Annex C – JAMMING-TO-SIGNAL RATIO

C.1 INTRODUCTION

J/S is one the most important measures in EA technique design and performance analysis. It is defined as the ratio of the jamming signal strength J within the victim receiver's bandwidth to the desired signal strength S. To be effective, a jamming technique must insert sufficient jamming energy into the receiver's pass band to produce a desired effect on the victim system. There are a number of different applications and EA techniques and the required J/S varies widely. Some techniques may be effective with less than 0 dB (1:1) while others may require 30 dB (1000:1) or more.

This annex shows the development of the J/S expression for two of the most common forms: defensive EA (SPJ) against a ground-based radar and offensive EA (SOJ) against a ground-based radar. Other cases such as defensive EA against a semi-active missile and communication jamming can be developed in a similar manner and are left to the reader.

C.2 J/S FOR DEFENSIVE EA AGAINST A GROUND-BASED RADAR

Figure C-1 illustrates the defensive EA case. A ground-based radar is tracking a target aircraft carrying a defensive EA system and the defensive EA system is jamming it. The main beam of the EA system is pointing toward the victim radar.

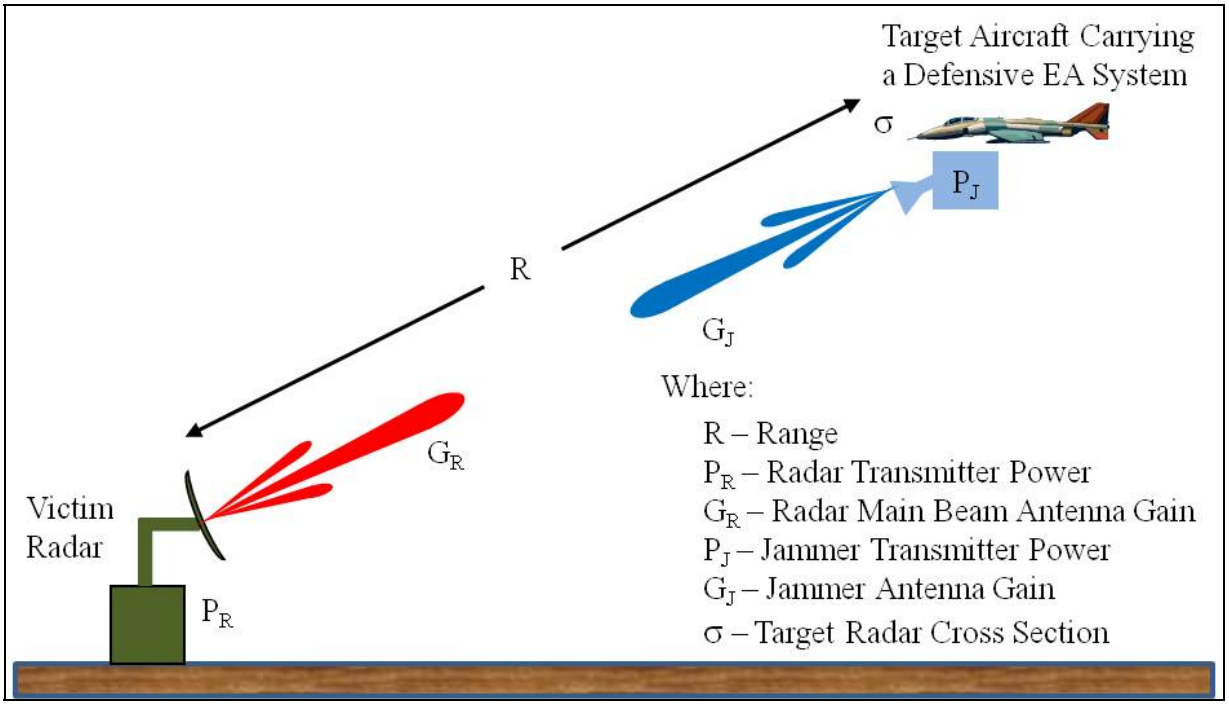

Figure C-1: J/S for Defensive EA Against a Ground-Based Radar.

The first step is to determine the signal power S returned from the target at the victim radar receiver.

If the power generated by the radar transmitter P_R is distributed isotropically (uniformly in all directions as over the surface area of a sphere) the power density, in Watts per unit area, at a given range R can be determined by the equation:

$$Power\ density\ from\ an\ isotropic\ antenna = \frac{P_R}{4\pi R^2} \tag{C1}$$

Radars, however, employ directive antennas to focus the transmitted energy in a desired direction, thereby multiplying the isotropic power density by the gain G_R of the radar antenna; therefore:

$$Power\ density\ from\ an\ directive\ antenna = \frac{P_R G_R}{4\pi R^2} \tag{C2}$$

A certain portion of that energy intercepting the target at range R is backscattered toward the radar. The amount of backscattered energy is related to the Radar Cross-Section (RCS) σ of the target. The RCS has units of area and is a function of the electrical properties of the target. The incident energy returning from the target to the radar also incurs a $1/4\pi R^2$ spreading loss. Therefore:

$$Power\ density\ of\ the\ returning\ signal\ \ at\ the\ radar = \frac{P_R G_R}{4\pi R^2}\ \frac{\sigma}{4\pi R^2} \tag{C3}$$

The radar antenna will capture a portion of returning signal. The amount of energy captured by the antenna is determined by its effective aperture A_e. The effective aperture, as with the RCS, has units of area and is also a function of the electrical properties of the antenna. The desired signal power S returned from the target is:

$$S = \frac{P_R G_R}{4\pi R^2}\ \frac{\sigma}{4\pi R^2}\ A_e = \left[\frac{P_R G_R\ \sigma A_e}{(4\pi)^2 R^4}\right] \tag{C4}$$

The relevant characteristic of this expression in the J/S discussion is that the desired signal power S at the radar varies as a function of R^{-4}.

The jammer power J at the victim radar can be derived in a similar manner using the jammer's transmitter power P_J and the jammer's antenna gain G_J. The power density transmitted by the jammer is:

$$Power\ density\ from\ a\ directive\ jammer\ antenna = \frac{P_J G_J}{4\pi R^2} \tag{C5}$$

The jammer energy entering the radar antenna will encounter the same effective aperture as the radar signal. Therefore, the jamming power produced at the radar antenna output is:

$$J = \frac{P_J G_J}{4\pi R^2}\ A_e \tag{C6}$$

Note that, unlike the expression for the desired radar signal S, which varies as a function of R^{-4}, the expression for jammer power at the victim radar varies as a function of R^{-2}. This is because the radar signal is a two-way path while the jammer transmission is only a one-way path.

J/S can then be described as:

$$J/S = \frac{P_R G_R\ 4\pi}{P_J G_J \sigma}\ R^2 \tag{C7}$$

The R^2 term dominates the equation and the somewhat counterintuitive effect is that J/S decreases exponentially as the jammer gets closer to the radar it is jamming. The extreme result is that when the range approaches zero, J/S also approaches zero.

Figure C-2 illustrates an example of how the jamming and signal powers vary as functions of range. Note that both signals are increasing in power as the range to the target decreases, but the target return signal is increasing at a faster rate, eventually equalling it and overtaking it. [1]

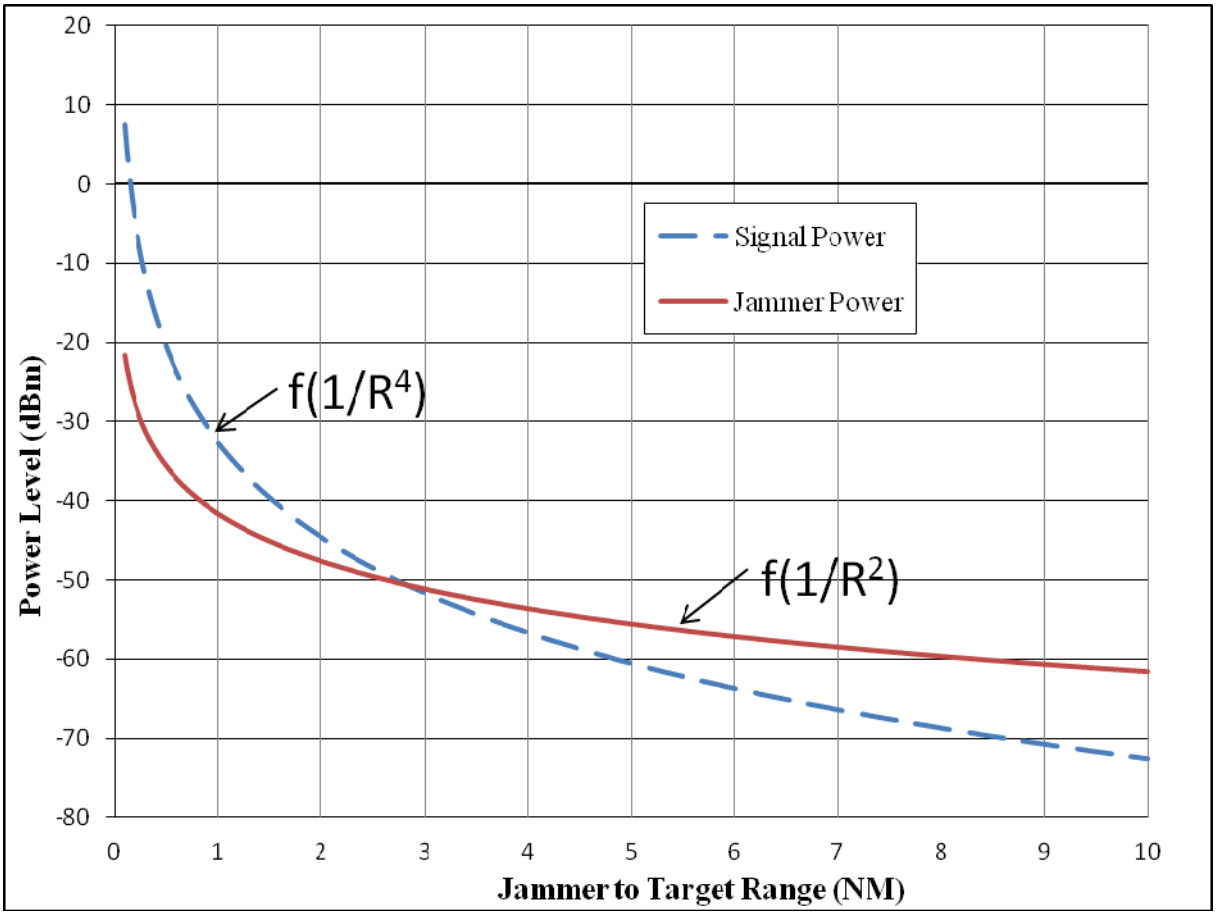

Figure C-2: Jamming and Target Return Signal Power Variation.

Figure C-3 shows the same data presented in terms of J/S. A hypothetical EA technique requires a minimum J/S of 4:1 (6 dB) to be effective. The J/S falls below 4 at approximately 5.7 Nautical Miles (NM). This range is often called the burnthrough range, i.e. the range at which the EA system no longer has enough of a power margin over the target signal return to be effective. In practice it is difficult to identify a specific burnthrough range as factors such as radar operator skill and target RCS variation can affect the ability of the radar system to engage a target.

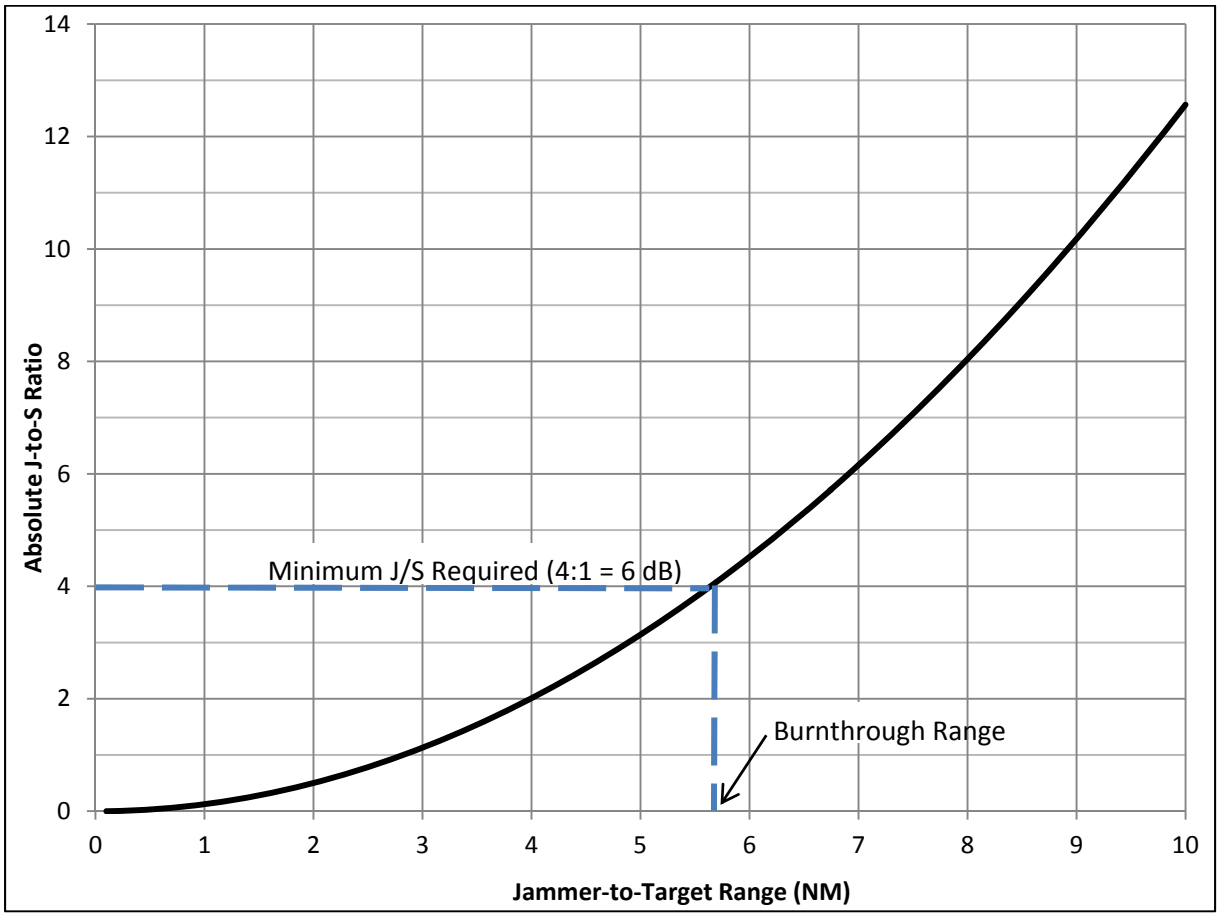

Figure C-3: J/S and Burnthrough Range.

C.3 J/S FOR OFFENSIVE EA AGAINST A GROUND-BASED RADAR

The J/S computation is different for the offensive EA case. The geometry is illustrated in Figure C-4. The stand-off jamming is performed by a support EA aircraft with the intent of protecting other aircraft. The radar signal return power S is calculated the same way as in the defensive EA case; however, the J calculation will be different since the aircraft carrying the jammer may be offset in angle from the protected aircraft and will be operating at a different range (R_J).

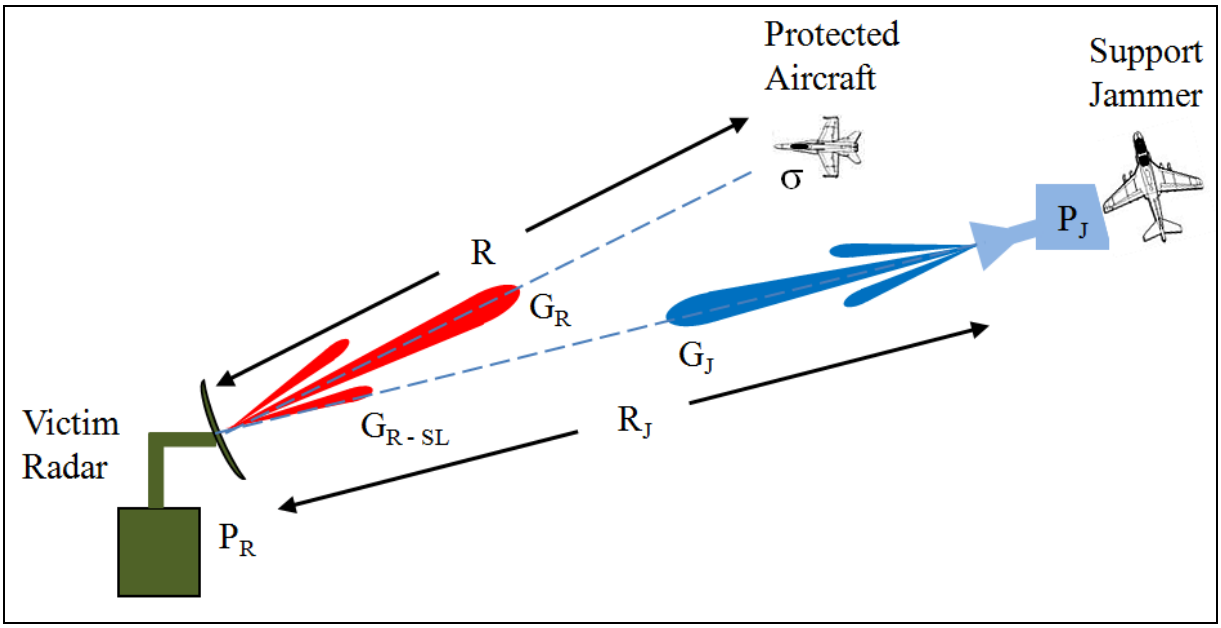

Figure C-4: J/S for Offensive EA Against a Ground-Based Radar.

Offensive EA is frequently directed against azimuth-scanning surveillance radars. Often the support jamming aircraft will be operating at a different azimuth than the protected aircraft. This means that when the protected aircraft is in the main beam of the surveillance radar, the jamming energy from the support jammer is entering the radar through a sidelobe with a different gain $G_{R\text{-}SL}$ than the radar antenna main lobe G_R. This also means that unlike in the defensive EA scenario shown in Figure C-4, the effective aperture will be different (A_e'). In practice, as the antenna rotates, the jammer will jam over the entire radar antenna pattern.

For the scenario shown, jammer power density at the victim radar is:

$$J = \frac{P_J G_J}{4\pi {R_J}^2} {A_e}' \tag{C8}$$

The resultant expression for J/S is:

$$J/S = \frac{P_J G_J}{P_R G_R} \frac{R^4}{R_J^2} \frac{4\pi}{\sigma} \frac{A_e'}{A_e} \tag{C9}$$

C.4 REFERENCES

[1] Stimson, G.W., "Introduction to Airborne Radar", Raleigh, NC, SciTech Publishing Inc., 1998, (ISBN 1-891121-01-4).

C.5 FURTHER READING

Adamy, D.L., EW 101: "A First Course in Electronic Warfare", Norwood, MA, Artech House, Inc., 2001, (ISBN 1-58053-169-5). Chapter 9, Jamming.

Chrzanowski, E.J., "Active Radar Electronic Countermeasures", Norwood, MA, Artech House, Inc., 1990, (ISBN 0-89006-290-0).

Van Brunt, L.B., “Applied ECM”, Dunn Loring, VA, EW Engineering, Inc., Vol. 1 (1978, ISBN 0-931728-00-2); Vol. 2 (1982, ISBN 0-931728-01-0); Vol. 3 (1995, ISBN 0-931728-03-7).

Weigand, R.J., “Radar Electronic Countermeasures System Design”, Artech House, Norwood, MA, 1991, ISBN 0-89006-381-8.