1.1 Definitions and EW Role in the Military Field

The formal military terminology [1] defines electronic warfare (EW) as a military action whose objective is control of the electromagnetic spectrum (EMS). This objective is achieved through offensive electronic attack (EA), defensive electronic protection (EP), intelligence gathering and threat recognition electronic warfare support (ES) actions. These current definitions give each function a broader scope with respect to terminology used previously, which was, respectively, electronic countermeasures (ECM), electronic counter-countermeasures (ECCM), and electronic warfare support measures (ESM).

The new EA function definition includes, in addition to the previous ECM function, the use of direct energy weapons (DEWs), antiradiation missiles (ARM), and electromagnetic and nuclear pulses (EMP and NEMP) to destroy enemy electronic equipment.

The new EP function definition includes, in addition to the previous ECCM function, the use of electromagnetic emissions control (EMCON), the electromagnetic hardening of electronic equipment, EW frequency conflict removal, and communications security (COMSEC) actions.

The new ES function definition is not very different from the previous ESM definition as both include near-real-time threat recognition in support of immediate decisions relevant to EA, EP, weapon avoidance, and targeting actions.

The classification of the EW functions is shown in Figure 1.1.

EW is one of the military actions of command and control (C2) warfare, whose objective is to obtain C2 superiority by breaking the connectivity of the adversary C2, thus leading to success in military operations. C2 systems are, in fact, the links through which the commanders’ decisions, based on the information and intelligence that flow through those systems, are communicated to battlefield forces.

A C2 system is a network of nodes, each consisting of a number of subsystems, such as sensors, navigation systems, command and data fusion centers, and communication links. A critical node is an element whose disruption or destruction
Introduction to Electronic Warfare Scenarios

C2 warfare (C2W) consists of five military actions, which are integrated in both C2 protection and C2 attack actions:

- Operation security (OPSEC);
- EW;
- Psychological operations (PSYOPS);
- Military deception;
- Physical destruction.

Usually OPSEC and military deception are most effective during the so-called “competitive phase,” which is the introductory phase to a military conflict, but all five actions are essential to war.

OPSEC is the process of denying the enemy any information about our own capabilities and intentions by controlling and hiding information about our military planning. PSYOPS is a planned process of conveying influential messages to enemy groups in order to convince them to perform actions that are beneficial to own forces.

Deception operations are meant to degrade the accuracy of hostile intelligence gathering, surveillance, target acquisition, and reconnaissance (ISTAR) so that the adversary will draw misleading conclusions about our forces’ capabilities and disposition.

EW supports deception operations with electromagnetic deception on intelligence collection, communications, and radar systems.

Physical destruction of a critical node is the most desired and effective option. It involves the use of weapons and of targeting and battle damage assessment (BDA) functions, which are usually accomplished by electronic and optical imagery equipment. EA also participates in the destruction process by the use of ARMs against
radar and communication sources and by DEWs in the disruption or burnout of adversary electronic equipment.

In conclusion, in the military field (and namely in the C2W framework), EW plays an important role in that EA supports C2W attacks for combat operations, EP contributes to C2W protection against enemy electronic attacks, and ES provides information that can be used to plan our own C2 attacks and to assess battle damage of the involved sites, thus providing feedback on the effectiveness of the C2W plan.

Section 1.2 gives a brief description of the principles of operation of the main weapons systems that are driven by electronic sensors and, thus, potentially prone to EW actions. We then discuss EW applications during symmetric conflicts (Section 1.3) and asymmetric conflicts (Section 1.4).

1.2 Main Weapons Systems of Interest to EW

The armed forces of each country and its alliances are usually comprised of at least three main groups: army, navy, and air force (marines are considered here to be a navy army), each tasked with different missions with respect to the defense of the country/alliance territory and to any war actions in enemy foreign territories. In the execution of those missions, the armed forces have at their disposal a number of different platforms employing weapons systems, such as munitions, guns, and missiles, whose task is the destruction of enemy assets.

Destruction of enemy assets is preferably accomplished from a distance in order to prevent any harm to our own assets: The larger the distance, the safer our own assets, because the probability of effective retaliation by the enemy is reduced. Modern weapons are being conceived to reach targets at ever longer ranges and to cover such distances at ever higher speeds, so as to reduce the time for an effective enemy defensive reaction, thus increasing the probability of success of the weapon. The provision that the weapons systems have sufficient aiming accuracy at long distances is ensured by electromagnetic sensors (with electronic equipment) that detect and accurately track targets at long distances, thus allowing for accurate bombing and accurate guidance of artillery fire or missiles toward the target. A pictorial representation of the various air attack to ground assets is reported in Figure 1.2 [2].

The air force mission is to ensure air/space superiority and air defense over the territories of interest. The accomplishment of those tasks is performed by an integrated air defense system (IADS) comprised of a number of assets, such as the following:

- An air defense system, composed of ground and airborne early warning radars, C2 centers for surface-to-air missiles (SAM) and antiaircraft artillery (AAA) for defense of important sites and airports;
- Air superiority (or counter-air) fighter aircraft (A/C);
- Intruder/strike A/C.
The objective of EW is to control the EMS in order to gain superiority for our own armed forces and to operate against enemy sensors, both by locating them and by performing actions aimed at reducing their performance. This is done by amplifying the enemy’s problems and limits in order to dilute the effectiveness (i.e., the kill probability) of their associated weapons systems.

In the brief notes that follow, the operating principles of the main weapons systems are discussed. A detailed discussion about their operation and the limits of their driving sensors is deferred to Chapter 2.

The main weapons systems employed by the armed forces are of the following types:

1. Early warning surveillance systems, either ground/shipboard or airborne. Early warning systems consist of long-range (in excess of 400 km) surveillance radars mainly operating in the lower radar RF band (from 100 to 3,500 MHz).

2. Missiles systems of various types:
   - Antiaircraft SAMs;
   - Antiaircraft AAMs;
   - Antiship or antiground value target missiles, either launched from the air (ASM) or from the surface (SSM).

All the above types of missiles can be guided either by radar or by an infrared (IR) seeker in accordance with the stand-off range (i.e., the range of the flight from the launch platform; IR-guided missiles usually have shorter ranges than the radar-guided ones). Antiship missiles are mostly radar guided, but some have hybrid guidance (radar + IR). Additional types of missiles are:
1.2 Main Weapons Systems of Interest to EW

- Antitank systems, mostly wire or IR laser guided, but some guided by millimeter-wave (MMW) radars,
- Antiradiation missiles (ARM);
- Ballistic missiles (types of attack capabilities are shown in Figure 1.3).

Typical ranges of the various types of missiles are reported in Figure 1.4.

3. Artillery systems, such as radar-guided AAA.
4. Precision guided munitions against tanks or buildings, consisting of projectiles guided by optical/IR trackers and laser range finders.

![Ballistic missiles](image1)

**Figure 1.3** Various types of missile attacks.

![Range (km)](image2)

**Figure 1.4** Typical stand-off ranges of land and maritime attack weapons compared to the range span of air defense systems.
5. Communication networks, which are the backbone of all military operations, providing combat situation information to the C2 and handling commands from it.

1.2.1 Artillery Systems

Artillery systems usually consist of guns of various calibers that shoot projectiles against fixed or mobile targets and are driven by commands from a fire control system (FCS). The FCS computes the projectile trajectory to the target on the basis of target parameters, projectile and gun parameters, and atmospheric conditions.

For mobile targets, usually aircraft, the AAA fire control system is provided with tracking radar that, on receipt of a 2-D data (dimensions: range and azimuth) designation from surveillance radar, starts an acquisition search at the elevation of the designated target. As soon as the target is acquired, the tracking radar continuously provides the FCS with accurate 3-D (range, azimuth, and elevation) target coordinates, which allow it to determine the kinematics data of the target. With these data and from an extrapolation of the target’s trajectory, we can determine the interception point of the fired projectile with the target as shown in Figure 1.5.

A number of shots must be fired in order to achieve the required kill probability. During the shooting period, the tracking radar measures the miss distances of

\[ V_o = \text{Target velocity (m/s)} \quad T = \text{flight time of the projectile (s)} \]

\[ V_p = \text{average velocity of the projectile during the flight time (m/s)} \]

\[ \alpha = \text{elevation angle (rad)} \]

\[ X_i = \text{Intercept point (m)} \]

\[ X_0 = \text{target position at firing time } t_i(m) \]

\[ X_i = X_0 \frac{V_o \cos \alpha}{V_a + V_p \cos \alpha} \]

**Figure 1.5** Intercept point on the target trajectory of an AAA engagement.
1.2 Main Weapons Systems of Interest to EW

the shot projectiles from the aircraft in order to enable the FCS to correct the gun’s aim and the computed projectile’s trajectory. In the case of a successful hit, the tracking radar also provides the kill assessment of the target engagement.

The kill probability of the AAA is mainly dependent on the measurement accuracy of the target kinematics and trajectory data as provided by the tracking radar and somewhat dependent on the lethal radius of the projectile.

1.2.2 Missile Systems

Artillery systems are very effective at short ranges, when target kinematics and trajectory measurement are quite accurate (especially if the target is not maneuvering) and the flight time of the projectile is also short. For long ranges, which require a longer projectile flight time, the target gains the opportunity to invalidate the computed interception point by performing a moderate maneuver.

The increases intercept point range is achieved by missiles that belong to two classes: those that attack fixed locations using inertial or global positioning system (GPS) guidance up to the target [ballistic missiles and terrain contour matching (TERCOM)], and those that are guided to a moving target even if the target is maneuvering during the engagement period (i.e., guided missiles).

The latter class of missiles has, in turn, two subclasses, which differ in terms of the type of guidance employed: command guidance or seeker guidance. Indeed, a missile can be guided to its target by being commanded either by a remote sensor (radar, IR, or EO head), which tracks the target and the missile, or by a sensor (called a seeker) internal to the missile.

A guided missile is constituted [3] by an airframe usually consisting of the following equipment:

- Either a receiver that demodulates the command data transmitted by the remote sensor or
- a seeker (radar, IR, or EO head), enclosed in an ogival radome/IR dome, which tracks the target and generates the command signals to the guidance system.
- A warhead containing the explosive material used to damage the target. The explosive material is usually ignited by a proximity fuse, which allows the target to be hit anywhere within the warhead’s lethal radius.
- A guidance system or autopilot that converts the command signals from the seeker into the positions of the control fins, hence guiding the missile toward the interception point with the target.
- An engine, fueled by propellant, which provides the thrust to the missile and feeds the power supply needed by both the seeker and the guidance system.

A schematic representation of a missile and of its seeker/guidance operation is shown in Figure 1.6.

Missile weapons systems have search radar that reports to a C2 in case of ground or shipboard systems, or to the main computer in the airborne case, which evaluates the threat and designates the tracking radar and associated missile
launcher of the weapons systems, which is usually able to launch multiple missiles in a quick sequence.

Missile systems are of various types, from the very-long-range ballistic missiles and long-range cruise missile systems designed to attack fixed locations in enemy territory, to the local-area medium- to long-range (50- to 150-km) missile systems designed to defend a relatively wide area (both at ground and at sea) and to the medium- to short-range (5- to 50-km) battlefield missile systems designed to defend/attack high-value targets such as ships, airfields, and military ground assets.

Missiles can employ many different guidance systems, from short-range command and beam-riding guidance to medium- to long-range semiactive and active homing missiles. Very-long-range and long-range missiles usually employ active homing only in the terminal part of their flight to the target; during the rest of their course they are guided by an inertial or satellite navigation system or by recorded terrain data.

Command missiles are guided by commands transmitted from the command link of the ground/shipboard missile weapons systems, which is provided with two tracking radars: a target tracking radar (TTR) and a missile tracking radar (MTR). The missile is usually provided with a beacon in order to ease the tracking of the
MTR. The two tracking radars are managed by a common C2 center that evaluates the data received from them and computes the commands to be sent to the missile. The use of two independent tracking radars ensures that the best possible trajectory-to-target interception is selected for the missile. Alternative command guidance is constituted by a single tracker for both the target and the missile. In this case, called command-to-line of sight (CLOS), the missile has to stay always within the radar beam aimed at the target.

Because the angular target tracking accuracy $\sigma_\theta$ is a fraction of the radar beam-width $\theta_B$ (usually $\sigma_\theta = 0.01$ to $0.05 \theta_B$), the miss distance $m_d$ from the target of the missile, which is supposed to be aligned with the radar boresight, increases with the distance $R$ of the target from the tracking radar, that is, $m_d = R \sigma_\theta$. For this reason command missiles are used for short ranges. The advantages of these systems are that the missile is a simple one and that the available high effective radiated power (ERP) of the tracking radars employed on ground/ships provides a good ECCM feature.

Beam-riding missiles have an on-board receiver that senses whether or not the missile is aligned with the tracking radar boresight and provides that data to the missile guidance system, which commands the missile to stay aligned with it. As shown in Figure 1.7, the missile is forced to follow a trajectory that requires strong accelerations in the terminal phase of the engagement even in the absence of target maneuvers. Therefore, this type of missile guidance is mostly exploited against slow nonmaneuvering targets, for which only weak accelerations are required.

Semiactive homing missiles are provided with an RF seeker that has a receiver capable of passively tracking in angles the scattered signal from a target when this is illuminated by a powerful continuous wave (CW) or interrupted continuous wave (ICW) tracking radar. The advantage of this type of missile is the absence of an onboard transmitter, which is usually quite expensive. This type of missile, similar to the active pulse Doppler (PD) missile, has the ability to discriminate between the target and clutter by using Doppler frequency signal processing. The angle tracking signals are processed within a very narrow bandwidth (on the order of 1 kHz, thus also achieving a high receiver sensitivity), which is positioned at the Doppler frequency $f_d$ relevant to the closing speed $v_c$ (i.e., $f_d = 2v_c/\lambda = 2(v_t + v_m)/\lambda$, where...
\( \lambda \) is the transmitted wavelength and \( v_t \) and \( v_m \) are, respectively, the projections of the target and missile speeds along the target–missile line, as shown in Figure 1.8.

The missile angular tracking accuracy in the terminal phase of the engagement no longer depends on the distance from the tracking/illuminator radar because the seeker is now close to the target. Because there is no more need for the missile to stay within the illuminator beam, the missile can exploit the proportional guidance, which is depicted in Figure 1.9.

The missile is launched toward the predicted interception point, while the seeker antenna tracks the target. With reference to Figure 1.7, in which the missile engagement with the target is reported and the angle parameters are defined, we can show that the correction commands to the missile velocity vector (i.e., only a lateral acceleration \( a_{lm} \), as the missile is flying at constant velocity \( v_m \) in modulus) are applied only through its rotation rate \( \frac{d\gamma}{dt} \), which is made proportional to the measured rotation rate of the seeker boresight \( \frac{d\alpha}{dt} \) in accordance with the selected navigation constant (dimensionless) \( N = k \frac{v_t}{v_m} \), where \( v_t \) is the target velocity and \( k \) is a constant (usually assumed to be between 2 and 4):

\[
\frac{d\gamma}{dt} = N \frac{d\alpha}{dt} = N \dot{\alpha} = k \frac{v_t}{v_m} \alpha
\]  

(1.1)

Because the lateral acceleration can be expressed as from the above equation, we then have:

\[
a_{lm} = v_m \gamma = v_m k \frac{v_t}{v_m} \alpha = k v_t \alpha = k v_t \alpha = k v_t \alpha
\]  

(1.2)

which means that the lateral acceleration impressed to the missile is proportional to the target lateral acceleration \( a_{lt} \). With this type of guidance, no lateral acceleration is impressed on the missile in order to intercept a target flying on a constant course. So the full available acceleration of the missile can be spared and impressed on the missile only in the case of an evasive maneuver by the target. This ability provides the missile with a longer intercept range and available residual acceleration in the terminal phase of the engagement with the target.

Semiactive missile systems are very effective and constitute the majority of the medium- to long-range SAM population. The major disadvantage of this type of guidance is that constant target illumination is required during the entire time of flight of the missile, which can be dangerous in the case of an air-to-air engagement because the launching platform has to keep on the approach to the target, thus becoming subject to possible retaliation from enemy aircraft.

### 1.2.3 Active Homing Missiles

Active homing missiles are provided with a seeker that is a complete tracking radar; that is, it is equipped with a transmitter that can engage its target autonomously without any further assistance from the launch platform. For this reason it is called a “fire-and-forget” missile.
1.2 Main Weapons Systems of Interest to EW

Figure 1.8 Principle of operation of a semiactive missile.

Figure 1.9 Proportional guidance law for trajectory for a semiactive missile during its engagement with an A/C.
Medium- to long-range active homing missiles are provided with a dual guidance system: an inertial or command guidance in the first phase of the flight toward the target, which is then switched to active homing proportional guidance on the target on arrival at some distance from the target.

Due to the presence of a transmitter of this type, the missile is quite expensive.

1.2.4 Track via Missile Systems

Track via missile (TVM) systems [4] employ a mix of command and semiactive missile guidance principles in order to achieve improved medium- to long-range performance at a reasonable cost.

They require a ground illuminator and a semiactive radar sensor on board the missile. However, the angular tracking data are not processed within the missile; they are instead sent via a downlink to a powerful central processor at the launch platform on the ground. Here the trajectory data of both the target and missile are processed, and accurate guidance commands are sent back to the missile via an uplink.

Modern systems use multifunction radar based on phased array technology (Patriot, PAAMS, etc.), which provides them with the ability to engage many targets simultaneously, regardless of which type of missile is use: semiactive and TVM (with the use of ICW illuminators), active seeker, or command guidance. A single missile system provided with a phased array fire control radar may launch and track simultaneously in time-sharing mode many missiles against several different targets. In the case of semiactive and TVM guidance, the phased array fire control radar illuminates the targets in ICW mode, thus providing both tracking of the target and the missile as well as target illumination. This type of weapons systems is shown in Figure 1.10.

Figure 1.10   A TVM weapons systems.
1.2.5 Passive IR-Guided Missiles

Passive IR-guided missiles are provided with an IR seeker that autonomously tracks the heat signature of the target and provides commands to the proportional navigation guidance system during its approach to the target. Thus they also are of the "fire-and-forget" type.

These types of missiles are extensively used both as medium-range AAMs, due to the relatively lower propagation attenuation at high altitude and their high maneuverability (because they are lightweight), and also as short-range SAMs, due to the higher propagation attenuation at low altitude. They are most often portable and shoulder-launched missiles (in fact, they are called MANPADs) for the defense of ground troops and armored vehicles (and, unfortunately, in current periods, also by terrorists).

Descriptions of the various types of IR seekers are discussed in Section 2.6 of Chapter 2.

1.2.6 Sea-Skimming Missiles

This type of active homing missile is dedicated to ship attacks and flies at a very low altitude over the sea surface as if it is skimming the waves. It can be launched from long distances either from aircraft or ships/littoral sites and is usually provided with a dual guidance system (inertial along the cruise phase and active homing on the target during the terminal phase) in the horizontal plane and with an altimeter to keep a constant height in the vertical plane. A pictorial representation of maritime missile attacks is reported in Figure 1.11.

Ship targets present both a problem and an advantage for these missiles. The problem is constituted by the large angular glint fluctuations (see Section 2.3.8

![Figure 1.11](image_url) Types of maritime missile attacks.
of Chapter 2) produced by the extended length of the ship that require robust angular data filtering to smooth them. The advantage is constituted by the large ship’s radar cross section (RCS), which provides large target returns that exceed the sea clutter ones, thus allowing the missile seeker to operate in superclutter conditions [i.e., with a high signal-to-noise power ratio (SNR) and signal-to-clutter (S/C) power ratio on a single radar pulse]. These conditions permit the use of large carrier frequency pulse-to-pulse agile radar waveforms with very short pulse widths, which constitutes a big challenge to the ECM ship defenses (as discussed in Section 6.2 of Chapter 6).

1.2.7 Antiradiation Missiles

An antiradiation missile (ARM) is provided with a passive seeker that is similar to a small wideband superheterodyne ESM receiver (see Section 3.4 of Chapter 3), which is capable of acquiring and tracking in angles the signal transmitted by a selected surface radar or communication source and to home on it with high precision. ARMs are mostly of the ASM type and are installed on board aircraft dedicated to the suppression of enemy air defense (SEAD) missions.

The ARM seeker is cued by the airborne ESM system of the A/C, which, upon interception, identification, and location of the victim radar, provides the ARM with all of the emitter data and verifies that the ARM is locked on to that emitter.

Once launched, the ARM seeker, through the use of highly accurate phase direction-finding (DF) antennas, computes from the received emitter signals (in a similar way as for the active homing missiles) the angular commands to be sent to the guidance system in order to home on the victim radar.

The ARM is a typical example of a stand-off “fire-and-forget” weapon because it can be launched from long distances without any further assistance from the launching platform. Many ARMs have been developed that cover the complete radar bands from 0.5 to 18 GHz. The only protective actions that the victim radar can use are to stop transmitting (this does not, however, ensure survival as the missile can home on it on the basis of memorized coordinates) or to activate nearby decoy transmitters that emit waveforms similar to those of the victim radar.

Table 1.1 lists various aircraft characteristics, and Tables 1.2 through 1.5 give the reader insight into the various missiles characteristics.

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Wing Span (m)</th>
<th>Wing Area (m²)</th>
<th>Number of Engines</th>
<th>Combat Radius (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/A-18</td>
<td>11.43</td>
<td>37.16</td>
<td>2</td>
<td>1,480</td>
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<tr>
<td>F-16</td>
<td>9.45</td>
<td>27.87</td>
<td>1</td>
<td>925</td>
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<td>47.01</td>
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<td>463</td>
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<td>1</td>
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<td>41.00</td>
<td>1</td>
<td>1,480</td>
</tr>
</tbody>
</table>
1.3 EW in Symmetric Conflicts

Symmetric conflicts occur when the two adversaries’ armed forces are both militarily structured, well organized, and provided with weapons systems such as the ones described in the previous sections. In such conflicts the concepts expressed in Section 1.1 about C2W apply.
In this section we expand on the description of the EW (ES, EA and EP) actions that play an important role in C2W.

C2W depends on all sources: timely intelligence about the adversary’s capabilities, objectives, and operational concepts. Intelligence sources are the means used to provide such information. Signal intelligence (SIGINT), an ES function, is one of those sources. SIGINT systems collect, analyze, identify and locate emitter signals throughout the entire communications and radar band. Usually they are composed of two dedicated systems: COMINT and ELINT.

Communications intelligence (COMINT) systems are concerned with the activity detection, collection, classification, identification, and DF of communications systems (both voice and digital), data links, satellite communications, and cellular phones. Location of emitters for real-time targeting is usually performed through signal time differential of arrival (TDOA) and differential Doppler frequency (DD) techniques applied in a multiple aircraft systems [5].

Electronic intelligence (ELINT) systems measure direction and time of arrival (DOA and TOA) along with all of the radar waveform signature parameters, such as carrier frequency, pulse width, signal bandwidth, and pulse repetition interval. These data are used both to upgrade the database on the adversary’s radars and their associated weapons systems, called ELINT parameters limits (EPLs), and to provide, after comparison with the data in the database, the electronic order of battle (EOB), that is, the disposition of the adversary’s weapons systems on his territory. The EPLs are provided to our own ESM equipment in order to allow emitter identification whenever they come in contact with them. Emitter location is accomplished through the methods described in Chapter 4, which include triangulation, trilateration, with time difference on arrival (TDOA), and frequency difference on arrival (FDOA).

ES is largely present in the C2W in the form of radar warning receivers or ESM on board aircraft to warn them of the presence and direction of radar threats.

EA is usually performed by aircraft penetrating the adversary’s territory for SEAD purposes or by ships and ground assets during self-protection or mutual protection actions against an air attack.

The adversary’s territory is usually protected by an IADS made up of surveillance, acquisition, and tracking radars, the latter providing the guidance to the weapons systems (AAA and missiles) as described in the previous section. A typical EW scenario during symmetric conflicts and its relevance to multirole A/C is shown in Figure 1.12.

EA performed by aircraft penetrating the adversary’s territory against search radars is performed either with jamming, with the goal of preventing or delaying their target designation to the associated weapons systems, or with ARMs, with the goal of destroying the radar. Common jamming modes are discussed next.

Active self-protection jamming (SPJ) is performed either by noise jamming, with the purpose of denying range, velocity, and angle information about its platform, or by the generation of a large number of false targets, with the purpose of producing confusion to both the radar operator and the automatic detection and tracking processing system.

Chaff is launched to effect jamming. Chaff consists of a large volume cloud composed of thousands of elemental radar reflectors that provide a very large amount of volume radar reflection with respect to the echo of the protected aircraft, thus preventing target detection. Chaff effects may persist for a relatively
1.3 EW in Symmetric Conflicts

Because chaff is relatively inexpensive, it is one of the most used EA techniques. A typical SPJ operation is shown in Figure 1.13.

Support jamming (also called mutual protection) includes stand-off jamming (SOJ); escort jamming (EJ), which usually operates in the search radar antenna’s sidelobe region, as shown in Figure 1.14 or stand-in jamming (SIJ), which has the same purpose as the SPJ but applies to the entire raid of intruders.

Support jamming can employ noise jamming, deceptive electronic countermeasures, or deployment of corridors of chaff. SOJ missions are conducted by an...
aircraft loitering outside the lethal zones of hostile weapons systems in order to hide the radar echoes of the friendly intruder aircraft, thus preventing their exposure to the hostile fire of air defense systems triggered by the designation from the search radar.

EJ missions are conducted by aircraft that accompany the intruders as they penetrate the enemy’s territory. As the EJ aircraft is penetrating the combat zone, it is vulnerable to enemy weapons and needs to be provided with self-protection jamming capabilities like those of the intruders. EJ aircraft are generally used when the intruder aircraft does not have a sufficient payload to protect itself.

EJ missions are usually conducted by multiple EJ aircraft, widely spaced among them, in order to provide confusion in the enemy’s defense systems, which are trying to determine the intruder attack direction through jamming strobes. The confusion that is generated helps in delaying the air defense system response, thus increasing the probability of success of the intruder attack.

SIJ missions are conducted by unmanned combat aerial vehicles (UCAVs), which come nearer to the victim radars and exploit a lower jamming power to perform the same mission as the EJs.

EA performed by aircraft penetrating the adversary’s territory is used primarily against target tracking radars (TTRs), which are used to guide the weapons systems (both defensive as well offensive) by locking on to the target and providing accurate direction (i.e., azimuth and elevation), range, and velocity data. The velocity data are used to predict the future position of the target and to point the weapon to the lead direction (as shown earlier in Figure 1.5). EA against TTRs is performed in a manner similar to that used for the search radars with jamming and ARM launches.
SPJ ECM systems are employed to counter the tracking radar through the use of deception techniques (DECM) that attempt to cause the tracking radar to break lock. Noise jamming is rarely employed against missiles, because most seeker heads can track the ECM radiation in angles (track-on jam), which is sufficient for many types of missiles (e.g., the semiactive missile) to lock on the target.

Illustrations of intruder aircraft attacks on an enemy’s highly defended territory are shown in Figures 1.13 and 1.14 for, respectively, attack with intruders only provided with SPJ and with intruders supported by SOJ, EJ, or SIJ.

EA is also performed by ships when attacked by air raids or by sea-skimming missiles. In the first case noise and deception jamming are performed in order to deny range and position information, thus preventing either the launch of ASMs or an accurate bomb release. In the latter case a combination of noise jamming, launch of chaff, and deception jamming is performed in conjunction with the ship’s close-in weapons systems (CIWS) operation to divert the missile from the ship or to destroy it.

EA is performed in a similar way for a ship (with the exception of chaff launches) in the defense
of ground assets against air raids with launch of RF-guided ASMs or ARMs.

EA is also performed against communications networks in C2W operations. The primary objective in military communications jamming is to disrupt the network communication links so as to separate the C2 from its asset nodes. EA in the communication bands is conducted against combat net radios, tactical data links, and military satellite communications.

Combat radio nets, which provide short- and medium-range voice communications in the 30- to 88-MHz VHF band and operate with digital messages in the frequency hopping (FH) mode, can be somewhat jammed with broadband noise jamming or frequency-follower jamming.

Tactical data links are used to provide connectivity among distributed ground, sea, and air mobile nodes. They are conceived to be nodeless, which means that no communication center is needed because all users transmit to everyone else and operate in very fast FH mode, thus preventing frequency-follower jamming. Only tone jamming can have some effect, as will be discussed in Chapter 6.

Satellite communication systems (SATCOMs) provide worldwide connectivity at high data rates among forces that are quite distant from each other. Old SATCOMs operate in the UHF band (250 to 400 MHz). More recent SATCOMs operate in the SHF band (7 to 8 GHz) or EHF band (20 to 44 GHz).

UHF communications have the advantage of using a simple antenna that can be easily installed in mobile platforms such as aircraft, small ships, and small land vehicles. But because of the large antenna beamwidth they can be easily disturbed by ground jammers. SHF and EHF communications are harder to jam, and only tone jamming can provide some effect.

EP is strongly present in all radar and communication receivers and signal processors with a number of very effective ECCMs, as will be described in Chapters 2 and 6, thus rendering the contest between EA and EP a sort of chess match where each move of a player is met with a countermove by the other player.
1.4 EW in Asymmetric Conflicts

Asymmetric warfare occurs when the two opponents have highly unequal military capabilities and the weaker one uses methods of attack such as sabotage, terrorism, or insurgency that avoid contact with military forces in areas where the opponent is stronger. Conceptually, it is similar to guerrilla warfare or to Special Forces operations. The weapon usually employed by the weaker opponent in the above-cited actions are light gunnery and improvised explosive devices (IEDs).

In the asymmetric conflicts EW is strictly limited to the communications bands, and it is used only by the stronger opponent and employed in slightly different modes in the two areas into which a territory can be divided: rural areas and urban areas.

In rural areas EW essentially performs detection of hostile communications and communication intelligence from an adversary’s messages using CESM and COMINT equipment (which is the same as that employed for symmetric conflicts), EW also involves countering a radio-controlled IED (RCIED) with some appropriate counter-RCIED jammer (CECM).

RCIEDs are triggered by an RF signal to initiate their explosive charge. They offer the user the advantage of flexibility because there is no physical proximity between him and the device. RCIEDs are used in ambushes of military convoys and patrols as they traverse roads. The RCIED is usually planted in locations where the convoy/patrol cannot go off-road to avoid the device. The RCIED user is located in an observation point where he can see the approach of the convoy/patrol to the device and is able to send the triggering message to the planted device at the right time. The radio link used is usually a short-range one, with the exception of the use of mobile phone systems, such as GSM, where existing networks are available. In the latter case the trigger command may be sent from up to a few kilometers away.

The following EW actions are applied to defend against RCIEDs:

- Detection of an adversary’s communications in the interested area (which may be performed by stand-off systems such as UAVs patrolling the area for reconnaissance and intelligence collection in the days prior to the passage of the convoy),
- Preemptive initiation of the explosive device before its intended use by using a high-power jammer,
- Force protection jamming around the convoy/patrol to create an RF shield.

The counter-RCIED methods and jammer devices are discussed in Section 6.3.4 of Chapter 6.

EW actions in urban areas employ CESM and COMINT equipment in the same way as for the rural area to provide, respectively, targeting for the EA equipment of the adversary’s communication links and the usual communication intelligence on the adversary’s information exchanged through those links. EW actions, however, differ in the type of CECM equipment employed because in this case they are part of an offensive information operation, called electronic isolation, where the CECM action to deny the adversary’s exchange of information through the radio links (by injecting noise or some appropriate signals into the target receivers) is accompanied
by a computer network attack and is extended to prevent all adversary’s communication with civilians, such as television, radio, mobile phones, wireless connectivity (Wi-Fi or Wi-max), and satellite communications.

An important consideration to be made regarding the use of EW attacks in urban areas is the collateral effects on friendly and neutral services. So these attacks need to be carefully planned.

Needless to say, in addition to the above–mentioned electronic isolation actions, urban combat requires the use of counter-RCIED jammers by every combat vehicle and dismounted patrol. The type of jammer required is the responsive type (also called a *signal-initiated jammer*) in order to allow our own radio links to be able to operate unaffected.

References


