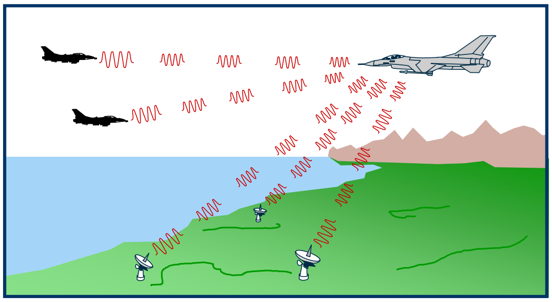
How Do We Measure RWR Performance?

- Typical RWR measures of performance (MOPs) are:
  - Detection range
  - Response time
  - Correct ID
  - DF accuracy
  - Age out
- Performance is usually measured by conducting a flight test on an open-air range.

Simplified RWR Processing Flow

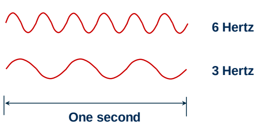


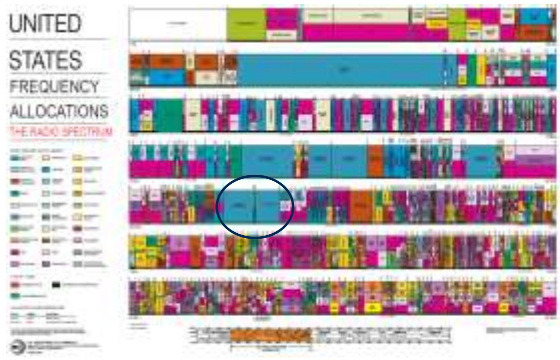
Origin of RWR Input

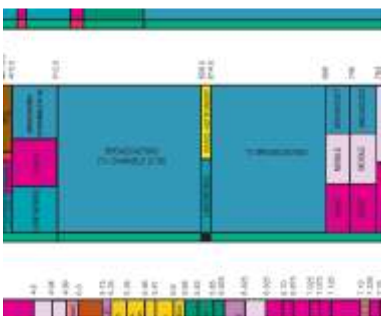


RWR Frequency Coverage

- A typical RWR detects pulsed radar signals in the 0.5-18 GHz frequency range.
- *Frequency* is measured in "Hertz"
- *Hertz* is a unit of frequency of one cycle per second.







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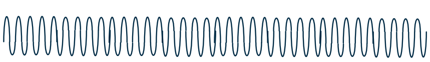
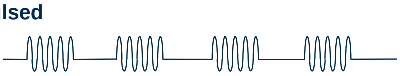
Types of Radar Signals

- Continuous Wave



- Pulsed



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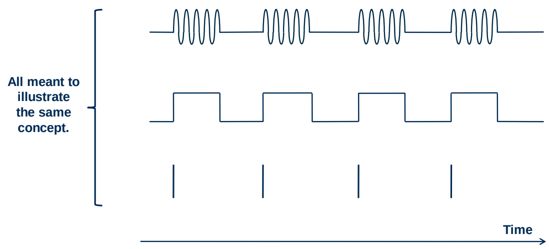
Quick Word About Notation for Pulsed Signals



What Measurements Does an RWR Make?

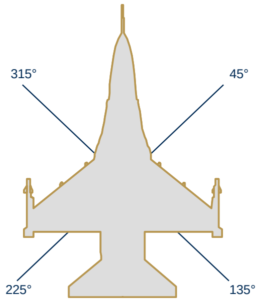
- For each CW *signal* the RWR will measure:
  - Frequency, angle of arrival, and power
- For *each pulse* in a pulsed signal the RWR will measure:
  - Frequency or frequency band, time of arrival (TOA), angle of arrival (AOA or DF), pulse width, and power
- For CW or pulsed signals outside the RF coverage of the RWR, *no measurement is made*.

First Step: Detect Signal with Antenna

E/J Band antenna - Four per aircraft

C/D Band antenna - One per aircraft

First Step: Detect Signal with Antenna



Four E/J band antennas are installed at quadrant locations around aircraft.

F-16 Forward Antenna Installation

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F-16 Aft Antenna Installation

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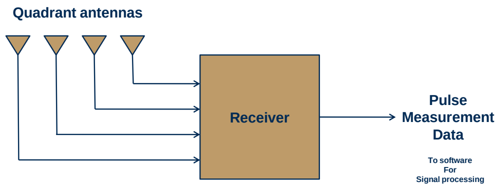
Converting RF Pulse to Digital Data



Basic Analog Receivers[1] (1/2)

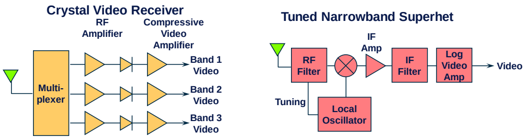
Receiver	Advantage	Disadvantage
Wideband Crystal Video	**Simple; Inexpensive Instantaneous High POI in frequency range**	**No frequency resolution Poor sensitivity Poor simultaneous signal**
Tuned RF Crystal Video	Simple Frequency measurement Higher sensitivity than wideband	Slow response time Poor POI
IFM	Relatively simple Frequency resolution Instantaneous; High POI	Simultaneous signal problem Relatively poor sensitivity
Narrow Band Scanning Superhet	**High sensitivity Good frequency resolution No simultaneous signals problem**	**Slow Response Poor POI Poor against freq agility**
Wideband Superhet	Better response time Better POI	Spurious signals generated Poorer sensitivity

Basic Analog Receivers[1] (2/2)

Receiver	Advantage	Disadvantage
Channelized	Wide bandwidth Near instantaneous Moderate frequency resolution	High complexity, cost Lower reliability Limited sensitivity
Microscan	Near instantaneous Good frequency resolution Good dynamic range Good simultaneous signal capability	High complexity Limited bandwidth No pulse modulation information Critical alignment
Acousto-optic	Near instantaneous Good frequency resolution Good simultaneous signal capability Good POI	High complexity New technology

[1] Electronic Warfare And Radar Systems Engineering Handbook, NAWCWPNS TP 8347, April 1, 1999

Most Common RWR Receiver Architectures



Narrow-Band Superheterodyne Receiver

- Narrow bandwidth
- -90 dBm sensitivity
- Low probability of intercept (POI)
- Good signal separation
- Measures frequency, PW, power, and AOA
- Excellent CW Capability
- Medium cost
- Medium volume

Wideband Crystal Video Receiver

- Wide instantaneous bandwidth
- - 45 dBm sensitivity
- High probability of intercept
- Poor signal separation
- Measures frequency band, PW, power, and AOA
- Poor CW Capability
- Low cost
- Small volume

Input Scheduling

- Another important RWR term is *input scheduling*.
- Both superhet and CVR architectures require sophisticated input schedulers.
  - The input schedule is usually defined in the mission data file.
- We have said that a typical RWR covers the 0.5-18 GHz frequency range, but they typically do not collect inputs from the entire range at one time.

CVR Input Scheduling

- A typical CVR RF signal is fed to an amplifier/detector that splits the covered RF range into multiple *frequency bands*.
- A typical CVR *looks* (collects input) from a single RF band at a time.
- Example band breaks are shown below.

Example CVR Input Schedules

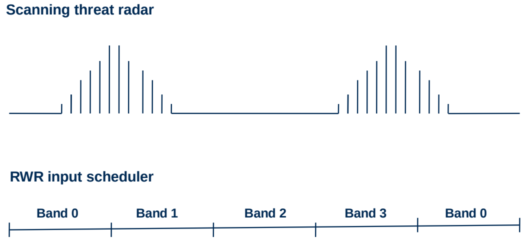
Really simple schedule

Band	Look Time
0	25 ms
1	25 ms
2	25 ms
3	25 ms

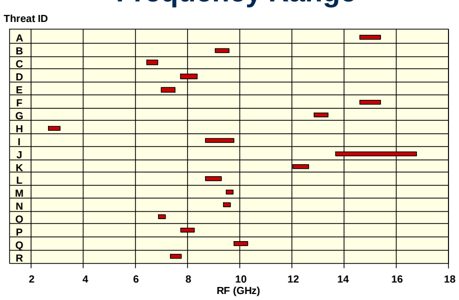
More realistic schedule

Band	Look Time
0	10 ms
1	12 ms
2	15 ms
3	15 ms
0	50 ms (conditional)
2	1 ms
3	1 ms
1	20 ms
3	25 ms

Simple Probability of Intercept Example



Emitter Transmitted Frequency Range



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Superhet Input Scheduler

- The input schedule for a superhet receiver is much more complex than the input schedule for a CVR.
- This is because the superhet is a narrow-band receiver, i.e. the total frequency range is broken into many smaller segments that must be covered.
- Superhet input schedulers contain more numerous, shorter looks.

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Pulse Measurements

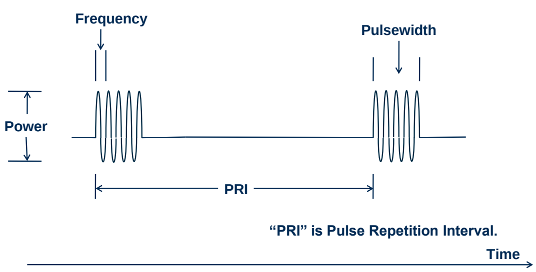
- If the RWR detects a pulse, it collects a set of data for that pulse.
- The formats differ among various RWRs, but this pulse data is generally called a ***pulse descriptor word*** (PDW).
- The PDW contains all data collected for a ***single*** RF pulse.

Pulse Descriptor Word

- A typical PDW contains time of arrival (TOA), angle, pulse width, power, and frequency (superhet) or frequency band (CVR).
- The ALR-69 PDW format is shown below:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TIME OF ARRIVAL (16 LSBs)															
PULSE WIDTH								TIME OF ARRIVAL (8 MSBs)							
POWER								ANGLE							
IP	PP	FO1	FO2	PRI	DT	RB1	RB2	DCB	COR	CDM	B0	B1	B2	B3	B4

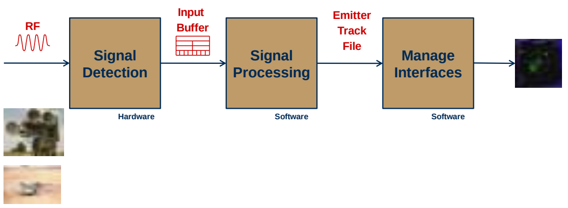
Key Pulse Parameters



Input Buffer

- The final output of the Signal Detection component of the RWR is an *Input Buffer*.
- An Input Buffer is a series of PDWs that were collected during a single look.
- The Input Buffer is processed by the RWR software to determine what type radar (or radars) transmitted the pulses.

Simplified RWR Processing Flow



OFP and MDF

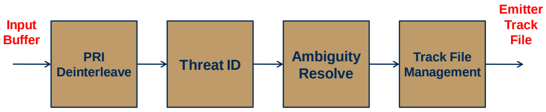
Operational Flight Program (OFP)

- Executable code
- Input scheduler
- PRI deinterleaver
- Track file management
- Missile guidance algorithms
- Interface management

Mission Data File (MDF)

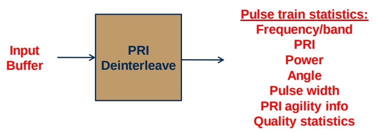
- Data (no executable code)
- Input schedule
- Threat identification
- Threat information
- Ambiguity resolve tables
- Missile guidance data

Major Signal Processing Components



PRI Deinterleaving Algorithm

- Many years of research have been done regarding PRI deinterleaving algorithms.
- The PRI deinterleaving algorithm is the most complex algorithm, and uses the most processor time, of any function in an RWR OFP.



PRI Agility
Stable

- For a "stable PRI" emitter the interpulse period is the same for every pulse.

PRI Agility
Stagger

- For a "staggered PRI" emitter, a set of interpulse periods are repeated continuously.
  - 2-level stagger

| 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 | 150 | 175 |

  - 3-level stagger

| 150 | 175 | 225 | 150 | 175 | 225 | 150 | 175 | 225 | 150 | 175 | 225 | 150 | 175 | 225 | 150 | 175 | 225 | 150 | 175 | 225 | 150 |

  - 4-level stagger

| 150 | 175 | 125 | 200 | 150 | 175 | 125 | 200 | 150 | 175 | 125 | 200 | 150 | 175 | 125 | 200 | 150 | 175 | 125 | 200 | 150 | 175 |

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PRI Agility
Cycler

- For a "cyclic PRI" emitter a stable PRI is generated for N pulses followed by another stable PRI for N pulses, etc.
  - For example, this cycler generates a PRI of 175 for seven pulses and then a PRI of 150 for four pulses.

| 175 | 175 | 175 | 175 | 175 | 175 | 175 | 150 | 150 | 150 | 150 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 150 | 150 | 150 | 150 |

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PRI Agility
Jitter

- For a "jitter PRI" emitter, the interpulse period varies between every pulse usually within a known percentage range.
  - For example, the pulse train below is a 200 +/- 10% jitter pulse train, i.e. the interpulse periods vary randomly between 180 and 220.

| 200 | 183 | 182 | 201 | 199 | 185 | 217 | 216 | 209 | 188 | 181 | 199 | 207 | 207 | 187 | 183 | 184 | 218 | 203 | 204 | 200 | 181 |

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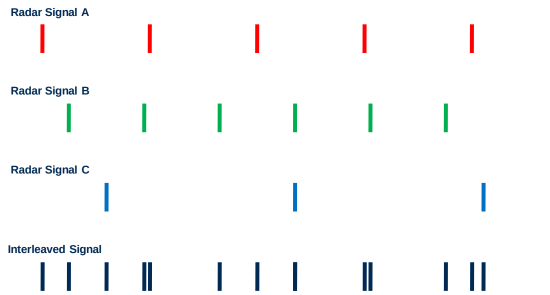
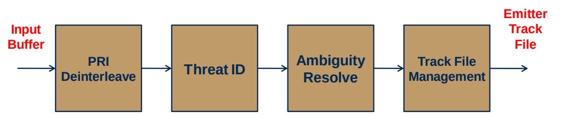
PRI Deinterleaving



PRI Deinterleaving - Sorting

Hardware Measurement	Useful for Sorting?
Frequency or Frequency Band	Yes
Time of Arrival	Yes
Angle of Arrival	Yes
Power	No
Pulse Width	Not so much

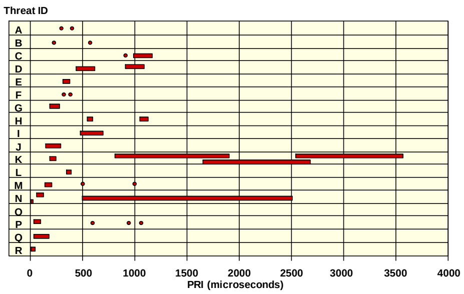
Major Signal Processing Components



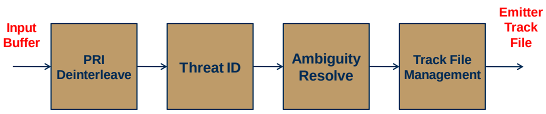
Threat Identification

- Initial threat identification is usually a very simple process.
- The MDF assigns an initial threat ID based on frequency/band and PRI.
  - So, “threat ID” is simply finding the corresponding entry in a table in the Mission Data File.
- Most initial threat IDs are *ambiguous* and require *ambiguity resolution*.

Emitter PRI Range



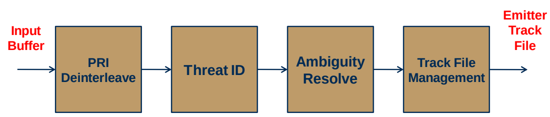
Major Signal Processing Components



Ambiguity Resolution

- Initial threat ID is done based on frequency/band and PRI.
  - This usually results in an ID that says “this could be either Threat A, Threat C, Threat D, or Threat H”.
- Additional measurements are used/required to resolve ambiguities and determine which a unique ID.
  - PRI agility (jitter, stagger, cycler)
  - Multiband
  - Scan type/rate
  - Missile guidance

Major Signal Processing Components



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Track File Management

- All RWRs have some concept of a *Track File*. It may be called different names in different RWRs, but the concept is the same.
- The Track File is where the OFP stores all threat information that is has measured/computed.

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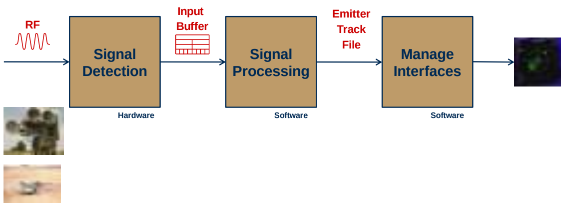
Track File Management (cont.)

- The Track File management software is almost as complex as the PRI Deinterleaving software.
- The OFP updates the track file as new information becomes available.
  - There are many sources of new information: correlation, missile guidance, angle, power, PRI agility, etc.

Track File Management (cont.)

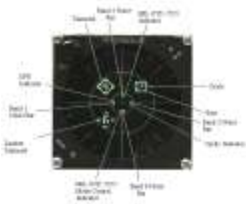
- *The Emitter Track File is the most important data maintained by the RWR OFP*.
- The ETF content affects operation of almost all other OFP functions
  - Pilot cues (audio and display)
  - Initiates additional measurements for ambiguity resolution
  - Alters input scheduling
- The ETF is output to other systems in an integrated EW suite and may drive their operation as well.

Simplified RWR Processing Flow



User Interface

- Buttons/Lamps
- CRT Display
- Audio
  - Missile launch
  - New guy
  - Diamond



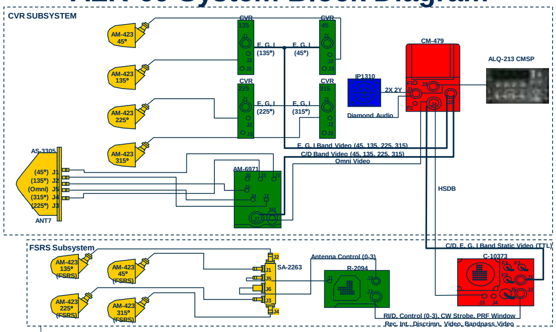
Interface Management

- Besides the user interface the OFP also manages other intrasystem and intersystem input/output.
  - Intrasystem: Setting up pulse collection hardware, messaging on intrasystem hardware interfaces, messaging between OFPs within the RWR, etc.
  - Intersystem: MIL-STD-1553B data bus (EW Bus and Avionics Bus), blanking interface, etc.

RWR “Challenges”

- There are many challenges to accurately and effectively operating an RWR in a real-world environment:
  - High pulse densities
  - Interference from other onboard systems
  - Aircraft maneuvers
  - Urban noise
  - Antenna patterns

ALR-69 System Block Diagram



The Travels of “Joe Pulse”