CISPR INTERFERENCE MEASUREMENTS

Interference Measurement

For the protection of Radio and TV communication most countries of the world have adopted the C.I.S.P.R. method of interference measurement. (Comite International Special des Perturbations Radioelectriques = International Special Committee on Radio Interference). Several Publications exist for various frequency ranges and on special subjects. Literature may be obtained by: Bureau Central de la Commission Electrotechnique Internationale, 1, rue de Varembe, GENEVE, Switzerland.

Many countries have Federal regulations which have been harmonized with CISPR dealing with the receiver-, network- and antenna specifications. In Germany, the VDE (Verband Detscher Elektrotechniker) has issued rules with the numbers VDE 0871 to 0879 (See McDonald, Pg. 144). CISPR Publications 1 to 4 deal with the specifications of interference measurement receivers from 10 kHz up to 1 GHz and the coupling networks.

Interference Voltages on lines is usually measured with a voltage probe in front of a suitable receiver. These voltage probes are common on low or high-impedance versions (150 or 1500 ohms). The disadvantage of this way of voltage measurement is the uncertainty of power line impedance which greatly affects the voltage drop due to interference currents. The other trouble is external interference penetrating via power line into the sample to be measured.

For this reason, interference measurement at the terminals of electrical equipment up to 25 amps (in some cases up to 400 amps)–also called conducted interference–is measured by inserting an *Artificial mains network* or *Line Impedance Stabilization Network.* This equipment provides a constant impedance at the sample terminals and rejects external power line interference. Two generally different types of networks are used: for the frequency range 0.15–30 MHz at present, CISPR calls for a constant impedance network with 150 ohms, either symmetrical or asymmetric. This has a historic origin: it is the mean value between the high impedance of free air lines and the low impedance of cables of considerable length, where the characteristic impedance is valid and is independent of frequency. It would be a better approximation of real power lines to use a lower and frequency dependent impedance for modern power lines, as it will come to use in CISPR 3 for the VLF range 10–150 kHz or in the MIL networks, where in the low frequency range the impedance is inductive and approximates 50 ohms in the higher frequency ranges.

ARTIFICIAL MAINS NETWORKS (LISN's)

V-Network 0,15–30 MHz, 150 Ohms: This type of Network is most common for standard Interference Measurement. It represents a frequency independent impedance of 150 Ohms resistive with a maximum error of 20 ohms and 20 degrees. This requires very elaborate rf chokes, if at the same time line currents up to 25 amps have to be provided. The standard impedance of 150 ohms is measured between line terminal at the sample point and ground. All other terminals for the sample are also loaded with 150 ohms to ground (for r.f. only). Thus, this type of asymmetrical network with live terminals of two to four is called 'V-network'. The r.f. voltage of either of the two or four terminals is fed to the receiver by a rotary switch while all other teminals are loaded with 150 ohms to ground. It is called asymmetric because the voltage of one sample terminal to ground is measured while the other terminal(s) will be terminated into 150 ohms. Thus also a symmetrical interference voltage component is fed to the receiver with 50% magnitude and 300 ohms load.

Delta-Network 0,15–30 MHz, 150 Ohms: In contrast to the previous network, the Delta (or Nabla-) LISN is capable of proceeding either the symmetrical voltage component or the difference voltage at two sample terminals–or the asymmetrical voltage of *both terminals simultaneously against ground.* The newest network of this kind (according to VDE 0872/7.72, 9.2.2) represents exactly 150 ohms to the two sample (device under test) terminals, no matter if it is switched to the symmetrical or asymmetrical mode. The difference of the asymmetrical measurement of the V-network and the same mode in the Delta network should be noted: a strictly symmetrical voltage at the two sample terminals will lead to a zero indication in the asymmetrical mode of the Delta-Network and to a 50% indication (or slightly more due to the increase of the standard 150 ohm impedance to 300 ohms) on a V-Network.

This comparison shows that to a certain degree an analysis of the type of interference is possible using these different networks. Finally, it should be noted that the Delta Network is recommended in several countries for general work and in other countries only for special applications as RFI-measurement for radio and tv receivers. The V-network is used throughout for powerful devices like three phase machines or generally for electric tools and domestic equipment.

As mentioned before the standardizing of a constant 150 ohms impedance is not very reasonable considering modern power line impedances. Furthermore problems for certain electrical systems will arise when high impedance chokes have to be used in the mains circuit to provide for 150 ohms resistive load. This problem will lead to ridculous dimensions of chokes and r.f. cables which must also have a characteristic impedance of 150 ohms, when currents increase to more than 25 amps or if such a network is intended to be used at lower frequencies.

So for the VLF range (10–150 kHz) a network is recommended (both by CISPR and MIL) with a reduced inductance of 50 (or 56) μH, parallelled by 50 ohms. The impedance decrease at very low frequencies of the 50 μH inductance is limited by a 5 ohms resistor. At 10 kHz, the impedance is close to 5 ohms, in an intermediate region it is approximating the ωL of 50 μH, and at higher frequencies the total impedance comes close to 50 ohms resistive. This type of network would also be representative for a 'standard power line' in the frequency region of CISPR 1 (0, 15–30 MHz). At some later date this type of network may be recommended generally for the range 10 kHz–30 MHz. In that case, LISN's for much higher currents will be possible and critical circuits (SCRs) will not suffer from high inductances in series to the power line. Finally, the 150/50 ohms reduction ratio from present networks to the standardized receiver input impedance will no longer be reason for misinterpretations. At present receivers with 50 or 60 or 75 ohms input a correction of 10 or 8 or 6 dB has to be observed for 150 ohms measurements–or these receivers have at the direct rf input connector a 0 dB sensitivity of 0.32 or 0.4 or 0.5 μV to compensate the voltage loss.

For interference measurement at motor car or ship installations for similar low impedance and low voltage lines) a special L.I.S.N. has been recommended which can be constructed up to 400 amps or even higher currents. It has a series inductance of 5 μH and is furnished in single cells.

For direct EMI voltage measurement, probes may be used if LISN's cannot be inserted. In this case of course the varying power line impedance and the external interference will possibly introduce some error. This way of voltage measurement however can be recommended in addition to using a LISN on the device input, when at the same time at the device *output* voltages have to be checked (control systems).

EMI/RFI Current, Field Intensity and Power Measurement

Voltage measurement with the Aid of LISN's (Artificial Mains) has been discussed. In the lower frequency ranges, sometimes current measurement is used with toroid clamps. The results of this measurement also depends on the source (line) and sample impedance and thus would as well require a LISN. For that reason, direct current measurement is not generally common. For certain applications it might be useful to measure currents. Small ferrite toroids with a few turns of insulated wire are recommended. The sample current path is fed through the center of the toroid. A calibration may be made with a signal generator of known impedance and a similar load.

The MDS Absorbing Clamp for the frequency range 30–300 MHz is an example of a generally used current (or power) pick-up device. It has been developed to avoid the troublesome field intensity measurement which requires an open place without obstracles and depends on suitable weather.

The absorbing clamp consists of a number of ferrite toroid cores. A small number of these act as a transformer for the asymmetrical current in the feed line to the device under test. The rest of the ferrite cores are used as damping devices for external interference and for reflections from the line. A full match even with standing waves on the device cable can be obtained by sliding the clamp along the cable until a maximum is reached at the EMI receiver. Thus, this type of measurement gives a result proportional to *EMI power*. Due to a certain insertion loss (near 17 dB) a dB (μV) reading becomes a direct evaluation of dB (pW)–decibels above one picowatt–in a 50 ohms system which makes work with the clamp very easy.

One of the classical ways of interference measurement and still modern is the field intensity measurement. In the low frequency ranges up to 30 MHz, this is usually done with loop antennas for the magnetic field component and with rod antennas for the electrical component.

In the VHF and UHF ranges, field intensity measurement is more generally used. For very high frequencies, it is the only possible way to obtain comparable results due to standing waves on the lines. In this frequency range, half wave dipole antennas are used in horizontal and vertical plane. These have to be adjusted to the correct length at every frequency of measurement and placed in a certain height (30–300 MHz usually 3m above ground) or varied in height for maximum indication. If minor disadvantages such as frequency dependent radiation pattern and slightly higher reflections can be tolerated, broadband antennas in double-cone or logarithmic-periodic design may be used with the great advantage that no length correction with frequency change is necessary.

All antennas have correction factors, often expressed in dB, which have to be added to the receiver reading to obtain the field intensity in dB (μV)/meter, provided the receiver is calibrated in dB above 1 Microvolt.

The distance of the antenna from the RFI source depends on the recommendations. (3, 10, or 30 m are often used distances.) The correct direction is the one with highest receiver indication. Evidently the signal must be checked by listening to the loudspeaker noise to avoid errors due to Radio or TV signals on the same frequency. The attenuation of the coaxial cable between antenna and receiver is usually contained in the antenna correction values, provided the correct cable is used.

Beyond 300 MHz the height of the antenna has to be adjusted for maximum receiver indication, because direct radiation and the reflection from ground might completely extinguish the signal reception at a certain antenna height. The antenna mast should be of insulating material and the measuring site must be free of obstacles in a radius of twice the measuring distance from source or receiving antenna. For investigation of radiating parts of a larger installation a dipole antenna can be held in the center by hand and brought into closer proximity of the device under test.

The prevention of EMI radiation becomes a difficult matter with very high frequencies. Shielding boxes must be totally closed with slots bypassed with shielding braid. Mechanical shafts must be radially grounded with braid, electrical wires entering or leaving the box must be equipped with coaxial low pass filters (feed-through-filters).

EMI RECEIVERS

The measurement of broadband and mixed interference signals requires special receivers which conform with very critical specifications, expecially if so called *Quasi-Peak Measurements* as prescribed by CISPR have to be made. It is not critical to measure pure sine wave signals. They are, however, the absolute exception in EMI work. Square-wave pulses generate an enormous number of harmonics and the simultaneous presence of very strong and weak signals causes intermodulation products at curved characteristics of semiconductors or valves. The peak value on the output of a receiver depends on bandwidth when several harmonics fall into the receiving range. Pulses measured with a level of microvolts behind the narrow-band output of a receiver might be as high as 100 V at the receiver input (if bandwidth is small and pulses are in the subnanosecond region).

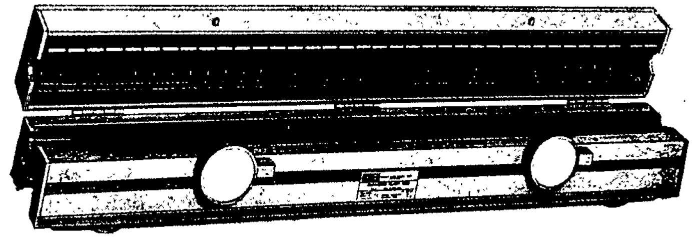

Figure 1: Absorbing Clamp MSD-20

Two different types of receivers are used for EMI measurement. The *Quasipeak* receiver according to CISPR specifications has a defined bandwidth, a peak detector with a defined charge and discharge time constant and a high linearity range which extends more than 30 dB (CISPR 1) or 43 dB (CISPR 2 and 4) beyond the sine wave meter range at the final IF stage preceding the detector. The combination of these qualifications results in a meter indication which is dependent on the pulse repetition frequency. Single pulses are indicated much lower (for instance 30 dB lower) than a prf of 100 Hz and about 40 dB lower than a very high prf. To obtain a readable indication, attenuation ahead of the receiver is reduced by 30 or 40 dB when measuring single clicks with the result of hundredtimes high voltage swing at all active elements from input to detector. As the bandwidth reduction in a typical receiver from front end to last IF-amplifier also causes a reduction of relative pulse voltage (and at the same time stretching of the pulse duration), it is easy to see that it might easily happen that the input pulse voltage of single clicks in an EMI receiver is tenthousand times higher than a sine wave voltage which gives the same meter deflection. This is the reason why receivers designed for other applications and spectrum analyzers can fail to give complete information.

The other type of EMI receiver is preferably used for military EMC work. These *True Peak EMI receivers* have a very large ratio of discharge to charge time constant and thus indicate the absolute peak value of the rectified IF pulses. This means that the pulse repetition frequency does not have any influence on the meter indication provided it is above a certain limit (for instant 10 Hz). This type of receiver is somewhat easier to verify, because the additional linearity for low prf is not necessary. For that reason, it is easier to incorporate a logarithmic range on the meter.

This type of receiver does not necessarily have a specified bandwidth. It must be known, however, to calculate the intensity *per bandwidth unit*. In fact, it is the *Impulse Bandwidth* (which is similar to the 6 dB bandwidth) that has to be known to find the Volt per Megahertz–indication of broadband interference.

All EMI receivers are calibrated with either sine wave or preferably pulse signals. The calibration is always referred to the rms value of a sine wave that gives the same indication.

Pulses of very short duration give a spectrum of harmonics spaced by the prf and extending to the frequency 1/T, where T is the pulse duration in a sin x/x function for rectangular pulses and $(\sin x/x)^2$ for triangular pulses. True pulse shapes usually give an average lobe shape between these extremes. At the 1/T frequency indication is zero and returns with increasing frequency in a second and further lobes of smaller magnitude.

Up to one third of this I/T-frequency the pulse spectrum can be considered flat for calibration purposes. This means that subnanosecond pulses must be used for calibration of receivers up to 1 GHz. The receiver indication is proportional to the pulse area. This means that–at lower frequencies–the indication of a 1 ns pulse with 100 V is the same as of a 10 ns pulse with 10 V amplitude. For the calibration of CISPR receivers up to 30 MHz (CISPR 1) the pulses should have a prf of 100 Hz and 0.5 times 0.316 μVsec. For CISPR 2 and 4 receivers, the prf is also 100 Hz and the area is 0.5 x 0.044 Microvoltseconds. The factor 0.5 results from the fact that the pulse area is defined for emf. values.

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