EMI SUSCEPTIBILITY SOURCES

Introduction

Devices using electrical power are susceptible to electromagnetic interference and interactions in several critical areas. The detrimental effects extend from nuisance type to malfunction of equipment. The dynamic range is compressed, gain is reduced at many frequencies, and threshold levels or false alarm rates deteriorate. Devices become conditionally stable and occasionally break into oscillations. Equipment can become increasingly vulnerable to jamming and accuracy may be completely lost. The system's compatibility may be adequate when it is delivered but without proper design the compatibility will not continue under normal use and aging. The following are some of the causes and effects of susceptibility.

Overloading: Overloading is caused by an increase in the amplitude of the desired signal. The increase may drive the channel into saturation so that no output response will result from an input command. There is a time lag between the period that the device goes into saturation and recovers from it. When the device becomes overloaded or saturated the position of the shaft may drift or run to its zero position or to the extreme unbalance at one or the other ends of its excursion.

Blocking: Blocking occurs in systems when an undesired input renders a channel ineffective, e.g., the blocking of the radar receiver by the transmitted radar pulse. Because of space and complexity limitations, the same waveguide and antenna system is often used for both transmitter and receiver. Although the radar receiver is isolated from the antenna and waveguide assembly during the time the transmitter is on, the transmitted pulse still leaks into the receiver. The receiver sees this RF energy as a returned signal of high amplitude. It saturates the radar receiver and when the pulse is over the receiver remains blocked. Unintentional blocking of one function by another can occur on a continuous basis or it may only produce a blind spot in a cycle of the operation. Continuous blocking can almost always be detected during the functional checkout and testing if the offering source or jammer is activated. The intermittent or partcycle blocking usually occurs when different equipments are integrated together into one system.

Offsets: Offsets may occur as a result of conducted, coupled, or radiated energy which may be internal or external to the system. Equipment is susceptible when its output may be offset or biased from that which should occur for given command inputs.

Dielectric Heating: At high frequency, dielectric materials exhibit a loss phenomenon which is analogous to hysteresis loss in magnetic materials. The material between the bridge wire and the case of a squib is susceptible to such effects. In the presence of high power jamming or radar equipment, squib action can occur due to dielectric heating.

Heating Value: When AC or DC current flows through any resistive device, the energy dissipated in the form of heat is I^2R. Heat can act as an undesirable signal and can cause heating of devices which should not be heated without the application of a specified control current or which have operating characteristics dependent on temperature. The AC resistance cannot, in general, be assumed to be the same as the DC resistance. Squibs, for example, which have DC resistances under one ohm characteristically exhibit 30-40 ohms at UHF frequencies. I^2R loss is further dependent on the reactance portion of the AC impedance. The reactance of a squib varies from zero to several hundred ohms at UHF and changes from inductive to capacitive. No power can be dissipated in a reactance, but it does control the current flowing through the AC resistance in series with it.

Spark-Through: Static voltages can build up on isolated or floating circuits. Winds blowing over ungrounded wires have resulted in static voltages which have caused inadvertent squib detonation. Squibs which employ ungrounded and shielded input cabling are subject to spark-through and placing a short across the squib input terminals will prevent inadvertent firing. Statis buildup in other circuitry causes the ungrounded secondary of a transformer feeding an ungrounded amplifier grid to be subject to error.

False Triggering: If a stray or false signal exhibits the characteristics of the true signal there is no way that a device (mechanical, electronic or human) can detect it.

False Signals: Bandwidth is the important consideration when evaluating susceptibility to false signals. Closed loops, servomechanisms, and regularors can often tolerate high levels of noise and false signals because of narrow bandwidth. Susceptibility to broadband noise is evaluated by determining the frequency spectra of the noise. Give consideration to the response of the system loop beyond its normal cutoff frequency. These characteristics are important because a high level interfering signal may exist a few octaves above the normal cutoff frequency and may be strong enough to penetrate the attenuation.

Stray Resonances: High-gain amplifiers are particularly subject to stray resonances. Capacitors which should ideally exhibit low impedances toward self-resonance and a high effective reactance to ground. Lead length inductance may be high enough to resonate with bypass capacitances below the normal frequency of operation. For example, at 10 MHz, a 1000-pf bypass capacitor will series resonate with only 1/4-μh inductance.

Subaudio Interference: Some important aspects of subaudio interference susceptibility are that it is not often sustained for more than a few seconds; that it is difficult to detect; and that it is usually superimposed on desired signal flow and marked by higher frequency hash, which is ignored by the loop. Subaudio interferences are generated as airborne vehicles exhibit dynamic structural resonances. The approximate frequencies of different vehicle assemblies resonate as follows: (1) the total vehicle resonates at a few hertz, (2) structural resonances go up to 10 hertz, and (3) bulkhead and equipment racks resonate at hundreds of hertz. Equipments and cable bundles vibrate as the airborne vehicle experiences agitation and electrical disturbances result in two ways: either transducers and sensors "see" the resultant displacement, velocity, or acceleration and generate an undesired output signal; or wires, cables, and bundles are moved through electric and magnetic fields. Induced voltages and current result, and under these conditions, rate gyros have produced enough undesired output to cause gross guidance disturbances.

Clipping: Clipping can generate unintentional effects in demodulator and detector circuits.

Limiting: When a desired signal frequency is intentionally limited, the output waveform is distorted. The networks to which the limited waveform is fed may be responsive to the harmonic frequencies of the distortion and produce a false output. Tuned circuits may exhibit spurious resonances at those frequencies. As limiting action is made stronger, the wave form of the original signal will be made steeper and will have higher frequency components which couple across transformers, resistors, amplifiers, stray capacitances, etc.

Receiver Sensitivity: All receivers exhibit an on-frequency sensitivity variation which is frequency-dependent. The image response of all receivers also varies as the receiver is tuned across the band. At a specific high frequency the shielding, decoupling, and bypassing components become self-resonant. At this point the interference begins to flow through the receiver by electrostatic coupling.

High Power Environments: Receivers are now designed without precautions against operation in high-power environments. In such an environment undesired responses can be categorized as destructive heating of front-end components, image responses, local oscillator harmonic heterodyne responses, stray resonant responses and high-end electrostatic coupling. The kilowatt and megawatt peak-power levels are capable of destructive effects in receiver front-ends. In addition, modulation characteristics can be detected by the receivers. The stray responses vary widely due to nonuniform components, wiring inductance, stray capacity, and layout variations.

Generation of High Level Fields

What is an EMI Susceptibility Generator? It is a signal generator, a power amplifier, a broadband power source, a spark gap and coil, or any device with a power output of sufficient magnitude to determine the susceptibility or vulnerability of an object under test.

Susceptibility is a term used in the Interference Technology to describe an equipment or systems' undesirable response to externally applied energy. This energy can be applied to an antenna to establish a radiation environment, and is commonly called radiated susceptibility test. It is also applied to power and other lines through coupling capacitors or current probes, and is commonly referred to as conducted susceptibility test.

When considering the purchase of an EMI susceptibility generator, you should look for features which could provide considerable time savings in the performance of tests. For instance, the peaking of the signal at each test frequency could take enough labor costs to pay for an expensive broadband source which is commercially available after one lengthy test. Some of the important features you should look for are:

1. Protection against damage under any magnitude or phase of source and load VSWR;
2. No tuning or band-switching (broadband);
3. Reproduction of AM or FM modulation appearing on the input signal;
4. Compatibility with reactive antennas;
5. Suppression of harmonic products;
6. Versatility in use for other purposes; and
7. Bandpass ripple.

Conducted Susceptibility

The application of a susceptibility signal to a power line may not be as simple as it may first seem. The use of a current probe will provide impedance isolation between the line and the power source. However, the probe which inductively couples the energy into the line may have losses. There is a danger of burning out the impedance matching resistors in the probe when applying high levels of energy. The lines must be monitored to determine the amount of energy pick-up by the line.

When susceptibility voltages are specified, capacitors are often used as the coupling device. The impedance of the capacitor must be small at the frequency of operation to avoid significant voltage drops across the device. Although the capacitor provides isolation between the source and line at low and power line frequencies, no isolation is present at the test frequency. Thus, when the line impedance is low, it will tend to load down the power source making it difficult to develop the desired voltage level. With an unlimited power source, it may be possible to burn out the equipment under test without ever reaching the desired or maximum safe voltage level.

For frequencies below 50 KHz, an isolation transformer is used as the coupling device. The secondary winding of the transformer is connected in series with the line under test, and must have a negligible impedance at the test frequency. The power is then applied to the primary winding and "modulates" the line. At power line frequencies, there is some danger of power being fed back to the power source causing damage to the source.

Radiated Susceptibility

Radiated susceptibility tests are usually performed to assure that the test specimen will operate in its intended radiated environment. The irradiation levels are either specified by a standard, or determined through a study or prediction of the intended environment. For instance, if you know that your equipment has to operate near a microwave oven, a radio or TV antenna installation, or close to communications equipment, the equipments' response to these fields should be tested in the laboratory. A measurement or calculation can define the field intensity (volts per meter) or power density (watts per square meter), and frequency of the environment. Then, by obtaining the proper antennas and power sources, it can nearly be duplicated in the laboratory.

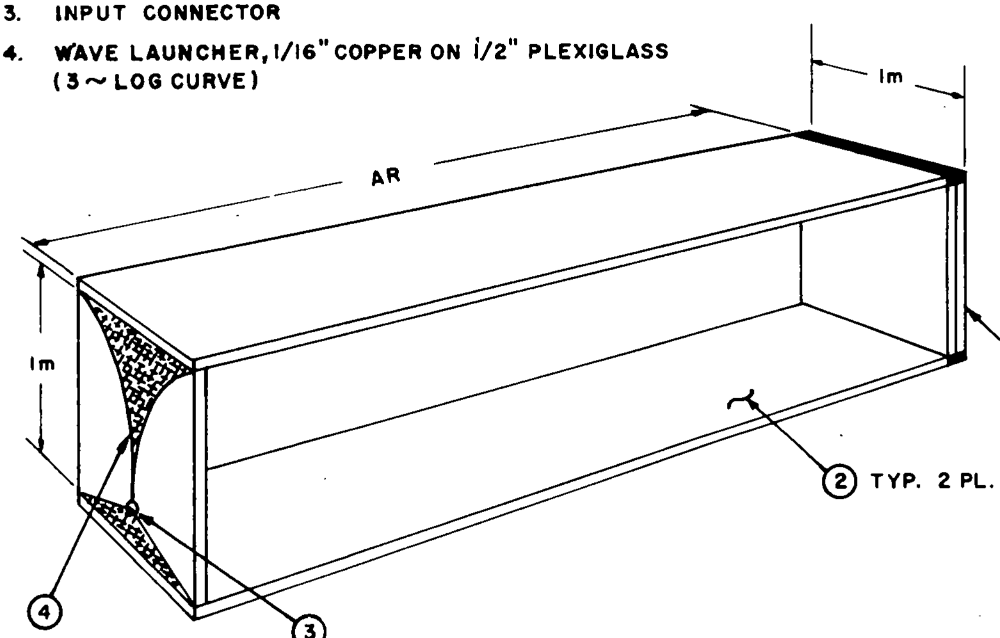
Military and other specifications define the fields which must be generated and imposed on electronic equipment. The earlier specifications merely defined the type of antenna to use as a function of frequency, specified the open circuit voltage into the antenna terminal, and the distance between the antenna and the test specimen. The frequency ranged from 150KHz to 106Hz. The Signal Corps was the only service to specify field intensity rather than antenna applied voltage.

The most widely used modern-day Government specification, MIL-STD-461A, specifies the required frequencies, test distances, field intensities and test antennas. However, considerable flexibility is allowed by the statement, "Antennas other than those specified can be used if described in the test plan and approved by the procuring activity." For several years, the standard required a susceptibility field strength of 1 volt/meter from 14kHz through 10GHz. However, in its Notice 3 and 4 revision the levels were changed as shown in Table 1 in the "Military EMI Specifications" section of this book.

Obviously, radiated levels of this order of magnitude cannot be generated using standard laboratory equipment. The military has found these levels to be realistic of intended environments. The consumer product manufacturer may also be surprised to learn the environments in which his products are operated.

A major drawback of the EMI specifications, and a trap that many product manufacturers may fall into, is the unchallenged application of a single modulated CW frequency. Often, there are two or more radiators generating the severe intended environment, and the combined effects on products or systems can be considerably different from that of a single CW signal. An undesirable response to a single CW signal can be referred to as a spurious response, but multiple signals produce intermodulation and cross-modulation products which can result in an undesirable response of the equipment under test. Also, a CW signal cannot realistically simulate the radiated environment of a fluorescent light, commutator noise from a motor, or automotive engine noise.

1. TERMINATION, COMPRISED OF THREE SEPARATED LAYERS OF 377 Ω/□ CONDUCTIVE PLASTIC FILM, JOINED AT ENDS AND CONNECTED TO CONDUCTIVE PLANES, ITEM 2 (≈ 125 Ω)
2. CONDUCTIVE PLANES, ALUMINUM, SLOTTED LONGITUDINALLY 1/2" O.C.
3. INPUT CONNECTOR
4. WAVE LAUNCHER, 1/16" COPPER ON 1/2" PLEXIGLASS (3 ~ LOG CURVE)



NOTE: ITERATIVE IMPEDANCE OF LINE, Z_0 = 120 Ω

Figure 1: Parallel Plate Line

Figures 1 through 3 illustrate the construction of a state-of-the-art parallel plate lines. (These figures are taken from chapter 6, section 6B of AFSC DH 1-4.) This design incorporates many good features and improvements as follows:

a. The longitudinal slots in the paralled plates prevent transverse current and help to maintain the TEM mode of propagation.

b. The termination reduces coupling between the end of the line and the shielded room wall. Each layer of conductive plastic (377 ohms/square) reduces the energy passing through by 6dB/later so that coupling is reduced by 36dB for the 3 layers.

c. The input is designed as a wave launcher rather than a matching section. The shape of the launcher has been determined empirically to minimize variations of wave front homogeneity at the sending end. The input is suitable for low-impedance (4 ohms) spike generators or conventional 50-ohm signal sources.

Grounding Investigations have indicated that grounding the bottom plate to the ground plane along its entire length creates a nonuniform field, concentrated along the grounded side. It is recommended that the bottom plate be grounded only at the termination, over the entire width of the bottom plate.

RF Power The parallel plate line will accept 250 watts continuously. Figure 4 shows that the typical RF power required to generate a 10 V/meter field. Each line should be calibrated individually.

Transmission Line Figure 4 illustrates the "electrical" construction of a transmission line atenna. Framing, bracing and supports are not shown. This antenna will accept 250 watts continuously.

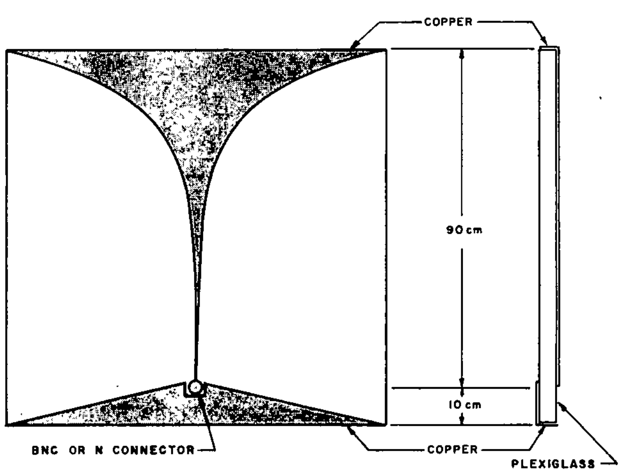


Figure 2: Wave Launcher Detail

RF Power Required to Generate a 10 V/m Field in
Parallel Plate Line Model

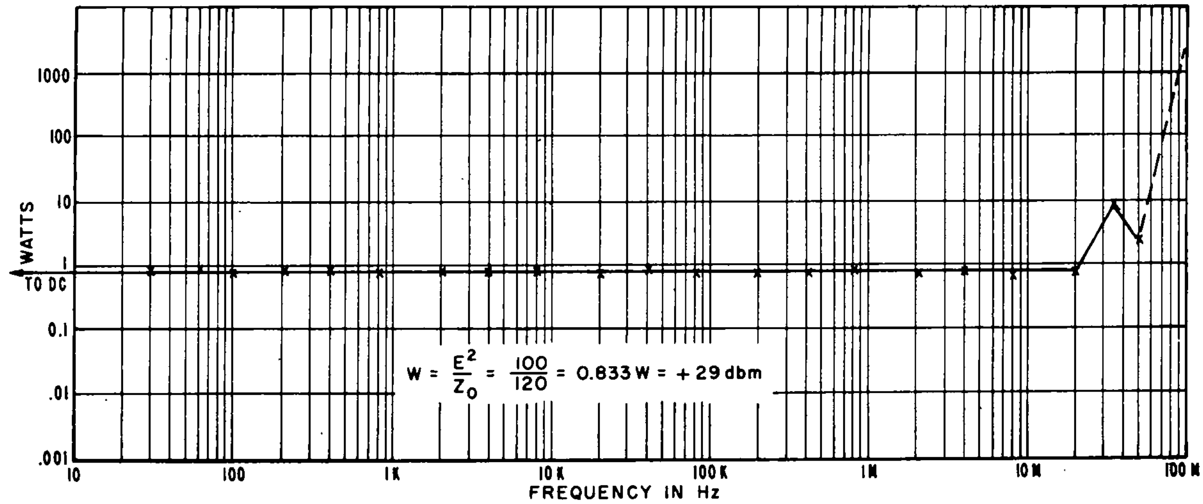


Figure 4: RF Power Required to Generate a 10 V/m Field in Parallel Plate Line Model

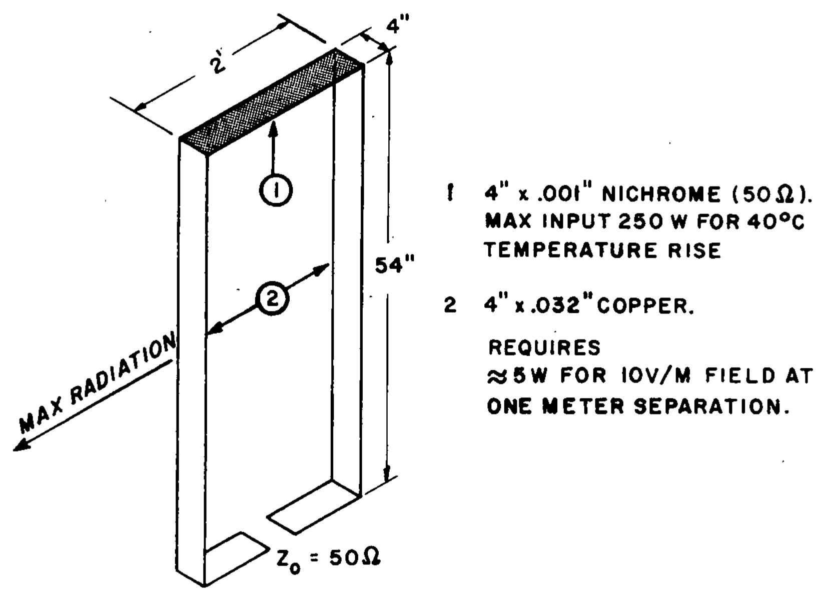


Figure 5: Transmission Line Antenna

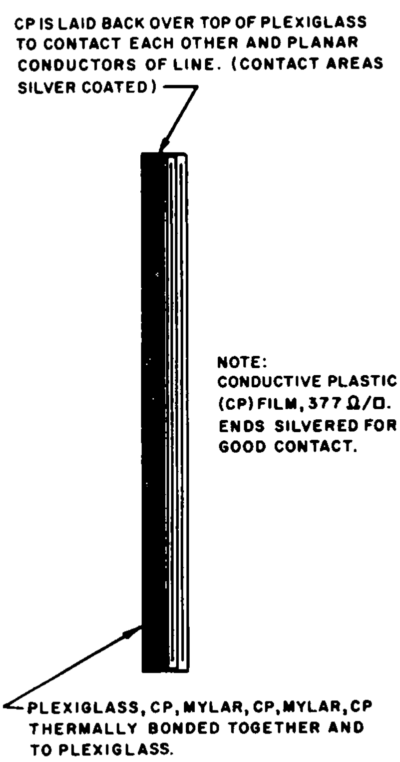


Figure 3: Termination Detail

Test Facilities

Conducted susceptibility tests may be performed in the open laboratory. However, the susceptibility signal may propagate through the laboratory's power lines and interfere with other equipment. The power lines also have the capability of radiating the energy. To protect the rest of your laboratory, power line filters should be used. An inductor should be placed between the filter and the coupling device so that the filter will not load down the susceptibility signal source or in other ways effect the results of the test.

A shielded anechoic chamber would probably provide the best facility in which to perform radiated susceptibility tests. The anechoic material is absorbative usually above 100MHz (depending upon size and shape of the anechoic material), and reflections from the walls are 30 dB or more down at the point of the test sample. Significant reflections and perhaps standing waves will be present at frequencies below the cut-off frequency of the anechoic material. However, the FCC, OTM, other laboratory users and the general public would greatly appreciate the containment of these high signal levels. Many cities and towns have ordinances to this effect, especially when your signals may interfere with police and fire communications.