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ET1 UNIT 4: ELECTRONIC EQUIPMENT INSPECTION & VERIFICATION

EPQ 6.A.09 How to Inspect Electronic Equipment for Electromagnetic Interference (EMI)

EPQ 6.A.10 6.A.11 How to Verify the Installation of Engineering Changes/Field Changes/ORDALTS to Electronic Equipment or Systems

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ET1 UNIT 4: ELECTRONIC EQUIPMENT INSPECTION

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U. S. Coast Guard
Training Center
Petaluma, CA. 94952
(707) 765-7129

QUESTIONS ABOUT THIS TEXT SHOULD BE ADDRESSED TO THE SUBJECT MATTER SPECIALIST FOR THE ELECTRONICS TECHNICIAN RATING

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Acknowledgments and References

Acknowledgments

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The Coast Guard wishes to thank the following individuals for their expertise and support in the development of this document:

LT Hector Castro

ETCS Russ Reichert

ET1 Jessica Martin

Dr. Kit Grimm

Mr. Terry Wall

List of References

This pamphlet contains original material developed at the U. S. Coast Guard Training Center, Petaluma, California, and excerpts from the following technical publications:

- *Electronics Manual*, COMDTINST M10550.25 (series)
- *CMplus 5.1 Job Aids*
- *Department Of Defense Standard Practice For Shipboard Bonding, Grounding, And Other Techniques For Electromagnetic Compatibility And Safety,* MIL-STD-1310G (NAVY), 28 JUNE 1996
- MLC Standard Operating Procedures
- System Integrated Logistics Support (SILS) Command Policy Manual, COMDTINST M4105.8 (series)
- ELC Support Gram http://cgweb.elcbalt.uscg.mil/sptgram/Default.htm

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Notice to Students

Purpose

This pamphlet serves to provide you with knowledge of how to address certain administration and documentation tasks required of an ET1.

Important Note

This text has been complied for TRAINING ONLY. It should NOT be used in place of official directives or publications. The test information is current according to the references listed. You should, however, remember that it is YOUR responsibility to keep up with the latest professional information available for your rating. Current information is available from the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

Course Content

This course content is based on the requirements stated in the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

Pamphlet Content

This pamphlet contains two lessons:

Lesson 1: How to Inspect Electronic Equipment for Electromagnetic Interference (EMI)

Lesson 2: How to Verify the Installation of Engineering Changes/Field Changes/ORDALTS to Electronic Equipment or Systems

Performance Qualifications

This pamphlet covers the following enlisted performance qualifications (EPQ) for ET1 from the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series):

6.A.09 INSPECT electronic systems for Electromagnetic Interference (EMI) hazards as per Standard Practice for Shipboard Bonding, Grounding & Other Techniques for Electromagnetic Compatibility & Safety, MIL-STD-1310G; and Navy Electronics Installation and Maintenance Book, EMI Reduction, NAVSEA SE000-00-EIM-150.

6.A.10 VERIFY the installation of an electronics equipment and/or system per the installation documentation (e.g. Engineering Change); per the Electronics Manual, COMDTINST M10500.25 (series); and the Navy Electronics Installation and Maintenance Book, NAVSEA SE000-00-EIM-160.

Continued on next page

Performance Qualifications (continued)

6.A.11 VERIFY the installation of a Field Change/ORDALT to an electronics equipment and/or system per the Field Change/ORDALT documentation; per the Electronics Manual, COMDTINST M10500.25 (series); Ordnance Manual, COMDTINST 8000.2 (series); and the Navy Electronics Installation and Maintenance Book, NAVSEA SE000-00-EIM-160.

Read the learning objectives before you begin reading the text. The objectives will guide you through the text and help you answer the questions in the self-quiz at the end of each lesson.

Quizzes

Each lesson has a self-quiz and pamphlets may have a pamphlet review quiz. You will find answers to each quiz on the pages following the quiz. Included are reference pages for the answers.

These self-quizzes are meant to check your comprehension of the material you covered. If you have problems understanding a section, go through it again or ask someone for help. The pamphlet review quiz questions are samples of the type of questions you will find on the end-of-course-test (EOCT).

SWE Study Suggestion

Servicewide exam questions for your rate and pay grade are based on the Professional and Military Requirements sections of the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

If you use the references from this text and consult the *Enlisted Performance Qualifications Manual*, you should have good information for review when you prepare for your servicewide exam (SWE).

Lesson 1

HOW TO INSPECT ELECTRONIC EQUIPMENT FOR ELECTROMAGNETIC INTERFERENCE (EMI)

Overview

Introduction

This lesson provides you with the information necessary to achieve electromagnetic compatibility among electronic systems. Electromagnetic interference (EMI) can make successful operation of electrical and electronic equipment difficult. In extreme cases, EMI can render entire systems inoperative, leaving vessels unable to navigate, communicate, susceptible to collision, and virtually helpless.

Throughout this pamphlet, reference is made to shipboard installations; however, all discussions apply to shore units and floating units alike.

Lesson Objectives

Upon completion of this lesson you will be able to:

Given electronic systems exhibiting symptoms of, or suspected of causing, Electromagnetic Interference (EMI), **INSPECT** the systems for EMI hazards in accordance with standard references.

References

The following references were used for this lesson:

- EIMB NAVSHIPS 0967-000-0150
- Electromagnetic Interference Control in Boats and Ships, Russel V. Carstensen
- *Electronics Manual*, COMDTINST M10550.25 MIL-HDBK-419, Volumes 1 and 2
- MIL-STD-1605
- NAVPERS 10087-C
- *Department Of Defense Standard Practice For Shipboard Bonding, Grounding, And Other Techniques For Electromagnetic Compatibility And Safety,* MIL-STD-1310G (NAVY), 28 JUNE 1996

Electromagnetic Interference (EMI)

Introduction

There are three types of EMI. They are:

- Man-made
- Natural
- Inherent.

EMI can be classified as either narrowband or broadband.

Man-made Interference

Man-made interference impedes the reliable and efficient use of electrical and electronic equipment. To control interference it is necessary to recognize the many possible sources and methods by which it is propagated, and its effects on susceptible equipment. The task becomes difficult when several different types of interference occur simultaneously.

Some of the more typical sources of interference are listed in the following table:

BROADBAND			NARROWBAND	
Transient	**Intermittent**	**Continuous**	**Intermittent**	**Continuous**
Function Switches	Electronic Computers	Commutation Noise	Doppler Shift Radar	Power line Hum
Motor Starters	Motor Speed Controls	Electronic Typewriters	Radio Transmitters: • Comms • Radar • ECM • IFF	Receiver Local Oscillators
Thermostats	Poor or Loose Ground Connections	Ignition Systems		
Timer Units	Welding Equipment	Arc and Vapor Lamps	Electronic Computers	
		Pulse Generators		
		Radar Modulators		
		Sliding Contacts		

Continued on next page

Narrowband Interference

Narrowband interference consists of a single frequency or a narrow band of frequencies that occupies little space in the total receiver passband. Because they are narrow with respect to the receiver bandwidth, narrowband signals are unaffected by the bandwidth of the receiving device. Tuning the susceptible receiver away from an interfering narrowband signal can sometimes prevent an undesired response. However, even out-of-band signals may interfere if they are strong enough to force their way past the attenuation of the pre-selector or RF stages.

Broadband Interference

Broadband interference occupies a relatively large part of the radio frequency spectrum. Usually, it is not possible to tune away from broadband interference, since it is much wider than either the assigned frequency channel or the receiver bandwidth.

Transmitter Interference

In theory, communications, navigation, radar, or other type of transmitters are required to radiate energy only over the band of frequencies necessary to convey the intelligence that it is processing. In practice, however, a transmitter may emit energy at many frequencies and thus create a potential interference problem.

Communications transmitters can produce spurious emissions from:

- Overdriven amplifiers;
- Frequency multiplier stages;
- Sideband splatter caused by overmodulation, excessive modulator bandwidths, or modulator nonlinearity;
- Modulator noise;
- Transmitter intermodulation and cross modulation caused by interaction between two or more transmitters.

Radar transmitters can produce spurious emissions from:

- Arcing in PA stage, waveguide rotary joint, or antenna.

Continued on next page

Electrical Controllers

The controller equipment associated with electrical installations directs the voltage and/or current applied to (or from) an electrical system. The control system may be a refined device with continuous and precise settings, or it may be a simple ON-OFF switch. Since continuous control results in slow variations of current waveform, there is relatively little interference. Make-brake contactors, such as switches and relays, cause sharp changes in the current waveform which may produce severe interference over a wide frequency band.

Motors and Generators

Electrical motors and generators are the most common sources of electromagnetic interference. Rotating electrical machinery interference is generated by the following:

- Arcing from brushes to commutator segments in DC motors or generators, or from brushes to slip rings in AC motors or generators.
- Induction of interference into nearby electronic equipment from the high energy magnetic fields associated with rotating machinery.
- Ripple, which is present to some degree, in the output of all DC generators.
- Slot harmonics appearing as harmonic frequencies in the output of generators. These harmonics are the result of a lack of uniformity in the magnetic field caused by the effect of the armature slots on the distribution of the magnetic flux.

Engines and Igniters

Ignition systems of gasoline engines can be sources of interference. Igniters for jet engines that use high voltage and high current can cause severe interference.

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Electromagnetic Interference (EMI) (Continued)

Lamps

The steep waveforms associated with the operation of fluorescent, mercury, sodium, and vapor lamps can cause broadband interference. This source of man-made interference is caused by electromagnetic coupling between wires or the degraded condition of conductors, insulators, and associated hardware.

Natural Interference

Natural interference, such as that caused by electrical storms, snowstorms, rain particles, or interstellar radiation, is referred to as atmospheric noise or static. This interference is characterized by the following types of noise in a receiver output:

- Impulses of high intensity, occurring intermittently, caused by local thunderstorms.
- A steady rattling or crackling produced by distant thunderstorms.
- Precipitation static (a continuous noise caused by the impact of charged particles against an antenna).
- A steady hiss type of static observed at high frequencies, apparently having an interstellar origin.

Inherent Interference

A certain amount of interference inherent in receiving equipment is caused by thermal agitation of electrons in the circuit resistance.

Random motion of free electrons develops voltages in the conductors and components, and these voltages contribute to receiver background noise.

Methods of Coupling EMI

Introduction

Interference is transferred from an interfering source to the affected equipment by two general methods:

- Conduction
- Radiation

Conducted EMI

Conducted EMI involves the transfer of undesired energy through conductors between a source of interference and a susceptible device. The complete circuit can be made up entirely of metallic conductors, or the return path may be through earth ground.

The most common and most important paths for conduction currents are:

- Power supply cables;
- Control and accessory cables;
- Grounding systems;
- Transmission lines.

Factors Affecting the Degree of Conducted EMI

The type of circuit, frequencies involved, power level, and amount of capacitive and inductive coupling between parts of the circuit, all have a bearing on the generation of interference that can be conducted from one piece of equipment to another. Different types of circuits are prone to generation of interference in different ways and to different degrees.

The care taken with lead dress, filtering, and shielding affects the amount of interference conducted from a piece of equipment and the degree of susceptibility of your equipment to this interference. In addition to the equipment features that may be responsible for conducted interference, energy radiated from high-power transmitters can be coupled into interconnecting cables and conducted into equipment.

Continued on next page

Methods of Coupling EMI (Continued)

Containment of Conducted EMI

The most effective approach to prevent conducted interference is through equipment design and proper installation practices. Among the methods used are:

- Filtering to shunt the interference to ground
- Shielding to confine interfering signals
- Properly grounding circuits, shields, and interconnecting cabling
- Using isolation transformers for circuit (and ground) isolation
- Separating low-level signal cables from other cables.

Radiated EMI

Radiated EMI is any interfering signal transferred through space by an electromagnetic field. The radiated field represents energy that escapes from a source and spreads out in free space according to the laws of wave propagation.

An electromagnetic field is generated whenever current flows in a conductor and some energy in this field is radiated.

Several factors determine the strength of the radiated signal. They are:

- Amount of current flow in the conductor from which the field radiates.
- Efficiency of the conductor as an antenna (for example, physical configuration and orientation) and amount of shielding offered by nearby metal items.
- Frequency of the current waveform causing the field. Very little energy is propagated at frequencies below 15 khz. Progressively stronger fields are radiated as the frequency of the current causing the field increases.

Suppression methods for radiated EMI include confinement of the interference to the source to prevent its being radiated. Metal shielding is used around the EMI source to reduce the strength of any stray radiation and prevent it from reaching susceptible equipment. It is usually less expensive and less difficult to suppress interference at the source than to eliminate it once it has been radiated.

Interference from Electric Devices

Introduction

Electrical machinery constitutes a serious source of broadband and narrowband interference. Broadband noise is generated during the commutation process by the brushes and the armature, arcing in bearings, friction between moving parts, internal arcing, and control windings. Narrowband interference arises from poor machine symmetry causing the generation of harmonic frequencies.

Generation of Interference by Rotating Machines

Rotating machinery includes motors and mechanically-driven generators. The following are included in the category of rotating machinery:

- Rotary inverter (a DC-to-AC converter)
- Dynamotor (a DC motor and generator, operated from a single magnetic field, that functions either to step up or to step down DC voltages)
- Alternator (an AC generator).

These machines operate on the principle of converting mechanical energy to electrical energy, or electrical energy to mechanical energy. Because of the nature of their operation, these machines create various forms of radio interference caused by the following:

- Arcing
- Induction
- Ripple
- Slot Harmonics

Arcing

Arcing occurs when brushes sweep over commutator segments in DC motors and generators. Although microscopic arcing results from brush action on the slip rings of an AC motor or generator, the arcing is much less intense than that which occurs in the DC motor and is normally not a problem.

Induction

Interference voltages may be induced in communication equipment by action of the magnetic fields associated with rotating electrical machines.

Continued on next page

Interference from Electric Devices (Continued)

Ripple

If the characteristic ripple found in the output of all DC generators is not adequately filtered it can result in interference in communication equipment.

Slot Harmonics

Harmonics in the output of the ship's service generators are usually caused by a changing field brought about mainly by the effects of the armature slots on the distribution of the magnetic flux. This effect causes harmonics to appear in the output. Harmonics are also produced by nonlinearities existing in the electrical system. Therefore, loads as well as generators can be the source of harmonic frequencies. The amplitude of these harmonics is dependent upon the extent of flux variations produced by the armature slot.

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Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise/s. The answers to the exercise/s will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1. When two metallic surfaces are joined by a weld, a/an ____________ bond is formed.

   A. direct
   B. indirect
   C. simple
   D. compound

2. The MOST common sources of EMI are _______ .

   A. light circuits
   B. electric controllers
   C. engines and igniters
   D. motors and generators

3. Which type of EMI is classified as natural interference?

   A. Precipitation static
   B. Image frequency
   C. Modulated carrier frequency
   D. Unmodulated carrier frequency

4. Broadband interference is usually caused by ______ .

   A. adjacent channel interference
   B. harmonic radiation
   C. high background noise
   D. arcing or corona

5. The BEST place to eliminate or suppress EMI is at the ______ .

   A. source
   B. input to the affected equipment
   C. power cables to the affected equipment
   D. antenna coupler or antenna input to the affected equipment

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	A	C-1
2.	D	1-4
3.	A	1-5
4.	D	1-8, C-1
5.	A	1-7

Communication Equipment Interference:
Interference Produced by Transmitters

Introduction

Transmitters are not usually susceptible to interference, but they may cause considerable interference to other equipment. The equipment designer provides for adequate interference suppression in the manufacture of the equipment. However, the most well designed transmitter can cause serious interference if it is not properly maintained.

Spurious Emissions

Any emission from the generation source other than the one meant to transmit intelligence is a spurious emission that can cause interference. Spurious emissions are usually categorized as:

- Broadband emissions caused by arcing;
- Spurious sidebands (splatter);
- Harmonic radiation;
- Spurious outputs caused by parasitic oscillations;
- Spurious outputs from the oscillator, frequency multipliers, and frequency synthesizer stages;
- Transmitter noise;
- Cross modulation and intermodulation.

Broadband Emissions

Broadband emissions are recognized by their distribution across a wide portion of the tuning range of the affected receiver. They have a characteristic irregular, ragged, hash sound in the receiver output and are usually caused by arcing either in the transmission line, tuner/coupler, transmitter, or in the rigging and deck equipment of the ship.

High-power shipboard transmitters induce very high RF currents and voltages in surrounding structures. When discontinuities are present in these structures, there is a strong tendency toward arcing, which generates broadband interference. Cable armor can arc to a ship's hull even if the armor is grounded at regular intervals. Arcing or corona can often be seen at night when the transmitters are radiating.

One solution to this problem is to eliminate discontinuities such as corroded junctions, stray metal objects, long length of guy wires, unused cables and antennas. The goal is to make the entire topside area of the ship a single conducting structure by welding, brazing, bonding, and other methods. Interference from arcing is especially misleading. It is sometimes misinterpreted as a high ambient noise level and corrective action is not taken.

Continued on next page

Spurious Sidebands (Splatter)

When a carrier is frequency or amplitude modulated by an intelligence-bearing signal, a group of new frequencies is generated around the carrier frequency. These frequencies are caused by, and are a function of, the modulating or intelligence signal. The usable and important range of frequencies necessary to transmit intelligence determines the bandwidth of a signal. Sidebands occurring outside this necessary bandwidth are undesirable and should be eliminated. Spurious sidebands may arise from improperly tuned circuits, over modulation, or faulty equipment.

In addition to creating wasteful and undesirable sidebands, splatter caused by overmodulation distorts the desired transmission. The received signal has a characteristic "mush" sound instead of the crispness associated with properly operated transmitters.

Another reason for overmodulation is the different speech characteristics of individual operators. One operator may speak softly into a microphone located several inches away. Another operator may practically shout into the microphone located almost at his lips. This leads to widely varying speech levels throughout the transmitter and, consequently, varying average power output levels. If the transmitter is properly adjusted for the softer speaking operator, then overmodulation will result when a louder speaking operator uses the transmitter. Voice compression circuits and transmitter gain control circuits are standard accessories on most transmitters, and operators should take full advantage of them. Usually, these circuits are automatic in operation once they are switched into the system, but they must be properly adjusted and maintained.

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Interference Produced by Transmitters (Continued)

Harmonic Radiation

Harmonic radiation is present to some degree in the output of all transmitters because of nonlinearity of the power output stage. Harmonics are integral multiples of the fundamental frequency. They are undesirable because they waste power and are a source of interference. Power transmitted in harmonics contributes nothing to desired communications.

Good design and correct tuning and loading usually ensure sufficient harmonic attenuation. Military specifications require that the second harmonic level be at least 60 db below the fundamental. Third and higher order harmonics must be at least 80 db below the fundamental. The use of multicouplers further attenuates transmitter-generated harmonics, thereby reducing their significance as sources of interference.

Spurious Outputs Caused by Parasitic Oscillations

Parasitic oscillations cause emissions at radio frequencies which are neither harmonics of the fundamental nor inter-modulation product frequencies. Parasitic emissions occur when a circuit is self-excited and goes into oscillation at a frequency other than the desired one. These emissions include shock excitation due to internal transients and unintentional excitation of circuit components by the carrier signal.

In a well-designed circuit, the usual cause of parasitic oscillation is improper lead dress following component replacement. The technician should ensure that component placement and wire positions are not haphazardly disturbed during troubleshooting or alignment. Parasitic oscillations may also occur in the output stage of a transmitter when improper neutralization follows tube replacement in that stage.

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Interference Produced by Transmitters (Continued)

Spurious Outputs

In some transmitter systems, a mixer is used to produce the system fundamental output frequency or a sub-multiple of it. When this is the case, spurious signals are generated because of non-linearity of the mixer. Tuned circuits are required following the mixer stage to attenuate these undesired frequencies. Usually four or five tuned circuits must be provided.

A second type of signal generation, using frequency multiplier stages and a single master oscillator, is used in many transmitting systems. Since frequency multipliers are nonlinear, harmonics of the master oscillator frequency are generated. Extremely high Q circuits must be used in the multiplier stages of the transmitter to prevent high levels of harmonics of the master oscillator from being emitted along with the fundamental frequency of the transmitter.

Transmitter Noise

Transmitter noise is generated in the various RF stages, together with noise from the audio system and power supply. It is inherent in the radiation process and is evenly distributed in the spectrum near the carrier frequency. The effect of transmitter noise is similar to atmospheric noise.

In general, transmitter noise does not degrade the desired transmitter signal appreciably because the depth of modulation, or deviation, is small compared to the desired signal modulation. It is usually ignored as a cause of interference because adjacent receivers are not tuned near enough to the transmitter frequency for its effect to be noticed.

Cross Modulation and Inter-modulation

Although cross modulation and intermodulation occur in both receivers and transmitters, only transmitters are considered in the following discussion. In both types of modulation, the mechanism responsible involves two or more signals present simultaneously in a nonlinear element. Both intermodulation and cross modulation can occur at the same time

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Interference Produced by Transmitters (Continued)

Cross Modulation and Intermodulation (continued)

Cross modulation is the transfer of modulation from one carrier to another.

Intermodulation is the generation of numerous new frequencies from two or more original signals.

When transmitting antennas are closely spaced, a large degree of coupling exists between them. Powerful off-frequency signals from one transmitter can feed back into the final stage of a second via the closely coupled antenna systems. The output-tuned coupling network of the second transmitter may not offer sufficient attenuation to the offending signal to prevent it from reaching the nonlinear final stage and interfering with the desired signal.

One solution is to physically separate the transmitting antennas to decrease the transfer of RF energy between them. This approach is limited aboard ship since space is at a premium and other factors must be considered in antenna placement.

The most common solution at present is to use tunable filters (multicouplers) between transmitters and antennas. The additional attenuation offered by such filters to off-frequency signals is usually adequate to prevent them from coupling into a susceptible output stage. Another major benefit of using multicouplers is that several transmitters at different frequencies can be coupled to one broadband antenna, thereby reducing antenna requirements aboard ship.

Receiver Susceptibility

Introduction

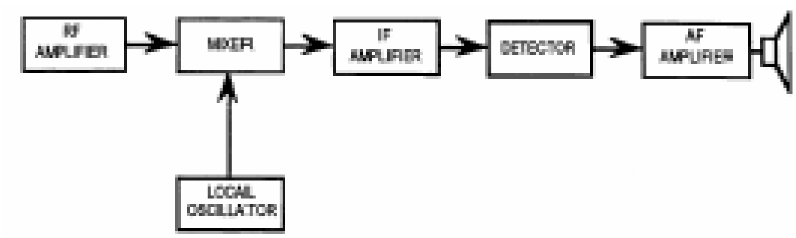
No interference will occur in a receiver if the receiver responds only to the desired signal. However, all receivers are less than ideal, and all receivers are susceptible in varying degrees to undesired signals.

There are three ways that undesired signals intrude on a selected or desired signal:

- Linear intrusion via normal input terminals
- Nonlinear intrusion via normal input terminals
- Intrusion through ports not intended as signal inputs.

Linear Intrusion

The following diagram shows the essential elements of a basic superheterodyne receiver:



This type of receiver circuit is inherently susceptible to certain frequencies other than the frequency to which it is tuned. Linear intrusion is possible because the receiver acts as a normal bandpass filter which accepts any input containing frequency components in the receiver passband. Unwanted inputs with a spectrum centered at, or near, the tuned frequency of the RF filter are the usual interference sources. These inputs come from a variety of sources:

- Broadband noise arising from natural or man-made sources. The spectrum of such noise is essentially flat over the bandpass of a typical receiver.
- Signals from communication sources assigned to a frequency at, or near, the receiver's center frequency. When these signals are separated from the receiver's center frequency by an amount less than the receiver's bandwidth, co-channel interference results.
- Signals from communication sources whose frequencies are separated from the receiver's center frequency by more than the receiver's bandwidth (adjacent channel interference).
- Signals from communication sources assigned to frequencies within one of the internal pass frequencies (IF interference).
- Discrete (narrowband) signals generated in nonlinear elements in the shipboard electromagnetic environment. These signals are both inter-modulation products and harmonics.

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Linear Intrusion (continued)

Typical natural broadband noise sources are:

- Thermal noise;
- Shot noise;
- Galactic noise;
- Solar noise;
- Atmospheric noise.

Typical man-made noise sources include:

- Discharges on high voltage lines and devices;
- Noise from automobile ignition systems;
- Commutator noise;
- Noise in complex switching systems;
- Noise generated by fluorescent lamps;
- Arcing across structural discontinuities located in high-energy radar beams;
- Arcing of the waveguide in a radar system.

Remedies For Broadband Noise

Remedies for broadband noise that overlaps the receiver bandpass must take advantage of differences between signal and noise characteristics. The most common methods of dealing with noise of a discrete impulse nature are **limiting** and **blanking.** Both are done before the broadband pulses have been filtered in the IF amplifier. This type of noise has short duration and large peak value. It can be limited to the level of the desired signal or totally blanked out for its brief duration. In either case, the signal is eliminated for the duration of the impulse with no significant loss of information.

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Remedies For Broadband Noise (continued)

A filter preceding the limiter or blanker widens the interference pulse and makes these elements less effective as noise reducers.

For example, a typical impulse type of noise burst, which may be only 1 or 2 microseconds wide at the receiver input, can be lengthened to 100 microseconds or more by the selectivity of the receiver's IF amplifier. This wider pulse is more difficult to remove than the narrow pulse. A gap of 100 microseconds in the detector output signal is much more noticeable than a gap of 1 or 2 microseconds.

Blanking systems require information concerning the interfering impulses. Systems for eliminating the periodic uses of a nearby transmitter may use direct synchronization from the transmitter. When there is no access to the source, the receiver itself must sense the pulse in one branch to eliminate it in a second branch.,

Broadband interference, such as white noise, that extends throughout the tuning range of a receiver can be suppressed by methods similar to those used against impulse noise, but the emphasis is on enhancing the desired signal. Advantage can be taken of known signal characteristics to design modulator and demodulator processes that increase the signal-to-noise ratio. An example of this is the matched filter detector which uses information about the shape of the signal pulses to discriminate between the signal and noise. The operator can increase the signal-to-noise ratio by selecting the minimum receiver bandwidth necessary for satisfactory signal reception.

Blanking Devices

One method used to reduce the effects of interference is cutting off or blanking the susceptible equipment during the time of the interference. This is very effective for pulse interference but not applicable for CW or continuous interference sources.

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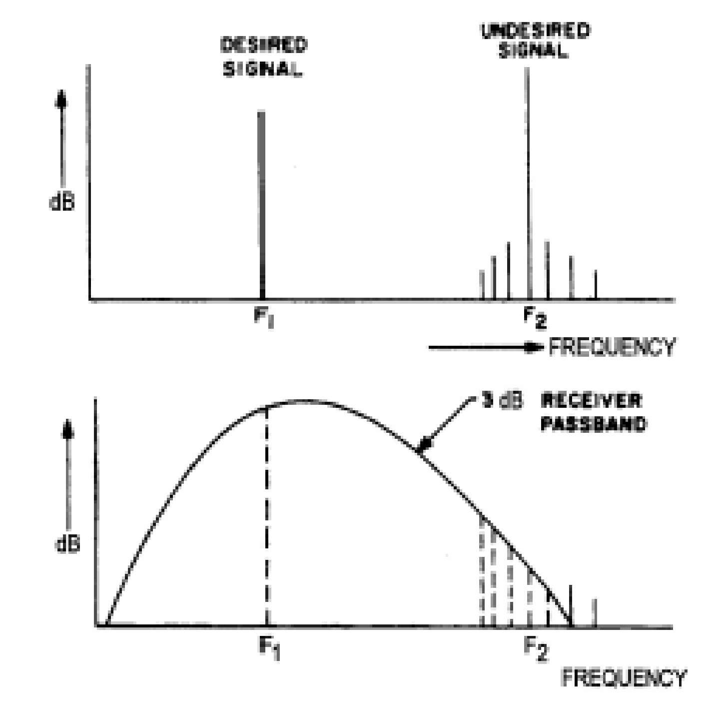
Receiver Susceptibility (Continued)

Shipboard ECM Blankers

The interfering pulse can be used to generate a blanking pulse, or if the interference is periodic, as in radar pulses, a pretrigger can be taken from the interfering equipment and used to develop a blanking pulse. An example of pulse blanking is the method used to disable shipboard electronic countermeasures (ECM) equipment when the ship’s radars are pulsed. A pretrigger from each radar is fed into a central pulse blanking device. This device generates blanking pulses which are used to turn off the ECM display. These “holes” in the display caused by blanking are not nearly as objectionable as the interference would be. If the blanking time is short, no significant detail is lost due to blanking.

Co-channel Interference

Co-channel interference takes place in communication systems that are assigned the same, or nearly the same, carrier frequencies. Co-channel interference occurs when the center frequency, or carrier of an undesired signal, falls in any portion of the passband of another receiver. The following diagram illustrates co-channel interference:



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Receiver Susceptibility (Continued)

Co-channel Interference (continued)

The interfering signal may be a normal authorized frequency. However, since its carrier frequency and some sidebands are within the bandpass of the victim receiver, they will follow a normal signal path and appear as interference.

The susceptibility of a receiver to co-channel interference is greater than other types of interference since a co-channel signal is received, amplified, heterodyned, and detected in the same manner as a desired signal.

Adjacent Channel Interference

Adjacent channel interference occurs when some sidebands (not the center frequency or carrier of an undesired signal) are within the receiver bandpass. Adjacent channel interference occurs between communication systems that have been assigned neighboring channels.

This effect, where energy on the skirt of an adjacent channel signal spectrum overlaps the receiver bandpass, is shown in the following figure:

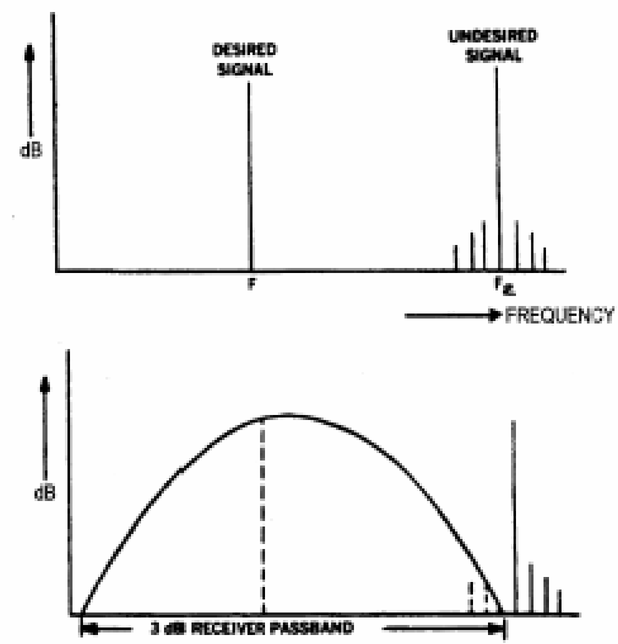

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Image Frequency Interference

In a heterodyne receiver, there are two signal frequencies that can combine (heterodyne) with the local oscillator signal to produce the receiver intermediate frequency (IF). One of these signals is the desired or tuned signal, and the other is called the image frequency.

The image frequency is separated from the desired signal by twice the IF, and is located on the side of the local oscillator signal opposite the desired frequency.

To keep an undesired signal at the image frequency from interfering, the undesired signal must be prevented from reaching the mixer stage where the unwanted combining takes place. Some receivers employ one or more resonant circuits, amplifier stages, or frequency selective filters between the antenna and the mixer stage. These resonant circuits or filters pass the desired signal and reject or attenuate the image frequency.

Little can be done to a receiver with poor inherent image rejection, but the technician can ensure that the receiver is carefully aligned, especially the front end. When additional image rejection is needed, an external preselector can be used with the receiver.

Intermediate Frequency Interference

One final type of linear intrusion is the penetration of unwanted signals that are centered at any pass frequency within the receiver.

For instance, a large amplitude signal centered at one of the IF amplifier frequencies may manage to get by the input selective circuits to the IF amplifier. Once there, the unwanted signal proceeds through the rest of the receiver in a normal manner. To correct this problem, the input circuit selectivity and/or stray paths to the sensitive circuits must be controlled. As a rule, the first IF amplifier frequency is the most vulnerable, but consideration should be given to any other internal passbands used.

A practical method of reducing this type of interference is to insert a series, or parallel-resonant circuit, tuned to the susceptible frequency in the RF stage. This will attenuate or reject any undesired signal at the intermediate frequency.

Continued on next page

Nonlinear Intrusion

Nonlinear intrusion occurs when a strong unwanted signal penetrates the input filter circuits and encounters a nonlinear element such as the mixer of an overloaded RF amplifier stage. The unwanted signal mixes with the desired signal to produce many new signals. If any of these new frequencies fall within the IF passband, they will be processed along with, and interfere with, the desired signal. The unwanted mixing can also take place in nonlinear elements external to the receiver. This is referred to as hull-generated interference. Any in-channel new signals radiated from the nonlinearity can cause interference once they are processed in the receiver.

Because a strong signal is required to cause interference by nonlinear intrusion, nearby transmitters are usually the only significant sources. Sources which are not designated to radiate, spurious outputs of transmitters, and broadband noise sources are rarely found to be major contributors to nonlinear intrusion

Intermodulation and Cross Modulation

Intermodulation and cross modulation, as previously discussed, are important in receivers as well as transmitters. The means of interference are essentially the same. Intermodulation or cross modulation in receivers, however, occurs when two or more signals are present simultaneously at the input. Intermodulation results in the generation of many new frequencies; cross modulation involves the transfer of information from an undesired carrier to a desired carrier. Both are caused by nonlinearity in a circuit near the receiver input.

Intermodulation is the most important. It becomes especially important when a range of frequencies is subdivided into separate communication channels, and when a number of these closely spaced channels are used simultaneously. When these signals meet in a nonlinear element, the new signals generated are sometimes spaced close in frequency to the original signals and fall within the tuned passband of the receiver.

Continued on next page

Receiver Susceptibility (Continued)

Inter-modulation and Cross Modulation (continued)

With three channels at frequencies f_1, + f_2, - f_3, intermodulation products (that is, those products near in frequency to the original generating frequencies but not coincident with them) are:

a. $f_l + f_2 - f_3$ e. $2f_2 - f_l$

b. $f_l - f_2 + f_3$ f. $2f_2 - f_3$

c. $2f_1 - f_2$ g. $2f_3 - f_l$

d. $2f_1 - f_3$ h. $2f_3 - f_2$

The above examples are only a few of the possible combinations - there are many more.

Intrusion Through Ports Not Intended as Signal Inputs

Numerous leads penetrate the case of a typical receiver. Each lead is potentially a vehicle for the transfer of electromagnetic energy into, or out of, the receiver. A method of dealing with this kind of problem is to install bypass capacitors or RF chokes to strip the wires of RF before they enter susceptible receiver circuits. This method also prevents conduction and subsequent radiation of interference energy from the receiver to other susceptible equipment. The local oscillator signal is the most significant energy source in the receiver, and radiation of this signal is a source of interference to nearby receivers. An RF stage ahead of the mixer serves to attenuate, and thus reduce the strength of the local oscillator signal reaching the antenna.

Holes put in equipment cabinets to provide air cooling also provide a route by which interference can be conveyed to susceptible equipment. Two techniques used to reduce the intrusion of interference are:

- Use of metal mesh screens to effectively close the air passages to RF
- Selection of the hole size to be equivalent dimensions of a waveguide that is below cutoff for the interfering frequency

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Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise. The answers to the exercise will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1. Interference from arcing is sometimes misinterpreted as a high _______ level.

   A. harmonic radiation
   B. ambient noise
   C. cross modulation
   D. modulation

2. Improper neutralization and/or improper lead dressing are the usual causes of ____________________________________ .

3. What are multicouplers used for?

4. The difference between cross modulation and intermodulation is that cross modulation _____________________ .

   A. is caused by a linear device
   B. results in the generation of many new frequencies
   C. is caused by a de-tuned transmitter
   D. is the transfer of a signal from an undesired to a desired carrier

5. Which circuit in a receiver radiates interference?

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	B	1-13
2.	Parasitic oscillations	1-15
3.	They allow the use of more than one transmitter and offer attenuation to off-frequency signals.	1-17
4.	D	1-17
5.	Local oscillator	1-25

Hull Generated Intermodulation Interference:
Formation of Nonlinearity in Ship Superstructures

Introduction

Hull-generated interference has become a major problem aboard ship because of:

- The increase in number and power level of transmitters;
- The increase in sensitivity and number of receivers;
- The requirement for increased use of the spectrum;
- The increase in number of antennas;
- The same, or in some cases, less mounting space for antennas.

Interference signals caused by hull nonlinearities are directly related to the number and power level of transmitters and antennas being used at the same time. The more transmitters you have on the air, the more interference you are likely to have. The more power these transmitters put out, the more serious the interference problem is likely to be.

Rusty-bolt Effect

A ship has all the elements necessary to produce a harmonic generating and radiating system. The elements are present in the complex ship structures, equipment, and other objects in the high intensity RF fields. RF energy from shipboard transmitters induces current flow in these structures. If a corroded joint or oxidized fastening is in the path of current flow, rectification occurs. The distorted waveforms resulting from this process contain new signals. These signals, created by nonlinear junctions in the ship structures, are commonly called the “rusty-bolt” effect.

There are thousands of nonlinear elements present in the topside areas of steel ships including steel hulls with aluminum superstructures. Steel is inherently nonlinear even when free from oxidation. The nonlinearities that cause the majority of intermodulation problems, however, are metallic junctions exposed to weather.

Continued on next page

Nonlinearity Due to Corrosion

Two pieces of clean metal held tightly together have near zero impedance at the junction, which has little restriction to current flow. Once the joint is exposed to weather, however, deterioration of the metal starts. This deterioration is due to corrosion. Since the oxides formed are a semiconductor, they destroy the metal-to-metal contact and the low impedance of the joint. The impedance varies under the influence of induced RF current from shipboard transmitters; that is, the junction becomes nonlinear. Corrosion is the culprit.

If moisture is present when metal objects are jointed, the junction will corrode. Corrosion is a complex process. Corrosive action may be either galvanic or electrolytic, or both, depending on the nature of the metals in contact and on whether the metal-to-metal contact is part of a direct current circuit. But, both types of corrosion take place only when moisture is in contact with the mating surfaces. The following is a partial list of the major causes of corrosion:

- Galvanic
- Fatigue
- Crevice
- Stress
- Welding

Galvanic Corrosion

When dissimilar metals are joined by the same corroding medium, electrochemical corrosion will occur. In order for galvanic action to occur, current must flow. In some cases, the current uses the metals as the prime conductor; in others, such as structures in a high RF field, the metals will intercept RF energy and become unexpected conductors. Reduction of galvanic corrosion requires a knowledgeable choice of construction materials and good construction techniques.

Continued on next page

Formation of Nonlinearity in Ship Superstructures (Continued)

Fatigue Corrosion

The dangers inherent from fatigue corrosion are those from breakdown of a protective film on the metals caused by bending or vibration

Crevice Corrosion

Corrosion is likely to form in crevices since they have a tendency to retain corrosive solutions. Elimination of this problem can be accomplished by smoothing surfaces and filling crevices. Crevices can be minimized by using welds instead of mechanical fasteners. Regardless of the torque applied to a bolt, it is practically impossible to eliminate crevices into which fluids can penetrate and cause corrosion.

Stress Corrosion

Stress corrosion occurs when internally or externally stressed metals are exposed to a corrosive environment. The loss of good bonds or structural integrity will depend upon:

- The amount of stress;
- Corrosion medium present;
- The structural configuration of the base metal.

Stress corrosion is one of the most important and common types, but it is virtually impossible to predict since the same conditions that cause cracking in one metal will not influence another in the same general category. In general, high strength aluminum alloys are susceptible to cracking and should be avoided if possible.

Welding Corrosion

Corrosion can occur in areas where variations in grain size are produced by the heat from welding. Corrosion rates vary according to the heat input of the welding method and the geometry of the joint. The grain structure is changed by high temperatures caused by the inability of the heat to dissipate. The possibility of corrosion in these areas can be avoided by increasing the surface area so that heat is dissipated more rapidly

Mechanism of New Signal Generation

Heterodyning

Mixing two signals in a nonlinear element to produce a new frequency is familiar to persons acquainted with the operation of a simple heterodyne receiver. A locally generated signal is applied along with the broadcast signal to a mixer or first detector stage. This stage is operated intentionally so as to distort and produce harmonics of the two input signals.

The output of this nonlinear stage consists of:

- Original two frequencies;
- The sums of the two original frequencies;
- The differences of the two original frequencies;
- All of their harmonics.

In a typical mixer stage, the difference frequency of the two original signals is selected for further processing. In some frequency translation schemes, however, any number of frequencies can be selected by inserting appropriately tuned circuits.

The point to keep in mind is that when a s ingle frequency sine wave is distorted in any manner, harmonics of that frequency are generated. When two or more single frequency sine waves are mixed in a distortion-producing (non-linear) element, then many new frequencies are generated.

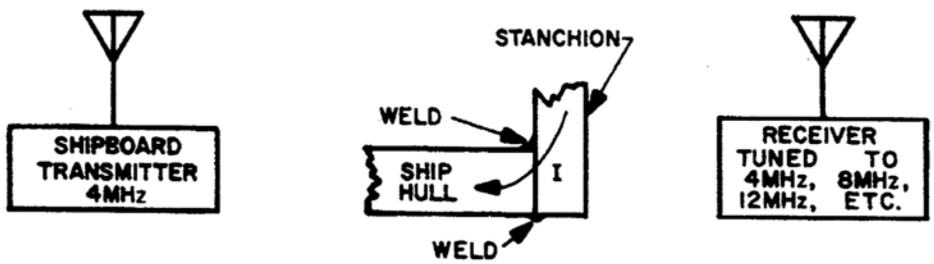
The process is called heterodyning. Little additional study is required to understand how a similar process occurs when corroded metallic objects are subjected to high intensity RF fields

Continued on next page

Mechanism of New Signal Generation (Continued)

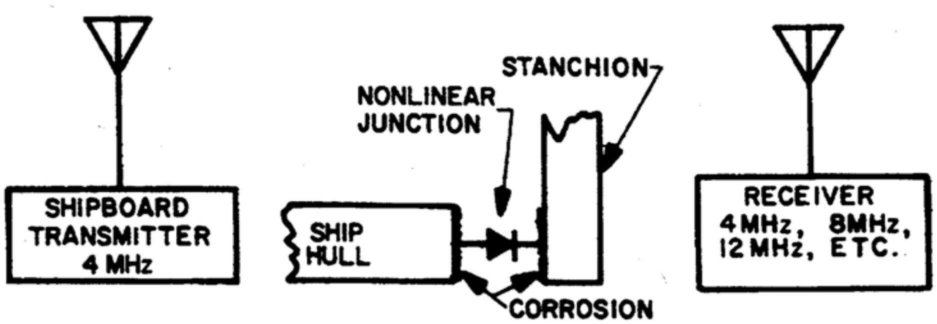
Re-radiation of Signals from Linear Junctions

To illustrate hull-generated interference, imagine that a welded lifeline stanchion (linear junction) aboard ship receives energy at 4 MHz from a shipboard transmitter. Induced RF current, undistorted by the welded junction, causes re-radiation of the driving signal and no others, as shown below:



The receiver can detect the fundamental at 4 MHz but does not detect any signal at 8 MHz, 12 MHz, etc., since they are not generated by the welded (linear) joint.

Now assume that the stanchion is bolted or riveted instead of welded to the hull. Assume further that the bolted (or riveted) junction has corroded and a nonlinearity has been formed due to metallic oxides between the two structures. The induced RF current flowing through the nonlinear impedance of the junction is not an exact replica of the RF driving voltage. A harmonic content has been added by the nonlinearity. These new signals are radiated and the receiver can detect signals at 4 MHz, 8 MHz, 12 MHz, etc, as shown below:



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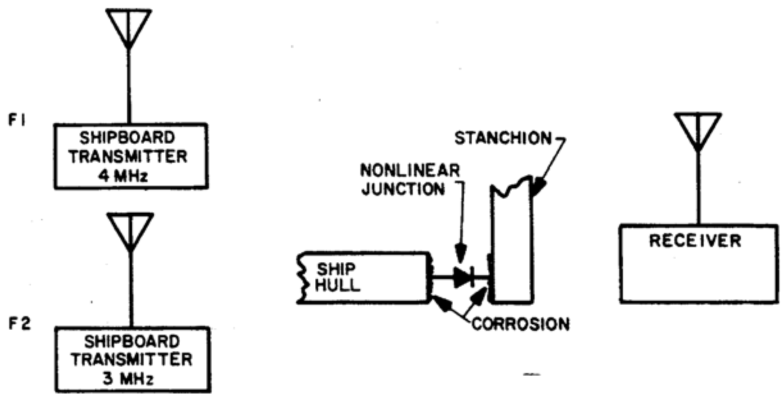
Mechanism of New Signal Generation (Continued)

Inter-modulation Product Radiation from Hull Nonlinearity

Assume now that a second transmitter is radiating at 3 MHz in addition to the original transmitter radiation at 4 MHz. Both signals illuminate the nonlinear junction and harmonics of each fundamental mix with each other and the two fundamentals as shown below:



Many new signals are generated in this process. A few of these are:

$f_1 + f_2 = 7$ MHz

$f_1 - f_2 = 1$ MHz

$f_1 + 2f_2 = 10$ MHz

$2f_1 + f_2 = 11$ MHz

$2f_1 - f_2 = 5$ MHz

$3f_1 + f_2 = 15$ MHz

$3f_1 - f_2 = 9$ MHz, and so forth

The receiver can now detect signals at each of the frequencies, and if one of these frequencies is close to a desired frequency, interference results.

Continued on next page

Mechanism of New Signal Generation (Continued)

Hull-Generated Interference Sources

Typical hull-generated interference sources are:

- Loose metallic items in topside area;
- Corroded stanchions and metallic lifelines;
- Rusty anchor chains and metallic cables;
- Rusty chains for accommodation ladders;
- Metallic safety nets, chains, and cables;
- Loose and rusty mast items.

Levels of Hull-Generated Interference

The level of hull-generated interference signals is determined by:

- Output power of the transmitters;
- Efficiency of the nonlinear element as a rectifier - that is, the degree of nonlinearity;
- Coupling and amount of shielding between the transmitter and the nonlinear element;
- The physical size, configuration and orientation of the metallic objects comprising the junction - that is, the larger the objects are with respect to a given wavelength, the more energy they will intercept and reradiate;
- Physical properties - that is, gain of the transmit antennas.

Additional Nonlinear Sources

Studies show that steel is inherently nonlinear and produces intermodulation products. However, the level of these products is well below those levels produced by corroded junctions and becomes significant only after all other nonlinear sources have been eliminated.

Intermodulation also occurs in receiver front ends when two or more strong signals penetrate the pre-selector attenuation, overdrive the RF amplifier stage, and cause the RF amplifier stage to become nonlinear. The same mixing occurs if the signals are strong enough to penetrate to the mixer stage which is normally operated nonlinearly. The cure here is to insert additional attenuation to off-frequency signals ahead of the receiver. A tunable bandpass filter that offers attenuation to off-frequency signals is usually sufficient.

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Mechanism of New Signal Generation (Continued)

Additional Nonlinear Sources Continued

Another nonlinear element across which two or more signals may intermodulate is the final, or output stage, of a shipboard transmitter. Signals from one transmitter may couple, via closely spaced antenna systems, into the output stage of another transmitter. Intermodulation products from the mixing process are then transmitted and become interference sources.

A solution to this problem is to insert a multicoupler between the transmitter and its antenna. The multicoupler serves to attenuate off-frequency signals regardless of whether they are entering or leaving the transmitter. If strong off-frequency signals are prevented from intruding in the final amplifier stage, then intermodulation products originating in transmitters are eliminated.

Suppression Techniques

To prevent harmful EMI caused by nonlinear or intermittent metal- to-metal contact junctions in the topside electromagnetic environment, the ship's topside areas shall be, as nearly as possible, a single conducting surface free of all pinned, snap-linked, chain-linked, or other metallic discontinuities that might act as sources of intermodulation interference and broadband noise.

The following are examples of hull-generated EMI control requirements as listed in the MIL-STD-1310 (NAVY):

- Metal-to-metal contact junctions in the topside electromagnetic environment should be avoided by use of nonmetallic substitutes when available.
- Metal-to-metal contact junctions, where movability or removability is not a requirement, should be class A bonded.
- Metal-to-metal contact junctions, where movability or removability is a requirement, should be class B or class C bonded to provide a low impedance current path around the junction.
- The joining of dissimilar metals by bolting or riveting should be minimized in topside areas.
- Except for anchor and anchor holding, metal chain shall not be installed in topside areas.
- Loose metallic items, such as pipes, cables, and portable rigging should not be stowed, stacked, or lashed down in topside areas.

COMDTINST M10550.25 lists the following (required and not required) bonding candidates for topside bonding on metallic hull surface ships with less than six high frequency (HF) transmitters.

Required	Not Required
1. Antennas	Lifelines
2. Antenna Couplers	Ladders
3. Loose metallic vertical structures within 10 feet of an antenna that radiates 750 watts or more.	Loose metallic horizontal structures

Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise/s. The answers to the exercise/s will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1. In order for galvanic corrosion to take place ________.

   A. an electrolyte must be in contact with the metal
   B. dissimilar metals must be in contact with each other
   C. current must flow
   D. bare metal must be exposed

2. Define heterodyning.

3. When a welded junction aboard ship receives a signal, and radiates this signal, a receiver will detect signals ____________ .

   A. at the fundamental frequency
   B. at the harmonic frequency
   C. at the sum and difference frequencies
   D. on all bands due to spurious signals caused by the junction

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	C	1-30
2.	When two or more single frequency sine waves are mixed in a nonlinear devise, many new frequencies are generated. These new frequencies include the original plus the sums and differences of the original and all of their harmonics.	1-32
3.	A	1-33

Radar Systems Interference

Introduction

Radar systems can create interference in the following ways:

- RF leakage from waveguides;
- Arcing in waveguides;
- Arcing in rotary joints;
- Arcing in mast cables.

This section explains ways to detect and correct for these types of interference.

RF Leakage from Waveguides

Leakage of RF power can occur at any waveguide or coaxial cable joint. Leakage from waveguide joints creates a narrowband interference source and also causes a decrease in transmission efficiency.

To minimize leakage:

- The waveguide should be firmly connected with an RF shielding gasket between sections.
- The bolts holding the waveguide joints together should be outside the high intensity RF area.
- The gasket should be located between the bolt holes and the RF area.

Arcing in Waveguides

Arcing can occur inside of waveguide causing a high voltage standing-wave ratio (VSWR) due to:

- Foreign objects (including moisture) in the waveguide;
- Corroded or flaked-off coating;
- A sharp bend in the waveguide run.

Continued on next page

Radar Systems Interference (Continued)

Arcing in Waveguide (continued)

Any arcing in wave guide will usually reduce the radar's range due to high VSWR. The radar's video will also be degraded.

To detect any arcing inside of wave guide:

- Look for discoloration in the wave guide caused by heat;
- Feel the waveguide for hot spots;
- Check forward and reflected power using a radar transmission test set.

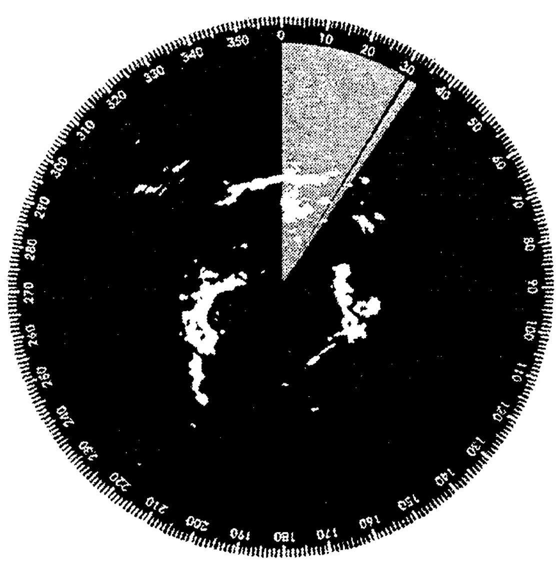
Arcing in Rotary Joints

Arcing may result when a radar rotary joint is:

- Dirty;
- Worn;
- Misaligned.

This is a cumulative process since arcing causes further deterioration of the joint which results in more arcing. Sustained arcing normally causes a complete breakdown of the rotary joint.

The following picture of a radar indicator shows an exaggerated indication of what you might see with a rotary joint obstruction:



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Arcing in Mast Cables

Arcing can result when high energy radar beams strike mast discontinuities, such as; corroded cables, cable hanger straps, service platform safety lines (of chains), and the like. This kind of arcing, which can normally be seen and heard, can be <u>best</u> <u>detected</u> at <u>night</u> when the radars are operating.

Good housekeeping practices, such as replacing corroded cables, cleaning and tightening loose strap brackets, and replacing all metal safety lines with nonmetallic rope, will eliminate interference from this source. Cables should be run inside the mast or on the opposite side of any radar antenna. Cables which are located in the main beam of radars should have RF shielding installed over them.

Arcing

No matter what the source, arcing produces a very intense, broad distribution of interference that may disrupt frequencies far removed from the radar's fundamental frequency.

PRF Overload

Receivers that are close to a radar antenna, experience interference due to "brute force" penetration of the RF pulse energy. The receiver does not have to be tuned to the frequency of the radar for this action to occur. Intense RF energy simply forces its way past the front-end selectivity and enters the active amplifier stage. The amplifier is driven alternately between cutoff and saturation by the interfering pulse, which gives the characteristic radar PRF buzz at the receiver output. Usually, the interference is heard only when the receiving antenna is illuminated by the radar beam.

The most effective method for preventing this kind of interference is to locate all receiving antennas out of the main beam of nearby high power radars. In some cases, it is necessary to install additional shielding of RF transmission cables that pass through the main radar beam.

It is also possible to run antenna cables inside the mast or on the side of the mast opposite the one in the path of the radar beam. The mast then serves as a shield to reduce the energy pickup on the antenna cables.

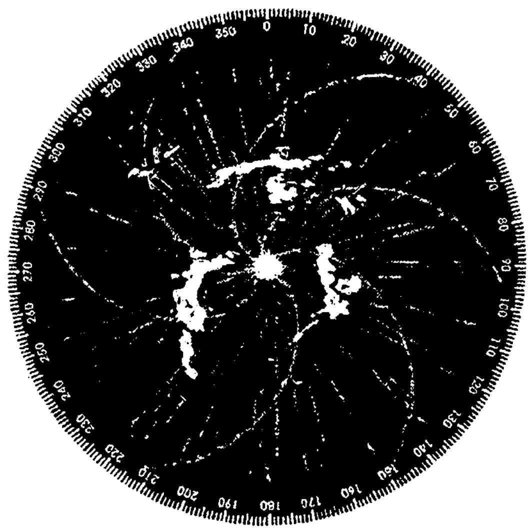
Continued on next page

Radar Systems Interference (Continued)

Running Rabbits

Interference between radars usually appears as a series of moving dots, “running rabbits,” on the CRT. It occurs when several ships with the same type of radars are operating within a few miles of each other. It can also occur between radars of different types aboard one ship. Since the offending radar is not at exactly the same PRF, the dots are moving radially along the indicator sweep creating spiral interference patterns. A trained operator can usually read through this interference. However, high pulses can obscure desired targets

The following is a picture of a radar indicator with “running rabbits” interference:



Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise/s. The answers to the exercise/s will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1.. What can cause arcing inside of waveguide?

2. Describe ways to detect arcing inside of wave guide.

3. Describe the EMI effects of arcing.

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	• Foreign objects (including moisture) in the waveguide. • Corroded or flaked-off coating. • A sharp bend in the waveguide run.	1-39
2.	• Look for discoloration in the wave guide caused by heat. • Feel the waveguide for hot spots. • Check forward and reflected power using a radar transmission test set.	1-40
3.	No matter what the source, arcing produces a very intense, broad distribution of interference that may disrupt frequencies far removed from the radar fundamental frequency.	1-41

EMI Reduction Methods: Bonding/Grounding

Introduction

The goal of personnel who design ships and equipment is to design, manufacture, and install the equipment so that all potential interference situations are eliminated. However, the goal of eliminating potential interference situations has not been achieved. Therefore, field EMI reduction techniques are necessary.

Bonding

Bonding is the process of providing a low impedance union between two metallic conductors. Grounding implies an extension of this definition to include the establishment of a common reference point with regard to electric potential. Bonding can be accomplished by a variety of means. The objective is to obtain minimum resistance between two surfaces.

The preferred method to use for reduction of electromagnetic interference is one in which the joint becomes a homogeneous mass of the joined metals. The best methods for accomplishing this are welding and brazing. Of lesser value than welding or brazing are methods that make extremely good physical contact, such as; pressure connections obtained by bolting or riveting, and the installation of a low impedance RF bonding strap that acts as a low linear impedance shunt around a deteriorated junction

Equipotential Ground Planes

The importance of equipotential ground planes for proper equipment operation, EMI suppression, and personnel safety cannot be over emphasized. An equipotential ground plane is a large conducting area which offers little impedance to current flow. It may consist of a single large conducting element or of many elements bonded together.

A single connection that offers a significant impedance to current flow can place an entire grounding system at a high potential with respect to ground. Shielding connected to the system will then be completely ineffective. When such a high impedance connection is subjected to large amounts of current, the potentials which result can be extremely hazardous to personnel and equipment.

Continued on next page

Equipotential Ground Planes (continued)

Oxides may form at mating surfaces of conductors which will greatly increase the impedance of the bond and form nonlinear junctions capable of generating and radiating various harmonic signals.

Effective bonding techniques must be used to prevent the degenerative and hazardous effects of high impedance bonds. Testing procedures and their limitations must be clearly understood to ensure that adequate bonding techniques are implemented properly.

General Bonding Techniques

There are two general techniques for bonding: direct and indirect. Direct bonding is achieved by direct metal-to-metal contact between two metal items through the process of welding or brazing. Indirect bonding is achieved by the use of a bonding jumper or bolts between two metal items.

Direct Bonding

Direct bonding is always the preferred method since the microscopic path length involved in direct bonding has a lower RF impedance than that of any practical indirect bonding method.

Indirect Bonding

Indirect bonding is at best only a substitute where physical constraints make it impractical to use direct bonding. When bonding by the indirect method, the length of the bond path should be as short as possible. In addition, when using bond straps, the welded-at-both-ends bond strap is preferred over the removable-end strap.

Bonding Specifications

MIL-STD-1310G (NAVY) is the present authority for all bonding/grounding procedures aboard Coast Guard ships. Items to be bonded, bond strap fabrication, installation details, and attachment methods are described in this publication.

Continued on next page

Shielding

Introduction

The two main purposes of shielding are to confine EMI within a specific region, and to prevent EMI from entering a specific region. Ideally, only a transmitter radiates energy and only a receiver receives energy. This seldom happens since electronic equipment is constantly producing energy that may interfere with adjacent equipment. Shielding is a means of de-coupling and reducing interaction between equipment.

Shielding Methods

The following are some examples of methods used to shield equipment:

- **Metal Seams - No Gasket.** It is necessary to have clean metal-to-metal mating surfaces. To make sure that good pressure contact is achieved between the metal surfaces, you should use set screws or rivets. If the metal seams become corroded or anodized, a serious interference source may develop.
- **Metal Seams - Metallic Gasket.** Metal seams can be improved by using metallic gaskets placed between the surfaces. These gaskets, often made of knitted wire mesh, are resilient and are good conductors. The metal-to-metal contacts must be maintained by a pressure of approximately 20 psi.
- **Holes and Screening.** Holes or openings in a shielding enclosure cause a decrease in shielding effectiveness. However, holes or openings usually cannot be avoided. Large holes, particularly in high-frequency applications, are bad offenders. So, holes should be as small as possible. If large holes are present, they must be covered with copper mesh screening.

Ventilation Panels

In many cases, shielding screens introduce excessive air resistance. Sometimes greater shielding effectiveness may be needed than the shielding screens can provide. In such cases, openings may be covered with specially designed ventilation panels (such as honeycomb) with openings that operate on the wave-guide-below-cutoff principle. Honeycomb-type ventilation panels have the following advantages when they are used in place of screening:

- They allow higher attenuation over a specified frequency range than can be obtained with mesh screening
- They allow more air to flow without pressure drop for the same diameter opening in a screen
- They cannot be damaged as easily as the mesh screen, therefore, ventilation panels are more reliable
- Honeycomb-type ventilation panels are less likely to deteriorate from the affects of oxidation and exposure.

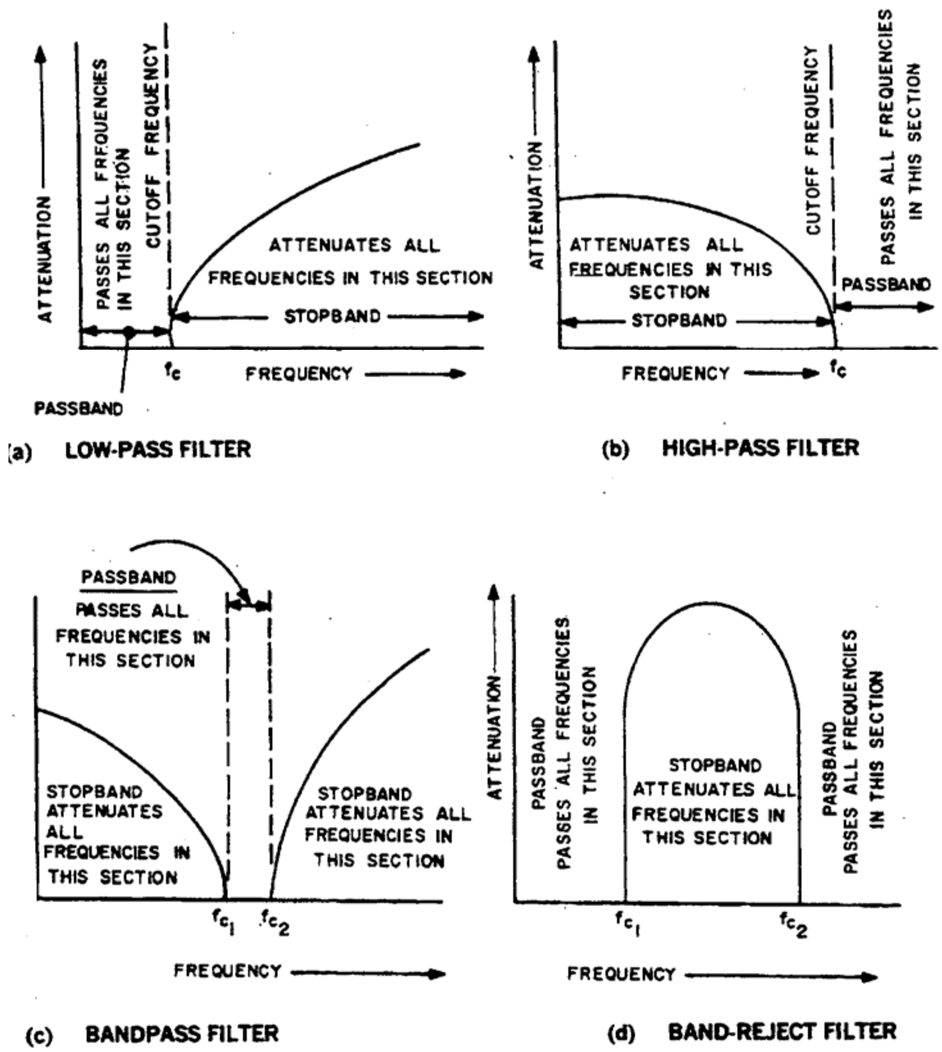
Continued on next page

Filtering

Introduction

Filters are combinations of circuit components designed to pass currents at certain frequencies or to attenuate currents at other frequencies. They use the resonance characteristics of series and parallel combinations of inductance and capacitance.

These reactances reduce interference by introducing a high impedance in series with the interference currents and/or shunting them to ground through a low impedance. The following figure shows the attenuation versus frequency curves for four common filters.



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Filter Selections

The following characteristics are common to all filter installations, and should be carefully considered in filter selection:

- Voltage rating of the circuit in which the filter is to be inserted and the maximum current that will pass through the filter. Unless otherwise specified, voltage and current ratings required of a filter are the maximum allowable for continuous operation. Any filter will perform satisfactorily when it is operated below its nameplate rating. The breakdown voltage of capacitors used in filters should also be considered. A safety factor of approximately 100% should be used. For a given application, the working voltage of a standard filter capacitor should be twice the voltage of the circuit in which it is used. In general, filter test voltage should be twice the filter's nameplate rating.
- Duty cycle of the filter. This applies to the decreased load current of intermittent operation.
- Operating frequency of the circuit and the frequencies to be filtered. Power-frequency specifications are primarily applicable to low-pass line filters. Filters should not be operated at power frequencies above those specified by the manufacturer. They will operate satisfactorily at frequencies below those marked on the nameplates.
- Voltage drop that can be tolerated at the operating frequency. All filters using series inductors cause some voltage drop. The amount of this drop is determined by the series resistance of the filter. It may be expressed, for example, as maximum voltage drop at rated current 0.1 volt. In some cases, only the series resistance is given. When this occurs, the voltage drop for AC filters (when cutoff frequency is far removed from the operating frequency) or DC filters can be calculated by applying Ohm's law.
- Maximum ambient temperature at which the filter must operate. If the ambient temperature varies from the range specified for the filter, failure or shortened service life may result.
- Attenuation required of the filter for adequate interference reduction.
- Minimum filter life is the number of hours a unit will operate satisfactorily under rated conditions and at maximum ambient temperature.
- Circuit requirements such as minimum (or maximum) capacitance or insulation resistance. The capacitance to ground of a filter often determines the application of the filter. Some circuits may limit the maximum capacitance to ground to prevent long time-constant currents from charging the capacitors through a resistor. Another instance in which capacitive limitations are important is when capacitors might cause danger to personnel because of charging currents.

Continued on next page

Filtering (Continued)

Filter Applications

The object of a filter is to discriminate against some frequencies while not affecting others. Typical applications include the following:

- Power-line filtering prevents HF signals from being conveyed by the power line to vulnerable equipment;
- Bypassing allows the passage of low frequencies or DC while providing a low impedance path to “ground” for high frequencies;
- Feedthrough allows LF signals to be passed through a panel or bulkhead while bypassing or blocking HF interference;
- Wave trapping uses high Q resonant or anti-resonant circuits to reject certain frequencies;
- Harmonic suppression prevents harmonics from reaching the antenna or radiating in any other way;
- Duct and shaft filtering prevents unwanted signals from leaving an equipment via air ducts or control shafts.

Cable Segregation

Introduction

One way to reduce or eliminate electromagnetic interference onboard ship is to segregate cables and equipment. By using separation structures, such as false decks, bulkheads, doors, and masts, energy in high level circuits may be prevented from coupling to low - level circuits. High - energy circuits may interfere with medium and low - level circuits either by direct coupling or inductive coupling. Whenever practicable, interference reduction segregation measures should be considered before equipment is installed, and should prove to be more effective than shielding and grounding at a later date.

Major Types of Cables

All cables are grouped into three major types:

- **Active** (high level)

  Includes; Radar Modulator pulse, MF and HF Transmitter cables.

- **Passive** (medium level)

  Power and lighting cables, control cables, intercommunication and fire control cables, and cables other than those which are active or susceptible.

- **Susceptible** (low level)
  Radio receiving antennas and transceiver cables.

Separation Requirements

The following table gives the minimum separation requirements between categories of cables:

Type of	Active	Passive	Susceptible
Active	18”	18”	18”
Passive	18”	none	2”
Susceptible	18”	2”	none

Continued on next page

Cable Segregation (Continued)

Separation Requirements (continued)	At times it may be physically impossible for you to meet the separation standards between cables. In those situations you should provide additional shielding between cables to prevent possible interference. The shortest cable run between equipments is not necessarily the best run if the cable is active and passes through a susceptible area compartment. Running the active cable around the susceptible compartment may prevent many problems at a later date.
AC Power Cables	Cables carrying varying current or voltage should be routed separately from cables carrying DC. Where it is necessary to run separate phase conductors for alternating current cables, the individual conductors should be as close as practicable throughout their entire length.
Audio Frequency Cables	Cables carrying audio frequency should be routed separately from each other. In installations where adequate separation is not practicable, audio frequency lines should be twisted pairs with an outer shield.
Inter Connecting Cables	Cables interconnecting the units of individual equipments, particularly radar equipment, should be grouped and routed separately from all other cables.
Coaxial and Unshielded Antenna Cables	Coaxial antenna cables should be routed separately from all other cables, such as control cables. Unshielded antenna transmission lines should be routed in the shortest, most direct route practicable and as far from other antenna cabling as possible throughout their length.

Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise/s. The answers to the exercise/s will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1. Describe the two general techniques for bonding.

2. What are the two main purposes of shielding?

3. Filters are combinations of circuit components designed to ________________ ____.

4. Loss of the desired signal in a filter is known as __________ loss.

5. Cables with twisted pair shielded leads should be used with a/an ______ .

   A. RF frequency line
   B. audio frequency line
   C. negative power lead
   D. unshielded antenna

6. When is the shortest cable run between two or more pieces of equipment not necessarily the best run?

   ____

   ____

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	There are two general techniques for bonding: direct and indirect. Direct bonding is achieved by direct metal-to-metal contact between two metal items through the process of welding or brazing. Indirect bonding is achieved by the use of a bonding jumper or bolts between two metal items.	1-46
2.	The two main purposes of shielding are to confine EMI within a specific region and to prevent EMI from entering a specific region.	1-47
3.	pass currents at certain frequencies or to attenuate currents at other frequencies	1-48
4.	Insertion	C-2
5.	B	1-52
6.	If the cable is active and passes through a susceptible area compartment	1-52

Troubleshooting EMI:
Six-Step Troubleshooting Procedure for EMI

Introduction

Troubleshooting an EMI problem should be approached in the same logical progression as you would troubleshoot any other electronic equipment. hen you get a report of a receiver not working properly you need to figure out if the problem is the just the receiver, the receiver's associated equipment, or an EMI problem from some other source. The more you understand about EMI, the easier it will be to either rule out EMI or find the cause. Using the Six-Step Troubleshooting Procedure will ensure that you make the best use of your time and effort.

Step 1 Symptom Recognition

When an operator tells you that a receiver isn't working you must get all the information you can about the problem. After verifying proper operating procedures ask the following questions.

1. Ask the operator questions about the type of interference such as:
   - Can you tune the receiver away from the interference?

     Yes - Narrowband interference
     No - Wideband interference
2. Ask the operator about the duration of the interference such as:
   - Does the interference happen just once in a while? (*Transient*)
   - Does the interference come and go? (*Intermittent*)
   - Is the interference always there? (*Continuous*)
3. Ask the operator questions about the sound of the interference to help classify if the interference is natural such as:
   - Does the interference have an intermittent crackling sound? (*Local thunderstorms*)
   - Does the interference have a steady crackling or rattling sound? (*Distant thunderstorms*)
   - Does the interference have a continuous static white noise sound? (*Precipitation static*)
   - Does the interference have a high hiss sound? (*Interstellar origin*)

Continued on next page

Troubleshooting EMI:
Six-Step Troubleshooting Procedure for EMI (Continued)

Step 1 Symptom Recognition (continued)

4. Ask the operator questions about the sound of the interference to help classify if the interference is man made such as:
   - Does the interference have a constant humming sound? (*Poorly filtered power*)
   - Does the received audio sound mushy instead of crisp? (Sp*urious sidebands from poorly aligned transmitters*)
   - Is the receiver picking up the ship's own transmissions on frequencies other than the assigned fundamental frequencies? (*Hull-generated intermodulation/cross modulation*)
   - Is the receiver picking up a high background noise? (*Arcing*)

These type of questions should help you to decide if you are dealing with an EMI type problem or not.

Step 2 Symptom Elaboration

Perform a functional check of the system and note any additional symptoms.

Expand on your list of symptoms:

- What is the frequency range of the interference?
- What time of day is the interference noticed?
- What type of operations are in progress when the interference is noticed?
- Does the interference only happen when more than one transmitter is transmitting?
- Does the interference only happen when a transmitter is transmitting in high power?
- Does the interference only happen when a certain antenna, receiver, etc.., is being used?
- What is your weather situation?
- Has the affected equipment recently been worked on? Are all screws, RF gaskets, cover plates, etc. securely in place?

Continued on next page

Step 2 Symptom Elaboration (continued)

Try to categorize the interference by its severity. The following are the three levels of severity as defined in MIL-STD-1605:

- **Mild -** A level of interference which, although detectable, does not hamper the detection and interpretation of a desired signal. This level of interference is mainly a background or nuisance type.
- **Medium -** A level of interference which interferes with the detection and interpretation of a desired signal. This level of interference causes partial break-up or masking of the desired signal with some loss of signal content.
- **Severe -** A level of interference which causes complete loss of a desired signal or interferes to the extent that the desired signal information or message content cannot be interpreted.

Step 3 Listing of Probable Faulty Functions

Ask yourself the following question:

"***Where can the trouble logically be in order to produce the symptoms given?***"

List the probable sources of the EMI.

Step 4 Localizing the Faulty Function

Let's say you listed "rotating machinery" as the probable source of the broadband EMI. Start and stop every piece of rotating machinery that was operating during the interference until you find the offending equipment.

If you suspect hull-generated intermodulation as your source of EMI, you can start and stop transmitters and patch different antennas to the affected receiver to see if the interference level changes. Inspect suspected topside bonds and welds for corrosion.

Use of a spectrum analyzer will help you to analyze the interference being generated.

Use an ohm meter and visually check the grounding system of equipment being affected.

Continued on next page

Troubleshooting EMI:
Six-Step Troubleshooting Procedure for EMI

Step 5 Localize Trouble to the Circuit

Continue logically troubleshooting until you identify the source of the EMI.

Reminder: *Document all troubleshooting symptoms and results*.

Step 6 Failure Analysis

Once you have identified the problem you will have to make a decision as to the best way to fix it so that the equipment can be returned to optimum serviceability. Below is a list of possible options:

- Repair existing EMI protection
- Replace existing EMI protection
- Install EMI protection
- Grounding/bonding
- Shielding
- Filtering
- Cable segregation

Conclusion

Using the Six Step Troubleshooting Procedure will help you solve any EMI problem you may encounter.

Being aware of EMI symptoms and the ways to suppress or eliminate EMI is a valuable asset for technicians maintaining communications equipment.

Lesson 2

HOW TO VERIFY THE INSTALLATION OF ENGINEERING CHANGES/FIELD CHANGES/ORDALTS TO ELECTRONIC EQUIPMENT OR SYSTEMS

Overview

Introduction

You know that Engineering Changes are used by the Coast Guard to administer the configuration management process when installing electronic equipment or systems.

You also know that a Field Change is a type of System Engineering Change used for the modification of the function, performance, or maintenance procedures of particular equipment. Engineering changes to Navy-owned ordnance equipment (ORDALTs) are promulgated by the Naval Sea System Command.

In all cases, it is important that any changes be documented; it will be up to you to verify that the required change documentation exists for new installations of, or modifications to, electronic equipment and systems at your unit.

Lesson Objectives

Given an installed or modified electronics equipment/system and access to unit records, **VERIFY** the documentation of the original installation or modification pursuant to the original Engineering Change or Field Change/ORDALT, in accordance with the CG Electronics Manual.

References

The following references were used for this lesson:

- *Electronics Manual*, COMDTINST M10550.25 (series)
- *CMplus 5.1 Job Aids*
- *Ordnance Manual*, COMDTINST M8000.2 (series)

Installation/Change Documentation

Engineering Certification Checklist

An installation team/activity or unit personnel perform an "Installation" in accordance with an approved Field Change or Engineering Change.

An Engineering Certification Checklist is used to "certify" the installation.

- The checklist should contain checks of all of the new or modified system functionality, as well as checking functionality of any ancillary equipment.
- The list should also contain checks concerning the quality of the installation (cables properly dressed, drawings properly "red-lined," training provided, etc.).
- Levels of engineering testing and evaluation must be documented; final testing must deliver a full record of methods used to test.
- Signature blocks are included for the installing activity and receiving unit.
- A copy should be left at the station and the original returned to the Project Manager's command.

Team Leader Duties

The Certification Team Leader is responsible for submitting a memorandum documenting the results of the certification not more than 30 days after certification completion, with a copy to the unit.

The certification memo should include the following:

a. References – All applicable references, Approved Engineering Changes, Projects, and Table of Electronic Drawings (TEDs).

b. Tests – If any tests other than equipment operation were performed, then these tests should be listed.

c. Installations –All installations are listed and annotated as to which were satisfactory or unsatisfactory.

d. Discrepancies – All discrepancies are listed and the party responsible for correction recommended.

e. Training – All training performed by the installing activity or contractor.

f. Recommendations – Any recommendations provided concerning changes to unit, system or equipment configurations or unsatisfactory installations.

g. Commendatory remarks –Any commendatory remarks concerning the quality of work performed, if appropriate.

Samples of a certification memo with a list of discrepancies are shown on the following pages.

Continued on next page

Reports of Completion

Upon completion of an Engineering Change, the unit fills in the completion section of the Engineering Change Authorization Form (CGHQ 3379).

- The unit then forwards two signed copies, one to the ELC and one to the servicing MLC.
- The unit also retains a copy in their files.

Configuration Change Forms (OPNAV 4790/CKs) are used to notify the ELC of the completion of an authorized Field Change or Platform/System Engineering Change that affects the unit's configuration.

- Units which are MICA/CALMS supported shall also submit a Configuration Change Form (OPNAV 4790/CK) when directed to do so by the Engineering Change.
- A unit that receives a class-related Engineering Change that does not apply to their particular boat/cutter/unit must note the same in the completion section of the form and send the signed copies as noted above.

Unit Records Responsibility

Each unit shall maintain a file of pending and completed Engineering Changes as part of the general engineering files, in accordance with Chapter 090 of the Naval Engineering Manual, COMDTINST M9000.6 (series).

- Appropriate entries must be made in the Machinery History, Hull History, etc.
- Units must also update their CMplus database to reflect completion of Engineering Changes.

ELC Records Responsibility

The ELC shall maintain the master Engineering Change file for all cutter and boat classes.

- This file will contain the original signed copies of each Engineering Change issued.
- The ELC shall also maintain a case file for each Engineering Change proposal. This file shall be a historical repository of all relevant documents associated with the Engineering Change issue.

Continued on next page

Field Change Bulletin

Field Change Bulletins (FCB) document approved changes to a Configuration Baseline. The SMEF is responsible for the development of Field Change Bulletins.

- Upon completion, a copy of this field change bulletin shall be inserted in front of all applicable technical manuals.
- Cognizant commands shall ensure that the field change has been accomplished and that applicable technical manual annotations and reports have been made.

Field Change Accomplishment Plate

A Field Change Accomplishment Plate shall be affixed, in a visible location, to all electronic equipment.

- Record completion of all field changes on the Field Change Accomplishment Plate.
- Each equipment that has an applicable field change should be physically checked, using the identification paragraph of the field change bulletin and the "Field Change Accomplished" plate, to ensure that the field change has actually been installed.
- Applicability of Coast Guard field changes may be verified in the CGPMS Work Schedule Book.

ORDALTS

ORDALTs are approved alterations to Navy-owned weapon systems. A list of all ORDALTs on Navy-owned weapon systems is provided in Navy publication NAVSEA ORDALT 00. Cutters shall submit an OPNAV Form 4790/CK within 30 days of an ORDALT installation. Consolidated Ship Allowance Lists (COSAL) updates are based on the information contained on Form 4790/CK.

(2) The installing activity shall return completed ORDALT sign-off sheets to the In-Service Engineering Activity/Agent (ISEA) to document proper installation.

Equipment Configuration Changes. All changes to equipment configuration shall be reported via Ships Configuration Change Form (OPNAV Form 4790/CK). Normally such changes will be the result of an ORDALT.

Continued on next page

Installation/Change Documentation (Continued)

CMplus Entries

Those units having and using CMplus (any version) must enter completed field changes into the unit configuration management database.

OPNAV 4790/CK Configuration Change Form

For any configuration change, (installation, de-installation, modification /field change, ORDALT), an OPNAV 4790/CK Configuration Change Form is required to be submitted.

- WHECs and 270' WMECs submit paper copy 4790/CKs to the local NESU for processing into the MDS.
- All other units submit paper copy 4790/CKs to the to the Configuration Data Manager at the ELC for processing:

  Engineering Logistics Center (Code 016)
  707 Ordinance Road
  Baltimore, MD 21226

Sample Engineering Change Certification Memo

U.S. Department
of Transportation

**United States
Coast Guard**

Commandant
United States Coast Guard

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: G-SCE
Phone: (202) 267-XXXX
Fax: (202) 267-4617
Email:

10550
20 Jun 2002

MEMORANDUM

From: John Doe, Rank

Reply to
Attn of:

To: Commandant (G-SCE)

Subj: TYPE A ELECTRONICS INSTALLATION CERTIFICATION OF USCGC CERT (WHEC 174)

Ref: (a) Electronics Manual, COMDTINST M10550.25A
(b) SHIPALT 378-B-204
(c) CG Yard Project 17214

1. As outlined in reference (a), a Type A certification of electronic equipment installed on CGC CERT was performed by the following personnel from 1 to 4 September 1998:

LT SMITH COMDT (G-SCE)
CWO SMITH CG YARD
CWO SMITH MLCLANT (te)
CWO SMITH CGC CERT
ETC SMITH CGC CERT

2. All installations authorized by references (b) and (c) were done satisfactorily with only minor discrepancies. The installations certified were the following:

AIMS-MK-XII-IFF System
TDL-708 LORAN-C Receivers
SR-216 MF Transmitters
Constant Level Amplifiers
Rewiring of CIC Evaluator

3. Enclosure (1) is a list of minor discrepancies. Parties responsible for correcting discrepancies are also listed.

4. Installations made by CG Yard personnel were done in a professional manner. Cooperation of shipboard personnel was excellent.

#

Subj: TYPE A ELECTRONICS INSTALLATION CERTIFICATION OF USCGC CERT (WHEC 714)

10550
20 Jun 2002

Enclosures: (1) List of Discrepancies

Copy: MLC(t) (as appropriate)
COMDT (G-SCE) (if applicable)
CGC CERT(WHEC-174)
CG Yard
G-S Centers of Excellence as Appropriate

LIST OF DISCREPANCIES

1. Power feed cable to panel (01-156-2) in STTY not labeled. (CG Yard correct.)

2. Power feed cable to panel (01-158-1) in the Air Search Radar Room not labeled. (CG Yard correct).

3. Power panel (01-156-2) in STTY:
   a. Feeder cable tag information incorrect. (CG Yard correct).
   b. Feeder cable information not contained on power panel label. (CG Yard correct).

4. Power Panel (01-155-1):
   a. Label plate missing. (CG Yard correct).
   b. Incorrect label on feeder cable. (CG Yard correct).

5. Feeder cable to power panel (01-155-0) incorrect. (CG Yard correct).

6. No label on power panel (01-146-22). (CG Yard correct).

7. The AN/UNQ-7D Tape Recorder used with the ESM system was inoperative. (Ship's force correct).

8. The modifications to the towed body storage rack in the Sonar Equipment Room were not accomplished due to delay in parts delivery. (District correct.)

9. The VHF-FM antenna (Type 925) should be replaced with a Columbia Products Mode 420 (District correct).

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Practice Exercise

Introduction

Use this exercise to increase the retention of the material covered in this lesson. The directions for each exercise will be given with that exercise/s. The answers to the exercise/s will be in the feedback section.

Exercise Questions

Indicate your answers to the following questions, and then check the Feedback on the next page.

1. An Engineering Certification Checklist is used to "_____" the installation.
2. The Certification Team Leader is responsible for submitting a memorandum documenting the results of the certification not more than _____ days after certification completion, with a copy to the unit.
3. What is/are used to notify the ELC of the completion of an authorized Field Change or Platform/System Engineering Change that affects the unit's configuration?
4. Who shall maintain the master Engineering Change file for all cutter and boat classes?

Feedback

Exercise Answers

Compare your answers to the following:

Question	Answer	Reference Page
1.	Certify	2-2
2.	30	2-2
3.	Configuration Change Forms (OPNAV 4790/CK	2-3
4.	ELC	2-3

Appendix A
PAMPHLET REVIEW QUIZ

1. Intermodulation is primarily caused by _____ .

   A. one frequency in a nonlinear element
   B. two or more frequencies in a nonlinear element
   C. two frequencies mixing in free space
   D. one harmonic frequency in a nonlinear element

2. Which type of EMI is classified as natural interference?

   A. Precipitation static
   B. Image frequency
   C. Modulated carrier frequency
   D. Unmodulated carrier frequency

3. Interference from arcing is sometimes misinterpreted as a high _____ level

   A. harmonic radiation
   B. ambient noise
   C. cross modulation
   D. modulation

4. Nonlinear intrusion is usually the result of _____ .

   A. nearby transmitter radiation
   B. spurious outputs of transmitters
   C. broadband noise from receivers
   D. unwanted signals entered in the passband of the receiver

5. When a welded junction aboard ship receives a signal and radiates this signal, a receiver will detect signals _____ .

   A. at the fundamental frequency
   B. at the harmonic frequency
   C. at the sum and difference frequencies
   D. on all bands due to spurious signals caused by the junction

6. Loss of the desired signal in a filter is known as _____ loss.

   A. shunt
   B. mismatch
   C. impedance
   D. insertion

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Appendix A

PAMPHLET REVIEW QUIZ (CONTINUED)

7. Broadband interference is usually caused by ______ .

   A. a nearby CW transmitter
   B. harmonic radiation
   C. high-background noise
   D. arcing or corona discharge

8. The difference between intermodulation and cross modulation is that intermodulation results in ____ .

   A. nonlinear distortion
   B. arcing in the transmitter PA
   C. the generation of many new frequencies
   D. the transfer of a signal from an undesired RF carrier

9. A communications receiver has a steady crackling or rattling in its audio output. The cause of this interference is probably _____ .

   A. nonlinear intrusion
   B. distant thunderstorm
   C. generator slot harmonics
   D. a nearby overmodulated transmitter

10. The only way to eliminate hull-generated EMI is to _____ .

    A. install multicouplers
    B. increase antenna spacing
    C. make the entire topside structure a single conductor
    D. limit the number of ship's operating transmitters

11. What shall be affixed, in a visible location, to all electronic equipment?

12. What are approved alterations to Navy-owned weapon systems called?

13. Cutters shall submit an OPNAV Form 4790/CK within _____ days of an ORDALT installation.

14. What documents approved changes to a Configuration Baseline?

15. Each unit shall maintain a file of pending and completed Engineering Changes as part of the general engineering files, in accordance with Chapter 090 of the ____________________.

Appendix B

PAMPHLET REVIEW QUIZ – ANSWER KEY

Question	Answer	Reference Page
1.	B	C-2
2.	A	1-5
3.	B	1-14
4.	A	1-24
5.	A	1-33
6.	D	C-2
7.	D	1-8, C-1
8.	C	1-17
9.	B	1-5
10.	C	1-36
11.	Field Change Accomplishment Plate	2-4
12.	ORDALTs	2-4
13.	30	2-4
14.	Field Change Bulletins (FCB)	2-4
15.	Naval Engineering Manual, COMDTINST M9000.6 (series)	2-3

Appendix C

GLOSSARY

Bandwidth The frequency separation between the 3 db cutoff frequencies. If the term is applied to a low-pass filter, it means the band from DC up to the cutoff frequency.

Below Decks and Interior Areas The inner or inside area of a ship. It consists of all areas in the interior of a ship from the lowest to the highest level.

Bonding (Bond) An electrical current path between two metallic surfaces established by welding (class A bond), bolting or clamping (class B bond), or the addition of a bond strap (class C bond). The direct (dc) resistance across bonded surfaces (not using the bolt, clamp or bond strap as one of the surfaces) must be 0.1 ohms or less.

Conduit A metallic structure containing one or more ducts used to protect and support wires and cables of electrical and electronic systems and to provide sufficient attenuation to radio frequencies for reduction of RF interference.

Corona A luminous discharge which occurs when a gaseous dielectric material, such as air, is subjected to high voltage and the gas ionizes. In high voltage equipment, the corona is most likely to be found in the air gap adjustment to high voltage buses, bushings, locations where small air gaps are present, and where the electrostatic field is non-uniform. For uniform fields, a corona usually precedes arc breakdown. The corona produces broadband interference at random frequencies and is very difficult to suppress.

Cutoff Frequency The frequency, or those frequencies, toward the edge of the response at which the attenuation is 3db greater than the insertion loss value. The reason for specifying the edges of the response is that some practical bandpass filters might tolerate a 3db (or greater ripple) in the bandpass.

Direct Bond The joining of two metallic surfaces by welding, brazing, or soldering.

Electrical Equipment Equipment that, by design, is not intended to generate radio frequency energy. Examples are: electric motors, office equipment, ship repair equipment, power supplies, ultrasonic equipment, medical equipment, and fluorescent lights.

Electrical Space A space used primarily to house installed units of electrical equipment. Spaces include 60-hertz and 400-hertz motor-generator (MG) rooms, power switchboard distribution rooms, gyrocompass rooms, and internal communications spaces. Spaces occupied by both electrical and electronic equipment are classified as electronic spaces.

Continued on next page

Appendix C

GLOSSARY (CONTINUED)

Electronic Equipment	Any item which uses electromagnetic properties to generate, transmit, convey, acquire, receive, store, process, or use information. Communications, radar, sonar, countermeasures, navigation, control, armament, computers, and test equipment are examples.
Electronic Space	A space used primarily to house installed units of electronic equipment. Spaces include radar rooms, EDM rooms, radio central, radio transmitter rooms (VHF-UHF), crypto rooms, chart rooms, CIC, ASW control rooms, television equipment spaces, and computer equipment spaces.
EMI	An electromagnetic or electrostatic disturbance that causes malfunctioning, or an undesirable response, in one or more electronic receivers. It may also include a condition which does not meet the requirements of interference tests.
Grounding (Ground)	The process of physically providing a metallic surface with a low resistance or impedance path to ground potential. (On metallic hull ships, the ship's hull is considered to be ground potential.)
Impedance Level	The value in ohms from which, and into which, the filter is to work. The input and output impedances may be the same or different, though they are often the same in communication work.
Indirect Bond	All bonds achieved by use of interconnecting straps, cables, etc.
Insertion Loss	The attenuation of the desired signal due to the insertion of the filter when properly terminated. Ideally, this should be zero – practically, it is kept as small as possible.
Intermodulation interference (IMI)	An electromagnetic (EM) disturbance resulting from the generation of frequencies equal to the sum or difference of integral multiples of two or more frequency sources when mixed in a nonlinear junction. The interference can be equipment generated or result from energy mixing in corroded junctions of ship's structure or rigging, and to a lesser extent, in ferrous metal parts in the RF path.
Mismatch Loss	The attenuation suffered because of impedance mismatch in the system. Sometimes mismatch loss and insertion loss are inseparable – in other cases, they are distinctly different.
Nonlinear junction	A contact area between two metallic surfaces which exhibits nonlinear voltage-current transfer characteristics when subjected to an RF voltage. This nonlinearity is usually caused by corrosion or other semi-conducting materials in the contact area.

Continued on next page

Appendix C

GLOSSARY (CONTINUED)

Power Handling Capacity	The average power that the filter will safely pass without degradation or failure of any component.
Q-Factor (applies to bandpass)	The ratio between the center frequency to the 3db bandwidth (defined as f2 - fl). A high Q-factor indicates good selectivity.
Shape Factor (for bandpass)	The ratio of the 60db bandwidth to the 6db bandwidth. It defines the selectivity of an amplifier stage
Spurious Emissions	Emissions from a transmitter at frequencies outside its assigned or intended frequency, including harmonics, parasites, and intermodulation product.
Topside Areas	Those areas on and above the main deck that are exposed to weather.
Transmission Lines	Structures forming a continuous path from one place to another for directing the transmission of electric or electromagnetic energy along this path. The term "transmission lines" includes such items as; telephone lines, power cables, waveguides, and coaxial cables.

Request for Feedback – ET1 UNIT 4: ELECTRONIC EQUIPMENT INSPECTION & VERIFICATION

Suggestions and Corrections

Please note your suggestions, corrections, and comments below:

Page	Location on Page	What Correction is Needed

Your Comments

If you were writing this pamphlet, what improvements would you make? What was good about it? What did you not like about it? Please be specific in your comments/suggestions.

To Contact You

Please provide the following so that we can contact you if needed.

Name	Unit	Phone
		( )

Mail, Fax, or Call

Please mail, fax, or call your information to:

Commanding Officer
U.S. Coast Guard Training Center
Petaluma, CA 94952-5000

PHONE/FAX: (707) 765-7129/7033

ATTN: ET Subject Matter Specialist