Objectives:

(a) Define and provide an example of Electronic Warfare (EW) and its three major subdivisions: Electronic Protection (EP), Electronic Support (ES) and Electronic Attack (EA).
(b) Define Time of Arrival (TOA) and calculate an emitter’s location based on TOA.
(c) Define Jamming to Signal ratio (J/S) and calculate the necessary power to jam an emitter.

In this lesson we will explore how the DoD views the Electromagnetic (EM) spectrum. You will also learn some basic techniques for conducting Electronic Warfare.

I. Electronic Warfare (EW)

*The term EW refers to any action involving the use of Electromagnetic Energy (EM) or directed energy (DE) to control the Electromagnetic Spectrum (EMS) or to attack the enemy. EW includes three major subdivisions: Electronic Attack (EA), Electronic Protection (EP), and Electronic warfare Support (ES).*

- Joint Publication 3-13-1 “Electronic Warfare”
So EW is anything that involves the Electromagnetic Spectrum such as Radio Waves, Gamma Rays or Light. We break it into three basic parts: Attack (offense), Protection (defense) and Support (information).

II. Electronic Protection (EP)

*EP is the subdivision of EW involving actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the EMS that degrade, neutralize, or destroy friendly combat capability.*

Examples of EP include the use of flare rejection logic on an Infrared Red missile to counter an adversary’s use of flares, use of Joint Restricted Frequency List (JRFL), emissions control (EMCON), low observability or "stealth," and spread spectrum technologies.

**Actions protecting us from enemy exploitation of the Electromagnetic Spectrum.**

**DEFENSE!!!**

We will devote an entire lesson to *jamming mitigation* (Lesson 21-Spread Spectrum) which is a fundamental and important form of Electronic Protection.

III. Electronic Warfare Support (ES)

*ES refers to that division of EW involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated EM energy for the purpose of immediate threat recognition, targeting, planning and conduct of future operations. ES data can be used to produce signals intelligence, provide targeting for electronic or destructive attack, and produce measurement and signature intelligence (MASINT).*

**Gaining knowledge of the enemy using the electromagnetic spectrum.**

**Gathering Information!!!!**

A good example of Electronic Support is *locating a Radio Emitter* of interest.
1. Line of Bearing Locating

Suppose you can pick up an adversary’s Radio Transmission. How could you determine the direction it is coming from?

Maybe a directional antenna like a Yagi…

Using a Yagi Antenna you could get a compass bearing in the direction of the emitter. If you get a compass bearing from three locations you could plot the bearings on a map and get a fix.

What, you’ve done this type of plotting before you say? In Navigation class?

Ok, since you think that is easy. What would be another method?
2. Time of Arrival (TOA) Locating

Suppose you know how long it took from when the transmission left the emitter of interest and arrived at your receiver. You could calculate the distance to the emitter as follows:

\[ d = ct_{TOA} \]

\( d \): distance (meters), \( c \): speed of light (m/s), \( t_{TOA} \): time the signal arrived (s)

Using these distances we can plot the location of the unknown emitter:

Or we can use a triangle calculation like below:

Assuming we are working on a flat map (like a Cartesian or X,Y plane) the distance from you to the emitter is the hypotenuse of a triangle.
So…

\[ d = cT_{TOA} = \sqrt{(x_r - x_t)^2 + (y_r - y_t)^2} \]

With two or more TOA measurements from different locations we can use ALGEBRA to solve for the emitters location. (In practice, three or more TOA measurements can be used just to be sure.)

\[ d_1 = cT_{TOA1} = \sqrt{(x_{r1} - x_t)^2 + (y_{r1} - y_t)^2} \]

\[ d_2 = cT_{TOA2} = \sqrt{(x_{r2} - x_t)^2 + (y_{r2} - y_t)^2} \]

Example

You are trying to locate an unknown transmitter at \( (x, y) \) meters. You have two receivers. The first receiver is located at \( (1000, 5000) \) meters and receives the transmission at \( t=12.69 \) µsec. The second receiver is located at \( (7000, 2000) \) meters and receives the transmission at \( t = 9.72 \) µsec.

a) What is the distance from each receiver to the transmitter?

b) Set up the two equations which would be useful for a TOA calculation?

c) Can you solve for a transmitter location at this point?
3. Time Difference of Arrival (TDOA)

Wait a minute you say. ..

TOA assumes you know when the signal left the transmitter. What if you don’t?

Well, we subtract the TOA from three or more receivers to get a Time Difference of Arrival (TDOA). This method, TDOA, makes knowing the time a signal left the transmitter unnecessary. Then taking the difference in distance from three or more locations, we get equations which look like this:

\[ d_1 - d_2 = c(t_{TOA1} - t_{TOA2}) = \sqrt{(x_{r1} - x_t)^2 + (y_{r1} - y_t)^2} - \sqrt{(x_{r2} - x_t)^2 + (y_{r2} - y_t)^2} \]

\[ d_1 - d_3 = c(t_{TOA1} - t_{TOA3}) = \sqrt{(x_{r1} - x_t)^2 + (y_{r1} - y_t)^2} - \sqrt{(x_{r3} - x_t)^2 + (y_{r3} - y_t)^2} \]

Don’t worry we won’t have you solve for TDOA. But understand it is the more practical means for locating an unknown transmitter.

IV. Electronic Attack (EA)

EA is the subdivision of EW involving the use of EM energy, Directed Energy, or antiradiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability and is considered a form of fires.

Attacking the enemy using the electromagnetic spectrum.

THE ATTACK!!!

An example of Electronic Attack is Jamming.

In jamming we target the receiver.
But will jamming a signal interfere with our own use of the EM spectrum? Yes, it might. So jamming all radio frequencies would be a poor strategy. A good jammer will be agile enough to only jam when the target transmits, at the frequency the target is on and only for the minimum amount of time needed.

Recall Signal to Noise Ratio?

$$\frac{S}{N_p} = \frac{P_s}{P_n}$$

where

\begin{align*}
P_s &= \text{signal power (W)} \\
P_n &= \text{noise power (W)}
\end{align*}

What if we replace the Noise at the receiver with another signal from the Jammer. Now we would have:

$$\frac{S}{J} = \frac{P_s}{P_j}$$

But we would want the Jammer to be “in charge” so we “flip” the ratio to get a Jammer to Signal relationship.

$$\frac{J}{S} = \frac{P_j}{P_s}$$

So, now a ratio greater than one or a positive dB will mean the Jamming is stronger than the Signal.

Now recall power at a receiver in free space or line of sight:

$$p_{rec} = \frac{EIRP}{4\pi d^2} A_e = \frac{p_i g_t g_r \lambda^2}{(4\pi d)^2}$$

Our J/S becomes:

$$\frac{J}{S} = \left(\frac{p_j}{p_s}\right)_{rec} = \frac{\left(\frac{EIRP_j}{4\pi d_j^2} A_e\right)}{\left(\frac{EIRP_s}{4\pi d_s^2} A_e\right)} = \left(\frac{EIRP_j}{EIRP_s}\right) \frac{d_s^2}{d_j^2}$$

Or in dB:

$$\frac{J}{S_{dB}} = EIRP_j - EIRP_s + 20 \log d_s - 20 \log d_j$$

*This equation assumes line of sight and an omnidirectional antenna at the target receiver.*
Example

You are located 5500 meters from the omnidirectional receiver you are jamming. The transmitted signal you are jamming originates 9500 meters from the receiver. The signal transmitter’s EIRP is 15 dBW. Assuming both the transmitter and jammer have line of sight, what EIRP must you transmit to jam the receiver with a J/S of 5 dB?

How many Watts is this?

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Help us improve these notes! Send comments, corrections and clarifications to whitty@usna.edu