Updating the Estimated Location of an RF Emitter and it's associated Platform

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Abstract: This paper aims to give a general guide to how the accuracy in a radar Platform's position can be improved. In particular, it illustrates how a better estimate can be made by using the Angle of Arrival (AoA) error information relating to the Emitters on the Platform. It also describes how the AoA can be filtered so that invalid values - calculated when the receiver is saturated - can be ignored.

1. Introduction

A typical radar system has to be able to detect RF emissions and determine where and what they have originated from. These emissions could be emanating from several different RF sources (Emitters) which reside on either the same system (Platform) or different systems.

The raw data received relating to each Emitter is processed in order to create a report of its most important characteristics. This will include details of – among others - the Pulse Width (PW), Pulse Repetition Frequency (PRF), Radio Frequency (RF), and AoA. This summary, known as an Intercept Report (IR), is sent to a module known as the Active Emitter File (AEF). This module is responsible for keeping a store of all the Emitters and their associated Platforms present, and tracking and updating important information, which will be sent periodically to a display in the form of Emitter and Platform Track Files (PTFs). This final message will enable the dynamic scenario to be recreated in a more user-friendly form, and allow the system to take appropriate action e.g. Electronic Counter Measures (ECM).

2. The AEF

The AEF builds up its store of Platforms and Emitters using the information in IRs. Each IR can result in Emitters and Platforms being created or updated. This store of track data is maintained by following the outline shown in Figure 1.

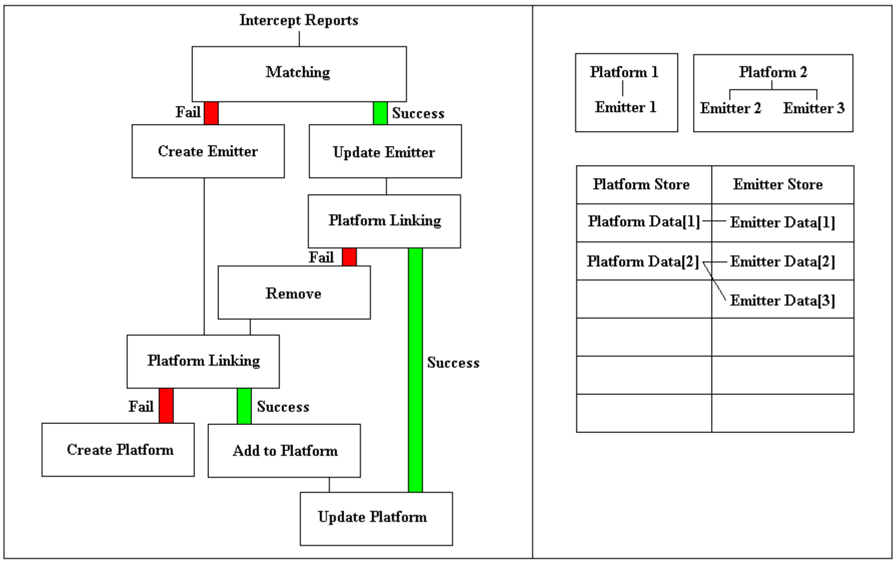

Figure 1

This shows that, on receipt of an IR, the AEF firstly tries to match it with any Emitter tracks it has already created. This match will include checking that the IR has attributes compatible with that of the track. If the AEF fails to find a match, a new Emitter track is created. An attempt will then be made to link this new Emitter track to any Platforms that have already been created. It does this by checking that the AoA is within certain limits and that it is feasible for the Platform to contain another Emitter of this specific identity. If the Emitter can be linked, then the Platform's information – including AoA – will be updated. Otherwise, a new Platform will be created for that Emitter.

If the matching process results in a match with an Emitter track, then its associated information will be updated. A check will then be performed to decide whether the Emitter can still reside on the Platform it is currently linked with. If it can, then that Platform's information – including AoA - will be updated. If it cannot - perhaps because the tracks AoA has changed significantly) - the Emitter track may have to be removed from its original Platform. If this occurs, then the AEF will search for any other Platforms in its store that the Emitter may be compatible with. If such a Platform exists, then it will be linked and that Platform's information – including AoA - will be updated. Otherwise a new Platform will be created.

The AEF needs to be able to use the AoA in each IR such that its ability to perform the following is optimised:-

- Track Emitters and Platforms.
- Link Emitters with Platforms.
- Remove Emitters from Platforms.

In order to do this, the AoA has to be estimated accurately, and ignored (filtered) if it has a dubious origin. Some examples of how this is done are given in the following chapters.

3. AOA Estimation

The AoA of detected radar emissions can be estimated by comparing the power received simultaneously at different antennas [1, 2], with the Emitter being closest to the antenna which received the largest power. Therefore, the AoA of an Emitter can be calculated using the received power at the antennas and the RF of the emission (as this affects the beam pattern and error). This AoA can be utilised in the following two ways in order to estimate the AoA of its Platform.

3.1 Average AOA

The AoA of a Platform – irrespective of the number of Emitters on it – can be calculated using the following equation.

$$Platform\_AoA = \frac{\sum_{n=1}^{N} Emitter\_AoA_n}{N}$$

Equation 1

Here, N is the number of Emitters on the Platform, and $Emitter\_AOA_n$ is the AOA of the nth Emitter on the Platform. The simplicity of this expression makes this method easy to implement, but it does not take into account the quality of each measurement. It does not bias the estimation toward those Emitters with high quality AoA measurements and can thus result in the system being more prone to invalid Emitter association and disassociation.

3.2 Error-based AOA

If a Platform has only one Emitter, then the Platform AoA estimate will be the same as that of the Emitter. If a Platform has more than one Emitter, the AoA can be calculated using the following equation:

$$Platform\_AoA = \sum_{n=1}^{N} \left(\frac{\sum_{n=1}^{N} (Emitter\_AoA_n) * - Emitter\_Error_n)}{\sum_{n=1}^{N} (Emitter\_AoA_n) * (N-1)} \right)$$

Equation 2

Here, Emitter_Error $_n$ is the error in the AOA of the nth Emitter, which is assumed to be Gaussian and is dependent on the antenna patterns associated with detection at the RF of the Emitter [3]. Additionally, the error will be affected by other structures on the Platform. For example, a wing of an aircraft or a mast on a ship may shield the antennas at certain angles.

How the Platform AoA can be improved by using the error associated with each Emitter is shown below in Figure 2.

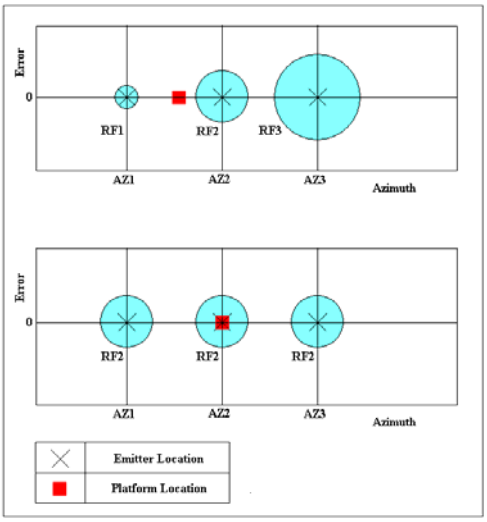

Figure 2

This shows how the AoA of a Platform containing three Emitters is estimated for two cases. The first case shows how the Platform AoA tends toward that of the Emitter with the smallest AoA error. The second case shows that, if every Emitter's AoA error is the same, the Platform AoA will be equal to the average, which could occur if all of the Emitters on a Platform have the same RF.

4. AOA Filtering

As an Emitter's AoA is estimated by comparing the power received at different antennas, problems can occur if the receiver is saturated [3]. If any of the antennas are saturated, then an Emitter will appear to be closer to those antennas where saturation has not occurred. In the extreme, all antennas may be saturated and the Emitter's apparent AoA will be fixed. If incorrect AoA values are used to update the Emitter and Platform, then problems will occur with respect to tracking and linking. To prevent this, the AEF can ignore AoA updates by comparing the maximum power received with a threshold, which represents the point that saturation happens.

Furthermore, if the receiver has the capability of applying attenuation, then attenuation can be requested if this threshold is breached. In this way, invalid AoA measurements can be reduced, as any subsequent detection will be made within the expected dynamic range of the receiver. However, attenuation should not be applied continuously to signals received in the RF range of the Emitter causing saturation, as some Emitters may not require it. A scheme for requesting attenuation is summarised below in Figure 3.

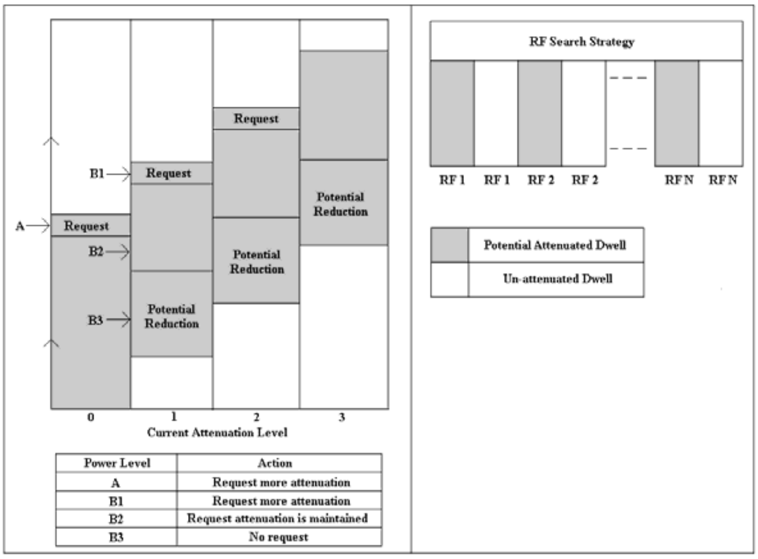

Figure 3

This shows how a request can be made to either maintain or increase the current level of attenuation in the relevant dwell. In this example, the receiver will apply attenuation in the available dwells until it has stopped receiving requests for a predefined time.

The AoA can also be filtered under other conditions. For example, the AoA updates may want to be controlled using hysteresis to smooth out spurious measurements. Also, to control the amount of processing involved, a minimum time between updates could be introduced. This time would have to be determined by considering how constant the AoA will tend to be i.e. it is not likely to change within a small time period.

5. Conclusions

A scheme has been proposed which shows how knowledge of the error in an Emitter AoA measurement should result in more accurate estimates of the AoA of a Platform. It also describes how saturation can invalidate an AoA measurement, and that such updates should be ignored. Finally, it explains how attenuation settings within the receiver can be dynamically altered to restrict the occurrence of these invalid AoA measurements.

6. Acknowledgments

I would like to thank Professor Hugh Griffiths of UCL and my colleagues at SELEX S&AS for their help.

7. References

[1] ‘Curve-Fitting for Signal Amplitude Estimation in Multi-Antenna Direction Finding’, M. Clark (SELEX S&AS).

[2] ‘Improvements in the Estimation of a Radar Platform's Location when Multiple Antennas are used’, P. Trevor, LCS 2004.

[3] ‘Introduction to Radar Systems’. M. Skolnik.