WHITE PAPER

PLATH SIGNAL PRODUCTS

INTERCEPTION CONFIDENCE · DIRECTION FINDING ASSURANCE

A COMPARISON OF RADIOLOCATION USING DOA RESPECTIVE TDOA

1 Motivation

"Despite the prevalence of IR threats facing the US Army's helicopters today in Iraq and Afghanistan, the Army also needs to start planning for the next generation of RF threats, IEW&S top EW official has warned"[1].

Due to the fact that today's signal scenarios' complexity is increasing (i.e. shorter signals, lower signal-to-noise ratios (SNR), higher bandwidths and – of course – better encoding and/or encryption) it is getting harder to get to the content of an unknown emission. Thus, for radio reconnaissance experts it is getting more and more of interest to determine the location of the original emitter (target). In the following, two location methods "Direction of Arrival" and "Time Difference of Arrival" will be explained and compared to each other.

2 Radiolocation

Radiolocation is the process of finding an emitter's location by the use of its emitted radio waves[2]. Due to the angle of incidence of an electromagnetic wave as well as the time or time difference the wave takes to arrive one can calculate an emitter's location[3] (in the first step the assumption is made that the angle of wave incidence is equal to the emitter's direction):

- The Angle of arrival (AOA) method requires at least two detectors at different sites for locating an emission. The emitter is found at the point of intersection where the lines of bearing intersect. This method is also known as direction of arrival (DOA) method. The

[1] JED, The Journal of Electronic Defence, Feb. 2007, Vol. 30, No. 2, "Army needs to think about future RF threat, says PEO IEW&S, p. 15.
[2] The term radiolocation is similar to radio navigation, whereby radiolocation usually refers to find a distant object's position in a passive way – that means in a non-cooperative manner - which against radio navigation is an active method to determine a location. Both are types of radio determination.
[3] In Doppler radar, the use of Doppler shift is also possible for the measurement of the emitter's direction. Also, Received Signal Strength (RSS) method won't be considered because the emitted signal's field strength is normally not known in non-cooperative missions.

process of calculation an emitter's location using the intersection of the lines of bearing is called triangulation4.

- If the time stamp is also transmitted by an emission, a network of at least three detectors (positioned in distinct distances at different sites) can calculate an emitter's location from its time of arrival (TOA) at each site compared to time of emission start. The process of calculating an emitter's location using TOA is called trilateration for a sensor net consisting of three detectors and multilateration (even known as hyperbolic positioning) if more than three detectors are used.
- Another method to determine an emitter's location is to determine the time difference of arrival (TDOA). This technique is commonly used by measuring the TDOA of an emission arriving at two (or more) detector sites compared to one further detector site. The process of locating an emitter by computing accurately its TDOA is also named trilateration/multilateration.

3 DOA

3.1 Derivation of location using DOA

As said above, triangulation can be used to determine an unknown emitter's location only by measuring different angles. First, at least two lines of bearing – i.e. the directions of arrival (DOA) – have to be known.

[4] The first system for radiolocation was a Radio Direction Finder (RDF). This was done by using a directional antenna to find the direction of an emitter by the maximum incident amplitude. Later, early systems used a loop antenna which was rotated by hand to find the angle of incidence. Afterwards, systems used much more directional antennas rotated by motor, with electronic calculation of the angle. These systems were called Automatic Direction Finders (ADF).

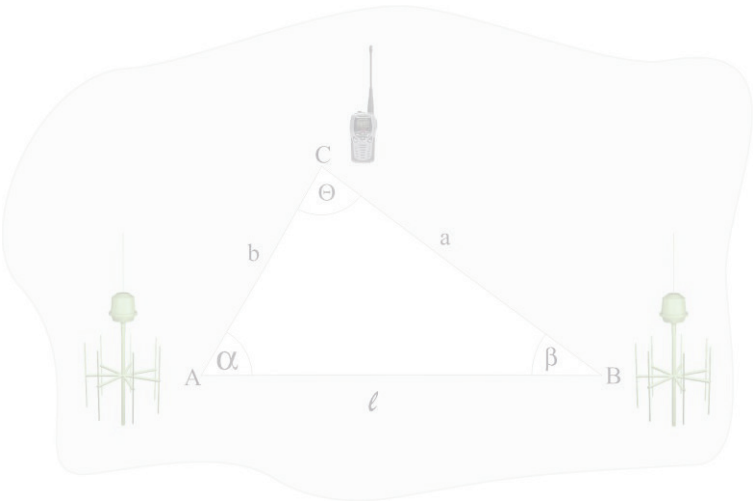

Figure 1: The first DF (at site *A*) and the second DF (at site *B*) bear an unknown emitter at site *C*

As shown in

Figure 1 the detector at site A measures the angle α between the north direction and incident wave emitted by the unknown emitter (target) at site C. The detector at site B does likewise for β. If the coordinates of A and B are known (of course, in location systems they are) the law of sine can be applied to find the searched emitters location C.

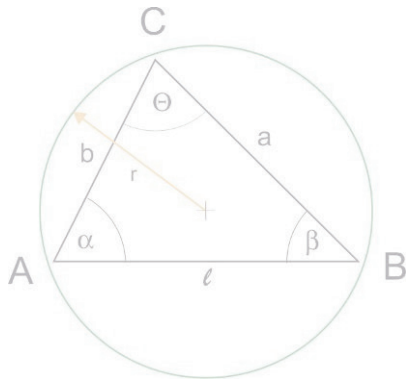

Figure 2: A triangle is shown to describe the laws of sine