MILITARY EMI SPECIFICATIONS

Introduction

Most military and many other Government agencies require the control of electrical interference in the design of the products and systems which they procure. The specifications most commonly used belongs to the MIL-STD-460 series which includes:

MIL-STD-461A–Electromagnetic Interference Characteristics Requirements for Equipment

MIL-STD-462 –Electromagnetic Interference Characteristics, Measurement of

MIL-STD-463 –Definition & Systems of Units, Electromagnetic Interference Technology

MIL-STD-469 –Radar Engineering Design Requirements, Electromagnetic Compatibility

In the past, the Army, Navy, and Air Force have used a number of general-purpose interference specifications and standards for equipments and subsystems used with shipboard, submarine, aerospace, and ground systems. In general, these specifications were similar but many of the individual requirements and test methods were stated differently and had major variations. Contractors had the problem of analyzing each of these differences to determine whether requirements were, in fact, the same or different. Since thousands of manufacturers did this every time a specification was changed, it became very costly and time consuming.

MIL-STD-461A

The purpose of MIL-STD-461 is to provide military interference reduction requirements in a coordinated document. The standards and specifications superseded by this document are as follows:

Coordinated Documents

MIL-I-6181
MIL-S-10379
MIL-S-12348
MIL-I-43121

Single Service Documents

Army	**Navy**	**Air Force**
MIL-E-55301(E)	MIL-I-16910	MIL-STD-826
MIL-I-11748	MIL-I-17623	MIL-I-26600
	NFEC-SPEC-50Y	

A detailed dissertation and explanation of these standards could involve a volume larger than this issue of **ITEM**. Therefore, this write-up will briefly highlight the differences in the active versions of MIL-STD-461 as of this writing. For a quick reference to MIL-STD-461 requirements, remove the attractive Requirements Tree and post it by your desk.

MIL-STD-461 was first issued on July 31, 1967, but was soon replaced by 461A, dated August 1, 1968. Since the basic document is inactive and superseded by the "A" revision, the resultant changes are not important. Notice 1, dated February 7, 1969, included an addition for GSA procurements, and a modification for electric hand tools. Tables showing a comparison of this standard with inactive standards were also added to the appendix. Notice 2, dated March 20, 1969, was even less significant, simply stating that the tables in the appendix were not applicable for Air Force procurements.

Through Notice 2, the standard was still effectively a joint service document. But then came the issuance of Notice 3 (USAF), dated May 1, 1970. This notice had the following first paragraph:

"This notice is applicable to all *Air Force procurements* and should be filed in front of MIL-STD-461A, dated 1 August and supersedes that document in those areas detailed herein. In case of joint military procurement, procurement specifications shall be determined by the Procurement Office."

Impact of Notice 3

Notice 3 contained significant changes. For instance, the conducted and radiated emission limits were relaxed (see Figure 1); the radiated susceptibility limits were increased (see Table 1); Figure 12 for broadband conducted emission from 20 Hz to 50 KHz was deleted; and many requirements were changed from mandatory to optional or "to be tailored". The subsystem concept was reintroduced with the following paragraph:

"**Subsystems.**–Units or equipments that are intended to be used together shall be tested as a subsystem. Tests on individual units of the subsystem are not required unless directed by the procuring activities. (For this purpose, a subsystem would not normally be considered to be an aircraft or ground C-E shelter.)"

TABLE 1
COMPARISON OF RADIATED SUSCEPTIBILITY LEVELS (RS03)

Notice 1 & 2	Notice 3	*Notice 4		
	Within metallic structure		**Sheltered**	**Non-Sheltered**
14 kHz to 10 GHz–1 V/M	14 kHz to 35 MHz–10 V/M	10 kHz to 1.9 MHz	10 V/M	1 V/M
	35 MHz to 10 GHz–5 V/M	2 to 29.9 MHz	20 V/M	5 V/M
	10 to 40 GHz–20 V/M (optional)	30 to 400 MHz	50 V/M	10 V/M
	Exposed	**RS03.1**		
	10 kHz to 40 GHz–200 V/M (frequency tailored)	2 to 29.9 MHz	20 V/M	5 V/M
		30 MHz to 1.9 GHz	50 V/M	10 V/M
		2 to 12.4 GHz	10 V/M	5 V/M
		RS03.2		
		function of Rcvr. freq.	20 V/M	5 V/M

*The susceptibility limits apply for both horizontally & vertically polarized fields from 30 MHz to 12.4 GH

Among many other changes, new paragraphs to cover production testing, armament and design guidance were added. Thus, Notice 3 was the first real polarization of the joint service standard to a single service (USAF) since its issuance.

Impact of Notice 4

Not to be outdone, the Army (USAEL, Fort Monmouth) issued Notice 4 (EL), dated 9 February 1971. The front page contained the following statement:

"This notice is applicable for all Army procurements and shall be filed in front of MIL-STD-461A, dated 1 August 1968 superseding the document in those areas detailed herein. In case of joint Military procurement, procurement specifications shall be determined and coordinated by the procurement office."

The changes contained within Notice 4 were even more far-reaching than Notice 3. In effect, a new 71 page document was issued which could stand alone without the basic standard or previous notices. Some of the changes can be seen on the Requirements Tree, Table 1 and Figure 1. Others include a new conducted transient emission requirement, a system/subsystem definition and application, a list of equipment which are specifically exempt from the requirements, plus extensive matrix tables of equipment types versus requirements.

Impact of Notice 5

Notice 5 dated 6 March 1973 was issued in midsummer of 1973. It is applicable only to mobile electric power (MEP) and supersedes the requirements for MEP contained in Notice 3 (USAF) and Notice 4 (EL). The amendments are referred back to the basic document modifying it appropriately to include separate provisions for MEP which was previously omitted. Rather than simply stating the changes, the Notice provides the complete page containing the modifications thus requiring the reader to go through the tedious exercise of comparing page-to-page to identify often minor changes.

In essence, the changes are as follows: Class V "Mobile Electric Power (MEP)–those supplying power to, or closely associated with C-E equipment" was added to Table I. Tests required for this equipment class includes CE03, RS02 and RS03. Three notes clarifying the application of the test requirements were also included. Two figures (Figs. 25 and 26) were added and Figure 1A, describing the loop used for radiating magnetic fields was modified.

The susceptibility limits per RS03 and (T) RS04 were given as follows:

Frequency	Field
2 – 400 MHz	10V/M
.400 – 10 GHz	5V/M

Impact of Notice 6

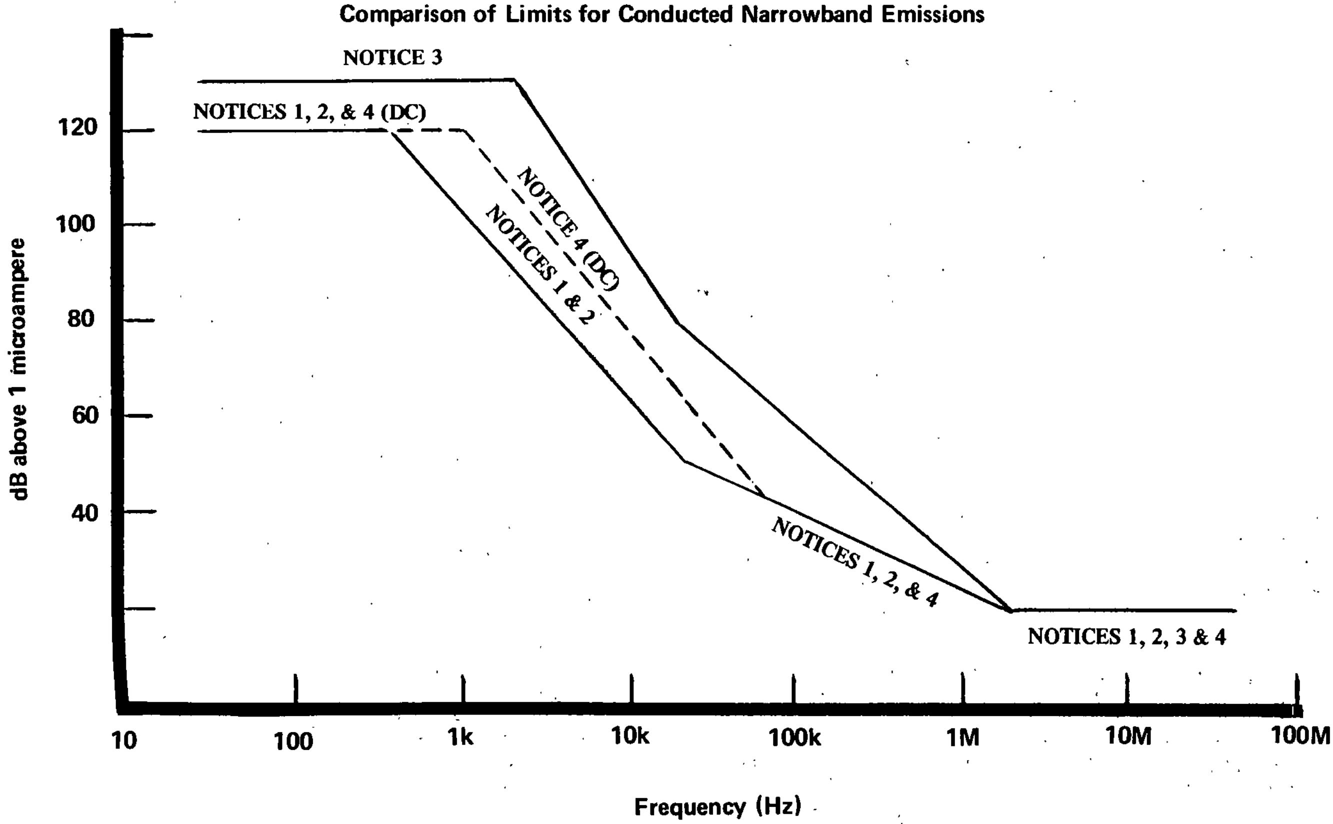
Shortly after the release of Notice 5, Notice 6, dated 2 July 1973 was issued, containing just two pages. These pages, containing Figures 25 and 26, were identical to those included in Notice 5! The only explanation given for issuing Notice 6 was that the figures in Notice 5 were poorly printed and difficult to read.

MIL-STD-461B

It is interesting to note that while notices 3 and 4 were being issued, MIL-STD-461B was distributed in November 1970 and presently is being circulated by the Electronic Industry Association (EIA) for comment on behalf of the tri-services.

The only significant difference in requirements between 461A Notice 3 and 461B is the application of RE01 and RS01, magnetic field emission and susceptibility. In Notice 3 they are not required and in Notice 4, they are to be tailored to the item. Actually, MIL-STD-461B encourages the tailoring of requirements and especially the limits to the end item and its intended use, where 461A is less flexible. It should be noted that the proposed tailoring includes making some limits more severe as well as relaxing others. All of the test requirements including limits have been written for use with the present MIL-STD-462 test techniques. MIL-STD-461B acknowledges that MIL-STD-462 is currently under revision which when issued, will result in further revision of MIL-STD-461B.

Figure 1:
Comparison of Limits for Conducted Narrowband Emissions



MICROWAVE ABSORBERS

There are two main families of materials, namely, resonant absorbers and broadband materials. Each of these main classes can be divided into a number of different sub-classes dependent on the actual physical principles around which they are designed.

Resonant materials rely both on the attenuation of the incident wave and on the interference effect produced by reflection from their backings. These materials themselves divide into three classes, namely, solid magnetically loaded, solid dielectric loaded, and sandwich-type absorbers. In theory, it is possible to design any one of these materials to resonate at any frequency in the radar bands, but practical limitations of weight in the case of longer wavelengths or of control of material thickness at the lower millimetric wavelength has caused limitations in the actual range available. Other considerations which have had to be taken into account are resistance to environmental conditions such as weather, heat, or possible exposure to contamination by fuels.

A range of tuned absorbers is in most cases obtainable either in rigid or flexible form depending on the metal actually used to provide the back reflecting plane. In certain cases they can be supplied unbacked for bonding to the customer's own metal structure.

Because of the use of the interference principle in their design, such absorbers are not only dependent on frequency, but are also limited in the permissible angle of incidence at which worthwhile absorption can be obtained. Accordingly, a range of broadband materials which are also not so critically dependent on angle of incidence has been developed. These can be divided into two classes, namely those based on foamed rubber, and the rigid absorbers based on coated granules of a foamed plastic. A good match to free space conditions over the wide band of frequencies is obtained by the use of a tapered profile in the form of inverted pyramids.

In general, all these materials are effective at Q band at one end of the radar spectrum, and at S band at the other. At this lower frequency end, increase in thickness permits worthwhile performance into the upper end of L band, and materials can be made which cover even the VHF band although they are not at present included in the standard range.

THEORETICAL CONSIDERATIONS

Ideally, the material should be such that the incident wave enters the surface with zero reflection and is then rapidly attenuated to a negligible amplitude in a short distance. For zero reflection, the wave should see no change of impedance on entering the material, i.e. $Z = \sqrt{\mu/\epsilon} = 1$, where μ and ϵ are the complex permeability, and the dielectric constant of the material. The wave is attenuated rapidly if the magnetic and dielectric losses are high. Furthermore, if the refractive index is also large, the amplitude of the wave can be reduced to a low value in a physically thin layer, the energy being converted to heat.

Unfortunately, in the region of most interest for radar use, e.g. above 10^9Hz, values of μ rapidly approach unity. Thus, for the non-reflecting condition to be realised, i.e. $\sqrt{\mu/\epsilon} = 1$ ϵ must also approach unity. This basically governs the design of current broadband (i.e. frequency indifferent) materials. These are generally high expanded, low density, low dielectric constant materials, with either magnetic or dielectric loss artificially introduced. Practical cases are carbon loaded expanded rubber, plastics, and conductive fibres.

For many applications where the wide frequency range is not required but space is of primary importance, an alternative approach can be made. By employing quasi-optical techniques, very low reflection can be obtained for thin layers of material over a moderate frequency range. Narrow band or resonant frequency absorbers are used in association with a metal reflector which can be either the metal surface to be treated, or more generally, on integral part of the absorber. The most successful of these is the quarter wave layer.

A wave incident upon the material gives rise to a reflected wave (R) from the front surface together with a series of emergent waves due to the multiple reflections within the metal backed material. By making the electrical thickness of the material a quarter wavelength, the emergent waves are in phase with each other but out of phase with the initial reflection. To obtain cancellation, it is necessary to make the amplitude of the sum of the emergent waves equal to that of the initial reflection. This is achieved by critical control of the attenuation in the layer. Alternatively, the system can be considered as a layer backed by a short circuit with the well known input impedance condition.

(1) $$Z \text{ input} = Z \tanh \gamma_0 d$$

when

$Z = \sqrt{\dfrac{\mu}{\epsilon}}$ is the characteristic impedance of the material

$\gamma_0 = j\dfrac{2\pi}{\lambda}\sqrt{\mu\epsilon}$ is the propogation coefficient

and d is the thickness of the layer.

For zero reflection (1) is equated to unity and a simple solution yields the following conditions.

$$d = \frac{\lambda}{4\nu}$$

$$K = \frac{2\mu_I}{\pi}$$

where

$$\sqrt{\mu\epsilon} = \nu - jx$$

and

$$\hat{\mu} = \hat{\epsilon}$$

This is not a unique solution and in most practical cases $\hat{\mu} \neq \hat{\epsilon}$. Here the solution is more complex and has been satisfactorily resolved for the Plessey magnetic and dielectric absorbers. Although subject to frequency and angle of incidence limitations, these materials are of particular value, for use in conjunction with equipments working on restricted ranges of frequency.

Bandwidth: The bandwidth is defined as the wavelength range over which the reflected power remains below a certain specified value, say 2%. The relationship between reflected power, $|R|^2$, and bandwidth for a material of equal magnetic and dielectric loss is given by:–

$$\Delta\lambda = \pm \frac{16\,\mu_I d}{\pi} \cdot \frac{|R|^2}{1 - |R|^2}$$

The quantity $2\,\Delta\,\lambda$ is known as the "bandwidth"

For materials of unequal losses ($\hat{\mu} \neq \hat{\epsilon}$) the expression is more complex but of similar form.

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