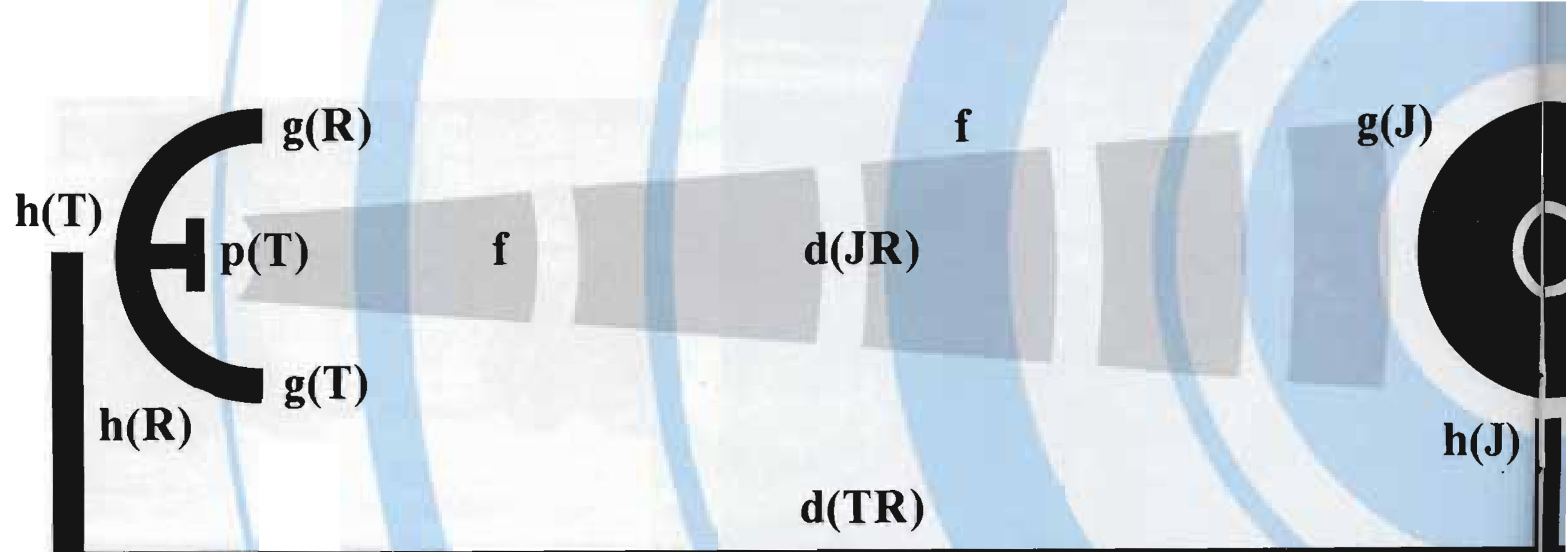
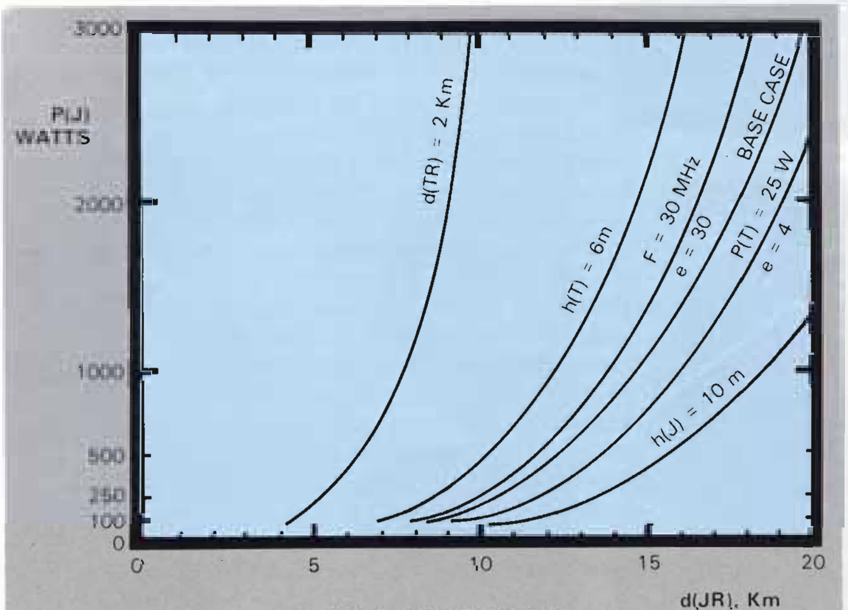


Evaluating the tactical

by Lawrence Follis

The purpose of this essay is to review the factors that influence attempted jamming of tactical FM/VHF receivers and to suggest a method for quantifying the tactical effects of this attempted jamming.



BASE CASE DEFINITION

h(T), Transmitter antenna height = 3m
h(R), Receiver antenna height = 3m
h(J), Jammer antenna height = 6m
F, Frequency = 50 MHZ
P(T), Transmitter power = 35 watts
P(J), Jammer power
d(TR), Transmitter-receiver distance, 4 Km
d(JR), Jammer-receiver distance, Km
G(T), Transmitter antenna gain = 2.15dB
G(R), Receiver antenna gain = 2.15dB
G(J), Jammer antenna gain = 7.15dB
e, Soil factor = 13

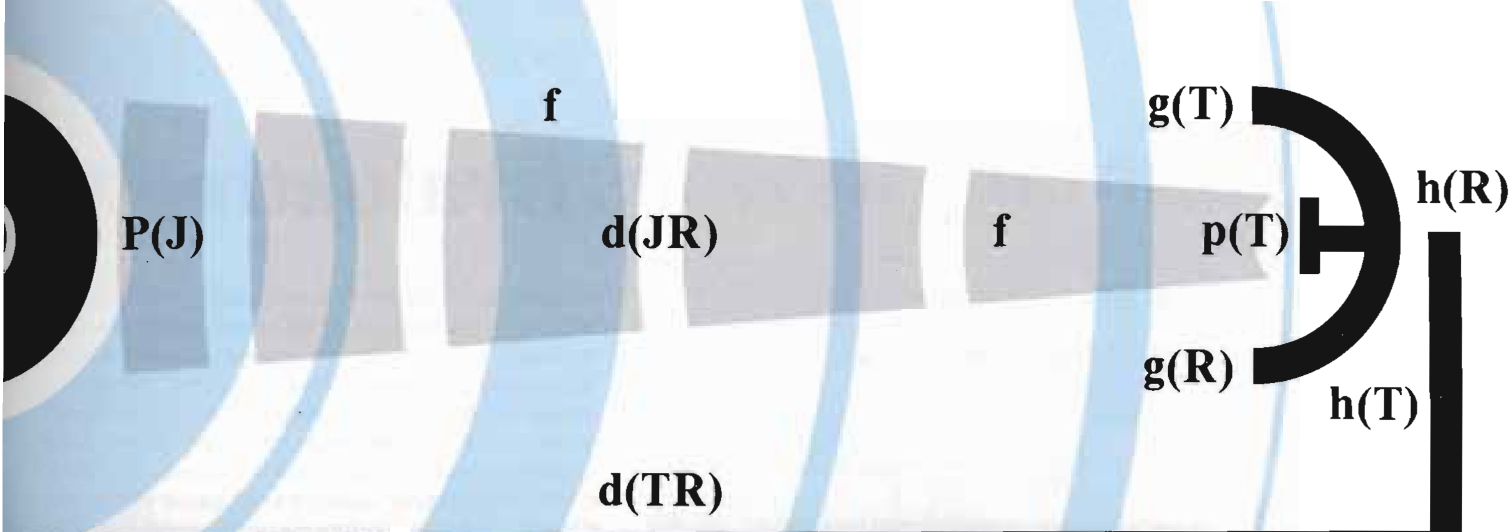
Figure 1. Jammer range performance.

In order to gain an appreciation of the several factors that affect jammer effectiveness, let us consider a base case, representative of many tactical situations, which will illustrate the importance of the basic factors impacting on the success of attempted jamming.

Consider the case where a jammer at distance d(FR) is trying to jam a receiver at distance d(TR) from a transmitter. The antenna heights and other factors we have selected for the base case are shown in figure 1. We can see that if we have 500 watts jammer output power together with an antenna with a gain of 7.15 dB (typical of log periodic antenna), then we can jam successfully out to a distance of 12.5 km from the receiver. Let us examine the effects of changing one factor at a time.

We can see immediately that changing soil factor e from 13 (European average) to 4 (desert) or to 30 (marsh) has noticeable but minor effects. Changing frequency from 50 MHz to 30 MHz or changing transmitter output power from 35 watts to 25 watts likewise has minor (but not necessarily negligible) effects. Two considerably more important factors relate to antenna height. Changing transmitter antenna height h(T) from 3m to 6m or changing jammer antenna height h(J) from 6m to 10m will have important effects on the range at which a jammer is effective (or on the jammer power required to jam successfully from a given range). However, the most important factor of all is d(TR), the link distance one is trying to jam. One cannot reasonably discuss jamming range without first specifying the link distance that one is trying to jam.

Before leaving figure 1, we note that increasing jammer power can be a very poor way of increasing jammer effectiveness. One might think that by



effectiveness of jamming

doubling jammer output power, he might double the distance at which a jammer might effectively jam — but this is not so. To double the range, one would have to increase jammer power by a factor of around 16. Or, as a corollary, we note that some quite low levels of jammer power can be effective at surprisingly long ranges.

Figure 2 is a replot of figure 1 for the same base case we used in figure 1. The information used to determine the propagation losses in figures 1 and 2 was based on a smooth earth equation which is very nearly as accurate as methods that are considerably more complicated. The equation applies to a smooth earth without rugged terrain features so that we are conservatively giving the jammer a real chance of being effective.

If we separate the factors involved in jamming into technical and tactical factors, we will get two lists as shown in figures 3 and 4. The technical factors are mostly design features or engineering performance factors and can be obtained from the manufacturer of the jammer equipment. CEOI* - Electronic Distribution refers to the way in which information on the use of friendly frequencies is distributed to friendlies. As an extreme (but possible) case, if the operating frequencies used by friendlies were changed frequently enough and distributed promptly by electronic means (perhaps without the users even being aware of it), then an enemy would never be able to isolate the critical nets that he wants to jam. Some progress is being made in this area.

Figure 4 shows the tactical factors grouped into four sets; the sets are described in figure 5. Set 1 isolates those factors dealing with the capability of a jammer to deliver enough energy at a receiver to jam it. Set 2 lists the countermeasures that may be used to defeat the attempted jamming. Set 3 lists the tactical factors that involve timing, and Set 4 lists some operational factors which can impact on one's decision to conduct jamming operations under specific tactical situations.

Let us now consider the individual items under Set 1. We have already discussed the importance of

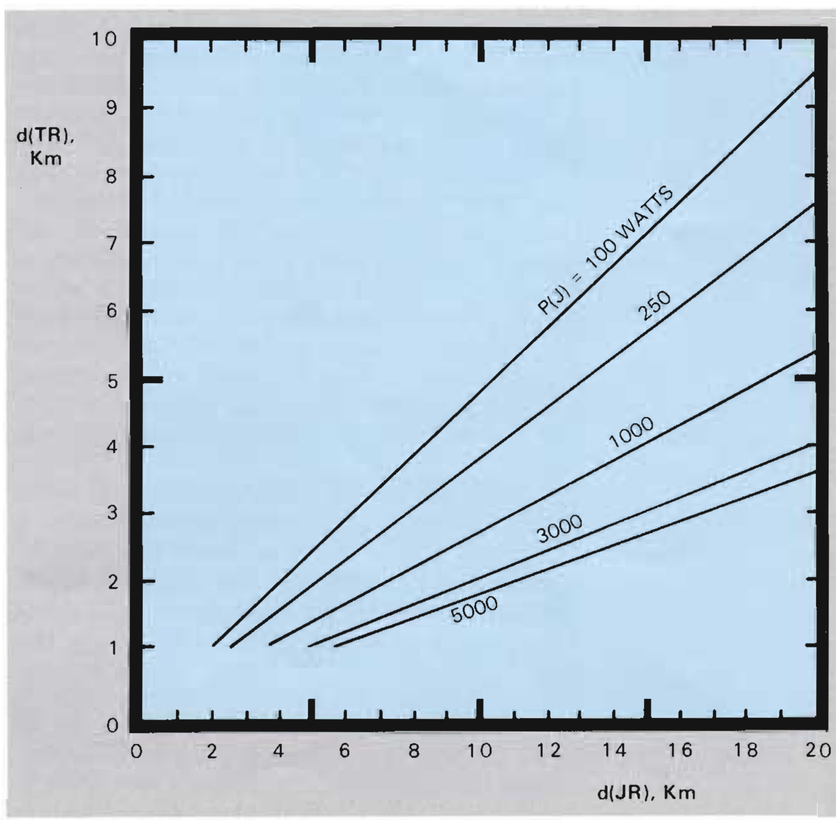


Figure 2. Jamming range.

Evaluating the

- RADIATED POWER
- ANTENNA TYPE/GAIN
- BANDWIDTH
- FREQUENCY COVERAGE
- NOISE MODULATION TYPES
- LOCKOUT CAPABILITY
- SCANNING CAPABILITY
- CEOI - ELECTRONIC DISTRIBUTION

Figure 3. Jamming/technical factors

jammer and link ranges in connection with figures 1 and 2. Propagation losses (the loss in signal strength) depend heavily not only on range but also on the type of terrain and the LOS situation. The last item in Set 1 refers to the fact that digital signals can be significantly easier to jam in the frequency range used by the VRC-12 tactical radios we are considering.

Set 2 refers to the ECCM protection which might be used to frustrate attempts at jamming. Backup or alternate means of communication such as HF rather than VF might be used. Or one might simply change to alternate or spare channels if these are available. The CEOI change period refers to how often frequency assignments are changed. Under the present system, the assignments are changed on a daily basis; if they were changed more frequently, it would become more difficult for an enemy to identify the critical nets he would like to jam. The last item in Set 2 is SNAP which stands for Steerable Null Antenna Processor. SNAP units are designed to be used with tactical radios and serve to null out (in effect, eliminate) attempted jamming signals.

There are several factors in Set 3. The first factor, probability of critical net detection, refers to the timely identification of those nets (usually command and control nets, fire control nets, and intelligence nets) that are worth jamming. The next item, density of jammers/nets, refers to the fact that, to be effective, the enemy would have to employ enough jammers to actually jam a significant percentage of our critical nets. If, say, 40 of the 400 nets in a division are critical enough to our operations to be worth jamming, then it would do little harm (practically speaking) for an enemy to jam only one or two of these nets; the density of jammers must evidently be a high percentage of the number of critical nets or the jamming effort will be wasted. The "mobility of the jammer" line is simply a reminder that some jammers will not be able to jam on the move. The "effects of delayed messages" refers to the fact that only a certain percent of the messages being transmitted contain critical information whose delay would cause significant effects on the outcome of combat. The "management of ECM assets" refers to the need, in some cases, to obtain approval from higher echelons to initiate jamming. The delay in obtaining such approval can, of course, lower the probability of success of the attempted jamming when it does occur. The last item in Set 3 is not

SET 1
- JAMMER RANGE VS LINK RANGE
- PROPAGATION LOSSES (TERRAIN & LOS)
- TYPE SIGNAL (DIGITAL, VOICE)

SET 2
- USE OF BACKUP/ALTERNATE MEANS OF COMM
- ABILITY TO SHIFT CHANNELS
- CEOI-CHANGE PERIOD
- SNAP

SET 3
- PROBABILITY OF CRITICAL NET DETECTION
- DENSITY OF JAMMERS/NETS
- MOBILITY OF JAMMER
- EFFECTS OF DELAYED MESSAGES
- MANAGEMENT OF ECM ASSETS
- PROBABILITY OF ACTUALLY JAMMING A SUFFICIENTLY HIGH PERCENTAGE OF CRITICAL NETS AT A CRITICAL TIME IN THE BATTLE WHEN CRITICAL INFORMATION IS BEING PASSED

SET 4
- RELIABILITY
- SELF-INTERFERENCE
- SUSCEPTIBILITY TO DESTRUCTION BY ARWS/ARTILLERY
- USE OF ECM APPLIQUE FOR COMM
- USE OF AFTES FOR FRIENDLY JAMMER POSITIONING

Figure 4. Jamming/tactical factors

independent of the other items; rather, it serves to summarize the factors in all three sets.

Most of the items in the three sets can be assigned probability numbers, and this can serve as the basis for determining tactical effectiveness. Consider the following example:

If receivers are protected by SNAP, which is 70% effective, and if we have a 50% probability of detecting critical nets, and if there is a 60% probability that the messages being delayed by the jamming will have a tactical effect, then (assuming the three events are independent) the overall probability of the attempted jamming being tactically successful is:

$(1-.70)\ (.50)\ (.60) = .09$ or 9%.

STEP 1

CAN NETS BE JAMMED (EXPECTED VALUE SITUATION, ANY NET AT ANY TIME) WHEN NO ECCM MEASURES ARE TAKEN? ANSWERS WILL BE BASED ON LOCATIONS (NOT NUMBERS) OF TRANSMITTERS, RECEIVERS, AND JAMMERS.

STEP 2

CAN NETS STILL BE JAMMED WHEN DELIBERATE ECCM MEASURES ARE TAKEN? (BASED ON ABOVE EXPECTED VALUE SITUATIONS.) NUMBER OF J-T-R WILL NOT BE CONSIDERED.

STEP 3

OF THOSE JAMMING ATTEMPTS WHICH WERE SUCCESSFUL, WHAT PERCENTAGE HAD A TACTICAL EFFECT, I.E. WERE A SUFFICIENT NUMBER OF CRITICAL NETS IN FACT DETECTED AND JAMMED AT A CRITICAL TIME IN THE BATTLE SUCH AS TO HAVE A TACTICAL EFFECT. THIS WILL BE BASED ON N JAMMERS TARGETED AGAINST M NETS.

STEP 4

CONSIDER ADDITIONAL OPERATIONS FACTORS (SELF-INTERFERENCE, RELIABILITY, ETC.).

Figure 5 Evaluation of tactical factors.

Consideration of other factors would, of course, lower this success percentage.

Finally, Set 4 lists some additional factors that will impact on the decision to attempt jamming. Reliability refers to the probability of equipment functioning as required; the reliability of ground jammers in the field today is not the best. Self-interference refers to the possible interference with friendly receivers when jammers are operating at the same frequency. The ARWS on the third line in Set 4 stands for Antiradiation Weapon Systems which might be used to destroy jammers or other emitters. Regarding artillery, an effort will generally be made to put jammers at good terrain positions which will often be preferred aiming points for enemy artillery. The ECM Applique is a device used to boost the output power of tactical radios. If the output power of a jeep-mounted radio can be boosted from 35 watts to, say, 250 watts, and if a log periodic antenna is employed, one has created a simple and very inexpensive jamming system. Furthermore, the system can be used as a high-power emergency transmitter which increases the probability of communicating successfully when an enemey is trying to jam. The last item, AFTES, refers to the computerized Army Tactical Frequency Engineering System being developed by the Electromagnetic Compatibility Analysis Center. One possible use for AFTES will be to determine preferred jamming locations.

In conclusion, it's important to know that a semantic difficulty constantly arises when discussing "jamming." The word "jamming" gives no indication of whether attempts are successful or not. Even the term "successful jamming" is ambiguous since it does not indicate whether the success was technical (some receivers were in fact jammed) or tactical (some receivers were in fact jammed and contributed to conditions that had an impact on the outcome of combat). It is thus suggested that terms such as "technically effective jamming" and "tactically effective jamming" should be used. A determination of just what the combat effects of "tactically effective jamming" might be is beyond the scope of this article. However, unless the attempted jamming is "tactically effective", one can hardly expect it to affect the outcome of combat.

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