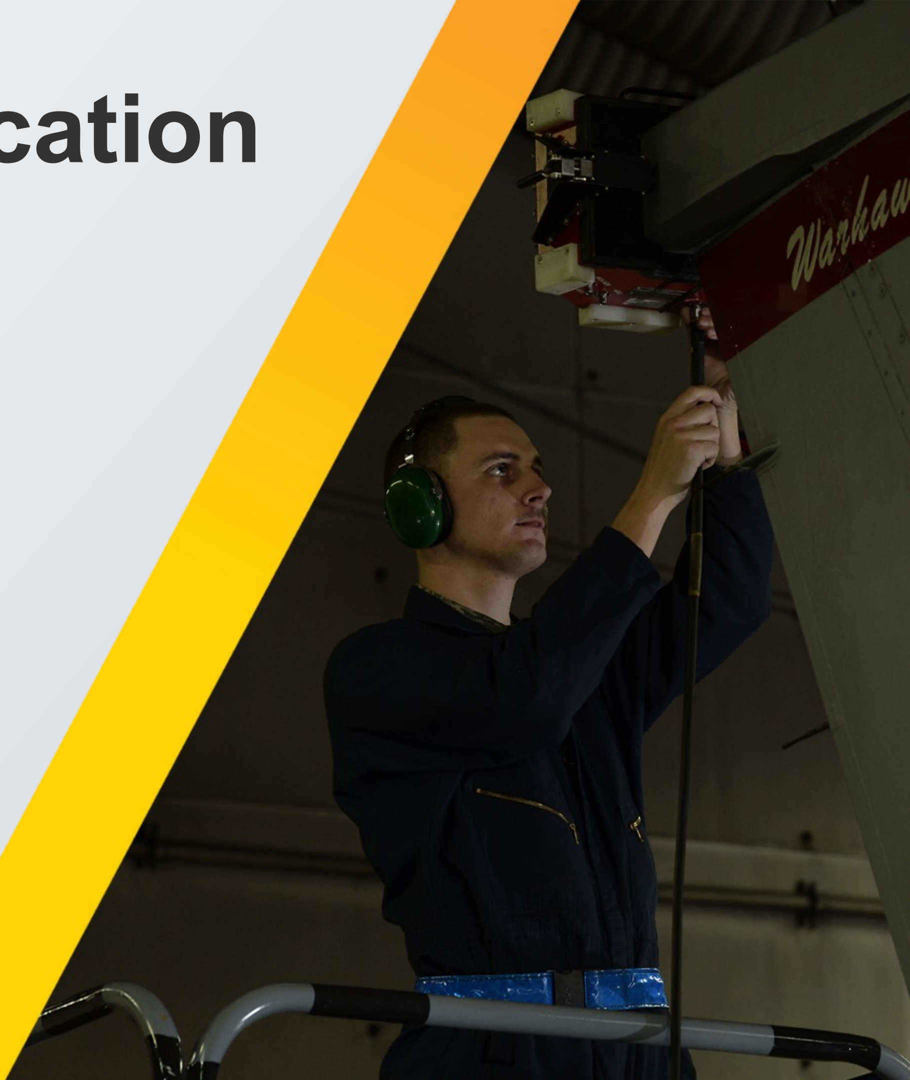
RWR Emitter Identification



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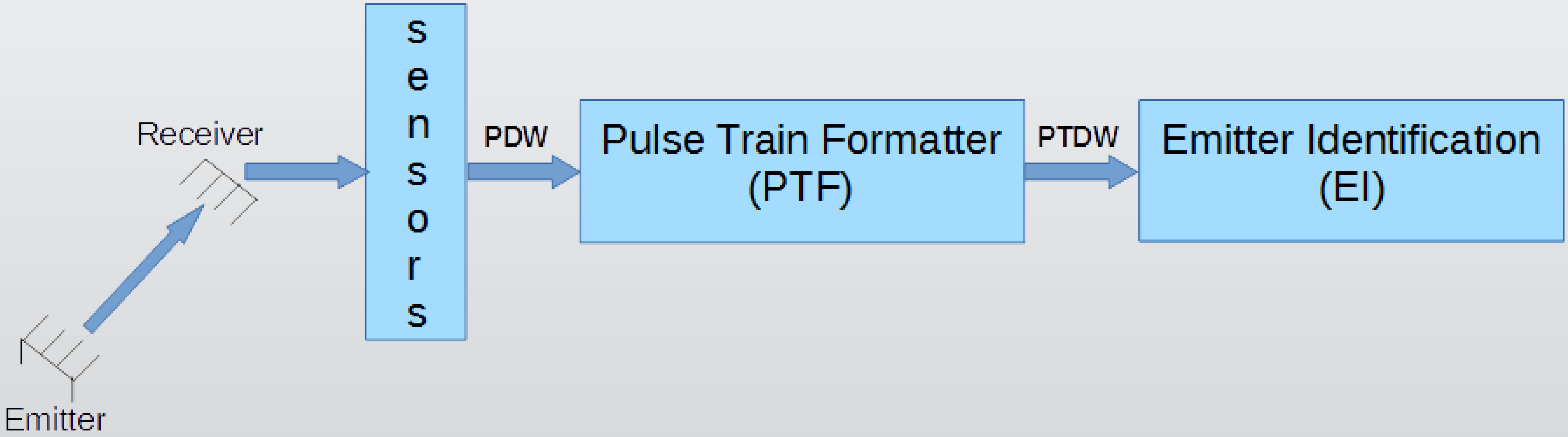
What is a Radar Warning Receiver

- **A conceptual view of an RWR**



We are interested in optimizing the EI

Goals

- Rapid identification of an emitter.
- Using all Emitters for any theater.
- Increase time/space scalability.
  - Linear growth.

Goals

Search Techniques

- Hashing
- Binary Search – focus of presentation
- Fuzzy Indexing

Goals
Hash Function Techniques

- Perfect HF, HF, Minimally Perfect HF
- HF
  - In theory yields a O(1) performance.
  - Single item 100 probes

$$O(1) = 1.1 = \frac{100}{1000}$$

  - Actual performance depends on HF.
  - Size is ≈ 1.5 # items, 1000 items, 1500 cells.

Assumptions

- Total of 4096 (2^{12}) virtual emitters
  - Each mode of a multi-mode emitter becomes a virtual emitter
  - 4096 virtual emitters can represent < 4096 real emitters
- The PTDW is the sole source of emitter data

Assumptions

- PTDW Paramaters
  - Polarization (8 values == $\log_2 8$ = 3 bits)
  - Modulation type (16 values == $\log_2 16$ = 4 bits)
  - Frequency (f)= 2^{13} intervals = 13 bits
  - Pulse Width (w) = 2^{10} intervals = 10 bits
  - Pulse Recurrence Interval (p) = 2^9 intervals = 9 bits

PTDW to Signature

- Pack all parameters into a Signature
  - Total size is 39 bits
  - Round-up to 48 bits – 3 16-bit words
- The set of Signatures are searchable
  - After sorting, a binary search is $\log_2 N$
  - For N = 2^{17} =131,072 entries, this are 17 probes
    - 2^{20} bytes = 1,048,576 bytes
  - Hash search is O(1)

Signature Ambiguity

- Suppose two signatures are the same in the sorted list.
  - $S_i == S_{i+1}$
- This is an ambiguity and means that two virtual radars have he same PTDW parameters.
- A resolution policy is required.

Signature Overdetermined

- It is possible that one or more items in a signature can be removed without impeding the search.
  - The hardware for the item in question can be removed.
  - This translates into a reduction in cost.
- Building a radar is not the same as searching for one.

Summary

- Actual data must be used.
- Signatures yield fast EMI identification times.
- The time per probe is installation specific and can alter the effectiveness of the paradigm.

Analysis

- The picture is too pretty!
- There are two types of data
  - Discrete data whose values can be enumerated
  - Continuous data whose values can not be enumerated

Analysis

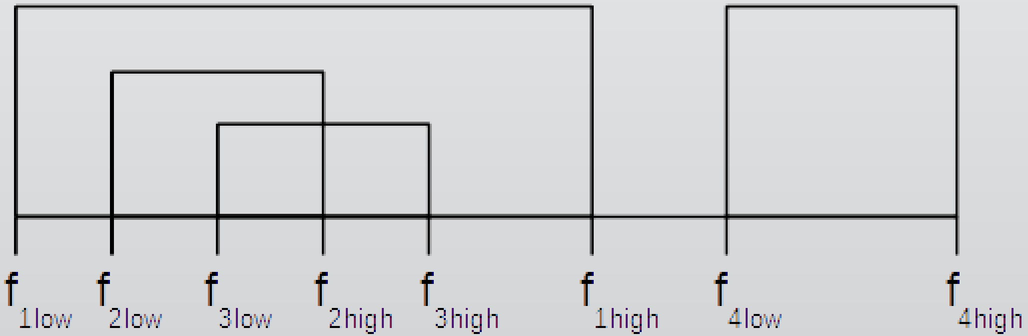
- Discrete data are things like:
  - Polarization (8 values): 3 bits = $\log_2 8$ bits
  - Modulation type (16 values): 4 bits = $\log_2 16$ bits
- Continuous data are things like:
  - Frequency (f)
  - Pulse Width (w)
  - Pulse Recurrence Interval (p)

Continuous Data (frequency)

- The frequencies need to be decimated.
  - Converted from continuous data an enumerable value
  - A 7 Mar 2019 AOC Webinar described a decimation algorithm
  - C++ code for this algorithm is at https://slipbits.com/interval-search/
    - Brute force takes > $O(n^3)$
    - Interval Analysis takes $O(3n + 2n \log_2 2n)$ steps

Range Decimation Overview

- Suppose we have four frequency ranges
  - f_1, f_2, f_3, f_4
- And
  - f_2 and f_3 are wholly contained in f_1,
  - f_2 intersects f_3, and
  - f_4 is disjoint
- Graphically

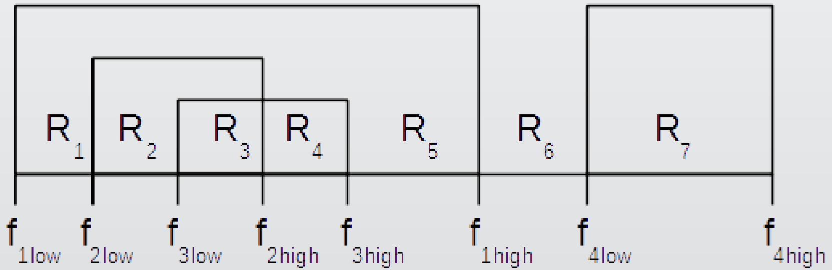


Range Decimation Overview

- Frequency intervals can not be used.
  - No sort order for a binary search.
  - A linear search is required.
- Ranges – unique intervals
  - Between [$f_i$start, $f_{(i+1)}$start), [$f_i$end, $f_{(i+1)}$start), etc.
- Ranges define non-overlapping frequencies.
  - Ranges are ordered ($R_i < R_{i+1}$).
  - A binary search can be done on enumerable ranges.

Range Decimation Overview

- This example decomposes.



- The regions are disjoint
  - An emitter can be in one or more frequency ranges
  - Range boundaries are coincident to frequency boundaries.

Range Decimation Overview
Range Sorting

- With a precedence order ranges can be sorted.
- Since all ranges, R, are disjoint:
  - Finding an *f* in any R is unique. *f* can not be in more than one range.

Time and Space

- Actual numbers for all values are based on the statistics of the EMI objects used.
  - My values are just poor guesses.
- The total number of signatures, 2^{17}, assumes that each of 4096 emitters have 32 signatures.
  - Signature search is 17 probes.
  - Maximum is 17 + 13 + 10 + 9 = 49 probes

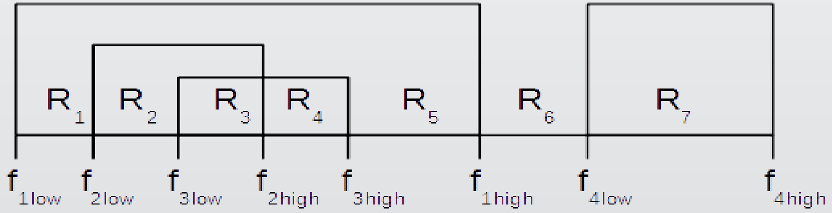
Order 1 probes

- The Range sizes have been variable.
  - Ranges are a subset of a frequency interval.
- Suppose we used fixed size Ranges.
  - Then a probe is: int(f/width) = 1

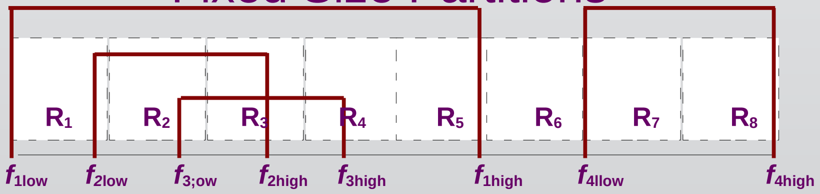
Order 1 probes

- Signatures may have ambiguities

Ideal Partitions



Fixed Size Partitions



Order 1 probes

- The dashed lines represent fixed sized intervals.
- Some frequency intervals are not fully contained in a fixed sized interval.
- This misrepresents the emitters in the signature set and leads to false ambiguities.
- These amguities can not be resolved programmitcally.
  - They require a search within an interval.

Order 1 probes

- With Ideal Partitions there area max of 49 probes.
  - Search interval tables (f, w, p) = (13, 10, 9)
  - Search Signature list (17)
- With Fixed Partitions there are:
  - Search interval tables (f, w, p) = (1, 1, 1)
  - Search Signature list (17) + bucket search
- If the bucket search < 29:
  - Using Fixed Partitions is better than Ideal Partitions

Data Growth

- Worst case a new radar is not wholly contained in existing (f, w, p) intervals.
  - This increases the number of ranges by 6 = (2, 2, 2)
  - The number of signatures increases by one for each range the new radar is in plus 1 for each existing radar in the new interval.