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MOBILE TACTICAL HF/VHF EW SYSTEM
FOR GROUND FORCES

BY

Issam Y. Almetlaq

September 1989

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This thesis specifies a mobile tactical C3CM system covering the HF/VHF frequencies for use by ground forces. The description and analysis of a system that can intercept, analyze, DF, monitor and, if necessary, jam the frequency bands of interest is presented. The system analysis and possibilities of ESM/ECM are considered in order to construct the overall theory of countering enemy communications from a tactical point of view. General system requirements, i.e., tactical, environmental, and human factors are also discussed. A concept of a mobile tactical HF/VHF system is described from a performance and functional points of view. Finally, a desired specification outline maximizing use of "off the shelf" available components is presented. A summary and future projections are also provided.

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MOBILE TACTICAL HF/VHF EW SYSTEM FOR GROUND FORCES

by

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ABSTRACT

This thesis specifies a mobile tactical C3CM system covering the HF/VHF frequencies for use by ground forces. The description and analysis of a system that can intercept, analyze, DF, monitor and, if necessary, jam the frequency bands of interest is presented. The system analysis and possibilities of ESM/ECM are considered in order to construct the overall theory of countering enemy communications from a tactical point of view. General system requirements, i.e., tactical, environmental, and human factors are also discussed. A concept of a mobile tactical HF/VHF system is described from performance and functional points of view. Finally, a desired specification is outlined, maximizing use of "off the shelf" available components is presented. A summary and future system projections are also provided.

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I. INTRODUCTION

Communications warfare is an element of combat that pits communications against potentially hostile forces that seek to intercept and/or disrupt communications connectivity. Wireless communication systems are essential for military command, especially during movements. Therefore, it is clear that these systems are targets for enemy actions such as reconnaissance, identification and localization for surveillance, targeting, and jamming.

The deployment of electronic communication systems as part of EW activities on the battlefield affords the commander the capability to control and maneuver his force with great flexibility during battle. Therefore, communication availability and performance become especially important and essential in the command and control of all elements on the battlefield.

However, the intentions behind mobility of ground forces of an army unit can, with respect to the daily increasing mission during a conflict, be determined with sophisticated surveillance, and utilization of mobile tactical Electronic Support Measures (ESM) and their purposes thwarted by Electronic Counter Measures (ECM) systems. The backbone of ESM is detection and intercept of communications for command and control including direction finding, and ECM.

The objective of this thesis is to develop, and specify a mobile tactical EW system covering the HF/VHF frequencies for use by ground forces. Description and analysis of a system that can intercept, analyze, DF, monitor and, if necessary, jam the frequency bands of interest is provided. The system must be mobile for relocation, set-up, and operation in hours.

Chapter II deals with the principles of Electronic Warfare, definitions and applicability against electronic communications. Chapter III presents the analysis of EW systems in which the overall theory of EW from a tactical point of view is dealt with. The tactical possibilities for ESM and ECM are discussed. The former addresses ground-born reconnaissance, direction finding, analysis, documentation, and evaluation. The latter looks at the possibilities of types of jamming signals, high power jamming, and jamming effectiveness by both ground and sky wave.

Chapter IV emphasizes the general system considerations, such as the tactical, environmental and human factors which relate to the employment of the system to full mobility potential.

Chapter V presents a concept of a mobile tactical EW system covering HF/VHF frequencies. The system is broken into three subsystems including Command and Control Center, DF and jamming stations. A description of each is provided operationally and structurally. It is shown how the system objectives are met.

Chapter VI presents a proposed mobile tactical EW System covering the HF/VHF frequencies. The desired specification of the system is discussed and identified making maximum use of "off the shelf" available hardware and components.

Chapter VII is a summary as well as future projections for systems and procedures.

II. ELECTRONIC WARFARE PRINCIPLES AND COMMUNICATIONS EW

A. ELECTRONIC WARFARE DEFINITIONS*

Electronic Warfare (EW) is defined as any military action involving the use of the electromagnetic spectrum, taking into account terrain, transmission time and power output of target communications. EW includes action to safeguard friendly use of the electromagnetic spectrum. EW is organized into three major categories; Electronic Warfare Support Measures (ESM), Electronic Countermeasures (ECM), and Electronic Counter-Countermeasures (ECCM). These major areas and several others are shown in Figure 2.1.

1. ELECTRONIC WARFARE SUPPORT MEASURES

Electronic Warfare Support Measures (ESM) is that division of EW involving the action taken to search for, intercept, locate and immediately identify radiated electromagnetic energy for the purpose of immediate threat recognition and the tactical employment of forces. The key functions of ESM are intercepting, identifying, analyzing, and locating sources of hostile emissions. Tactical ESM is for purposes that require immediate action as contrasted with similar functions which are performed for intelligence gathering, such as SIGINT, ELINT, COMINT, and RINT.

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* Much material is derived from chapter 1 of introduction to EW by Curtis D. Schleher.

ESM is completely passive when used as a detector of enemy systems. It also provides the potential of detecting enemy radiations from such diverse emitters as radar and lasers. However, it has the disadvantage that range to the intercepted emitter must generally be obtained through triangulation from multiple ESM fixes on the target. To defeat ESM systems, a military force practices various levels of emission control (EMCON), which restricts transmissions until it knows that it as been detected, or until transmission is absolutely necessary.

2. ELECTRONIC COUNTERMEASURES

Electronic Countermeasures (ECM) is action taken to prevent or reduce the enemy's effective use of the electromagnetic spectrum. ECM includes jamming and deception. Jamming is the deliberate radiation or reflection of electromagnetic energy with the object of impairing the reception by electronic devices, equipment, or systems being used by a hostile force. Deception is the deliberate radiation, re-radiation, alteration, absorption, or reflection of electromagnetic energy in a manner intended to mislead a hostile force in the interpretations or use of information received by his electronic systems.

ESM in land engagements is primarily concerned with the intercept and location of short range and low power HF, VHF, and UHF radio transmitters used by the enemy in the forward battle area. Typical ESM systems include both intercept and Direction Finding (DF) capabilities.

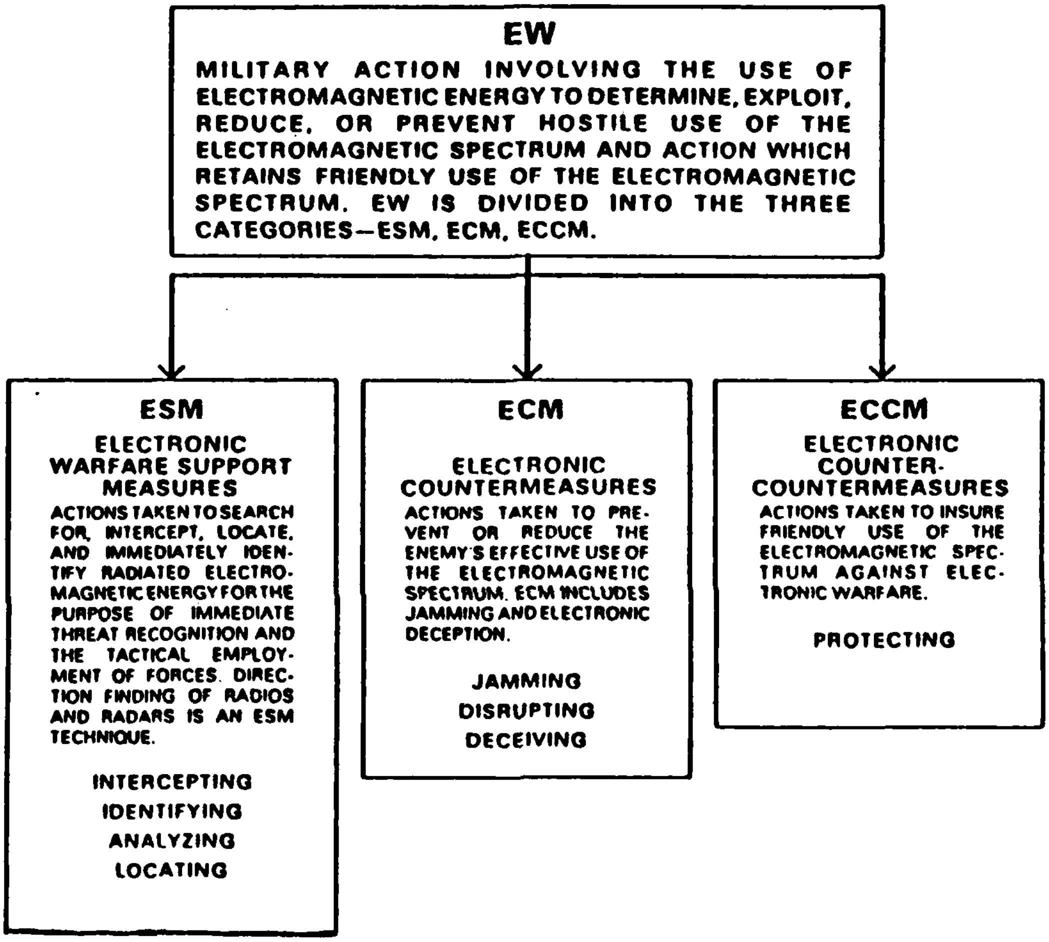
ECM against communications is somewhat different than that against radar. Intercepted communications traffic, exploited rather than jammed, becomes a major intelligence source available to the battlefield commander. Also, the density and methods of operating tactical radios, particularly netting, are different from radar. An essential ingredient to communications jamming is radio Direction Finding (DF).

The three options open to battlefield commanders, once a tactical communication emitter is located, are; physical destruction, intelligence exploitation, or electronic jamming. Therefore, forces with a variety of mobile communications jammers for VHF, UHF and HF are capable of neutralizing tactical radio-communication links. An accepted military principle is that enormous tactical advantages can be gained by jamming or feeding confusing signals into enemy forward communications nets.

3. ELECTRONIC COUNTER-COUNTERMEASURES

Electronic Counter-Countermeasures (ECCM) are actions taken to ensure friendly use of the electromagnetic spectrum against ECM. ECCM includes techniques which are embodied in the good design of communications equipment, while ECM usually requires a separate item of equipment which operates in its own right and not as an adjunct to another system. In modern communications systems, spread-spectrum techniques are used as ECCM. The design of spread-spectrum communication waveforms may use frequency or phase modulation of the carrier waveform in accordance with a pseudorandom noise code.

ECCM, however, shall not be seen to stand alone; EW is a feedback loop continuing ESM, ECM and ECCM; each affecting the other. Own ESM observes hostile radiation, recognizes the targets for the own ECM and gives advice for the action of own ECCM. Hostile ESM observes own ECM and evaluates a basis for action by the hostile ECCM. Own ESM tries to point out how to use own ECM and ECCM in a more efficient way. The hostile ESM, on the other hand, observes the changes of own ECM and ECCM and makes possible further exploitation of enemy ECM and ECCM, which again will be registered by own ESM. Each action



EW

MILITARY ACTION INVOLVING THE USE OF ELECTROMAGNETIC ENERGY TO DETERMINE, EXPLOIT, REDUCE, OR PREVENT HOSTILE USE OF THE ELECTROMAGNETIC SPECTRUM AND ACTION WHICH RETAINS FRIENDLY USE OF THE ELECTROMAGNETIC SPECTRUM. EW IS DIVIDED INTO THE THREE CATEGORIES—ESM, ECM, ECCM.

ESM

ELECTRONIC WARFARE SUPPORT MEASURES

ACTIONS TAKEN TO SEARCH FOR, INTERCEPT, LOCATE, AND IMMEDIATELY IDENTIFY RADIATED ELECTROMAGNETIC ENERGY FOR THE PURPOSE OF IMMEDIATE THREAT RECOGNITION AND THE TACTICAL EMPLOYMENT OF FORCES. DIRECTION FINDING OF RADIOS AND RADARS IS AN ESM TECHNIQUE.

INTERCEPTING
IDENTIFYING
ANALYZING
LOCATING

ECM

ELECTRONIC COUNTERMEASURES

ACTIONS TAKEN TO PREVENT OR REDUCE THE ENEMY'S EFFECTIVE USE OF THE ELECTROMAGNETIC SPECTRUM. ECM INCLUDES JAMMING AND ELECTRONIC DECEPTION.

JAMMING
DISRUPTING
DECEIVING

ECCM

ELECTRONIC COUNTER-COUNTERMEASURES

ACTIONS TAKEN TO INSURE FRIENDLY USE OF THE ELECTROMAGNETIC SPECTRUM AGAINST ELECTRONIC WARFARE.

PROTECTING

Figure 2.1 Electronic Warfare Definitions will cause a hostile reaction which again will result in further moves by both, so a circuit of reactions will develop a feedback loop.

B. COUNTER-COMMUNICATIONS *

1. OVERVIEW

Modern defense needs a well organized Electronic Warfare capability. The goal of the Electronic Warfare measures used is to reconnoiter and to interfere with hostile electromagnetic radiation, and to ensure that their own electromagnetic radiation is used effectively.

Radio communication systems are essential for battlefield command, especially in mobile forces. Therefore, it is clear that these systems represent targets for enemy action such as reconnaissance, identification, and localization for the purposes of surveillance and targeting.

The command of the modern Army can, with respect to daily increasing information and communication requirements, only be performed with sophisticated surveillance, data and communication systems. Their nerve system is the wireless detection, communication and command systems like radar, radio relay and radios, which form vital targets to enemy EW.

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* Much material is derived from chapter 1 of introduction to EW by Curtis D.Schleher

The use of electronics on the battlefield affords the commander the capability to control and maneuver his force with great flexibility during battle. Therefore, communications have become especially important and essential in command and control of elements on the battlefield.

Through the utilization of specialized equipment, communications signals can be intercepted and analyzed. Listening to, and locating sources of opposing force communications can provide the tactical commander with indicators about the enemy. These indicators may include the magnitude of the enemy forces, enemy intentions, technical information for disrupting enemy electronic capabilities, and other information which may be useful in developing the order of the battle.

Intelligence derived from information obtained through utilization of such specialized equipment, called "Signal Intelligence (SIGINT)", is an important input to the commander's estimation. The increased reliance on communication, at all levels of command, has created a strong concern for the survivability, dependability, and accuracy of any communication system.

2. THE COUNTER-COMMUNICATIONS SCENARIO

Radio communication equipment generally operates in the high frequency (HF), very high frequency (VHF), and ultra-high frequency (UHF) portions of the electromagnetics spectrum. The HF (2-30 Mhz) band is used for both longer range, over the horizon, transmission (using sky waves), and shorter range communication using ground waves; and the VHF (30-88 Mhz) and (110-150 Mhz) and UHF (225-400 Mhz) bands are used for line-of-sight communications. The volume of communication signals can be very large with 9000 channels potentially available at HF, 3680 at VHF, and 7000 at UHF.

In addition to radio communications equipment, a large volume of military communications is transmitted by telephonic and telegraphic means over wire/land line. EW is generally not targeted at these types of communication systems, since hard-wired types are not susceptible to intercept or jamming.

The philosophy of communications jamming emphasizes the neutralization of a weapon system by disabling critical communication nodes. A counter philosophy, which seems to be losing favor, is that more can be gained by listening to enemy communication than by jamming them. The introduction of frequency hopping Spread-Spectrum Communications Systems is rapidly making the listener-jamming debate academic because the complex pseudonoise codes built into these systems makes it virtually impossible to "listen" to these types of transmissions.

The primary functions performed by communication ESM Systems are; identification of the operating frequency of active emitters, measurement of their bearing or location, analysis of traffic to assess its threat significance, and establishing and maintaining a current data base. The first two ESM processor functions are performed by spectrum analysis and Direction Finding (DF) equipment. DF is a key element in sorting and locating communication signals due to the dense communication signal environment.

The large number of communications signals, both AM and FM, are transmitted by both low power mobile, and high power fixed stations at various locations. This causes the dynamic range required at a particular intercept site, to equal 80 db. The exceptionally long propagation path and non line-of-sight (LOS) nature of HF generally cause high channel occupancy in this band. Occupancies of over 45 percent have been reported over the entire 3-30 MHZ band and above 75 percent in a busy 1 MHZ segment of the band. In reduced coverage VHF/UHF Communication Systems, with typical 25 KHZ channels, the occupancy is much less than in the HF band. These high occupancies and wide dynamic range require the use of a high sensitivity receiver with typically 100 dB channel separation or isolation.

The DF function can be implemented using either wide or narrow aperture arrays. Wide aperture systems are normally used when high accuracy is the prime consideration, or with HF signals where severe multi-path is experienced. Narrow aperture systems generally use arrays consisting of four dipoles positioned in a square configuration where outputs are taken from diagonally opposite dipoles. These outputs are then applied to matched receivers, which provide a measure of the azimuth or bearing location of the emitter. Generally, bearings from three DF sites are used to determine location, which requires a communication and coordination link between the various sites.

Communication ESM receivers must be sensitive, accurate, invulnerable to large out-of-channel interfering signals, and remotely controlled. The frequency coverage extends from 2 to 500 MHz, where the lower band (HF) consists of both long range sky-wave and short range ground-wave transmissions, and the upper band (VHF/UHF) is used for short range vehicle and man pack communications. Intercept receivers which look for short range emitters must be sited in forward areas, and therefore must be mobile and rugged.

Communications ESM receivers typically feed into a command center, where the various interceptions are analyzed and decisions are made to deploy ECM techniques against high priority communication links. Communications jamming is generally not indiscriminately employed; but rather as needed, in concert with COMINT/Exploitation, to accomplish a strategic objective; such as stopping a critical message during a crisis situation.

III. ELECTRONIC WARFARE SYSTEM ANALYSIS

A. ELECTRONIC WARFARE THEORY *

Communications EW is concerned with operation of military systems that employ electromagnetic communication links. The term communication link assumes that all systems convey information from one point to another. This includes voice and data links.

This thesis researches maximum utilization of EW, against HF/VHF communication systems in ground forces, employed during mobile tactical missions. For that reason, almost all theoretical background material, necessary to understand the concepts, is detailed in texts on communication systems, (i.e., types of modulation, HF propagation links, VHF propagation links, frequency management), and therefore will not be presented within the scope of this thesis.

1. Electronic Reconnaissance

The gathering of information, in ESM activities, by ground forces takes place at three levels. The strategic, tactical, and combat level.

The strategic level is called electronic intelligence (ELINT) and is a long-term process involving large amounts of data and extensive analysis. ELINT data

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* Much material is derived from the strategy of electromagnetic conflict by LT. Colonel Richard Fitts

is usually acquired by long-range signal-monitoring receivers positioned outside of the combat zone and is used in the design of EW equipment as well as in strategic planning. HF DF is used extensively here.

The tactical level, called ESM, is concerned with the gathering of information for "near real time" use in immediate operations. The intercept equipment is generally located in the combat zone, and its purpose is limited to determining the location and types of the enemy equipment currently deployed. This data will be used to perform tactical location planning and to adjust EW equipment to meet current threats.

The combat level is concerned with identification of immediate threats and targets. The information is collected and analyzed for immediate use. Because of the urgency, data analysis and presentation are usually automated and, therefore, limited in scope.

2. Electronic Countermeasures

ECM techniques fall into two broad categories: radiating and non-radiating, or active and passive. These categories, however, are not mutually exclusive.

In 'non-radiating', the ECM techniques do not involve the radiation of electromagnetic signals. An example of this is emission reduction, which applies primarily to the HF/VHF bands. The reduction of radio frequency emission can be effected by limiting or eliminating the use of radiating equipment. It can also be achieved by the use of spread-spectrum techniques (also an ECCM measure). Other types of non-radiating ECM techniques are, cross section reduction, chaff or rope and decoys, (radar).

In radiating ECM systems, which is the employment of jamming systems (i.e., noise, deception and use of expendable jammers), two basic objectives are set; obstruction of the information signal and generation of false information signals.

The term "noise" jamming derives from the fact that noise jammers generally employ a noise like modulation on the jamming signal. The main disadvantage of noise jamming is the difficulty of generating sufficient power within the bandwidth of the victim receiver to obscure commmunications, even when the frequency of the jammed system is known and the jammer is tuned to that frequency. Noise jamming can be a relatively inefficient use of power. A possible exception is "COMB" jamming.

B. Electronic Warfare Opportunities*

1. ESM

Own reconnaissance submits information about the tactical employment of enemy forces, enemy organization, technical equipment and capabilities. This results from

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* Much material is derived from refrence 2

hostile technical equipment giving information about its specifications, deployment and employment; allowing formation of a basis for the development and adjustment of own EW system use.

Reconnaissance sensors work passively. Therefore, they cannot easily be recognized by the enemy. Therefore, their existence and operation have to be considered at all times.

Ground borne reconnaissance normally works inside the range of ground-born defense systems. It can, without high expense, detect radio communication, air and ground search emitters. Reconnaissance equipment performs the following functions in order to achieve this goal.

a. Search Function

This function monitors the frequency spectrum. Difficulties arise from the density of these frequency bands both by own force and enemy emitters.

The detection and reception of signals is performed with either omnidirectional or directional antennas. Regarding the importance of each, the latter has the advantage of increased gain, but the disadvantage that only a small angle can be searched in a azimuth at one time. These antennas allow only intermittent search capabilities.

A further drawback is that during the scanning of space, the targets may not emit continuous radiation. The scanning of space can be performed by mechanically rotating antennas or with fixed antennas (like a phase array).

Searching for radio communication in the HF and VHF bands requires a frequency capability from 1.6 - 30 MHz for HF and 20 - 500 MHz for VHF. These bands cannot be searched with one antenna due to the limitation in antenna bandwidth, therefore several antennas are required.

Continuous, multiple signal operations require broadband receivers, which have moderate sensitivity and medium to high noise levels. This causes difficulties in frequency resolution. Frequency resolution is important for jamming measures, because power can be saved if the target frequency can be set accurately. Alternatives to wideband receivers are fast scanning receivers. They possess better sensitivity and detection-probability characteristics.

b. Direction Finding

After determination that the received signal is hostile, direction finding starts. This may be performed using parabolic reflector antennas or dipole arrays.

Localization can be done if direction finding is performed from several bearings, however, at low frequencies large antenna apertures are required.

c. Analysis

This is the immediate evaluation of received and processed signals, according to technical and operational characteristics of the emitter, i.e., to so-called "fingerprint", in order to recognize already known emitters and to define new and unknown emitters. The result of the analysis may be used to adjust and control the search system.

In the past this analysis was performed manually, but now newer systems have come into use which perform quick analysis and comparison of field data. For analysis, the following presentations are performed:

(1) Signal frequency as a function of time

(2) Signal amplitude as a function of time

(3) Polarization

(4) Voice Synthesis/recognition

With number one, the carrier frequency can be evaluated to know the frequency agility of the emitter and other frequency modulation characteristics. Number two is used to evaluate amplitude modulation, detailing the pulse form, width, and modulation data rate. Number three gives emitter polarization.

The results of the analysis in the above three areas are combined to determine the following additional information about the emitter:

Identify emitters which are linked, along with their locations.

Output power (estimate only)

These are then combined to allow evaluation of tactical employment and deployment of emitter networks and Electronic Order of Battle (EOB).

d. Documentation

Documentation of all targets (emitters) is required to give information on both known and unknown, and to correlate characteristics. Documentation can be partly performed via real-time data link (which is of course both jammable and detectable) using data such as that stored on magnetic tape, video 'photographs', and electronic storage on data file (such as disks).

e. Evaluation

The evaluation process may be long term, consisting of the evaluation of the pre-analyzed information to provide a situational awareness picture, incorporated according to enemy forces' initiatives. From this, technical and tactical modes of the enemy can be established.

2. ECM

Based on results of the reconnaissance above, ECM measures will be employed to maximize performance against hostile enemy radiations. In communications jamming the two basic types of jammers are barrage and spot. They are categorized, according to the amount of frequencies they can cover at any one time.

Barrage jammers are theoretically capable of jamming simultaneously all receivers within the band width of the jammer, given enough power. In actual practice, they will probably not be completely effective since the power output of the jammer decreases with each additional frequency covered.

The spot jammer concentrates power on a specific channel or frequency, and is effective at longer ranges. There are variations of spot jamming, such as multiple spots where more than one frequency is jammed at one time, or sequential spot transporter jamming where the jammer moves following threats from one frequency to another. Normally, jamming is thought of as an electronic emitter radiating energy on a frequency or frequencies, but can also be accomplished by re-radiating energy with repeating jammers. Whatever can effectively confuse, harass, or impair the enemy's use of communications (with the least amount of expense and fratricide to friendly forces) should be utilized.

a. Types of Jamming Signals

A signal transmitted for the purpose of jamming electronic emitters may be varied in amplitude, frequency, or phase by an almost unlimited variety of modulating signals. The type of signal used in any given situation is determined by the nature of the target signal, capabilities of the jamming equipment, and the desired results. Specific equipment and techniques are continually developed to deal with new threats. Equipment specifically designed, for jamming specific signals, produce the best results. However, any piece of equipment that radiates on the desired frequency may become a jammer. Common transceiver radios can be used as effective jammers under special circumstances. The following are general types of jamming signals:

(1) **Babbled voice** - This signal is composed of mixed voices engaged in simultaneous conversations, preferably in the same language, with voice characteristics similar to those found in the victim communications net.

(2) **Tone** - This jamming signal is a single frequency constant tone. It is used to jam manually keyed morse code, as well as voice and circuits.

(3) **Random Keyed Morse Code** - This jamming signal is produced by keying a morse signal at random and mixing the keyed signal with spark-gap noise. It is effective against voice and morse code communications.

(4) **Pulse** - This signal resembles the monotonous rumble of rotating machinery. Pulse jamming signals produce a low frequency nuisance effect on voice communication circuits.

(5) **Recorded Sounds** - This is any audible sound, especially of a variable nature, that can be used to distract operations and distrupt communication circuits, i.e., music, screams, applause, whistles, machinery noise and laughter are examples.

(6) **Gulls** - The gull signal is generated by a quick rise and slow fall of a variable audio frequency similar to the rise and pitch of the cry of a sea gull. It produces a nuisance effect on voice circuits.

(7) **Random noise** - This is recorded, or synthetic, radio noise which is random in amplitude and frequency. It is similar to normal background noise and can be used to degrade all types of signals; however, it may require higher power to jam voice communications.

(8) **Stepped tones** - These are tones transmitted in increasing pitch, producing an audible effect similar to the sound of bag pipes. Stepped tones are normally used against AM and FM voice signal channel circuits.

(9) Random pulse - Pulses of varying amplitude, duration and rate are generated and transmitted to disrupt teletype, radar, and all types of data transmission systems.

(10) Spark - This signal is easily produced and is one of the most effective for jamming. Bursts of short duration and high intensity are repeated at a rapid rate. The time required for receiver circuitry and human ear to recover after each burst makes this signal effective in disrupting all types of radio communications.

(11) Wobbler - The wobbler signal is a single frequency varied by a low and slowly varying tone. The result is a howling sound which causes a nuisance effect on voice communications.

(12) Rotary - The rotary signal is produced by a low pitched slowly varying audio frequency resulting in a grunting sound. It is used against voice communication.

b. High power jamming

The task of the high power jammer is to disturb the reception of high power broadcasting transmitters. It is presumed that these transmitters transmit on known frequencies (and at a known time for HF). Although "look through jamming" is normally utilized with tactical systems, with high power jamming, provision for look through is more difficult. Site selection of the high power jammer requires the following aspects to be taken into consideration.

Jamming may be performed over a wide area and long distance using skywave propagation (1000's of Km's)

Small areas may be jammed over shorter distances by using ground wave propagation (100's of Km's).

In each mode of operation, different antennas will be employed. An ideal site from which to jam a city area would be in close proximity to the city, where jamming can be done by ground wave. Site selection for jamming over long distances is relatively unrestrained, depending on sky-wave propagation, since site displacement of 100 Km and more will have negligible influence.

c. Jamming effectiveness

The targets to be jammed by high power HF jamming include those out to a distance of about 2000 Km. The required radiated power is approximately 500 Kw, to ensure effectiveness. Effective jamming should be possible for large areas of the targeted region, depending on frequency, timing, and Sky-wave propagation. Limited areas may also be jammed, particularly urban.

1. Jamming by Ground Wave

Jamming inside a limited area may be effected by ground wave propagation. Difficulties arise from the fact that the frequencies used for the above-mentioned

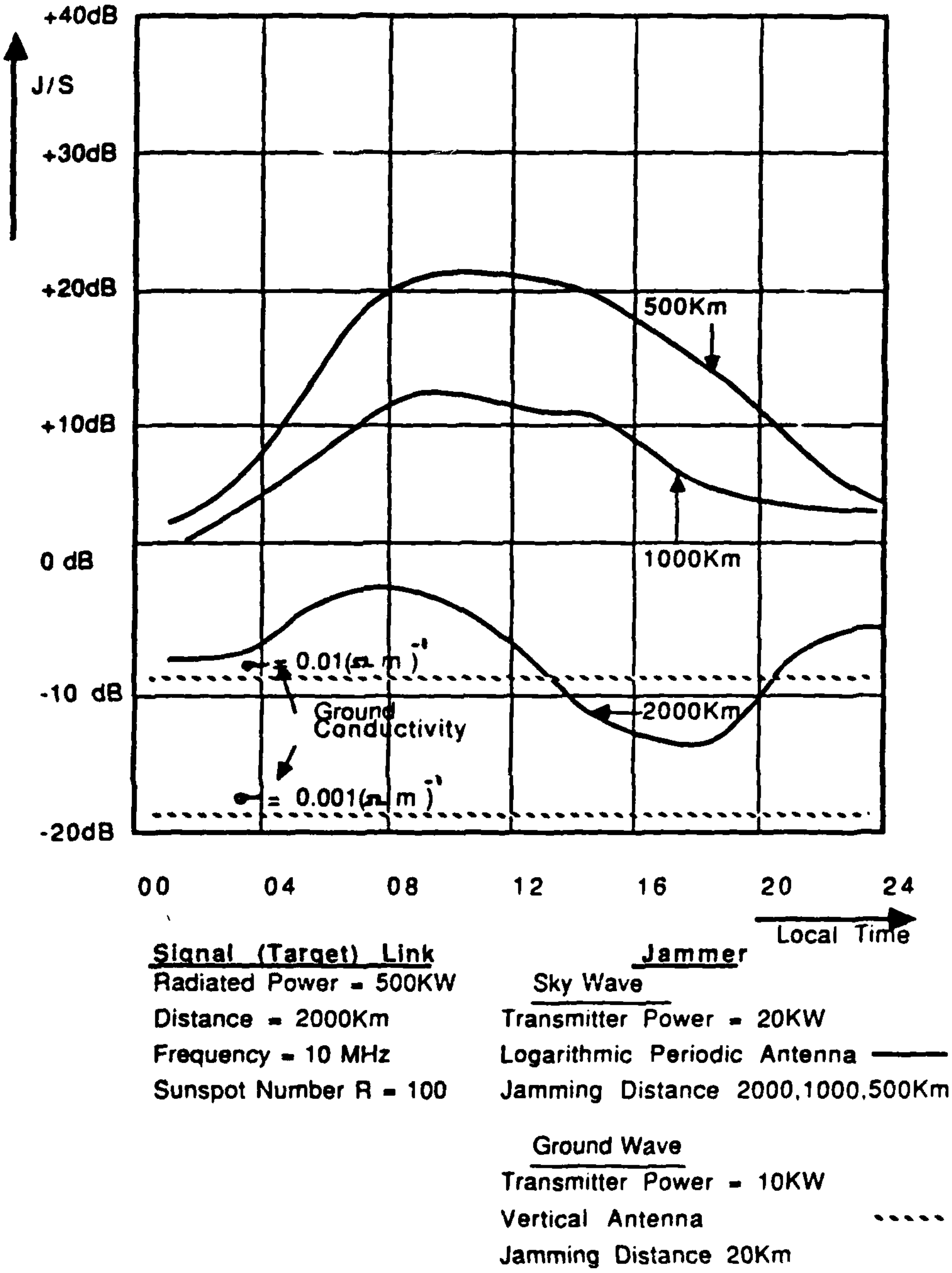


Figure 3.1 Jamming to Signal Ratio (J/S) Versus Time of Day

emissions will be relatively high in most cases, which leads to high propagation loss for the ground wave. Figure 3.1 shows that the jamming effectiveness at a distance of 20 Km will be at the lowest tolerable limit.

2. Jamming by sky wave

For transmissions over long distances by sky wave, relatively high frequencies can be used. This means that, for a certain range around the jamming station no jamming is possible because the maximum usable frequency (MUF) cannot be as high for steeper radiation angles. This range may be some hundred or so kilometers wide, so that it also cannot be covered by ground wave. Therefore, an arrangement of two stations is necessary to provide reliable coverage of the total territory in question. Each station covers a range from about 500 to 1500 Km. This takes into consideration that the transmissions to be jammed will, in each case, not use the highest possible frequency but rather the optimum frequency, for skywave propagation, see Figure 3.2.

For the calculation of jamming effectiveness, a computer program is used that provides very detailed HF-radio predictions. HF prediction charts can also be used, taking into account not only the ionospheric parameters but also the properties of the antennas. The computer provides a median value of field strength, receiver input power, noise level, the fraction of days

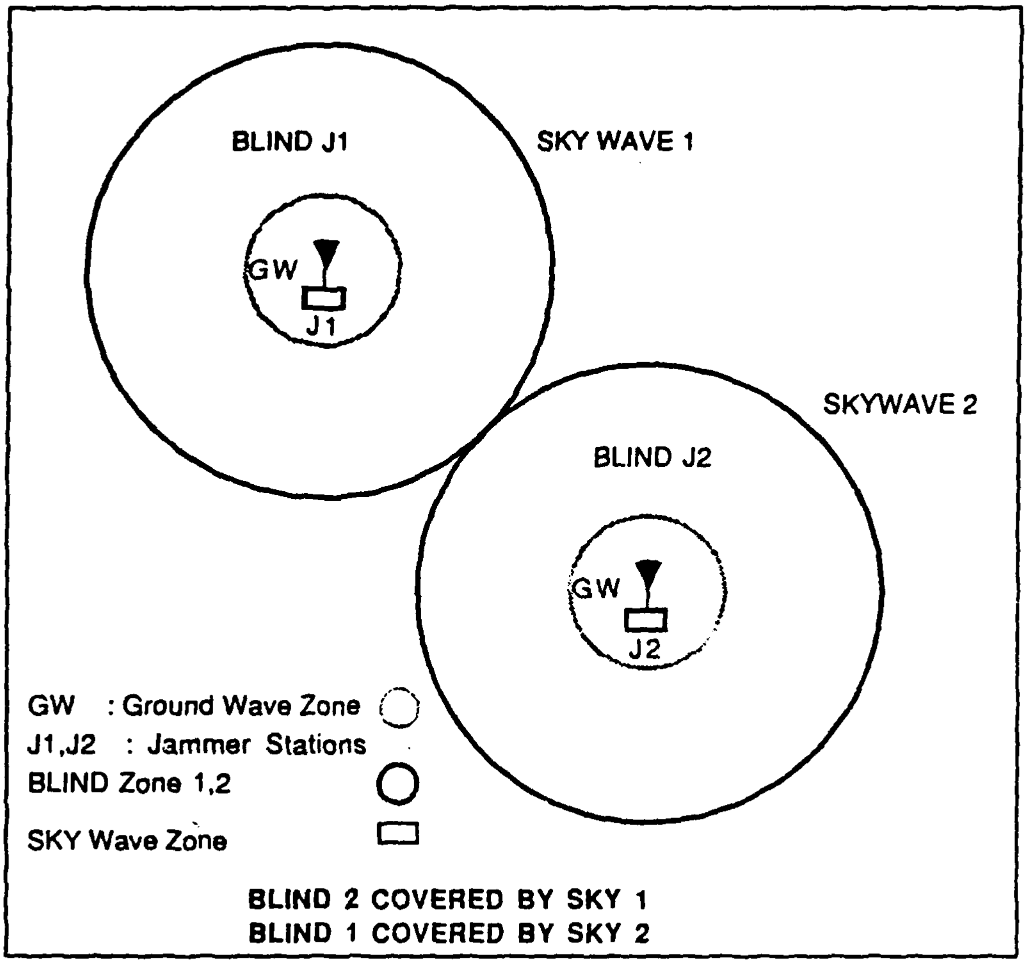


Figure 3.2 Typical Location of Two Jammers

in a month during which a certain propagation path exists, and the probability that a predefined signal-to-noise ratio will be exceeded. All data are printed out as frequency versus time of day. The necessary input data are, month, sunspot number, coordinates of the stations, types of antennas or special characteristics, ground constant, transmitter power, man made noise level, and required signal to noise ratio.

In assessing the potential effectiveness of jamming, it is useful to calculate a jamming-to-signal ratio at the communication receiver. A concept of jamming-to-signal ratio is derived in Appendix A.3.

Figure 3.3 shows how jammer power decreases at a rate of 20 dB per decade of range increase. The transmission to be jammed is characterized by a link distance of 2000 Km and 500 KW radiated power. The power of the jammer transmitter is 20Kw. The increase of effective power by superimposing of the two jamming signals has not been taken into account. Frequencies above 10MHz will decrease the jamming-to-signal ratio. Figure 3.1 shows the variation of the jamming to signal ratio with time of day.

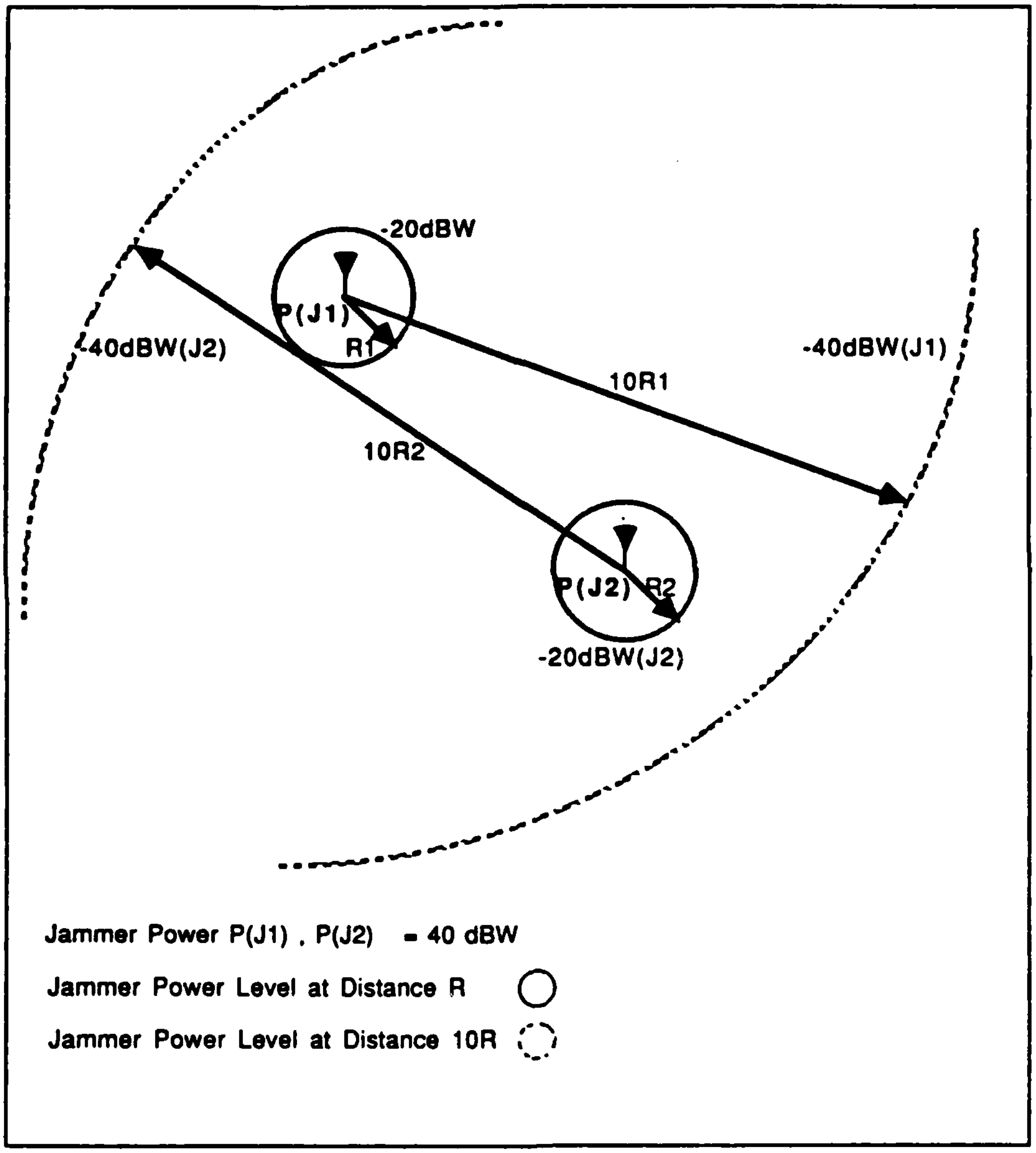


Figure 3.3 Power Levels Example of How Range Affects of Two High Power Jammers

IV. SYSTEM REQUIREMENTS

A. OVERVIEW

The modern battlefield utilizes and depends increasingly on electronic devices. The dependence on such devices requires a careful, intelligent and judicious employment of these devices from a tactical, environmental and human-factors point-of-view. A rapidly changing tactical situation, and enormous threat dimensions by the enemy, needs a system employment which is self supporting, flexible, mobile and capable of adapting to unforeseen requirements.

Modern surveillance and DF equipment employs a highly sophisticated technology, which requires skillful handling. These systems only prove efficient reliable, and purposeful if their operation and maintenance is carried out religiously and diligently. Prior knowledge of enemy communication systems, which is obtained through COMINT, helps in the exploitation of enemy use of the frequency spectrum, power output of its emitters, antenna polarization, and dynamic range.

As the equipment used by armed forces becomes progressively more complex, it places a greater demand on the individual soldier. To avoid overloading the mental and physical capabilities of the soldier, it is important to analyze newly developed systems to determine how the man-machine interfaces of such systems can best be designed for optimal use by the operators.

B. TACTICAL REQUIREMENTS

Any tactical plan, no matter how versatile it is, may prove futile if not made while considering the communication limitations. Therefore, there is a dire need to understand the tactical requirements of communication systems which can closely support the tactical plan made by general staff officers. The axis of advance of the main force must be considered in the light of the means of communication available, its capabilities and limitations. The following considerations must be kept in mind while formulating any tactical plan.

(1) The Mobility of the System

Since the communication equipment is utilized by personnel it should be light weight and compact, so that it is not cumbersome for the soldiers. Heavy and bulky systems must be vehicle mounted.

(2) Flexibility of the System

Since the todays' battlefield is characterized by a rapidly changing tactical situation, the communication systems must be designed to handle dynamic situations without any major changes in the employment and mode of operation of the systems.

(3) Alternate Routing

Passing of timely information enables the commander to engage his available resources at the right time and at the right place. Since the direct route of communication are subject to a breakdown, each command echelon must be accessible through alternate routes as well. This will allow a smooth change from one route to another without any delay in passing the information.

(4) Local Defense

The deployment of communication echelons may require a separate location away from the main headquarters. This will expose the communication echelon to enemy special task forces or fighting patrol action. Therefore, a small body of troops must be given these echelons for their protection and safety. This will enhance the efficiency and output of the system. Since communication personnel need not to worry about their self defense and only concentrate on their required job.

(5) Conservation of Equipment

To save equipments for important phase of operation, one must not employ all his resources during the initial stage of operation. One of the ways to achieve this is to make use of the existing means of communications already available in the area of operation.

(6) Operational Worthiness of Equipment

Under battlefield conditions the equipment is subject to vibrations, excessive temperatures, wind and dust, and mishandling by the personnel during the transportation and use. Therefore, the system must be rugged to sustain the odds. This will ensure battle worthiness, of the system, for the purpose it is designed for.

(7) Future Expansion

The site selected for the deployment of the communication system must allow for the expansion of the system in that area to meet the challenge of new developments in the battle situations. The principles of camouflage, concealment and dispersion should not be compromised.

C. ENVIRONMENTS CONSIDERATION

The human organism has substantial adaptability to environmental variables. However, there are limits to the human range of adaptability. Similarly the systems which are manufactured, acquired and operated also have certain environmental limitations. In order to make optimum use of the system in a particular environment, there is a need to incorporate those hardware specifications which can sustain the environmental conditions being operated in. Different system platforms for example, tactical aircraft, surface ships, tracked vehicles, and man packed applications require definite hardware specifications to operate successfully in a given environment.

The environmental field conditions are unique to mobile tactical systems. These are atmospheric, motion, noise, illumination, and geographical. A brief description of these is as follows:

(1) Atmospheric

A system operating in any given environment face wide temperature variation, humidity, wind, and other meteorlogical conditions. Having knowledge of atmospheric conditions one must look for the system whose system hardware specification must be tailored to the range of tactical environments.

(2) Motion

The variables imposed by ever increasing, necesary mobility include vibrations, acceleration, and deceleration. Vibration can be two types; sinusoidal and random, the most common types of vibration encountered in the field. Any mobile system must incorporate hardware requirements to sustain these vibrations accordingly.

(3) Illumination

Every system requires a human being for its operation and maintenance, especially in field conditions where activities are carried out day and night. Therefore, it is necessary to provide some form of artificial illumination for effective operation of the system by the operator. The system must provide a proper ambient lighting environment for the visual display terminals and other controls. If factors like luminance ratio, reflectance, glare illuminance are allowed for good man-machine interface then an effective operation of the system by the operator is more readily guaranteed.

(4) Geography

The geographical location in which a particular system to be used poses significant hardware limitations/requirements. Since weather conditions vary from one location to another. For example, a location where rainfall is a permanent feature requires a system to offer heightened water proofing requirements for successful operation. The desert environment with its high temperature during the day may cause damage to sophisticated electronic components. These components require air conditioning arrangements to maintain the temperature level of the installed system. The altitude of the location is also an important consideration in the design of the system.

D. Human Factors Considerations

Because of the high stakes involved in an armed conflict, it becomes even more important for a mobile tactical Communications Electronic Warfare System for ground forces to be efficient, because of the limited time it is employed in operation and its vulnerability, and mobility limitations.

To ensure maximum effectiveness in such a system, it is necessary to identify any man-machine interface problems that might reduce the effectiveness of the system and to develop changes in hardware design, operating procedures, and training programs to optimize the effectiveness of the system.

The proposed system is made up of three subsystems with respect to man-machine interface, namely; Command and Control Center, mobile tactical direction finder system, and mobile tactical jamming system. The mobility of these systems and their deployments emphasize the importance of human factor considerations in the areas of handling, flexibility, ease, and day-to-day usage. In order to meet the human factor requirements the following should be considered:

(1) Work Space Arrangement

When determining how controls and displays should be arranged in front of the operator, the overriding consideration must be speed and accuracy. For this reason, one needs to ensure that the arrangements of components by position suggest to the operators the manner in which they should be used. This means that they are to be arranged according to the sequence in which they would normally be used, their frequency of use and their importance, i.e., ergonomics.

Paramount is the basic requirement that the components be accessible to the operator when he needs them. This must take into account the appropriate anthropometric data and the position the operator adopts when carrying out his task. Finally, any restrictions which are placed upon the operator's movements, by his clothing or by other equipment, must be considered.

(2) Work Station Layouts

The field of human factor engineering has developed techniques for assessing the adequacy of tasks, subsystems, and organizations. From the work space development point of view, human factor engineering techniques need to address the arrangement of systems as applied to the space as a whole and the entire mission work areas. The dynamic nature of a proposed system as it is in an equipped mobile station, e.g., new equipment with new functions and increased capabilities are constantly being introduced into space barely adaquate for the original equipment.

When considering how the operator's workplace, i.e., layout, should be arranged around him, two factors need to be assessed. The first concerns his communication requirements, and the second relates to his feeling of ease and comfort with respect to the accessability of the other people in his environment.

(3) Operator Communication Requirements

The operator's communication requirements consist of links between operator-machine communication and operator-operator directions. These may occur via any of the operator's sensory systems, although the visual, auditory and tactical system will most often be used. This means that the operator must be able to see his machines, be able to move around quickly to operate them, and should be in a position to hear and to talk to other operators. Also, the operator's visibility and auditory requirements, and the necessity to arrange machines so that movement from one to another is reduced.

(4) Information Flow

Success of any system and its optimum utilization is only possible once there is an uninterrupted and timely flow of information within each component and between different components working in relation to each other. The information obtained through (ELINT) should be passed to various intercept and jamming sites to enable their operators to reduce their workloads and concentrate on other priority tasks.

The commanders can only make timely decisions and place their assests at the right place provided the information received is fed to them in real time. This also avoids taxing the critical resources at the disposal of a decision maker. The operator's workload is greatly reduced if the information passage is smooth and efficient. In the heat of battle when stress and strain is at its peak, the timely flow of information via reliable means, contributes in reducing the prevelent strain atmosphere of combact conditions. A smooth information flow process develops the confidence of the operator in the usage, effectiveness, and compatibility of the system he is making use.

(5) Maintainability

Maintainability is the characteristic which ensures the availability of the system, when required, for the desired mission. This is only possible if the operator has the required training, tools, and technical reference material for maintenance of the system. Efficient and easy maintainability of a system results an increasing the Mean Time Between Failure (MTBF). Operator intensive maintenance may result in overloading the operator, thus limiting operation.

(6) Ease of Portability

The system's size and weight requirements play an important role in a mobile and fluid combat situation. Combact size and light weight lead to an easy and meaningful configuration. Requiring a minimum build tear-down time, enhances the availability and operation time for the system. This ensures less labor intensive efforts required of the operators, and derives maximum human efficiency.

V. MOBILE TACTICAL EW HF/VHF PROPOSED SYSTEM CONCEPT

A. OVERVIEW

In this chapter, a concept of a mobile tactical EW HF/VHF system will be described. The entire concept of such a system is based on its mobility; so that the subsystems are accommodated in shelters. Depending on the volume of the equipment and the number of operating positions, there are different dimensions for shelters.

The proposed system concept is broken into three main sub-systems; firstly, Command and Control Center, which includes interception and communication stations; secondly, mobile tactical direction finder system (for which a detailed description of performance will be presented) and thirdly mobile jamming system (for which an HF and VHF jammer station will be discussed). In addition, a typical operating scenario for the system deployment in the field is discussed and analyzed from DF and jamming points of view in Appendix A.

B. MOBILE TACTICAL EW SYSTEM

The system is one with which a radio network, in the vicinity 1.6 - 30 MHz and 20 - 500 MHz, can be intercepted, analyzed, DF'ed, monitored, subjected to surveillance, and also jammed. The system consists of three sub-systems, namely; the command and control center, DF Station and jamming station. The heart of the entire system is the command and control center which comprises the command and control station, the intercept station and communication station.

The main tasks of the command and control center are; the search for active frequencies, analysis and classification of traffic, control of DF stations, calculation of the most probable transmitter location, and control of jamming stations. The communication station provides a radio link to the direction finder and jamming station. Transmitter positions are directed from the command and control station using the bearing obtained from the DF station. Figure 5.1 shows a mobile tactical ESM/ECM System configuration.

The command and control center, Figure 5.2, receives general reconnaissance and jamming tasks from superior authorities. These tasks are split up into sub-tasks, and passed on to the monitoring position in the intercept station for search and surveillance action. The monitoring operators register their intercept result in the form of reports or by means of cassette recordings.

To determine the location of a transmitter, DF commands are issued to monitoring positions, whereby the direction finders are set according to the parameters of the signal in question.

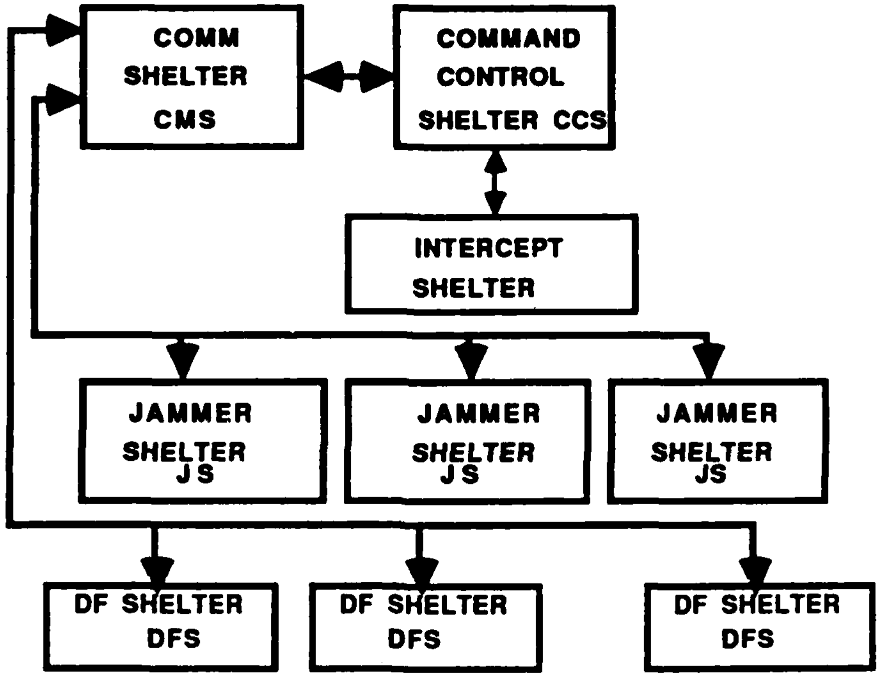


Figure 5.1 Mobile Tactical ESM/ECM System Configuration

The bearing is taken automatically and transmitted in digital form to the command and central center. There the transmitter's location is calculated from the bearings and the known locations of the direction finders.

The bearings and reports of the monitoring operators are evaluated in the command and control station to assess the tactical significance and location of the transmission. This information is reported to superior command authorities.

C. DESCRIPTION OF THE STATIONS

1. Command Control Center

The command control center comprises the command and control, intercept, and communication stations shown in Figure 5.2.

a. Command and Control Station

The command and control station is required to perform certain tasks. The tasks are; search and analysis, issue of frequencies to monitoring operators, supervision of monitoring operator, DF command and control, calculation of locations, storage of intercept results, control of jamming, and link to upper command echelons for receiving tasks and reporting results.

For such tasks to be carried out adequately, it is required to delegate the tasks between two or more operating positions. For example, issuing the search and surveillance tasks to the monitoring positions in the intercept stations, control of DF command system, calculation of location and further processing of location results and control of the jammers can be carried by one operating position. Other tasks such as evaluation of the monitoring operators notes, insertion of location results, presentation of the situation and the drawing up a report for higher command can be carried out by the other operating position, called the pre-evaluator position.

The command control station, as shown in Figure 5.2, illustrates the kind of equipment needed to perform these tasks. The following types of units (equipment) can be employed to achieve the object of this station:

Receivers with a panoramic display unit

Searching, surveillance, and analysis tasks are to be performed by panoramic receivers. The receiver's settings can be transferred via the computer terminal to any selected monitoring position, or transmitted to the DF stations by issuing a DF command. The operator can take over the settings of any selected monitoring receiver from his own receiver for further assessment. For the receivers to accommodate full performance, as intended, a set of technical characteristics is required.

Control unit

This unit would transmit receiver settings from the operator position to the monitoring position, and vice-versa, and would also administer the DF command link.

Intercom units

These units need to provide voice communication between all operating positions.

A connection to the direction finders and jammers is established via radio or wire. Line balancers are used for this purpose, where data signals are converted and provide modulation in the modem for transmission via voice channel.

b. INTERCEPT STATION (IC's) - Figure 5.3.

The purpose of this station is to provide means for searching and surveillance of bands and individual frequencies, and also to record transmissions. To perform such tasks, the station needs to have the capability of monitoring signal channels, i.e., automatic surveillance of the occupancy of individual channels and automatic search of frequency bands for occupied channels. For this capability to be achieved, receiver characteristics must match the task, i.e., bandwidth, resolution, sensitivity, dynamic range, etc. need to be

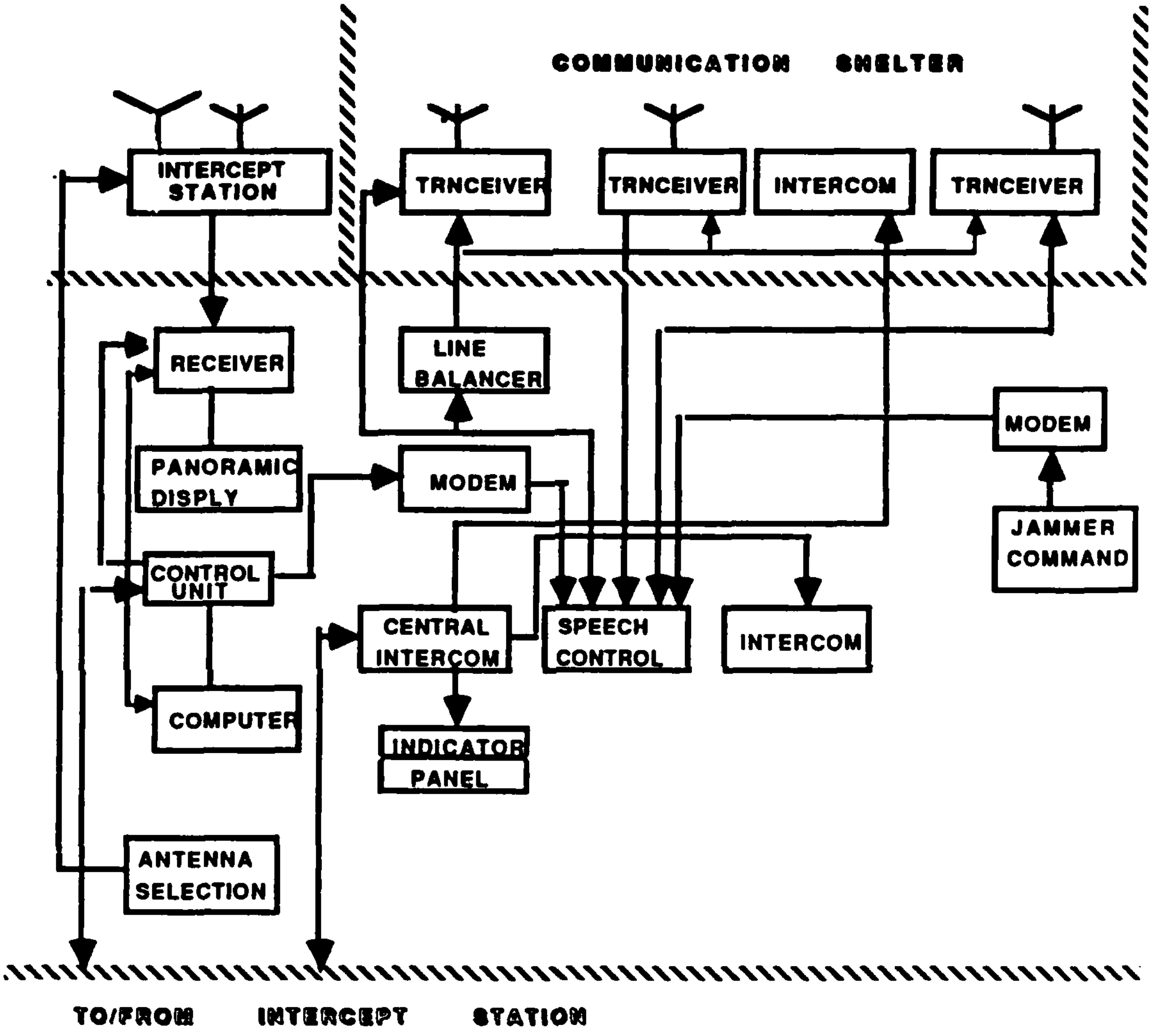


Figure 5.2 Command And Control Station (CCS) Block Diagram

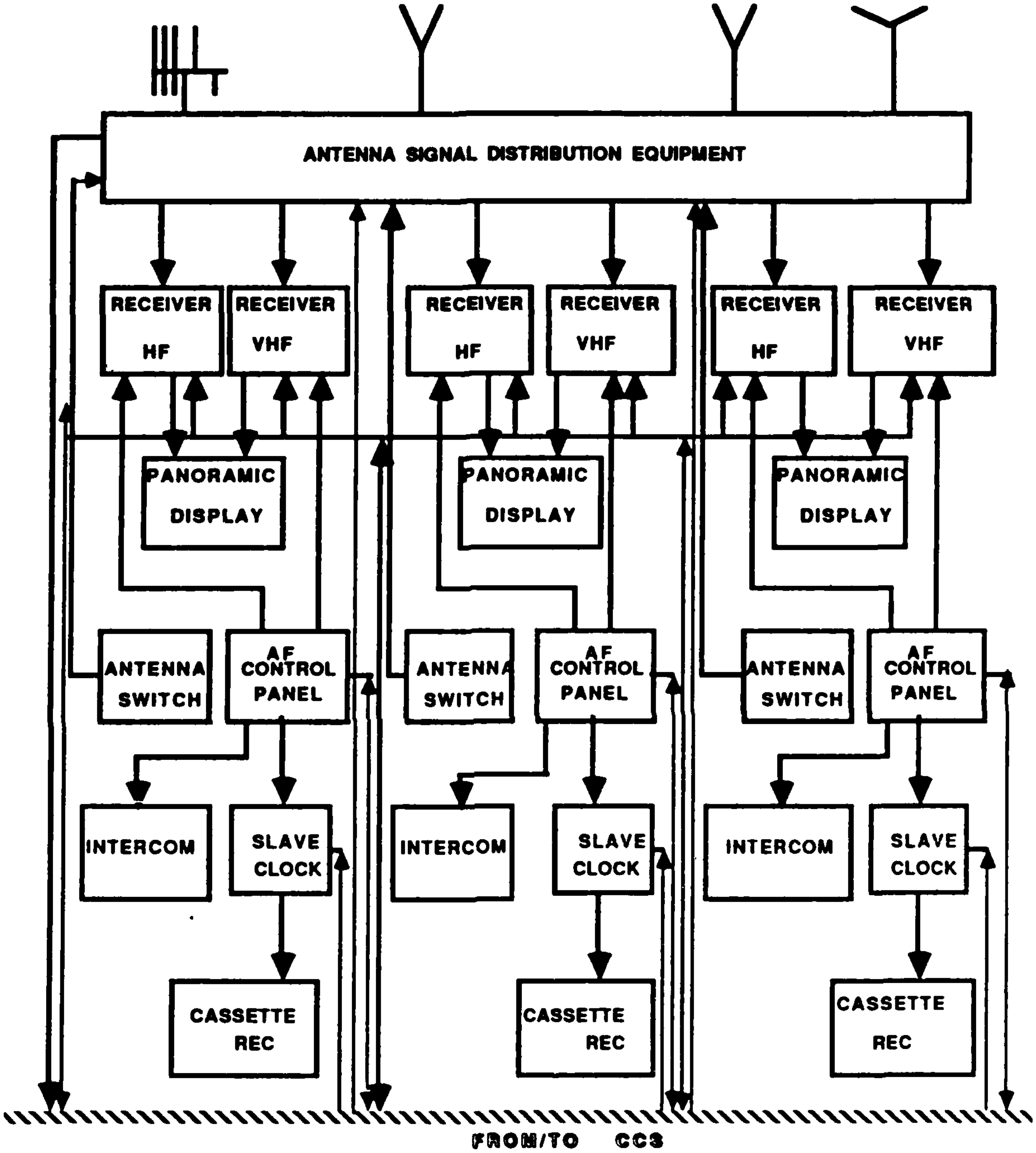


Figure 5.3 Intercept Station Block Diagram

compatible. A proposed station consists of three monitoring positions each with two receivers, an intercom unit to allow voice communication between the operator and command position, and an antenna system to deal with the band of frequencies of interest, (i.e., HF/VHF, by means of the antenna switch, in which the output of any antenna can be fed to any receiver).

c. COMMUNICATION STATION (CMS)

The DF stations and jammer stations are controlled via either wire or by radio. In case of radio transmission, a communication station is needed and this is set up a distance away from the receiving antenna system. The communication station contains transceivers for the transmission of data and speech. For this proposed system three VHF/HF transceivers are required to perform the following tasks:

(1) Data radio link for commanding jammer.

(2) Data radio link for commanding direction finders.

(3) Receiver/transmitter link to direction finder and jammers.

2. Mobile Tactical Direction Finder System

Mobile direction finding station are important as part of modern radio surveillance radio reconnaissance systems. It is their task to locate unknown transmitters and to locate operating sites of mobile enemy forces.

Mobile direction finding stations are operated as independent systems, or to support fixed systems. They are primarily used to locate transmitters, within areas where fixed systems are unable to fulfill these tasks, because of the size and typographic conditions of the area where unknown transmitters are assumed to be. Their mobility and independence enable them to quickly obtain bearings which intersect and also to track mobile transmitters. The main purposes of a direction finder can be defined and summarized as follows:

(a) Receive direction finding orders.

(b) Obtain a bearing on the unknown transmitter.

(c) Report bearings.

The speed and quality with which these tasks are carried out depends almost entirely on the specifications of the direction finding equipment used, as well as, on the vehicles and shelters which have to fulfill the following requirements:

- Fast determination of azimuth with high accuracy and resolution.
- Direction finding of the unknown transmitter also under condition of strong disturbance and with multi-transmitter reception.
- Location of the transmitter by relative field strength measurement of close range.
- The direction finding result has to be displayed immediately.
- Simple operation of the equipment.

- Operation should be capable while the vehicle is being driven.
- The direction finding station must be independent of external power sources.

The aforementioned requirements need to be economically fulfilled with a direction finding system in HF/VHF range. The outstanding features required are:

- High sensitivity.
- Simple operation.
- Automatic direction finding.
- Simultaneous analog and digital display of the DF results.

Fully automatic operation of the direction finder.

As there are various DF antenna systems which can be used, the DF stations can be adapted to any site used and purpose. For semi-mobile use, a need for a highly sensitive DF antenna system becomes vital. For a fully mobile, a camouflaged DF station, ferrite DF antenna systems are required to be installed on the the shelter or vehicle.

a. Structure of the System

HF/VHF systems require installation in the smallest of military standard shelters, and therefore may be transported on small trucks or by helicopters. A typical system of DF consists of: master shelter with a DF·command, control position and DF position; and slave shelter with a DF position. The DF master shelter is to be equipped with minimum equipment to achieve its tasks, such as; a computer system, antenna system installed a distance from the DF station a teletype, ciphering, transceiver and power supply system. The DF slave shelters also need to be equipped with a channel DF system, an antenna system, ciphering, teletype, transceiver and power supply system. A typical tactical direction finding system configuration for HF/VHF is shown in Figure 5.4, 5.5.

For exchange of information, a voice or teletype or even digital data via HF/VHF link must be commanded with provisions for security.

b. Principles of Operation

The DF master station receives reconnaissance tasks from a higher command or generates its tasks by itself with the aid of its own intercept receiver. The received or generated tasks are given an order number. To determine the location of the intercepted transmitter, a DF command is issued by the DF master station to the DF slave station and to its won DF position, whereby, the direction finders are set by the received data. The bearing is taken automatically and transmitted back in digital form to the DF command and control position of the DF master station. There, the transmitter's location

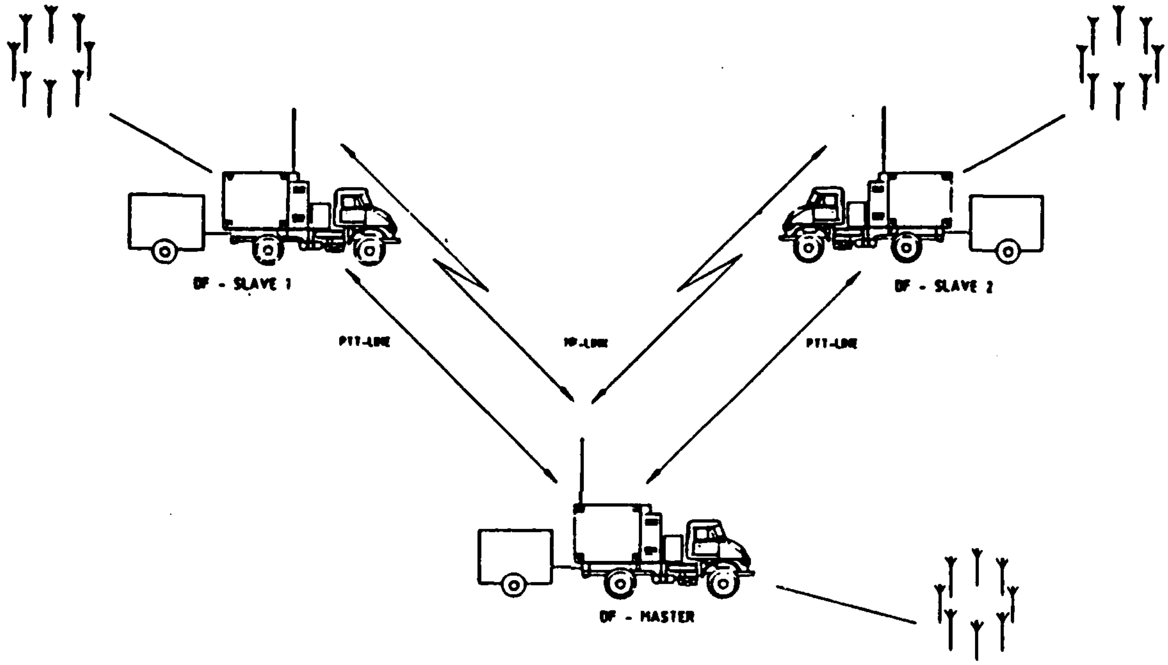


Figure 5.4 Tactical Mobile HF - Direction Finding System Configuration

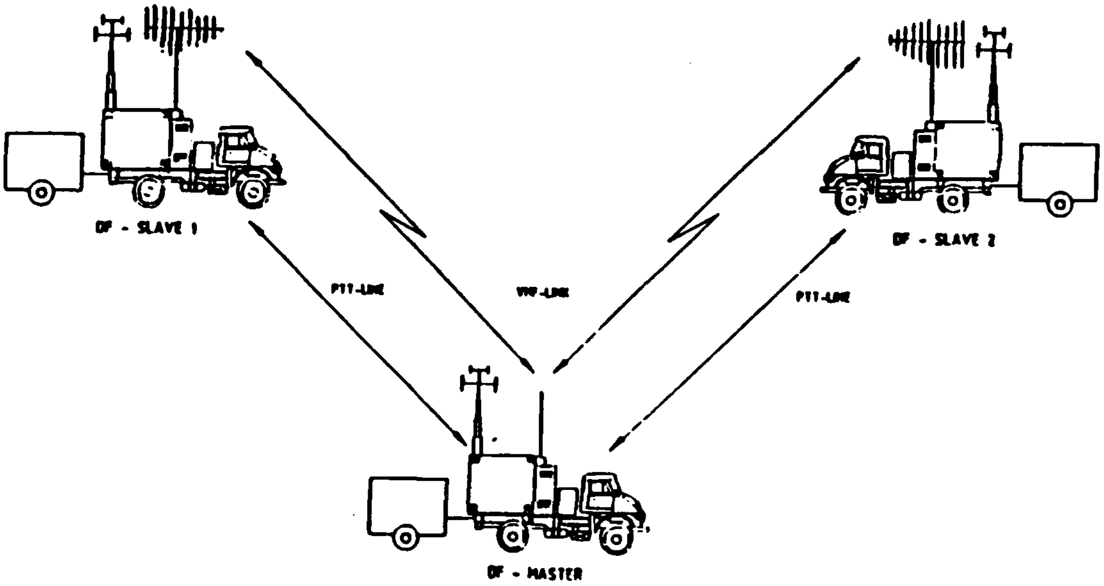


Figure 5.5 Tactical Mobile VHF/UHF-Direction Finding System Configuration

is calculated from the received bearings and the known locations of the direction finders. This result is reported to the command control station.

c. Description of the Stations

1. DF (Master) Station Figure 5.6 - The tasks the master station needs to perform in order to fulfill its objective can be summarized as:

(a) Search and analysis.

(b) Direction finding and control.

(c) Issuing a DF command.

(d) Calculation of locations.

(e) Storage of DF results.

(f) Transmission of voice and data.

An intercept receiver is used for searching, surveillance, and analysis of the transmission within the frequency range under observation. To supply the intercept receiver with a signal, the sense output from the DF antenna system is fed to an antenna multicoupler which distributes it to the intercept receiver and the DF position at the DF master station. The receiver's setting can be transferred to the terminal computer which gives it a DF order number. The DF command is indicated on the computer display. This command is transferred to the direction finders via VHF/HF link in a digital form. The digital data signals are converted and modulated in the modem for transmission via voice channel; a data encryption set is used if there is a requirement to send ciphered data messages.

To find out the bearing of an unknown transmitter, the DF master station is also equipped with a DF system for the band of interest. The DF command data coming in a digital form from the DF command and control position set the DF receiver. The bearing data is stored in memory which is taken either automatically during a predetermined sequence or on call by the DF command and central position. The bearing is reported to the DF command and control position in the same manner as the command data was sent to the DF position.

During the time the DF command made the information transmission, facilities get their signals either from the DF command and control equipment or from the DF sets via the modem which converts the signals for transmission over the voice channel, which could be enciphered too. To fulfill the tasks of information transmission the station is also equipped with the following:

- HF/VHF Transceiver
- Link/line switch
- Line balance
- Teleprinter unit
- Modem

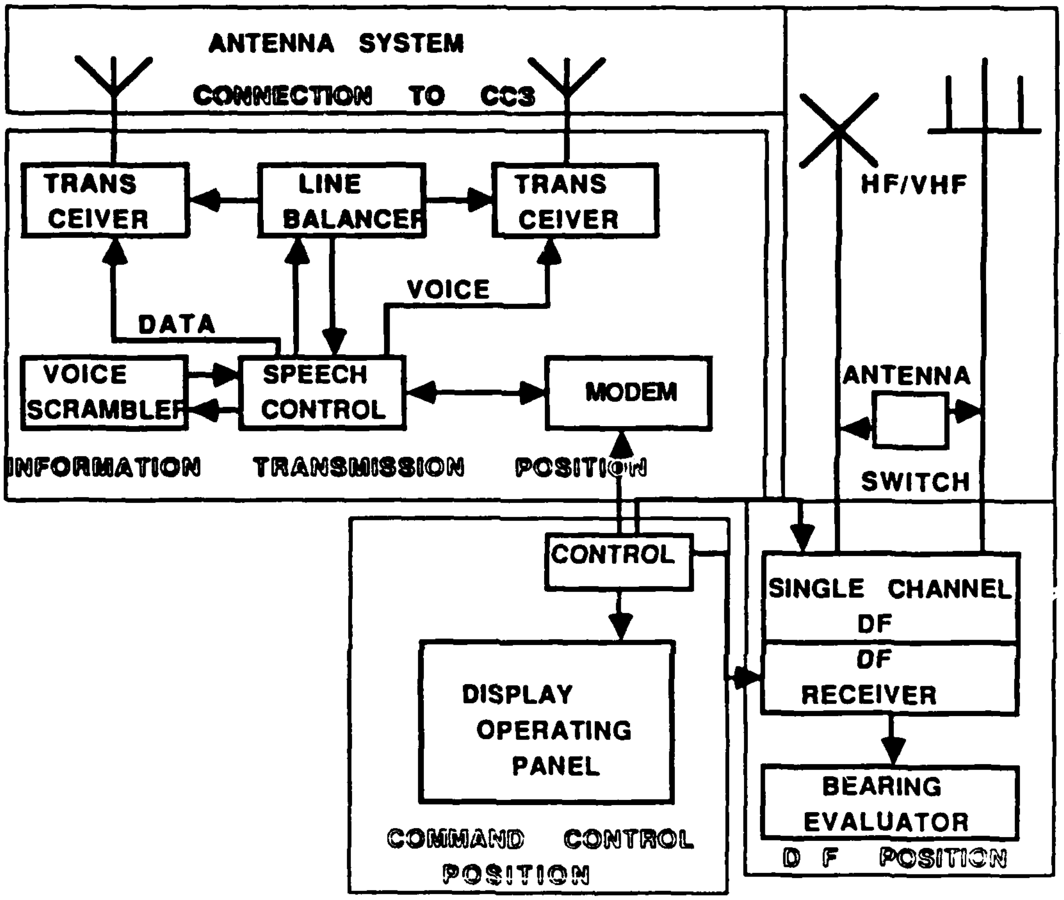


Figure 5.6 DF Master Station Block Diagram

The DF master station is equipped with two antennas; one for direction finding purposes with either VHF/HF DF antenna system, the other is for information exchange purposes via HF or VHF link. In the case of VHF application the DF antenna is mounted on top of a mast system for fast pneumatic erection, the mast is secured to the shelter of the DF master station. In the case of HF to keep interference low the DF antenna should be installed no less than a minimum distance apart from the DF station on the site.

2. **DF Slave Stations** - The tasks the slave station needs to perform in order to fulfill its objective can be summarized as:

- Direction finding
- Reporting bearing
- Transmission of voice and data

To determine the bearing of an unknown transmitter, the HF or VHF DF slave station requires a set of DF equipment to cover its range of frequencies of interest. The command data, arriving in digital form from the master station, sets the DF receivers which is part of the DF set. After a given time of direction finding the bearing is stored in memory, and is taken either automatically during a predetermined sequence or when called for by the master station. The bearing results are reported back to the master station in the same manner as the command data was sent to the slave station. The exchange of information data or speech can be achieved by either HF/VHF link or Push-to-Talk (PTT) tone. To fulfill these tasks the stations are further equipped with:

- VHF/HF transceiver
- Intercom unit
- Teleprinter
- Modem

During the DF command mode the information transmission facilities get their signals either from the master station or from a DF set via the modem which converts the digital signal for transmission over the voice channel and vice versa.

The DF slave station is equipped with two antennas; one for DF direction finding purposes with HF or VHF antenna type, the other for information exchange purposes via HF or VHF link with either a whip antenna or directional antenna. To keep the interference low, the DF antenna for HF application should be installed a minimum distance away from the DF station. The transceiver's whip antenna is mounted on a base fitted externally to one of the DF shelter's walls. In VHF application the DF antenna is mounted on top of a mast system for fast pneumatic extension, the mast system must be secured to the ground with guys at its fully extended height.

3. Jamming System

The task of the HF/VHF communications jammer is to disrupt command reception, and to jam enemy radio links in the frequencies range from 1.6-30 MHz and 20 to 110 MHz. In HF jamming it is presumed that these transmitters transmit on known frequency and at known times, although no so-called "look through jamming" operations are performed with this high power jammer as with normal tactical systems. This means that the frequencies of interest are checked periodically for occupancy and will only be jammed in the following jamming phase if the frequency is occupied. VHF jamming operation is performed in a response mode of operation, i.e., look through operation.

a. HF High Power Jammer

In the selection of the high power jammer the following must be taken into consideration:

- Jamming may be performed over a wide area, and long distance using sky wave propagation
- Small areas may be jammed over short distance by using ground wave propagation.

In each of the above modes of operation, different antennas will be employed. Site selection for jamming over long distances is relatively unrestrained, since site displacement of 100 Km and more will have negligible influence. Transmitter locations can very seldom be changed when operating high power HF, consequently the jammer is designed for semi-mobile operation. Set-up and disassembly time of the station will mainly be determined by the set up time for the antenna employed. An overview of the total HF high power jamming system set up is shown in Figure 5.7.

For effective deception and jamming the operator has at his disposal a jamming signal generator, which is designed for effective jamming of voice communication, teletype transmissions, and morse communication modulated signals. The operator receives his instruction via telephone or telex or even via VHF link or HF link.

Such stations try to employ effective jamming over the band 1.6 - 30 MHz. The set of equipment to achieve such employment is presented in the complete configuration of the various equipment components shown in Figure 5.8. The following are the components:

- Transmitter automatically tuned, having a linear power amplifier of high efficiency over the HF band, with modes of operation; voice, morse, and teletype.

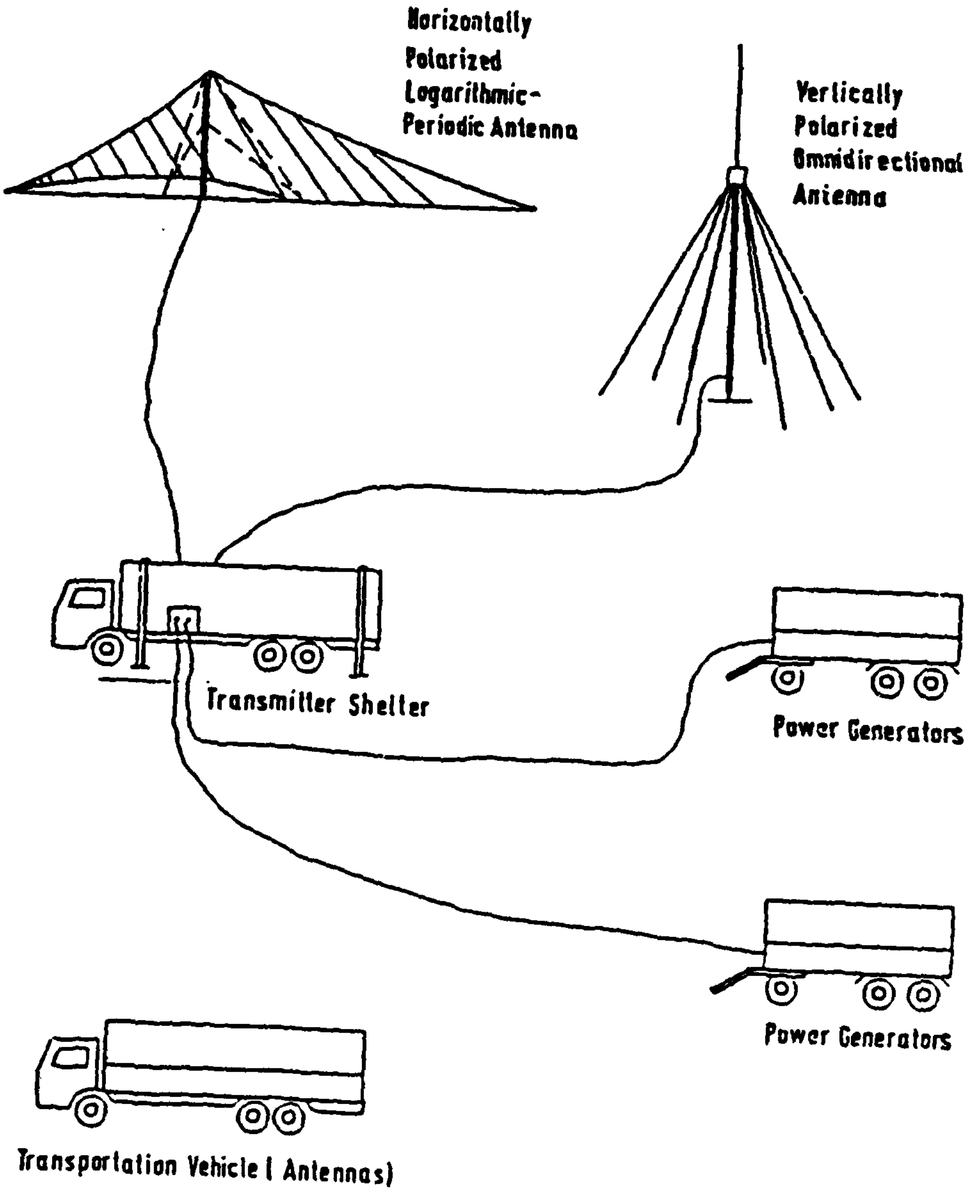


Figure 5.7 High Power Jammer System Configuration

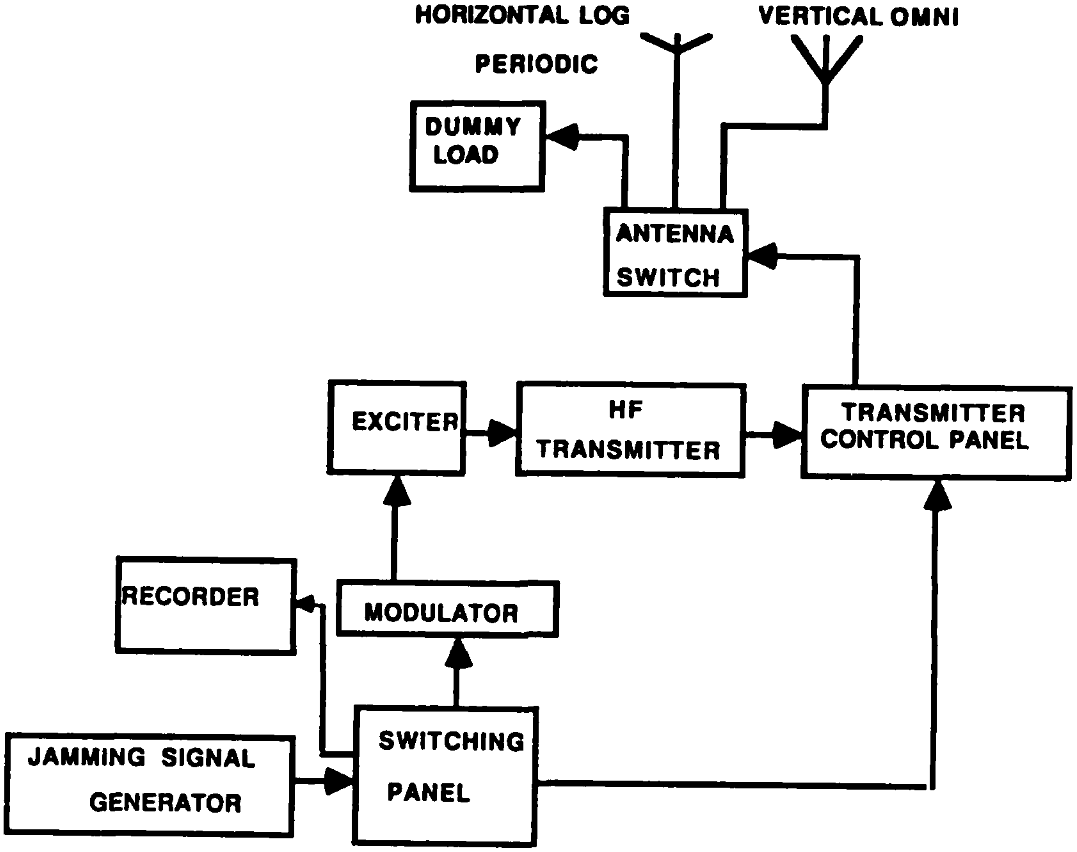


Figure 5.8 HF High Power Jammer Block Diagram

- Frequency synthesizer drive unit preceeding RF transmitter.

- Jamming generator to generate voice communication, teletype, and morse communication jamming signals.

- Antenna system - according to the jamming tasks. Two types of antennas must be employed. One for smaller area coverage, i.e., urban jamming, using ground wave propagation with the vertical HF transmitting antenna. a second for large areas, using sky wave propagation, having horizontal log periodic HF transmitting antennas.

b. VHF Communications Jammer

The task of the VHF communications jammer is to jam enemy radio links in the frequency range from 20-110 MHz, functioning in both reconnaissance and jamming of tactical communications, as shown in Figure 5.9. The jamming operation is performed in a responding mode of operation, also referred to as "look-through" operation. That means, the frequencies of interest are checked periodically for occupancy and will only be jammed when threat frequency is active. The operation takes place across the entire frequency range, without any limitation or frequency band subdivision.

VHF jamming transmitters are controlled by means of direct input at the jamming station or by a remote control commands via a line or VHF radio link. The command unit is part of the jammer system. One command unit can handle the command communication to and from several jammers.

The VHF jammer consists of the following parts as shown in the Figure 5.10.

- System control which controls all functions during atomic of operation.
- Keyboard and display which interface between the operator and jammer systems.
- Remote control and communication which allows communication between the system and command control station.
- Receiver which detect occupied frequencies during look-through operations.
- Jammer transmitters which consist of an exciter and broadband power amplifier.
- TR switch which allows the use of the antenna for both receiving and transmitting.
- The antenna system contains two types of broadband antennas, i.e.,, a broadband directional antenna for standard use and an omnidirectional antenna for use under lower power, shorter range, multiple bearing conditions.

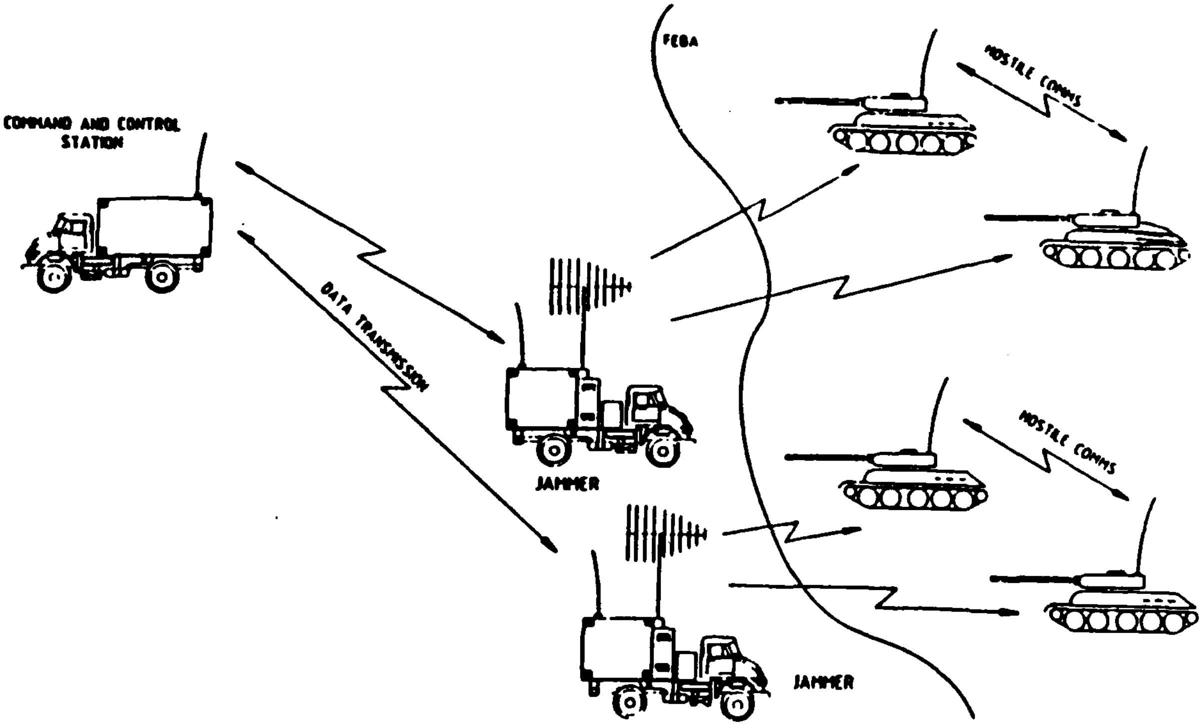


Figure 5.9 Tactical Mobile Jamming System Configuration

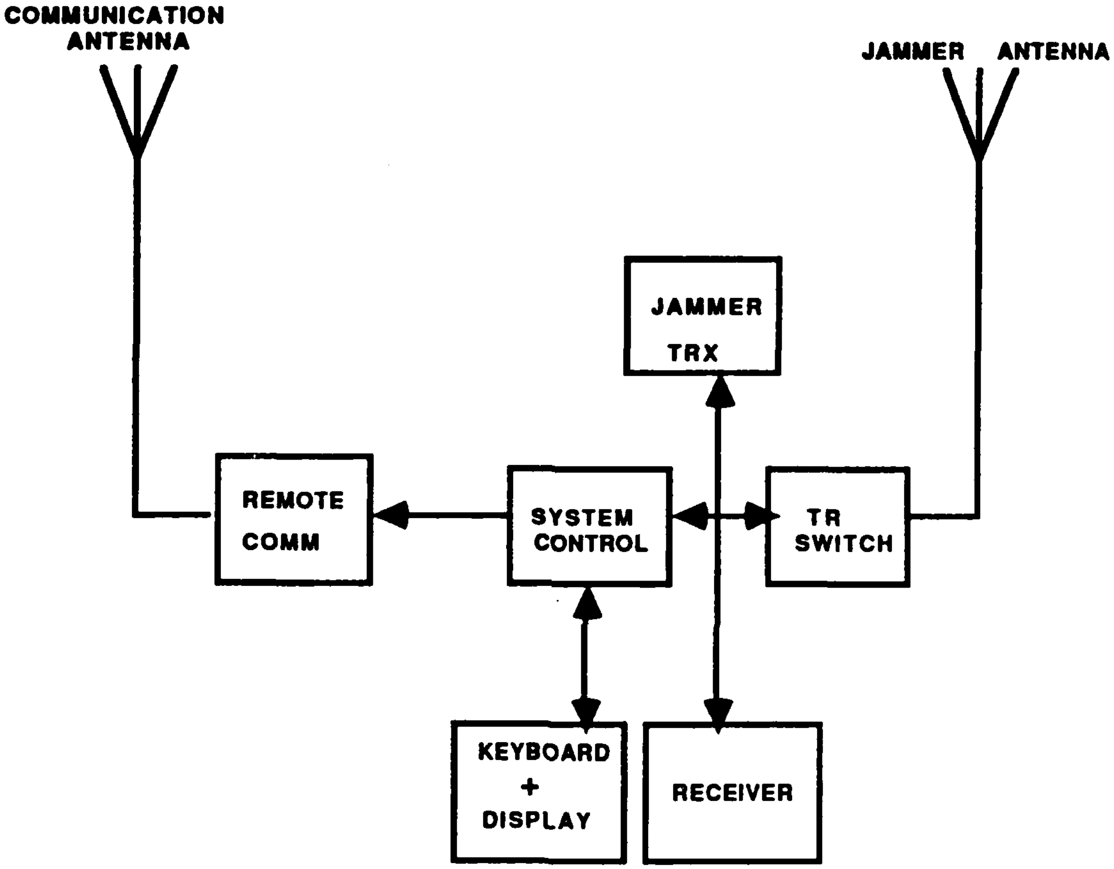


Figure 5.10 VHF Jammer System Block Diagram

VI. PROPOSED HF/VHF COUNTER-COMMUNICATIONS SYSTEM SPECIFICATION

A. OVERVIEW

The system needs and requirements, play an important role in the process of acquisition for battlefield use. This emphasizes the need to assess the requirements on the basis of posed threat environment and scenario. Before the development of a system, the operational requirements must be studied and discussed in detail. This will enable the acquired system to effectively meet the mission needs and objectives.

In chapter five, a detailed concept of a mobile tactical EW system has been presented, which provides an adequate background related to operation, judicious employment and effective performance. In view of various discussions carried out in previous chapters, a definite mission objective has been proposed.

Various systems and sub-systems which constitute an ESM/ECM platform were considered from the mission category and performance point of view. The desired specification of systems/sub-systems are discussed and identified in the subsequent paragraphs. During this process of evaluation, a sincere effort was made to ensure a maximum use of "off the shelf" available products, if possible units made by one manufacturer to assure compatibility.

B. COMMAND AND CONTROL CENTER

As already discussed in Chapter V, it consists of command and control station, intercept and communication stations. The types and technical specifications of each piece of equipment, to achieve the desired mission performance, appears in Appendices B.1, B.2 and B.3.

C. MOBILE DF SYSTEM

Similarly, this system consist of a master and slave station. The type of equipment and its specification, appears in Appendix C.1 and C.2.

D. JAMMING STATIONS SPECIFICATION

Further more the jamming station consist of HF and VHF jammers. The proposed system specification appears in Appendix D.1 and D.2.

VII. SUMMARY AND CONCLUSION

The thrust of this thesis has been to propose a mobile tactical EW system covering the HF/VHF frequencies in use by ground forces worldwide. The applications for this system are varied, although the system described here has been directed toward establishing guidelines for selecting an effective system for ground forces.

The first phase of the research was to develop a general understanding of the concept of communications applied in EW environments. This is necessary to achieve an overall view of tactical analysis of both, ESM and ECM. The primary objective was to gain a clear idea of the importance of these elements in the communications field, which in turn determines the optimum utilization of the system. The concept was provided in Chapters III and V.

Chapter IV proposed actual system requirements, viewed from tactical, environmental, and human factors points of view. The importance of these considerations is vital to achieving better performance and usage under all circumstances of use either in combat or in surveillance of pre-hostility situations.

The concept of an EW system, as viewed in Chapter V, was structured in order to fulfill the need for its performance to intercept, analyze, monitor, DF, and jam. The principle operations of each subsystem, i.e., the command and control, intercept, DF, and jamming stations, are explained. The description and structure of each station block diagram was explained within their scope, in order to update new needs and requirements for any classified planning. Finally a proposed specification of the system was discussed and identified, making maximum use of "off the shelf" available market technology.

This work requires further development in relation to existing available operational hardware and logistic plans in order to produce a well integrated plan, duly supported by EW resources. The evaluation and survey of existing means of communications and jamming hardware is proposed to assess integration and utility with the proposed system.

Lastly, a dedicated and well organized training program, plan, and, facility must be envisioned for effective and efficient operation and maintenance of this system.

APPENDIX A

EW COMMUNICATIONS SCENARIO ANALYSIS

A.1 MOBILE TACTICAL EW COMMUNICATIONS SCENARIO

Fig A.1.1 showes a typical operating scenario for a mobile tactical EW communications system. The architecture is such that existing EW units employed to support limited military operations which can be enhanced by the addition of more sophistecated sensors and data processing facilities to serve mojor formation on wide fronts.

On a small scale implementation a typical EW Communications System includes three or more DF vehicles controlled from an ESM (Intercept) shelter using Combat Net Radio (CNR). Remote tasking of the DF net, return of bearings and production of emitter location are processor controlled using ESM equipments. The resulting emitter locations are entered in the data base, where they are supplemented by other data entered by intercept operators using their own receiver equipments.

For larger scale operations, the activities of two or more ESM units are controlled from an EW Command and Control Center (CCC). Here, the EW data base is used to collect and evalute the reports from all the ESM units, and to merge in other source information, including ELINT. The resulting intelligence reports are passed to the tactical commander. At the same time the CCC updates the jammer lists for remote automated control of the ECM units.

The intercept and Command and Control Center are inter-connected by radio relay links to facilitate data exchange and automatic updating of the distributed EW data base at all relevant points. Alternatively, they may be connected by a suitable, existing communications network. In this way all users have instant access to the required data, while the distributed data-base approach ensures an inherently survivable system.

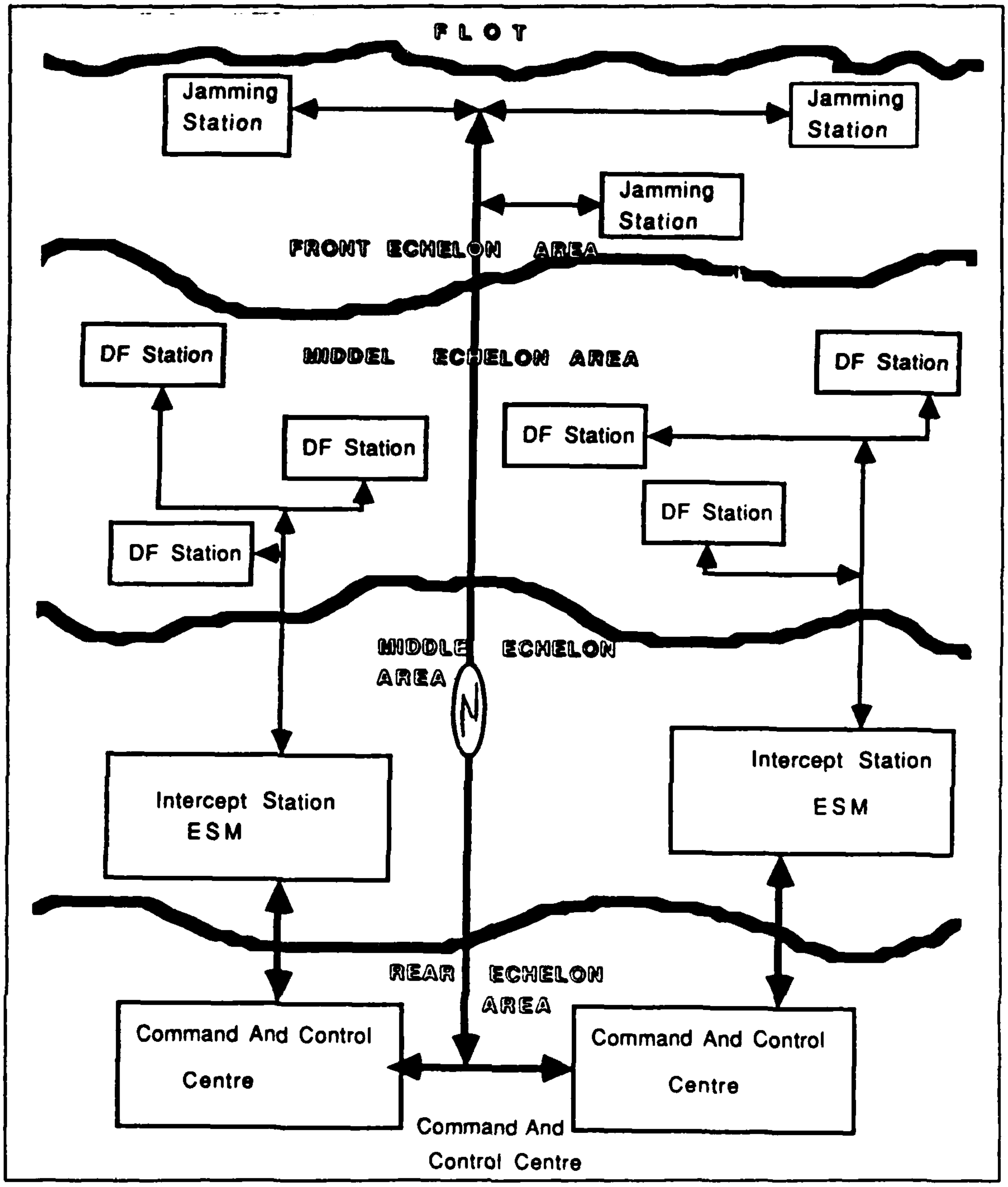


Figure A.1.1 Typical Operating Scenario For A Mobile Tactical EW Cmmunications System

A.2 MOBILE TACTICAL DF OPERATING SYSTEM ANALYSIS

Fig A.2.1 showes a typical operating scenario for a mobile DF system. The geographical area in which emitters are located in relation to the avilable locations of the DF stations will determine the maximum and minimum distance over which signals must be received. These maximum and minimum distances, together with the frequency range in which the emitters operate, enable the most likely propagation mode to be identified, so that the optimum DF system can be chosen. For mobile system, it assumes that the area of the emitters may vary or be located so that is not possible to receive adequate signals from the emitters at a fixed site. In this case a mobile DF system with electrically small antenna elements is necessary.

In determining the location of an emitter by means of DF stations, the number and location of stations in a DF network have a direct effect on the accuracy with which an emitter can be located. The limitations of radio propagation as well as usual geometric limitations on the accuracy of triangulation must be considered. Ideally, the site of a DF system would be placed uniformly a round the edge of the area containing the emitters, but geographic features, national boundaries (which a mobile tactical system is employed), and communication problems between the DF sites sometimes make this impossible. In such case the best arrangement is to locate the sites of DF network as close as possible to the area containing the emitters, keeping the sites as far apart as possible.

Mobile DF's stations require the intersection of three or more bearings from the transmitting antenna for accurate triangulation of targets. They also require Line-Of-Sight (LOS) paths to the transmitting stations. Terrain, which masks radio signals and eliminates one or more of the LOS paths to the radio DF's locations, greatly decrease their ability to determine precise transmitter locations. Also radio waves may be reflected by terrain features. The combination of all above results in bearing error, which will not be considered in the analysis of determining the location of the emitter.

Calculation Of Gravity Center

The LOB's from the DF stations intersect each other. The line connecting these points compose a triangle whose gravity center is the starting point for the subsequent iteration. For the calculation of Gravity, all intersecting points of concerning LOB's have to be determined. This is realized by the "Forward Intersection Method". The triangle abc Fig A.2.1 is considered as a mass system. The coordinates of its gravity center are calculated as

$$X = \frac{\sum_{i=a}^{c} x_i G_i}{\sum_{i=a}^{c} G_i} \qquad (A.2.1)$$

$$Y = \frac{\sum_{i=a}^{c} y_i G_i}{\sum_{i=a}^{c} G_i} \qquad (A.2.2)$$

Where x_i and y_i are the coordinates of the intersection points abc , and G_i is the products of weight factor of both LOB's intersecting in a, b, and c. Assuming that all the three DF stations are identical, hence

$$G_a = G_b = G_c \qquad (A.2.3)$$

. Therefore equation A.2.1 and A.2.2 reduced to

$$X = \frac{x_a + x_b + x_c}{3} \qquad (A.2.4)$$

$$Y = \frac{y_a + y_b + x_c}{3} \qquad (A.2.5)$$

For a given location of three DF's stations in latitude and longitude in degrees, and knowing the bearing of each, the intersection coordinates between LOB's are determined based on a simple trigonometry of solving two simultaneous straight line equations . The intersection coordinates and the estimated center of gravity was determined by using **MATHCAD 2.0** computer software as in the latter part of this Appendix. Further, jammer to transmitter distance was also determined.

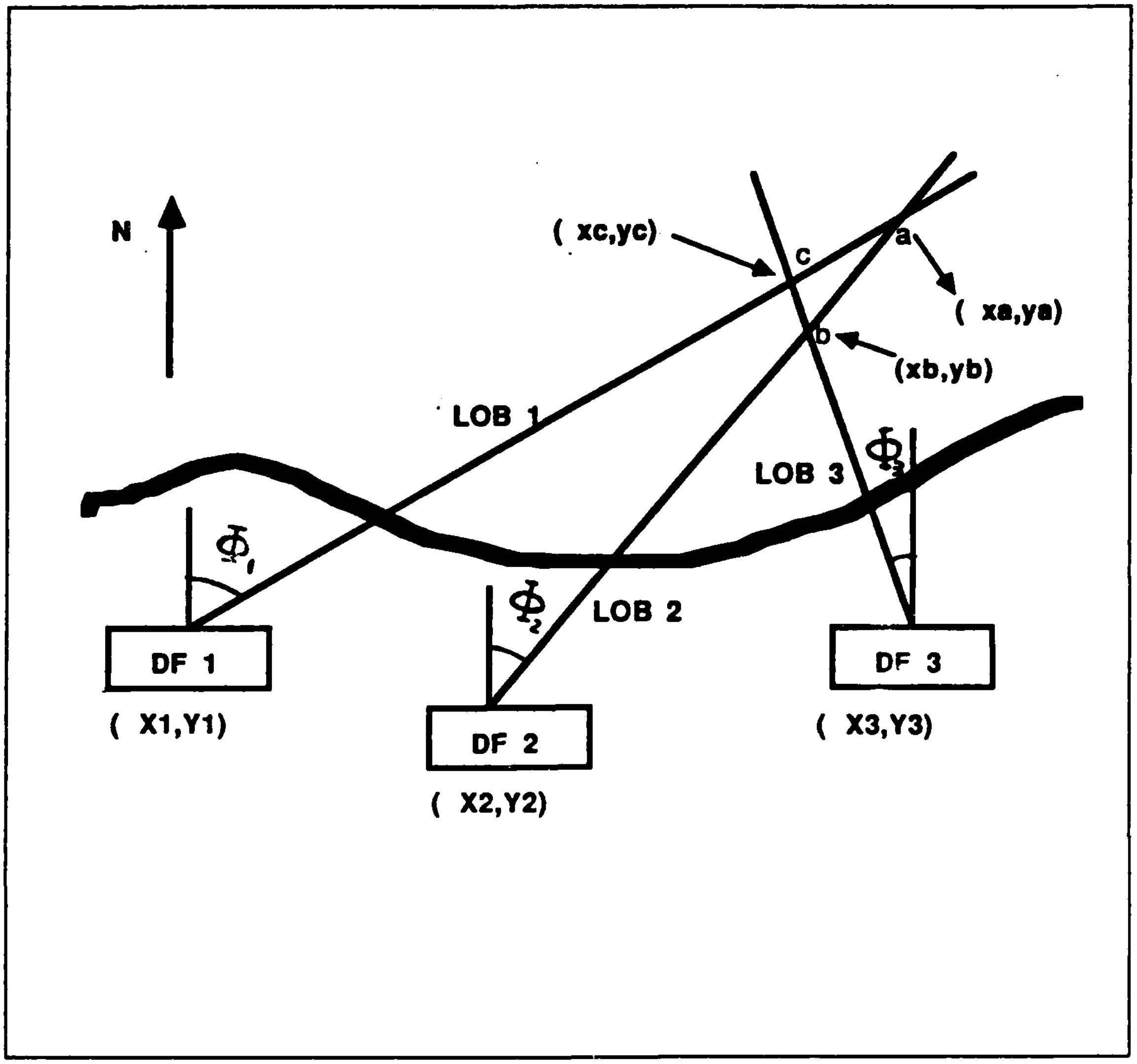


Figure A.2.1 The Geometry Of A DF System

MATHCAD.1: DF Analysis In Determining The Location Of A Transmitter Fig A.2.1.

Conversion Units

$m \equiv 1L \qquad Km \equiv 1000\ m \qquad sec \equiv 1T \qquad Kg \equiv 1M$

$Hz \equiv \frac{1}{sec} \qquad KHz \equiv 1000\ Hz \qquad newton \equiv Kg\ \frac{m}{sec^2}$

$joule \equiv newton\ m \qquad watt \equiv \frac{joule}{sec} \qquad KW \equiv 1000\ watt$

$R_e := 6378.155\ Km$

$x := \begin{bmatrix} 32.30 \\ 32.35 \\ 32.40 \end{bmatrix} \qquad y := \begin{bmatrix} 36.225 \\ 36.180 \\ 36.225 \end{bmatrix}$

x and y matrices represent the latitude and longitude of DF's locations in degrees

$\theta_d := \begin{bmatrix} 12.5 \\ 7.5 \\ -2.5 \end{bmatrix} \qquad \theta := \theta_d \left[\frac{\pi}{180}\right]$

θ.d: represents the bearig angle of each DF measured or given in degrees.

θ : represents the bearings in radiance

$$x_a := \frac{x_1 \tan\left[\frac{\pi}{2} - \theta_1\right] - \left[x_2 \tan\left[\frac{\pi}{2} - \theta_2\right]\right] - \left[y_1 - y_2\right]}{\tan\left[\frac{\pi}{2} - \theta_1\right] - \tan\left[\frac{\pi}{2} - \theta_2\right]} \qquad (A.2.5)$$

$$y_a := \left[x_a - x_1\right] \tan\left[\frac{\pi}{2} - \theta_1\right] + y_1 \qquad (A.2.6)$$

$$x_b := \frac{x_2 \tan\left[\frac{\pi}{2} - \theta_2\right] - \left[x_3 \tan\left[\frac{\pi}{2} - \theta_3\right]\right] - \left[y_2 - y_3\right]}{\tan\left[\frac{\pi}{2} - \theta_2\right] - \tan\left[\frac{\pi}{2} - \theta_3\right]} \qquad (A.2.7)$$

$$y_b := \left[x_b - x_2\right] \tan\left[\frac{\pi}{2} - \phi_2\right] + y_2 \qquad (A.2.8)$$

$$x_c := \frac{x_1 \tan\left[\frac{\pi}{2} - \phi_1\right] - \left[x_3 \tan\left[\frac{\pi}{2} - \phi_3\right]\right] - \left[y_1 - y_3\right]}{\tan\left[\frac{\pi}{2} - \phi_1\right] - \tan\left[\frac{\pi}{2} - \phi_3\right]} \qquad (A.2.9)$$

$$y_c := \left[x_c - x_3\right] \tan\left[\frac{\pi}{2} - \phi_3\right] + y_3 \qquad (A.2.10)$$

$$X := \frac{x_a + x_b + x_c}{3} \qquad (A.2.11)$$

$$Y := \frac{y_a + y_b + y_c}{3} \qquad (A.2.12)$$

$x_a = 32.438$ $y_a = 36.845$	x_a and y_a	represents the coordinates of the intersection between LOB1 and LOB3.
$x_b = 32.389$ $y_b = 36.475$	x_b and y_b	represents the coordinates of the intersection between LOB2 and LOB3.
$x_c = 32.434$ $y_c = 36.602$	x_c and y_c	represents the coordinates of the intersection between LOB1 and LOB3.
$X = 32.423$ $Y = 36.641$	X and Y	represents the centroid of the traiangle as the most probable location of the target.

$$x_J := \begin{bmatrix} 32.31 \\ 32.36 \\ 32.45 \end{bmatrix}$$

$$y_J := \begin{bmatrix} 36.23 \\ 36.15 \\ 36.30 \end{bmatrix}$$

x_J y_J represents the location of jammers in degrees

$$R_{j1} := \left[\frac{\pi}{180}\right] R_e \sqrt{\left[X - x_{J_1}\right]^2 + \left[Y - y_{J_1}\right]^2} \qquad (A.2.13)$$

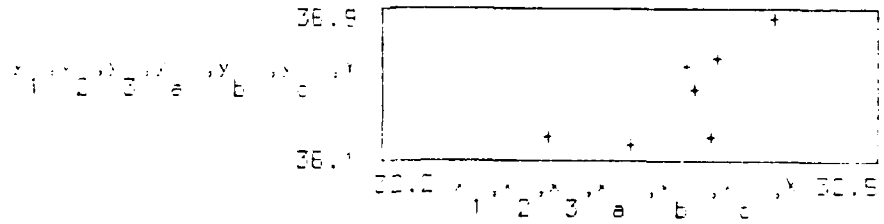
$R_{j1} = 41.559$ km Jammer1-to-Transmitter

$$R_{j2} := \left[\frac{\pi}{180}\right] R_e \sqrt{\left[X - x_{J_2}\right]^2 + \left[Y - y_{J_2}\right]^2} \qquad (A.2.14)$$

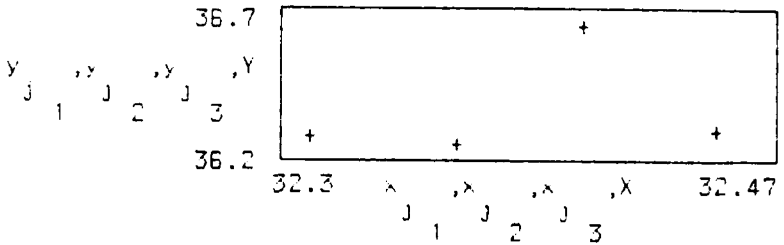
$R_{j2} = 42.844$ km Jammer2-to-Transmitter

$$R_{j3} := \left[\frac{\pi}{180}\right] R_e \sqrt{\left[X - x_{J_3}\right]^2 + \left[Y - y_{J_3}\right]^2} \qquad (A.2.15)$$

$R_{j3} = 33.382$ km Jammer3-to-Transmitter



DF Scenario see Fig A.2.1



Location Of Transmitter w.r.t Jammers
See Fig A.3.2

A.3 JAMMING-TO- SIGNAL RATIO EFFECTIVENESS*

In order to disrupt a communication system, in a given location and at a given time, two fundamental questions arise for the jamming. One is, what is the best jamming waveform and strategy and the second, how effective will jamming be against the system.

Today, development of communication techniques has severely curtailed the possibilities of intercepting and communications. Thus, it seems inevitable that military communications, in the battlefield, is forced to operating in a jamming environment.

Intercepting communication is more difficult since the communication energy is usually not directed toward the jammer and the transmitted power is low. Although the communication system uses relatively low power, the jamming signal must compete with a transmitted signal traveling a one-way path. The jammer is usually farther away from the communication receiver than the communication transmitter is.

In assessing the potential effectiveness of jamming, it is useful to calculate a signal-to-jamming ratio at the communication receiver. Figure A.3.1 illustrates the geometric configuration, where D_T is the distance between the transmitter and the receiver, and D_J the distance between the jammer and the receiver. The average power of the desired signal at the input of the communication receiver is:

$$P_1 = \frac{P_T G_{TR} G_{RT} \lambda^2}{(4\pi)^2 D_T^2 L_{TR}} \qquad (A.3.1)$$

Where P_1 is the desired signal power, P_T is the average transmitted power, G_{TR} is the gain of the transmitter antenna in the direction of the receiver, G_{RT} is the gain of the receiver antenna in the direction of the transmitter, λ is the wave length, and L_{TR} represents propagation and equipment losses. Similarly power at the receiver antenna due to the jammer ideally should be:

$$P_2 = \frac{P_J G_{TR} G_{RT} \lambda^2}{(4\pi)^2 D_J^2 L_{LR}} \qquad (A.3.2)$$

Where P_J is the average jamming power, G_{JR} is the gain of the jammer antenna in the direction of the receiver, D_J is the distance between jammer and receiver, L_{JR} repre-

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* Much material is derived from reference 2 and ECM and ECCM Techniques for digitsl communication systems by Ray H.Pettit

sent propagation and equipment losses of jammer and receiver, and P_2 is the desired signal power received from the jammer.

The amount of jamming power which reaches the receiver may be reduced by two factors. First, there is a polarization loss due to the jammers different polarization. This may be described by a factor P which has the range $0 \le P \le 1$. A second jamming power reduction may be caused by receiver bandpass filtering. This effect is described by the function f (B_R, B_J), which has the range $0 \le f(B_R, B_J) \le 1$, where B_R is the effective bandwidth of the receiver bandpass filter, and B_J is the bandwidth of the jamming signal. If the jamming spectrum is included in the receiver bandpass ($B_J \le B_R$) then:

$$f(B_R, B_J) = 1 \qquad (A.3.3)$$

If jamming spectrum includes the entire receiver passband ($B_J > B_R$) then:

$$f(B_R, B_J) = \frac{B_R}{B_J} \qquad (A.3.4)$$

Hence the net jamming power effecting the receiver becomes

$$P_2 = \frac{P_J G_{RJ} \lambda^2 f(B_R, B_J) P}{(4\pi)^2 D_J^2 L_{JR}} \qquad (A.3.5)$$

At the communication receiver, the environment noise is equal to KT_eB_R, where K is Boltzmann's constant and T_e is the effective noise temperature. The total interference power is the sum of the environmental power and the jamming power. Thus the signal-to-jamming ratio is

$$S/J = \frac{P_1}{P_2 + KT_eB_R} \qquad (A.3.6)$$

If the jamming is to be effective, it is generally necessary that $P_2 \gg KT_eB_R$ hence

$$S/J = \frac{P_T G_{TR} G_{RT} L_{JR} D_J^2}{P_J G_{JR} G_{RJ} L_{TR} f(B_R, B_J) P D_T^2} \qquad (A.3.7)$$

Equation A.3.7 indicates that S J varies as the square of the distance ratio, [illegible] This is attained only if the communication system elements and the jammer are [illegible] and atmospheric attenuation is negligible. If both the communication system [illegible] and the jammer are on the ground and we consider the curvature of the [illegible]

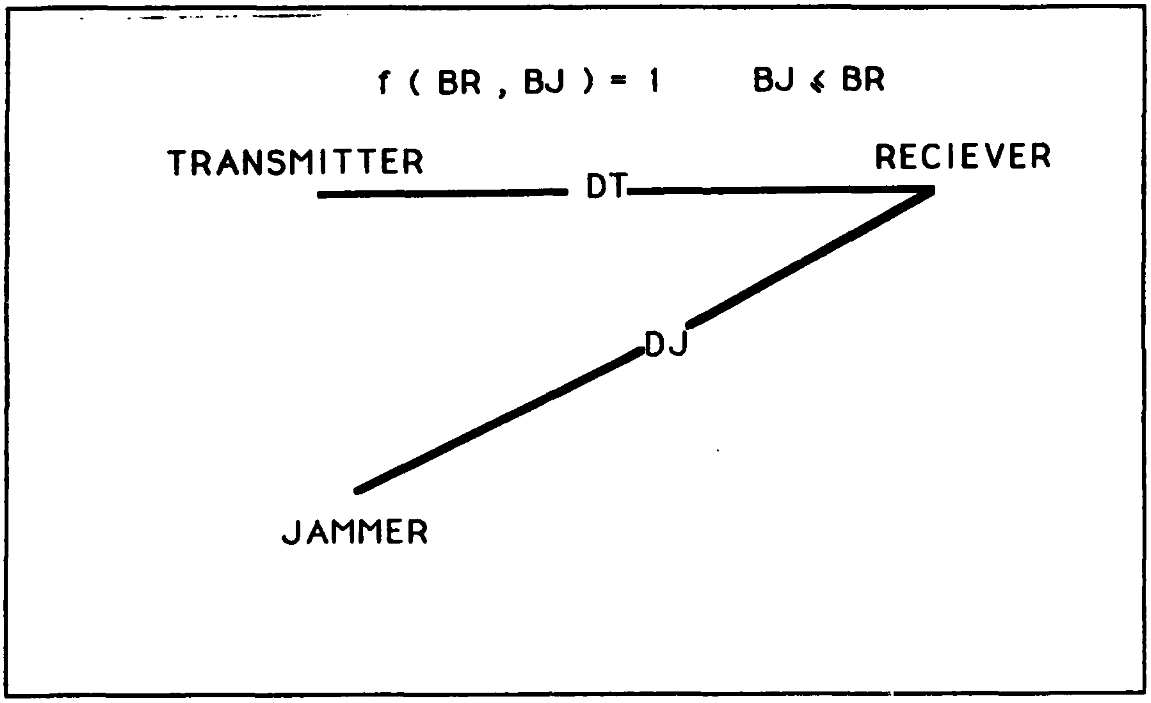


Figure A.31 The Geometry Of Communications Jamming Warfare

the relative dielectric constant, antenna heights, presence of obstacles, and other propagation effects, then S/J ratio varies as the fourth or larger power of the distance ratio [*reference*11].

For acceptable communication system performance, S/J must exceed some minimum level that is determined by the nature of the system. Effective jamming may force the communication system to change its operating frequency. If the jammer can detect this change in frequency, This is an indication that the jamming probably is disrupting communications. The jammer then changes the center frequency of the jamming accordingly.

In order to deny the jammer this opportunity to confirm his effectiveness, the communication system can be designed to revisit operating frequencies periodically. An alternative or supplementary tactic is to relocate one or more elements of a disrupted communication network to make best use of a terrain. The goal of relocation is to establish a line-of-sight path between the transmitters and receivers and, if the jammer's location is known, to make the receivers invulnerable to the jammer by means of terrain obstacles.

In short, multi-frequency transmissions by communications makes it difficult for jammer to obtain accurate estimates of the operating frequencies, locations and measures of effectiveness against communications. Rapid frequency changes preclude the effectiveness of jamming by means of a repeater, a technique often used in radar. If communicators store, compress, and rapidly transmit all messages, the difficulties of the jammer are further increased.

In a typical operating scenario as shown in Fig A.3.2, a minimum jamming power can be estimated based on the parameters of the transmitter being analyzed by the intercept station and the location of the transmitter being reported by DF's.

Prior knowledge of the jammers location and the estimated location of its target, will allow an approximate range determinations between the jammers and the victim receiver. The jammers to receiver ranges can be approximated as being a third,a half and two thirds of the range between the jammers and the transmitter; since the victim receiver is assumed to be located closer to the jammers than the transmitter in a typical tactical situation. Employing a number of jammers at different locations will allow full coverage of battle front.

With the assumption that the gain of the receiver antenna towards both jammer and transmitter is the same, and equal propagation losses, and also assuming that the polarization loss is 1; Equation A.3.7 is reduced,(for the approximations made above) as follows respectively:

$$S/J = \frac{P_T G_{TR} B_J}{9 P_J G_{JR} B_R} \qquad (A.3.8a)$$

$$P_J = \left(\frac{J}{S}\right) \frac{P_T G_{TR} B_J}{9 G_{JR} B_R} \quad \left[i.e. \ \frac{D_J}{D_T} = \frac{1}{3} \right] \qquad (A.3.8b)$$

$$S/J = \frac{P_T G_{TR} B_J}{4 P_J G_{JR} B_R} \qquad (A.3.9a)$$

$$P_J = \left(\frac{J}{S}\right) \frac{P_T G_{TR} B_J}{4 G_{JR} B_R} \quad \left[i.e. \ \frac{D_J}{D_T} = \frac{1}{2} \right] \qquad (A.3.9b)$$

$$S/J = \frac{4 P_T G_{TR} B_J}{9 P_J G_{JR} B_R} \qquad (A.3.10a)$$

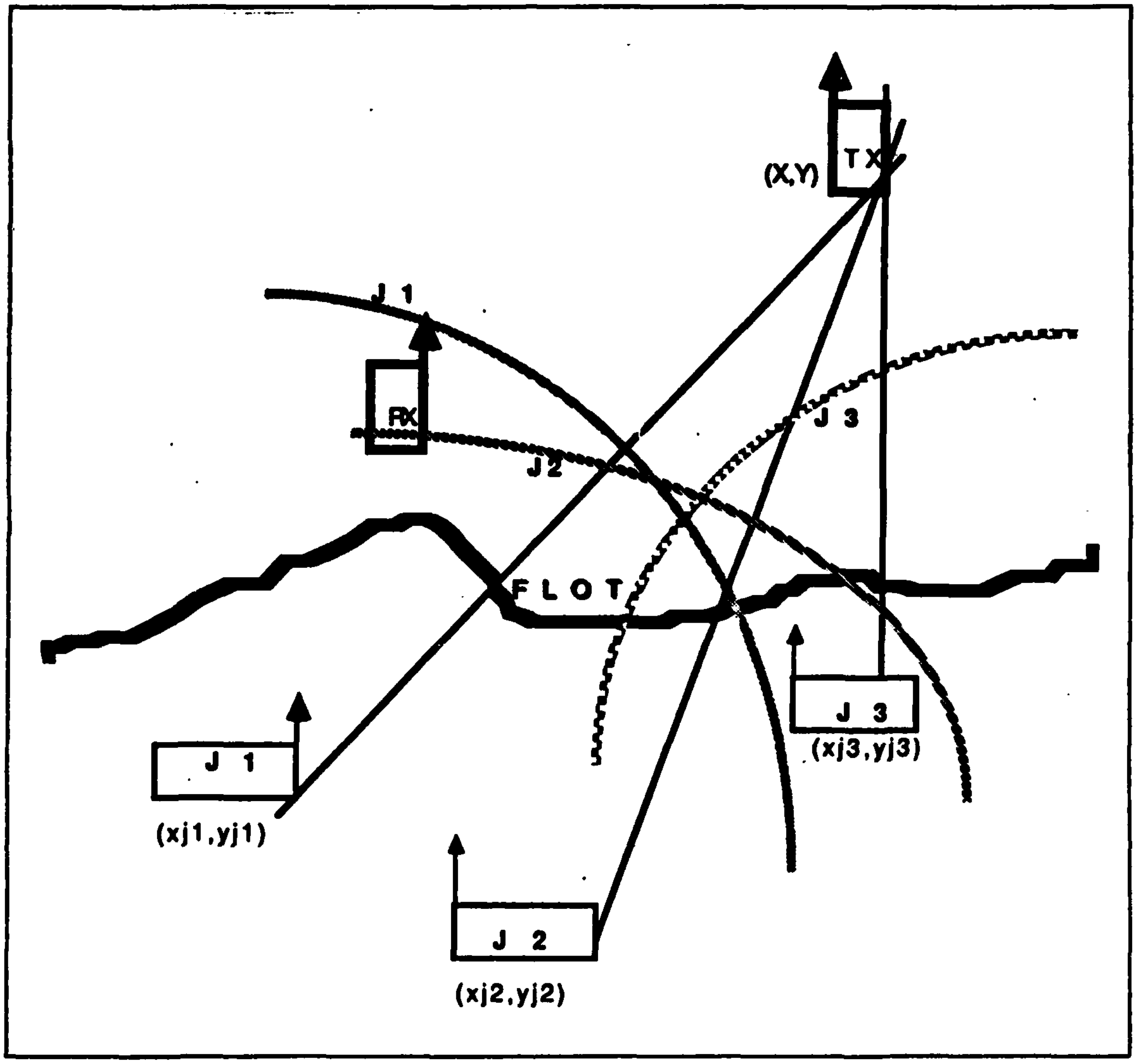


Figure A 32 Typical Operating scenario For Jammers

$$P_J = \left(\frac{J}{S}\right)\frac{4P_TG_{TR}B_J}{9G_{JR}B_R} \qquad \left[i.e. \quad \frac{D_J}{D_T} = \frac{2}{3}\right] \qquad (A.3.10b)$$

Taking into consideration the scenario depicted in Fig A.3.2, the following analysis is carried out to show the trade off between the jammers bandwidth and its gain for determining the minimum jamming power required to jam the victim receiver effectively.

MATCAD.2.Minimum Jamming Power Estimations

Supposing a transmitter is located distance RJ from the jammers locations as showen in Appendix A.2. It is transmitting a power PT watts, with an antenna gain GTR. The receiver bandwidth is BR KHz and its signal-to-noise ratio typically 10 dB (i.e. assumming that these parameters are already determined and reported to Jammers by the Command and Control Center.

Assuming the jamming power output is uniformaly distributed over a bandwidth BJi KHz with an antenna gain GJRi; and they are the predominant source of the victim reciver noise(i.e. S/N ratio of the receiver is equal to the J/S ratio).The minimum jamming power required by the jammer to jam the victim receiver for the given scenario is analyzed based on the trade off between its bandwidths and antenna gains at a particular distance ratio.

Transmitter Parameters

$P_T := 100$ watt

$G_{TR} := 100$

Receiver Parameters

$S := .0001$ watt

$J := .001$ watt

$B_R := 100$ kHz

Jammer Parameters

Assume the jammers have the capability of varing their bandwidth and antenna gain as follows.

$i := 1 \,..3$

Bandwidth

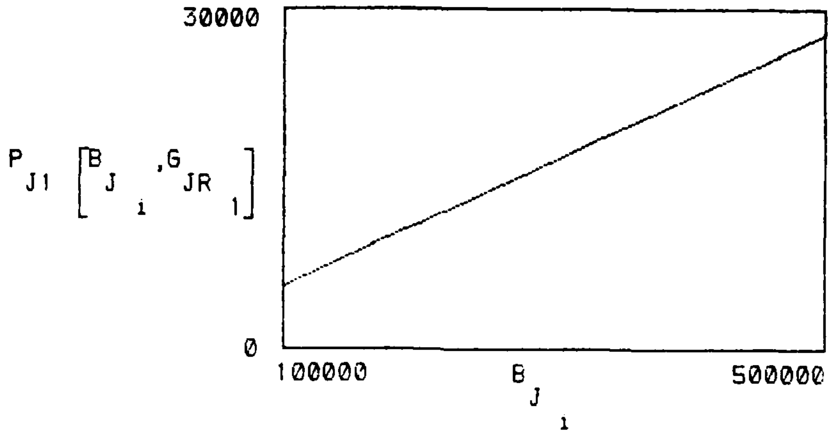
$$B_{J_i} := \begin{array}{|c|}\hline 100 \text{ kHz} \\ \hline 200 \text{ kHz} \\ \hline 500 \text{ kHz} \\ \hline \end{array}$$

Antenna Gain

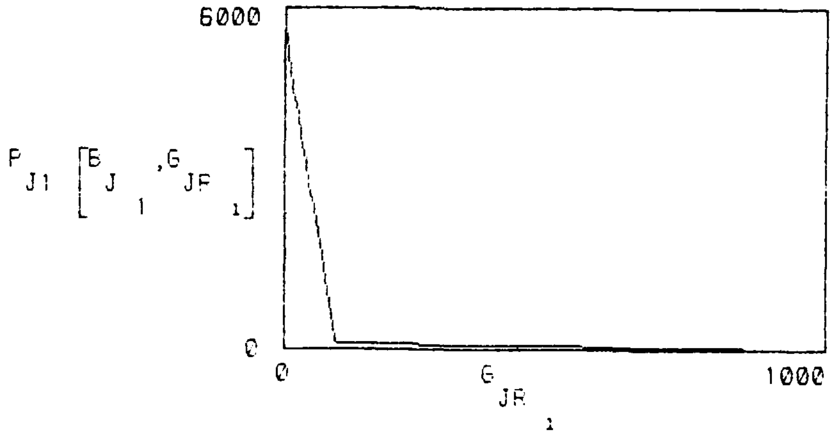
$$G_{JR_i} := \begin{array}{|c|}\hline 1 \\ \hline 100 \\ \hline 1000 \\ \hline \end{array}$$

1. Minimum effective jamming power at a distance ratio of 1/3 (i.e. Equation A.3.9b)

$$P_{J1}\left[B_J, G_{JR}\right] := \left[\frac{J}{S}\right]\cdot\left[\frac{P_T \cdot G_{TR} \cdot B_J}{9\, G_{JR} \cdot B_R}\right] \qquad (A.3.11)$$



This Figure Shows Jammer Power VS Bandwidth For A Fixed Antenna Gain



This Figure shows Jammer Power VS Antenna Gain For A Fixed Bandwidth

Output jamming power required to jam the victim receiver at a distance ratio of 1/3 for the three Bandwidth/Gain combinations.

$B_{J_1} := 100 \cdot \mathrm{KHz}$ $\qquad G_{JR_1} := 2$

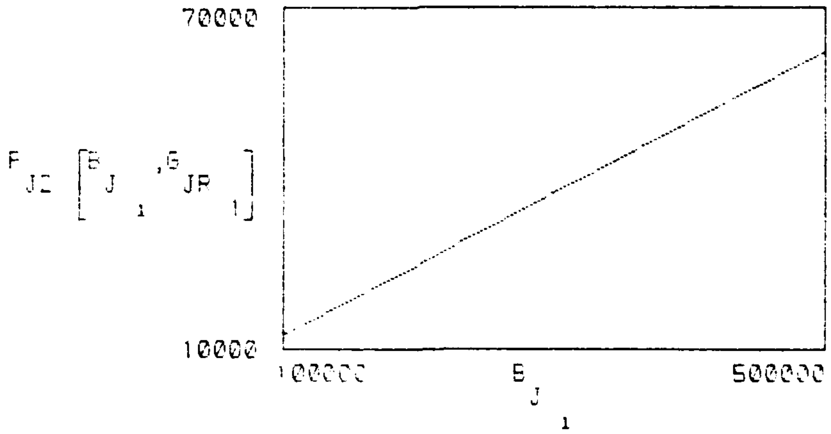
$B_{J_2} := 200\ \mathrm{KHz}$ $\qquad G_{JR_2} := 100$

$B_{J_3} := 500\ \mathrm{KHz}$ $\qquad G_{JR_3} := 1000$

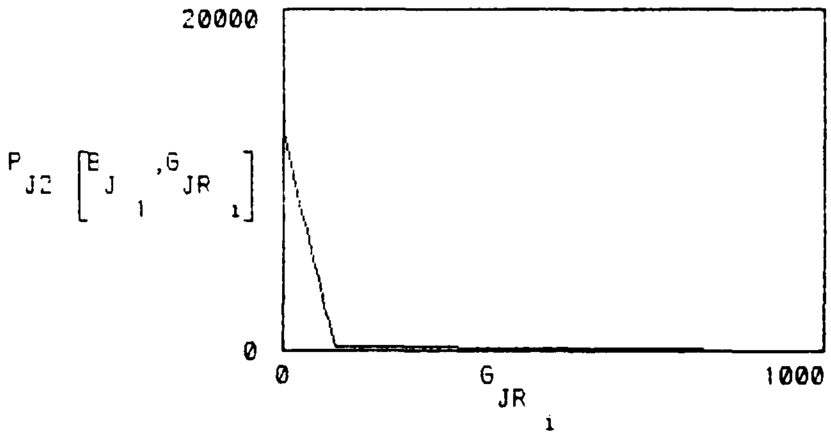
	$P_{J1}\left[B_{J_1}, G_{JR_i}\right]$ KW	$P_{J1}\left[B_{J_2}, G_{JR_i}\right]$ KW	$P_{J1}\left[B_{J_3}, G_{JR_i}\right]$ KW
GJR1	5.556	11.111	27.778
GJR2	0.111	0.222	0.556
GJR3	0.011	0.022	0.056

2. Minimum effective jamming power at a distance ratio of 1/2 (i.e. Equation A.3.10b)

$$P_{J2}\left[B_J, G_{JR}\right] := \left[\frac{J}{S}\right] \cdot \left[\frac{P_T \cdot F \cdot B_J}{4 \cdot G_{JR} \cdot B_R}\right] \qquad (A.3.12)$$



This Fig Showes Jammer Power VS Bandwidth For a Fixed Antenna Gain



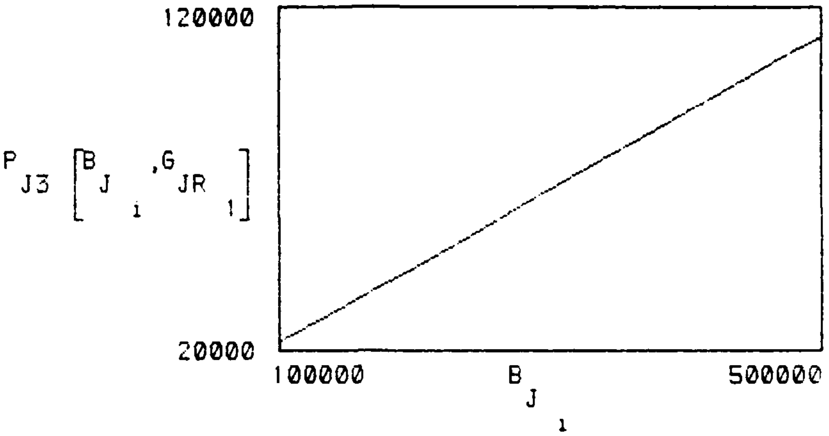
This Figure shows Jammer Power VS Antenna Gain For A Fixed Bandwidth

Output jamming power required to jam the victim receiver at a distance ratio of 1/2 for the same Bandwidth/Gain combinations as above.

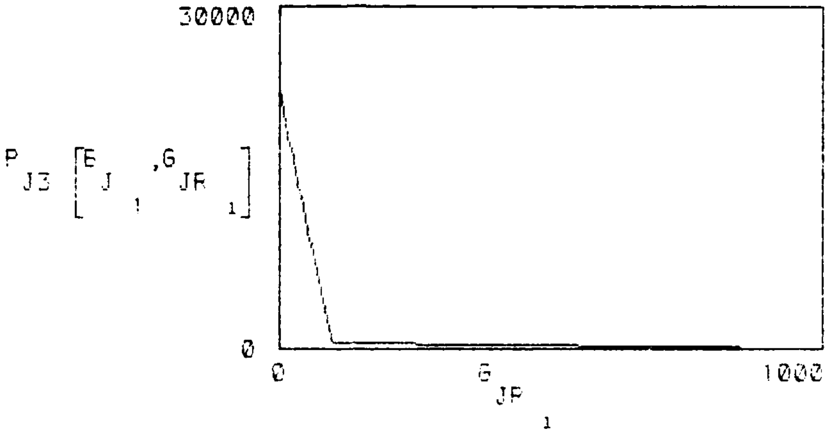
	$P_{J2}\left[B_{J_1}, G_{JR_i}\right]$	$P_{J2}\left[B_{J_2}, G_{JR_i}\right]$	$P_{J2}\left[B_{J_3}, G_{JR_i}\right]$
	KW	KW	KW
GJR1	12.5	25	62.5
GJR2	0.25	0.5	1.25
GJR3	0.025	0.05	0.125

3. Minimum effective jamming power at a distance ratio of 1/2 (i.e. Equation A.3.10b)

$$P_{J2}\left[B_J, G_{JR}\right] := \left[\frac{J}{S}\right]\left[\frac{4\ P_T\ G_{TR}\ B_J}{9\ G_{JR}\ B_R}\right] \qquad A.3.13$$



This Figure Shows Jammer Power VS Bandwidth
For A Fixed Antenna Gain



This Figure shows Jammer Power VS Antenna Gain
For A Fixed Bandwidth

Output jamming power required to jam the victim receiver at a distanc
ratio of 2/3 for the same Bandwidth/Gain combinations as above.

	$P_{J3}\left[B_{J_1}, G_{JR_1}\right]$ kW	$P_{J3}\left[B_{J_2}, G_{JR_1}\right]$ kW	$P_{J3}\left[B_{J_3}, G_{JR_1}\right]$ kW
GJR1	22.222	44.444	111.111
GJR2	0.444	0.889	2.222
GJR3	0.044	0.089	0.222

Conclusions from the above illustrations show

---

1. Jamming Power varies linearly with its bandwidth for a given antenna gain. See Fig Power VS Bandwidth above.
2. Jamming Power varies exponentialy with antenna gain for a given bandwidth . See Fig Power VS Antenna Gain above.
3. Output jamming power required to jam the victim receiver at a given distance ratio as computed above, allows the jammer to selection of the optimum case.

APPENDIX B

COMMAND AND CONTROL CENTER SPECIFICATION

B.1 COMMAND AND CONTROL STATION . FIG. 5.2.

1. Receiver Equipments.

a. Receivers

The receivers E1800 and E1900 are HF and VHF search monitoring receivers. The principle features of these receivers are a remote control facility, microprocessor control and compact design. With its built-in microprocessor the E1800 and E1900 provide self test capabilities for verification of proper operation.

Modes	A1A, A2A, A3E, F3E, R3E, H3E and J3E
Frequency	10Kz to 30Kz.
Serial Interface	
Power Supply	115/220 V ac , 47-440 Hz
Manufacturer	AEG.Ulm

Table B.1.1 E1800 TECHNICAL SPECIFICATION

Modes	A1A, A2A, A3E, F3E and J3E
Frequency	20 MHz to 500 MHz
serial Interface	
Power supply	115/220 V ac, 47-440 Hz
Manufacturer	AEG.Ulm W.Germany

Table B.1.2 E1900 TECHNICAL SPECIFICATION

b. Panoramic Display Unit PSG 1700/2

The PSG 1700/2 panoramic display unit in conjunction with E1800 and E1900 receivers is used to observe and analyses individual transmitter spectra. The unit has high frequency resolution levels. It can be used for the identification of operating modes. It is designed for mobile operation and can be equipped with either a mains or battery supply unit.

Scan Range	HF 10 KHz, 100 KHz, 1 MHz
	VHF 100 KHz, 200 KHz, 5 MHz
Resolution BW	HF 20 Hz, 200 Hz, 2 KHz, 10 KHz
	VHF 200 Hz, 2 KHz, 10 KHz, 50KHz
Amplitude Input	-107 dBm to +23dBm
Power Supply	110 220 V ac , 45-66 Hz or 24V dc
Manufacturer	AEG.Ulm

Table B.1.3 AF PSG 1700/2 TECHNICAL SPECIFICATION

c. Antenna Selector Switch Type AS1275

This unit is designed to provide a switching capability between different types of antenna selection. Manufacturer AEG.Ulm

2. Intercom And AF Distribution Equipments

a. Control Unit MA6005

This unit is designed for use with HF and VHF receivers. The controller is firmware adaptable to meet specialized system requirements. The primary design criteria is system control. The unit control all receiver parameters such as frequency, detection mode, IF bandwidth, AGC and channels for scan and sweep.

Detection Modes	Am, CW, USB, LSB, FM, ISB
IF gain	110 db, 150 steps
Data Transfer rate	50-19.2 K baud selectable
Power supply	115 230 V ac, 48-470 Hz
Manufacturer	Racal Communication

Table B.1.4 MA6005 TECHNICAL SPECIFICATION

b. Indicator Panel AF 1228

This unit is designed to provide high intelligibility intercom and radio monitoring facilities for aircraft and ground installation. It also provides for selection, control and modulation of four radio transmitters for mobile stations.

Frequency	300-6000 Hz
Noise	5 V ripple on 27.5 V line, 100mV 400-5000Hz
Gain	Listen 16+/- 3dB
	Talk 68+/- 5dB
Power supply	27.5 V dc
Manufacturer	AEG.Ulm

Table B.1.5 AF 1228 TECHNICAL SPECIFICATION

c. Central Intercom C2104/AC1-18

The unit is a panel mounted assembly designed to provide highly intelligible radio monitoring facilities. The set control also provides for selection, control and modulation of transmitter for mobile stations.

Frequency	300 - 6000 Hz
Gain	Talk 68 +/- 5 dB
	Listen 22 +/- 5 dB
Headset Output	1W
Noise	3 mV max
Power supply	27.5 Vdc
Manufacturer	Andrea Radio Corp USA

Table B.1.6 C2104/AC1-18 TECHNICAL SPECIFICATION

3. Data Control Equipment

a. Terminal Computer Set T53/E

This unit is designed to provide data control of station. It is equipped with floppy disk and printer. Manufacturer AEG.Ulm

4. Radio And Wire Line Matching Equipment

a. Modem Type AE 2014M

The unit is designed for mobile tactical environment to enable transmitter or transceiver to be operated remotely over 2 or 4 wire link. It operates over distance of several Kilometers and can be connected to control unit. Manufacturer AEG.Ulm

b. Line Balancer Type AE1285

The unit is designed to provide a matching of the signals either to the PTT line condition or to the transceiver *modulation input*. Manufacturer AEG.Ulm

5. Jammer Command

This unit consist of data terminal, code call generator and AF-processing unit. It is designed as part of command and control station to send a call to jamming station to jam.

6. Shelter

The shelter mainly consist of

- Standard cabin type sandwich built with 2.4x2.2x2.0 meter cub
- Air conditioner unit
- Set of mounting facilities like racks, special built in unit, holders and installation materials.
- Set of supplement arq equipment like chairs, illumination, cable drums, earth spike, tools and lightning protection
- Power distribution equipment with cut off transformer. battery charging and switch board with mains switch, fault current trip, current meter, voltmeter and fuses.
- Set of external connecting plates for mains power supply, AF and data line and RF line.

7. Power supply Trailer

The power supply trailer mainly consist of

- Power Generator 220/120 V, 7.5 KVA
- Mains cable with cable drum
- Earth spike
- Cans
- set of tools

B. INTERCEPT STATION FIG.5.3

1. Receiving Equipment

The station is equipped with the same receiving equipment as in Comma nd and Control Station.

2. Antenna System

a. Antenna signal distribution equipment Type A 1275H

This unit includes the HF/VHF antenna multicoupler which is designed for connection within the frequency range without loss or reflection. Features include full transistorization, low current drain , long service life . Manufacturer AEG.Ulm.

b. Omnidirectional Receiving Antenna .

The antenna is vertically and horizontally polarized, it includes the A1201, A12016, A1205, and A1206V types, covering selected bands in the 10 KHz to 1 GHz frequency range. Manufacturer AEG.Ulm

c. Directional Receiving Antenna

The antenna is vertically and horizontally polarized, it include the A1238, A1146,A1147,Ak12241,A1148 and A1149 series. Manufacturer AEG.Ulm.

3. Shelter

The shelter is the same Command and Control Station

4. Power Supply

The same as used in Command and Control Station

C. .3. COMMUNICATION STATION SECTION 5.2.C

1. Transceiver COM-80GY

The unit is a family of vehicular radio systems based on the various types of the RT-841/PRC-77/GY transceiver. A large number of configurations exist with different types of audio amplifiers, mountings, antenna sets and intercoms.

Frequency	30 - 88 MHz
Number of Channels	920
power output	50W
Antenna Tuning	Automatic, Semi-Automatic
Power supply	24 V dc
Manufacturer	AEG.Ulm W.Germany

Table B.3.1 COM-80GY TECHNICAL SPECIFICATION

APPENDIX C

DF STATIONS SPECIFICATION

C.1 DF MASTER STATION FIG.5.6

1. DF Command and Control Position

a. Intercept Receiver Type E1800 and E1900

An intercept receiver is used for searching, surveillance and analyzing the transmissions within the range under observation. Technical Specification of E1800 and E1900 receivers are in Appendix B.1.

b. Display Operating Panel

This unit consist of a computer terminal type T53/E. It is designed to provide a DF command to be transferred to the slave direction finders via PTT line or HF/VHF link. The same computer terminal as in Appendix B.1.

2. Direction Finding Position

To determine bearing of unknown transmitter. The HF/VHF DF master station is also equipped with a DF System for the HF/VHF frequency range consisting of:

a. Telegon 8 CRT Direction Finder

The Telegon 8 is a high quality Watson- Watt direction finder for the frequency range from 10 KHz to 30 MHz. It is characterized by small dimensions, lightweight and low power consumption. Features include; the Watson-Watt system with three channels, direct digital read-out of bearing angle and tuning frequency on Crt-screen, electronic signal- Knob tuning and control of cursor position by means of the same Knob, high frequency stability due to synthesizer with resolution of 10 Hz, optimal DF through selectable DF band-width, and control and display units remoted from the receiver.

Frequency	10 KHz to 30 MHz
Frequency display	7 digits display on Crt
Frequency resolution	10 Hz
Equipment error	Typical value 1%
Power consumption	115 w
Manufacturer	AEG.Ulm/W.Germany.

Table C.1.1 TELEGON 8 TECHNICAL SPECIFICATION

b. Telegon 9 CRT Direction Finder

Telegon 9 is a Watson- Watt direction finder which can also be used as a multi channel equipment with various evaluation algorithms. Depending on the particular application and antenna array, different methods and algorithms can be applied(for the processing of data), including generation of histograms,multi -wave resolution on a time basis, and interferometer methods . The Telegon 9 is of modular design, has a special control method for short signals and Crt display . An additional version, Telegon 7, is available for homing/mobile applications.

Frequency	20 to 500 MHz
Frequency Display	10 Digit Display
Frequency resolution	100 Hz
Equipment error	1% Less
Power Consumption	150 w
Manufacturer	AEG.Ulm W.germany.

Table C.1.2 TELEGON 9 TECHNICAL SPECIFICATION

c. DF Antenna System Type 1281 VU and AK 1205

A series of antenna types are available to provide adequate performance with Telegon 8 and 9. Manufacturer AEG.Ulm W.Germany.

3. Information Transmission Position

The exchange of information data and speech can be effected by means of PTT line or VHF link. To fulfil these tasks the station is further equipped with the following, as in Appendix B.

- VHF Transceiver, type COM-80 GY
- Link line switch
- Line balancer, type AE 1285
- Intercom unit C2104/AC1-18
- Modem, type AE 2014m
- Speech control, type BT 3600

4. Antenna System

The DF master station is equipped with two antenna types.

- The active HF DF Adcock antenna, type AK 1205 and the VHF/UHF DF Adcock antenna, type A1281/2 VU are used for direction finding purposes. Manufacturer AEG.Ulm/W.Germany.
- A whip antenna for information exchange purposes (via HF/VHF link).

5. Power supply System

The power supply system for normal operation is the same as in Appendix B

6. Shelter

Because the DF system operates in tactical situations, all stations are housed in shelters. The shelter are mainly as in Appendix B.

C.2 SLAVE STATION SECTION 5.C.2.C.2.

The DF slave station is equipped with the same equipment as the Master station but without the DF and control positions.

APPENDIX D

JAMMING STATIONS SPECIFICATION

D.1. HF HIGH POWER JAMMER FIG 5.8

1. HF Transmitter SV 2479

The SV 2479 transmitter is intended for all the usual classes of emission in the HF range, including single-sideband operation with two independent sidebands. It is modular and capable of transmission in half- duplex mode for protected telegraphy and data transmission. The transmitter can be remotely controlled with the aid of an accessory unit. For mobile application a vibration-isolating frame is available.

Type	Linear amplifier transmitter
Frequency	1.5 to 30 MHz
Modes	A3A, A3B, A3H, A3J, A1, F1, F6
Output Power	30 Kw (can be reduced to P/3, P/10)
Impedance	50 ohms, unbalance row.
Audio Frequency	120 to 6000 Hz
Power supply	220 V ac.
Manufacturer	AEG.Ulm W.Germany.

Table D.1.1 SV 2479 TECHNICAL SPECIFICATION

2. Exciter MMX-2 multi-mode exciter

The MMX-2 series is a multi-mode solid-state exciter, containing a modulator-synthesizer-keyer combination, which provides low RF excitation on all modes of transmission normally encountered in the HF frequency spectrum. It is tuned from 1.6 to 30 MHz continuously via six decade controls, which display the output frequency directly in 100 Hz increments.

Modes	LSB, USB, DSB, AM, CW, FSK, fax
Frequency	1.6 to 30 MHz
Power output	0 to 250 mW
Keying Speed	up to 75 Baud
power Supply	110/230 ac, 50-60 Hz
Temperature	0-50 Degrees C
Manufacturer	The Technical Material Corp/USA.

Table D.1.2 EXCITER MMX-2 TECHNICAL SPECIFICATION

3. Jamming Signal Generator

The jamming signal generator is part of the transmitter. It is designed to generate a jamming signal for voice communication A3/A3J, for teletype transmission F1 and for morse communication A1.

4. Antenna System

a. Vertical HF Transmitting Antenna AVE 0436

Frequency	2.5 to 12.5 MHz
Power Handling	10 KW row.
Polarization	Vertical
Antenna Height	32 m
Diameter of counterpoise with 32 wires	32m
Manufacturer	AEG.Ulm W.Germany.

Table D.1.3 AVE 0436 ANTENNA TECHNICAL SPECIFICATION

b. Horizontal Log-Periodic HF 747CD-44

Frequency	4 to 30 MHz
Power Handling	20 to 40 KW
Polarization	Horizontal
Antenna	Height 22.9 m
	Length 56.7 m
	Width 92.4 m
Manufacturer	AEG.Ulm/W.Germany.

Table D.1.4 ANTENNA 747CD-44 TECHNICAL SPECIFICATION.

5. Shelter

The shelter is of aluminum sandwich construction. It may be unloaded from the transport vehicle by means of an attached manually operated lifting device. The shelter is similiar to Appendix A, having different dimensions.

6. Power generator

The diesel type power generator has the following specifications.

Power output	80 KVA row.
Voltage	400 230 V
Frequency	50Hz
Engine	Air cooled diesel

Table D.1.5 POWER GENERATOR

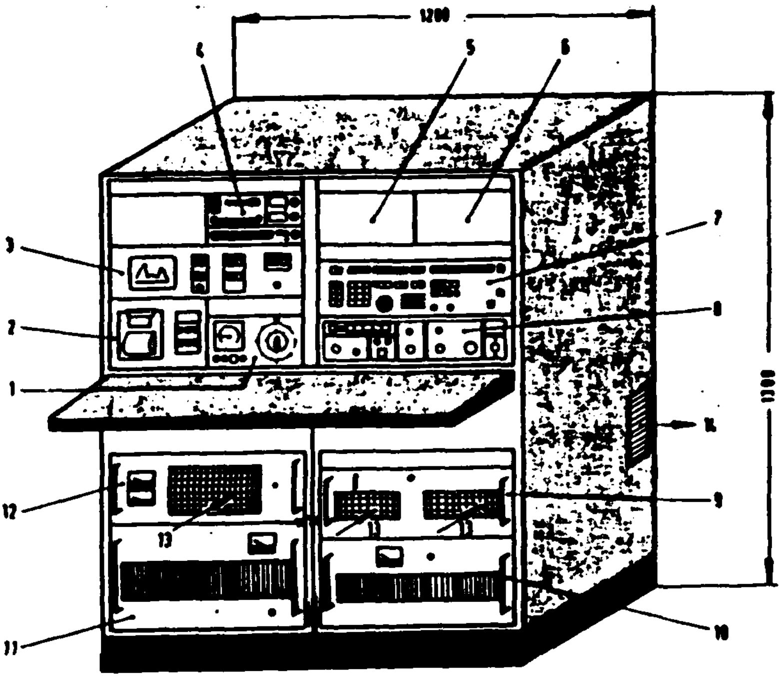
B. D.2. VHF JAMMER FIG 5.9

The VHF communication jammer, type SGS 2300V, made by AEG.Ulm is designed to meet the following specifications.

- Frequency range , 20 to 110 MHz.
- Transmitter output , 1KW.
- Effective Radiated power 4KW.
- look-through capability.
- Quasi-simultaneous jamming of several channels in time division multiplex (TDM) mode.

- Preselect priority and mode of jamming for all channels.
- Scan capability within a specified frequency band.
- Memory for protected frequencies not to be jammed.
- Optimized ratio between receiving detection sensitivity and jamming range.
- preselectable jamming AF signals such as white noise or electronic music.
- Microphone or other external AF signals for effective deception.
- Remotely controllable from a central command station via line or radio link.
- protection unit to avoid damage of communication tranceiver during jamming period.
- Wideband dipole antenna (LPD) mounted on an extendable mast to increase detection sensitivity and jamming range.
- Antenna rotator to permit azimuth orientation of the antenna in optimum direction.
- Antenna polarization : Vertical or Horizontal(switchable).
- Air conditioning permits operation under extreme climactic conditions

Fig D.2.1. shows a view of the equipment rack of the jammer, SGS 2300V. The system is installed in a shelter which contains : operator seat, shelf for manuals, tools, spares, personal equipment, and etc. as shown in Fig D.2.2.



1 Control unit for antenna rotor
2 Printer
3 Panoramic display PSG 1700
4 Cassette tape recorder C3/20
5 Control processor
6 Exciter STS 1900
7 Receiver E 1900)
8 AF Control unit UT 3600)
9 Harmonic filters and VR switch
10 Driver amplifier
11 Broadband power amplifier
12 Power supply
13 Cooling air inlet
14 Cooling air outlet

dimension in mm

Figure D21 A View Of Equipments Rack Of The SGS 2300VJammer

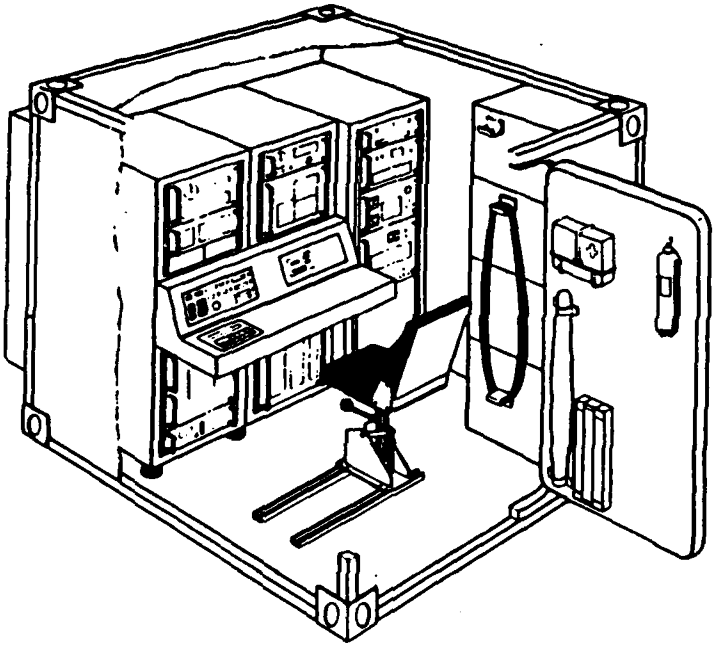


Figure D.2.2. View Of SGS 2300V Jammer Shelter

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