BASIC EMI MEASUREMENT TECHNIQUES

In order to properly analyze your EMI problem, basic measurement techniques are required. Measurement techniques covering conducted and radiated emissions, as well as conducted and radiated susceptibility, are presented to give the reader an idea of what has to be done to perform these measurements. Typical test set-ups are presented to indicate the type of equipment required for EMI measurements.

INTRODUCTION

Analysis and solution of EMI problems is only as good as the ability to make accurate basic EMI measurements. EMI measurements can be broken down into the following categories such as:

Emissions
Susceptibility

These are further divided into:

Conducted measurements
Radiated measurements

Various EMI specifications covering commercial, government and military requirements are available which deal with various aspects of EMI. Some of these are FCC Rules and Regulation Part 15 entitled "Radio Frequency Services" which deals with incidental Radiation from RF Devices; MIL-STD-461A "Electromagnetic Interference characteristic requirements for Equipment"; MIL-STD-462 "Electromagnetic Interference Characteristics, Measurement of"; DO 160 entitled "Environmental Conditions and test Procedures for airborne electronic/Electrical equipment and instruments"; and MDS-201-0004 "Electromagnetic Compatibility Standard for Medical Device", a proposed specification dealing with medical instrumentation. Each of these specifications have the four basic tests listed above but in varying forms.

Emissions—Emissions are conducted and radiated levels of RF energy emanating from the particular item under test which can interfere with other equipments.

Susceptibility—Susceptibility levels are determined by feeding conducted and radiated RF signals into an item under test to determine to what degree the item can withstand the various RF energy being injected into it.

CONDUCTED EMISSION MEASUREMENTS

In order to analyze your equipment such as an electrical appliance, office or communication equipment, conducted emissions are normally performed first. This generally gives one a good insight into the problems that may lie ahead.

The first conducted emissions test is that of the power input lines to determine the RF levels being emanated to the "outside world" via power lines, line impedance stabilization networks, or 10 μfd feed through capacitors are inserted in series with the power line between the item under test and the power source. In this manner the impedance of the power source is stabilized to a nominal impedance of 50 ohms. The LISN* or 10 μfd Feed through capacitor is used depending upon the specification involved, and also whether voltage or current measurements are required. Figure 1 shows a typical conducted emissions test set-up for measuring EMI on power lines.

*LISN (Line Impedance Stabilization Network)

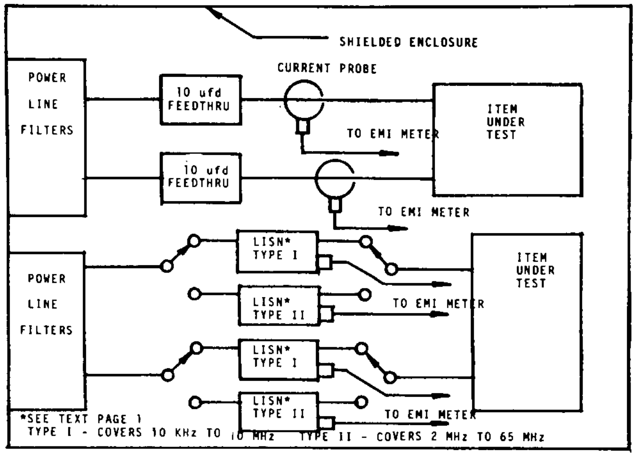

Figure 1. Powerline Conducted Emissions Test Setup Showing Both the Current (Upper Circuit) and Voltage (Lower Circuit) Measuring Setups Normally Used in EMI Specifications.

Conducted emissions measurements are also performed on control and signal leads leading to and from the item under test. The current probe is placed around the leads under investigation and the current measured over the required frequency range such as 14 kHz to 50 mHz or 150 mHz. The amplitude of these signals can then be measured and analyzed to determine whether or not they are causing interference with other equipments. Figure 2 shows a typical set-up for measuring conducted emissions in signal and control lines. Signal and control lines are those lines, other than power lines, connected to your equipment.

RADIATED EMISSION MEASUREMENTS

The next series of emissions tests which are of very great importance, is the radiated emissions testing. This testing can consist of either the electric field or magnetic field emissions. Electrical Field emissions normally cover the frequency range from 14 kHz to 1000 mHz for broadband interference and from 14 kHz to 10,000 mHz for narrowband type emissions. Broadband emissions are those emissions which emanate from electric motors, arcing of switch contacts, rectifier noise and that type of interference which is greater than the band width of the test instrumentation.

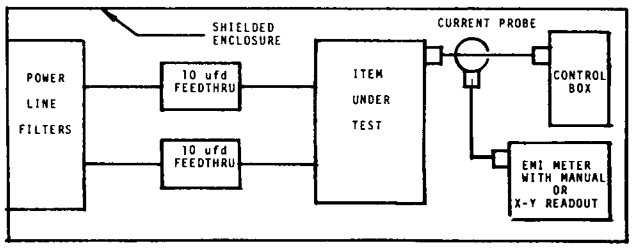

Figure 2. Control Line Conducted Emission Test Setup Showing Clamp-On Current Probe Measuring Conducted Emissions Between Control Box and Test Item.

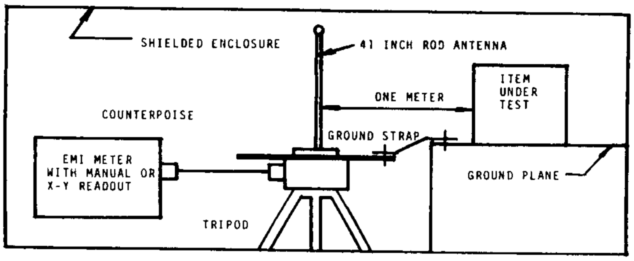

Figure 3. Radiated Electric Field Test Setup

Narrowband emissions are those emissions which consist of single frequencies, such as signals from oscillators, tuned radio circuits, transmitters, and others which emit signals at a given definite frequency and are within the band width of the measurement instrumentation.

RADIATED ELECTRIC FIELD MEASUREMENTS

Electric field radiated emanations are measured using vertical rod antenna in the frequency range of 13 kHz to 30 mHz. Tuned dipole, broadband biconical, and broadband log spiral antenna are used over the frequency range of 20 mHz to 1,000 mHz. From 1 gHz to 10 gHz the ridged wave guide antenna or log conical antenna are used. The ridged wave guide antenna is a higher gain antenna and can be used to detect voltage levels of a much lower order than with the log conical antenna. Figure 3 shows test set-ups for electric field radiated measurements.

RADIATED MAGNETIC FIELD MEASUREMENTS

Magnetic field emanations are normally performed over the frequency range of 30 Hz to 30 kHz. They are also performed on up to frequencies of approximately 25 mHz. Loop antennas ranging from 3 ft. in diameter to 1 ft. in diameter with an electrostatic shield are used to perform magnetic field measurements over these frequency ranges. The larger loop antennas are used at the lower frequencies and the smaller loop antennas are used at the higher frequencies. In magnetic field measurements only the narrow band signals are normally of any importance. It is the fields set-up by oscillators, power line transformers, and other current producing generators that set up magnetic fields which are troublesome. Magnetic field emanations are considered because they can be very difficult to shield from if they are operating in close proximity to sensitive circuitry. Figure 4 shows a typical test set-up employing magnetic field test equipment using loop antenna and calibrated receivers.

Radiated measurements are of great importance to both commercial and military specificattions. Commercial specifications cover radiation from local oscillators of radios, television and other communication equipment which can cause interference with radio compasses and other sensitive communication equipment aboard aircraft. Radiated emissions from broadband sources, such as spark ignition devices used in lawn mowers, motorcycles, automobiles, busses, heating systems, and any other number of applications can cause problems not only in the home but with communication equipment and micro-processing apparatus aboard vehicles. Radiated harmonic emanations from transmitters and oscillators such as dielectric heating equipment and induction heaters are required to be measured to determine whether or not these levels are interfering with regularly scheduled broadcast stations. If they cause problems they can be located and eliminated.

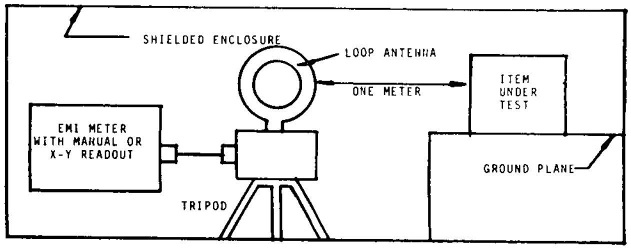

Figure 4. Radiated Magnetic Field Test Setup

SUSCEPTIBILITY MEASUREMENT

Susceptibility measurements are required in order to determine whether or not a particular piece of equipment will malfunction or cause erroneous information to be given out when subjected to either a radiated field of known intensity or a signal which is injected into its power lines. Problems occur in hospital areas where diagnostic measurements of various types are made. Equipments such as EEG, Electroencephalograph, EKG, Electrocardiograph, and EMG, Electromyograph can cause misleading information to make the doctors' diagnosis either incomplete or inadequate in his treatment of his patients. The electric and magnetic fields at various frequencies are set up with intensities of values that would normally be received in the given area such as a hospital near an FM or TV station in a downtown area or in close proximity to the broadcast station. The field intensities can be in the order of 1 v/m to 100 v/m. The broadband nature of these equipments cause them to be very susceptible to external radiation.

RADIATED SUSCEPTIBILITY TEST

These fields are set up in a shielded enclosure so that extraneous fields will not cause problems while the tests are in progress. By simulating known field intensities in the laboratory, a piece of equipment can be analyzed rather thoroughly and the threshold level of susceptibility be determined. If the threshold level is low, and it can be seen that it will cause a problem when placed in its natural RF environment, various means can be then employed to prevent this from happening. One method of generating fields for this type of test is to use high powered amplifiers driven by a CW type oscillator. If desired, the oscillator can be modulated with either AM, FM, or other types of pulse modulation, depending upon the frequency range of the test. Various types of antennas are used to set up the fields necessary to produce the high level of field intensity that is sometimes required. In the lower frequency ranges, from 14

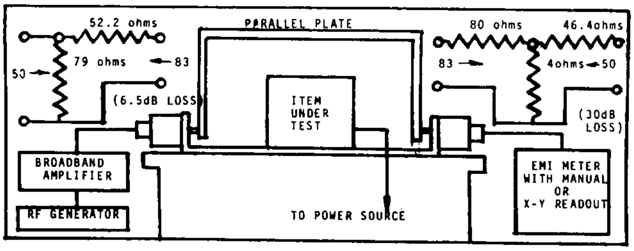

Figure 5. Parallel Plate Setup for Susceptibility in 14KHz to 30MHz Range

kHz to approximately 30 mHz, parallel plate antennas are used if the equipment to be tested is not too large. Rather high fields can be generated in this fashion. Figure 5 shows a parallel plate set-up that can be used to perform tests of this type. If the object is large, then various types of antennas can be used to produce the desired fields. These antennas are then placed at various locátions about the equipment under test so that it will be uniformly radiated with the desired field. At frequencies above 30 mHz, tuned dipole antenna and broadband biconical antenna along with specially designed antennas can be used to create fields of various intensity. The log conical antenna can also be used in the frequency of 200 mHz to 1,000 mHz and also up to 10,000 mHz in order to generate the desired field. Again broadband amplifiers or high powered oscillators, tunable throughout the required frequency range, are used to set up the field intensities required for a given study. Figure 6 shows the biconical antennas and amplifiers and oscillators used while Figure 7 shows a log conical antenna with its amplifier or oscillator. Magnetic field susceptibility measurements are normally performed in the lower frequency ranges from 30 hz to 30 kHz using a multiturn loop antenna. This antenna is energized by amplifiers driven by signal generators which are then placed at a given distance from the item under test and moved about the item over the outer surface of the item to determine if magnetic susceptibility exists. With a given field applied, if susceptibility occurs, the area is located so that it can be further analyzed to determine what might be done to correct the situation.

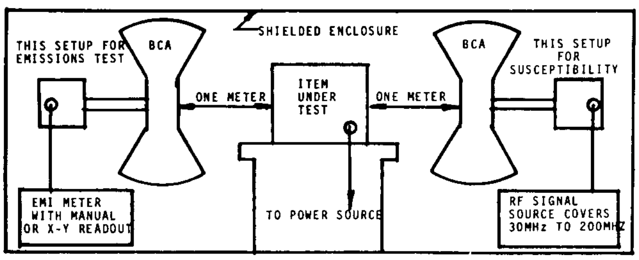

Figure 6. Biconical Antenna Radiated Test Setup. Note Similar Setups Are Used For Either Emissions or Susceptibility Testing.

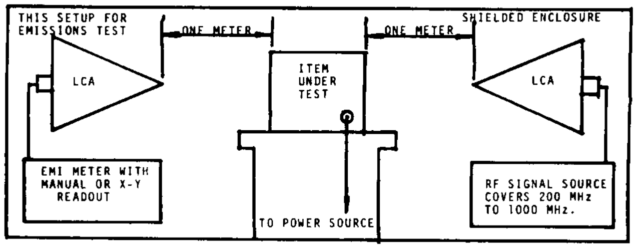

Figure 7. Log Conical Antenna Radiated Test Setup. Note Similar Setups Used For Either Emissions or Susceptibility Testing.

CONDUCTED SUSCEPTIBILITY TESTS

Conducted susceptibility on power lines also takes the form of injecting a voltage of varying amplitude and of varying pulse width onto the power lines. This is used to determine if the equipment is susceptible to voltage spikes on the power line and will cause a malfunction or failure of the equipment, either temporarily or permanently. Spike generators are connected as shown on figure 8, and the pulse injected into the power line on either the DC or AC power line. When injected onto AC power lines the test set-up can be made so that the pulse can by synchronized at any phase relationship with the AC input power.

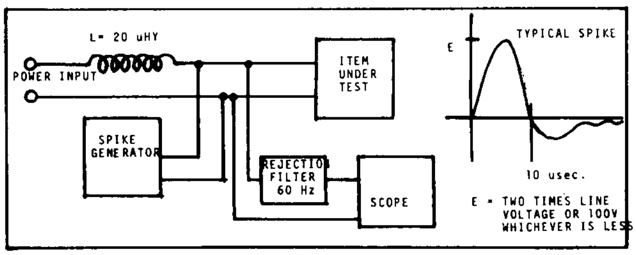

Figure 8. Spike Generator Setup for Injecting Pulses onto Power Lines.

Another type of conducted susceptibility test is to input CW signals directly into the power lines via transformer coupling at low frequencies and capacitor injection at higher frequencies.

In the frequency range of 30 Hz to 50 kHz transformer coupling (see figure 9) is used to inject the interfering signal. The impedance of the secondary of the transformer must be low enough to prevent a significant voltage drop to the item under test. The amplitude of the signal injected into the power lines can be anywhere from 1 v to 10 v RMS depending upon the test specification and problems the item may be subjected to.

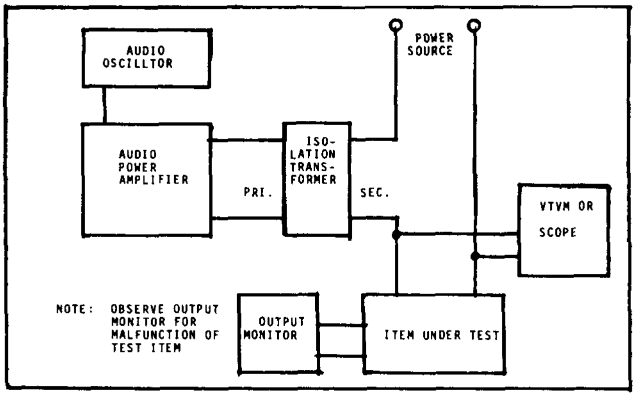

Figure 9. Audio Frequency Conducted Susceptibility Test Setup For 30 Hz to 50 KHz.

Higher frequency susceptibility in the range of 50 kHz to 400 mHz is usually referred to as RF conducted susceptibility and is capacitor injected. (See figure 10.) In this case the apparent power injected into the system is measured to prevent an excess amount of interfering signal from being "pumped" into the item under test. If this precaution is not taken, an abnormal amount of signal will be injected if only the voltage level is measured.

RECEIVER SUSCEPTIBILITY TEST

For receivers, conducted susceptibility measurements are also performed on the RF input to the receiver to determine intermodulation problems and rejection of undesired signals. Intermodulation of a receiver is when two or more emissions outside the receiver bandwidth, but not significantly rejected by the front end, mix in any stage of the RF amplifier or in the mixer by nonlinear action to provide sum and difference frequencies, one of which lies in the receiver pass band. This new frequency is then processed as an intentional signal. Cross modulation is when an adjacent-channel emission sufficiently penetrates the receiver front end to cause any stage of the RF amplifier to perform in a non linear region. When the intentional signal is processed through this amplifier, it becomes cross modulated with the modulation from the undesired signal.

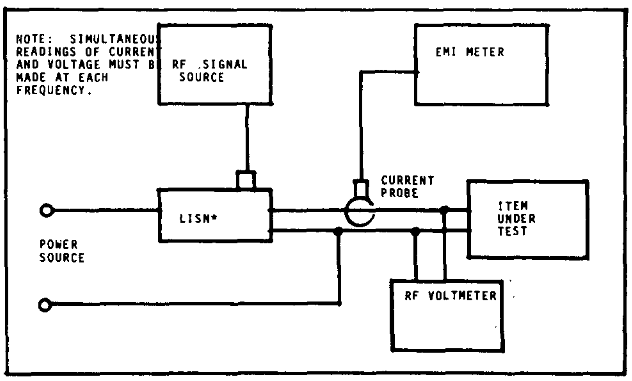

Figure 10. RF Conducted Susceptibility Test Setup for 50 KHz to 400 MHz Range.

The next type of test on receivers is front end rejection, or rejection to out of band emissions. This is when an undesired signal penetrates the receiver front end and mixes with the local oscillator to provide sum and difference frequencies, one of which lies at the receiver IF to be processed like an intentional signal. Examples of these spurious responses are image response, harmonics of the local oscillator, plus and minus the IF, and the same frequencies divided by harmonics of the interfering signal. These test set-ups can become rather complicated and are peculiar to each individual equipment involved, and are mentioned here as some of the types of tests that are to be performed.

For further information regarding these tests, MIL-STD-462 does describe them in more detail as well as the other test set-ups that have been discussed here. Some of the references listed below would be a good start in obtaining more information regarding test procedures. With these basic EMI test procedures almost any equipment can be adequately analyzed to determine how it will function in the "outer world" prior to actually placing the unit in its environment. In this way needless unexpected disasters and retrofitting of equipments can be avoided. This will not only save money but will save a lot of headaches and heartaches along with it.

REFERENCES

1. MIL-STD-461A "Electromagnetic Interference Characteristic Requirements for Electronic Equipment."
2. White, D.R.J., "A Handbook Series on Electromagnetic Interference and Compatibility," Volumes 1 thru 5. (Don White Consultants, Inc. 1971-74)

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