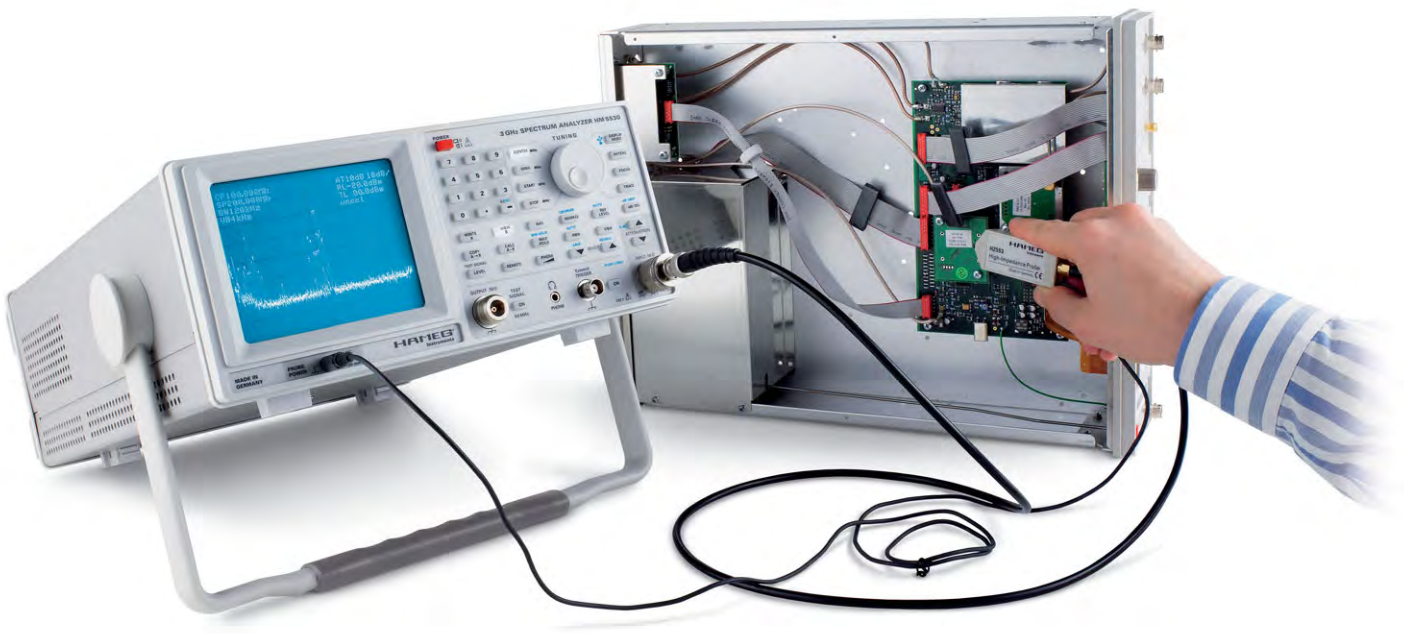
HAMEG
EMI measurement tools

Whoever sells an electric or electronic instrument or apparatus within the EWR must conform to the European Union Directives on Electromagnetic Compatibility, EMC. This applies as well to manufacturers as to importers in the European Union plus Island, Liechtenstein, and Norway.

HAMEG offers very cost-effective solutions to active (emission) measurement problems which allow to perform so called pre-compliance measurements.



Active and passive electromagnetic interference

Due to increasing operating frequencies and integration the measuring instruments must meet ever increasing demands for higher performance in order to guarantee that electric and electronic apparatus will conform to the standards. The frequency range to be covered extends from 150 kHz to 1 GHz.

The equipment necessary and thus cost can become partly immense, however, if good judgment is used and proper instruments and suitable methods applied cost will remain under control.

How much does it cost to comply with EMI standards?

Compliance with EMI standards needs not be expensive. Provided EMI considerations were taken into account from the beginning of a design and provided that EMI tests were performed all along the design cycle it was shown that the material cost of EMI components amount to 3 to 5 % of the total material bill.

Negligence towards EMI compliance may become very costly, especially if the first EMI test was performed at the completion of the design. In such a case easily 30 to 50 % of the total design cost will be consumed by EMI prevention measures. It may become necessary to start all over again, high costs will be incurred by extensive tests and having to resort to external expertise.

Compliance measurements are mainly reserved to specialized, well equipped laboratories. The equipment required is very expensive, and the procedures are extensive. This being the case it becomes necessary to perform one's own tests during the design cycle, good enough to come close to compliance and with moderate effort and affordable measuring instruments. In order to achieve this it is not necessary to own the expensive equipment nor to set up a test installation which conforms strictly to the standards. It is more important to quickly identify the critical zones within an electronics circuit and the wiring where interference emanates in order to determine the optimum and cost-effective counter EMI measures.

Oscilloscope or...

Inspite of its versatility the oscilloscope is not the best choice for EMI measurements. It will display the waveform of the interference signal vs. time but not the spectral lines involved.

The EMI standards require "average" and "quasi-peak" measurements. The bandwidths of the frequency selective measurements are dependent on the frequency.

The frequency range to be covered when measuring active interference, i.e. emissions, reaches from 150 kHz to 1 GHz. In addition to featuring this range a measuring instrument must sport a very high sensitivity; it must be able to measure down to a few µV.

The display of a large frequency range and the logarithmic display of amplitude with a range of 80 dB allow to see at a glance where the problems arise as well as which effects countermeasures have.

Spectrum analyzer, and ...

It is still disappointing how seldomly spectrum analyzers can be found in design labs. Quite often their high cost is mentioned. The spectrum analysis equipment required during the course of a design need not be of Rolls Royce standard, however. Regarding the fact that spectrum analyzers are rarely used daily it is advantageous to have instruments which can be used easily, i.e. those which can be used by any design engineer immediately without awe and without time-consuming training. It is most important to be able to perform comparative measurements quickly and inexpensively. The following example demonstrates how quickly a spectrum analyzer will be amortised: It costs 1,000 Euro or more to hire a specialized lab for one day. A simple and inexpensive spectrum analyzer will be already amortised if it can save 2 to 3 days in such a lab. It should be the goal of efficient design management to have to hire such a lab only once.

Thus the spectrum analyzer belongs to the standard equipment of any designer right next to his oscilloscope. As soon as you once worked with a spectrum analyzer you will be well able to judge its usefulness.

Line-impedance stabilization network (LISN)

This instrument is required in additon to a spectrum analyzer in any design and compliance test lab. It serves to isolate, identify, and quantify conducted interference in the frequency range 150 kHz to 30 MHz. Compliance test labs use the LISN in conjunction with a special test receiver. For pre-compliance tests the use of the LISN together with a spectrum analyzer is a much faster and thus more practical solution. HAMEG series 5000 spectrum analyzers and the HM6050 LISN offer results which are comparable to those obtained in external labs.

... and sniffer probes

What to do upon return from an unsuccessful visit to an external test lab? All you know is there is something which generates interference, but where?

E.g.: free-field emissions

Interference may be radiated or conducted. EMI rules specify the range to be tested from 30 MHz to 1 GHz. It is to be expected that the upper limit will be extended.

The measurements of radiated interference are conducted using antennae and receivers in a set-up free from reflections and third-party interference. Mostly such measurements are performed in anechoic chambers (rooms).

Such measurements are inefficient, time consuming and expensive if performed during the design phase. In practice it is necessary to have a means which allows to quickly identify sources of interference inside of circuits and especially from conductors and the harness. Although we speak of free-field emissions mostly it is the conductors and the wiring harness which act like antennae and thus ease radiation.

Measurement of conducted interferences via Spectrum Analyzer and LISN.

In the design lab most of the EMI work will have to do with the interference caused by conductors. With suitable means it is possible to perform such measurements directly close or even on conductors carrying signals, power, ground or their shield.

He who performs such measurements for the first time using a spectrum analyzer will be much astonished to see even strong high frequency signals on "slow" signal or static conductors which stem from other sources and which ride on those slow conductors.

Using an oscilloscope will not reveal this interference as it will be buried in the noise. The electromagnetic interference field uses the metallic conductor as a guide to propagate efficiently alongside.

In the design lab a spectrum analyzer and a suitable probe will be all that is necessary to identify such interference. Different types of probes are required, however.

How to test sources of interference in detail

Sniffer probes are especially useful to test the effect of EMI countermeasures. There are E field and H field probes available which, together with high impedance and low capacitance probes, help the engineer to select the appropriate EMI countermeasures.

Active E field probe

The active E field probe is a high bandwidth high sensitivity device. It allows judging the total radiation emitted from a complete set or modules thereof. The normal measuring distance is 0.5 to 1.5 m. The efficiency of shields can be tested as well as the effects of filters on all conductors and cables connected to the unit under test.

Due to its high sensitivity the active E field probe may receive interference emanating from other instruments in the lab. In order to exclude such disturbances from the measurements intended it is customary to make a first measurement with the unit under test switched off thus receiving only disturbing interference, then to perform a second measurement after turning on the unit under test and watching for signals which now appear.

All measurements with an active E field probe are similar to far-field antenna measurements and thus dependent on the measurement set-up. Placement of cables will play an important role. If reproducible measurement results are desired it is necessary to define the set-up precisely, preferably by mounting everything onto a board.

The active E field probe may also be used to analyze interference from the surroundings. In case such interference may exist an active E field probe together with a spectrum analyzer will allow detecting any such interference. As the analysis is performed in the frequency domain the source of interference will mostly be quickly identified. This allows to improve the set's EMI properties such it will pass a second compliance test.

Probe set HAMEG HZ530 consisting of 3 active probes (E field, H field, high impedance probe)

Active H field probe

Watching for interference currents is the route to success when searching for its sources. The use of oscilloscopes creates a tendency to look for voltages only. Successful EMI engineers have learnt to look for currents. In order to test for interference currents without disrupting circuits or dissecting conductors on EC boards active H field probes are the optimum choice.

Active H field probes are near-field probes which measure the H field. In the near-field this is directly related to the currents flowing. H field probes are fairly insensitive to external interference (third party interference). They show an intense increase in output when closing in on an interference source. They allow thus to locate such sources very precisely.

Leaks alongside the seam of a shield or housing are easily detectable with an H field probe, e.g. slots.

However, the ever increasing integration on EC boards makes it difficult to localize interference sources with ordinary H field probes. Here the HAMEG µH field probe HZ545 is applicable which allows locating sources down to the mm region and thus is ideal for EC board tests.

As mentioned all metallic cables are antennae for interference radiation as well as reception.

Testing cables with an H field probe in contact and a spectrum analyzer, one will be astonished to find sizeable levels of RF interference even on mains cables, telephone cables or slow data transmission lines like harmonics of clock frequencies. Making use of the H field probe and the logarithmic amplitude display of a spectrum analyzer it is easy to ascertain whether all cables carry the same level of interference or whether some conduct more. This will allow to determine proper countermeasures. The usefulness of which can be tested and verified fast and efficiently in the lab, without the need for shielded cabins and also without extensive measuring setups.

High impedance probe

The high impedance probe allows to connect e.g. to an IC pin or any single conductor without loading the pin with the usual 50 Ω of a spectrum analyzer. The bandwidth is > 1 GHz. The impedance of HAMEG high impedance probes contained in the sets is predominantly capacitive and < 2 pF. The high impedance probe may also be connected to an oscilloscope with 50 Ω input impedance or 50 Ω feedthrough termination, thus acting as a probe featuring the above mentioned bandwidth and impedance.

The load on the point of measurement may be further reduced by the low capacity probe HZ543 with <0.3 pF and 3 GHz bandwidth. This lower load will allow very true measurements even in critical RF circuits.

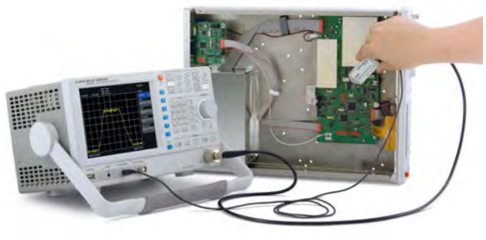
The essential advantage is that the point of measurement will see practically no load. Otherwise a low impedance probe may suppress or reduce just that oscillation which was to be measured. This problem is aggravated as the frequency of interest moves upward. Each pF is of enormous importance. Using the HZ543 this problem may be disregarded up to the bandwidth limit. The low capacitance probe features just a tiny tip and is used without a ground connection. The circuit is closed through the capacitance of the probe to the body of the test person. Thus it is indeed possible to test the individual interference of an IC pin or a conductor. The capacitive and high impedance coupling of the probe also allows to test for common mode interference and identify its source.

Practical EMI problems

The electronics circuit designer meanwhile became knowledgeable as regards EMI prevention e.g. on EC boards. The worth of EMI countermeasures often is seen only when radiation is measured. As the amount of time and cost for such measurements is high, the effect of individual circuit changes is seldomly tested. After several circuit changes were made a test will not reveal anymore which effect an individual measure had.

It is hence advantageous to test prior to going to a test lab using the near-field probes resp. sniffer probes mentioned. The E field probe reacts to electric AC fields, the H field probe is sensitive to changes of magnetic flux.

Before using these probes one is well advised to realize which fields play the decisive role in modern EC boards. In the case of high voltages but low currents the E field will be predominant. In the case of low voltages and high currents the H field will dominate. The former case was the rule with electron tube circuits.



Determination of radiated distortion using a magnetic field probe (H-Field) and a Spectrum Analyser

Modern IC's operate with low voltages and high currents. Of course, it is not the amplitude of a current which counts but in addition its rate of change (or frequency). If an electromagnetic wave is generated it is also the rate of change of the magnetic field vs. unit of time which is the determining factor.

It is exactly this component which is sensed by the H field probe. The amplitude of the probe signal is directly proportional to the flux change and thus to the change of the current creating the field. Hence these probes are eminently suited to a first and rough test of the efficiency of EMI countermeasures.

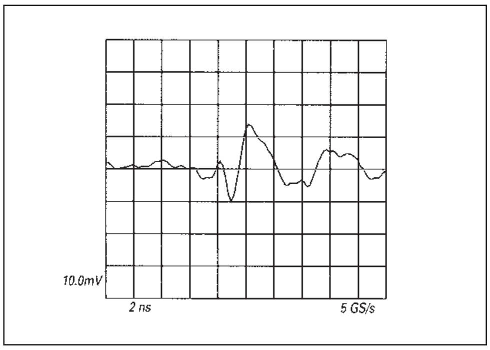
The majority of such probes suffer from a disadvantage: their spatial resolution is very limited. It is hence difficult to locate the source of the measured signal. Therefore, when shopping for a probe, it is advisable to look especially for a probe with high resolution of the magnetic field. This becomes ever more important as the degree of integration on EC boards increases so that localizing individual sources of interference requires resolution down to millimeters.

Measurements on 4 layer EC boards

The following describes how to extract interesting details from the probe signals. Principally the signals may be displayed in the time or frequency domains. The display vs. time may be more transparent. The following measurements were taken from a 4 layer EC board of "Europe" format 100 x 160 mm square. The power distribution on this board is on individual layers.

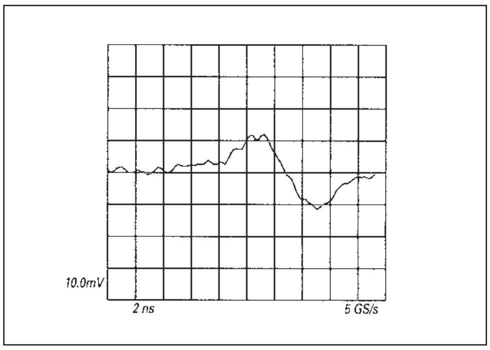
The distance between the V_{CC}- and ground layers is 100 µm. In the middle of this board a set of capacitors is located which connect both layers for AC.

Picture 1 shows the current signal in the vicinity of the V_{CC} pin of a 74AC163. The signal amplitude is proportional to the rate of change of the magnetic field and thus of the current at this location of the layer. The rise and fall times are in the subnanosecond range.



Picture 1: Current signal in the V_{CC} layer and close to the V_{CC} pin of a 74AC163.

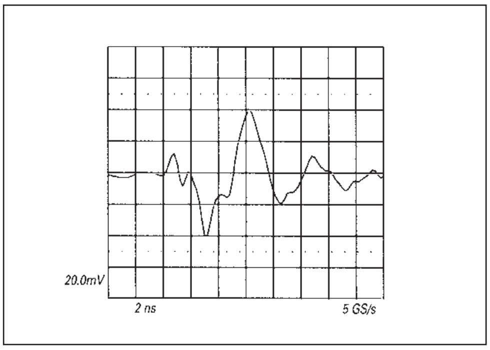
The reason is that the high frequency currents will flow mostly close to the V_{CC} pin as they can only be fed from the charge of the layers there. Such high frequency components can not be fetched far as the impedance would become too high. There is no bypassing capacitor at the V_{CC} pin as it would not be able to deliver high frequency current. Of course, the two layers V_{CC} and ground have a set of capacitors in the middle of the board. But this set can only deliver the low frequency components.



Picture 2: Current changes in the power distribution layers close to the set of capacitors.

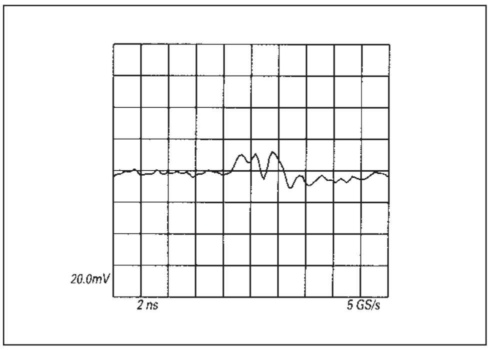
Picture 2 shows the current changes in the vicinity of this set of capacitors. It is obvious that this signal is much slower than that of picture 1. Here the rise and fall times are approx. 3 ns. The set of capacitors can only deliver current slowly to the layers. Such details are only visible with high resolution probes such as the µH field probe.

The following example demonstrates the effect of absorption measures. In picture 3 the signal was taken directly at the V_{CC} pin of a 74AC00 using the µH field probe. This IC is powered by a V_{CC}-ground system which is undamped. The changes of the magnetic field are strong.



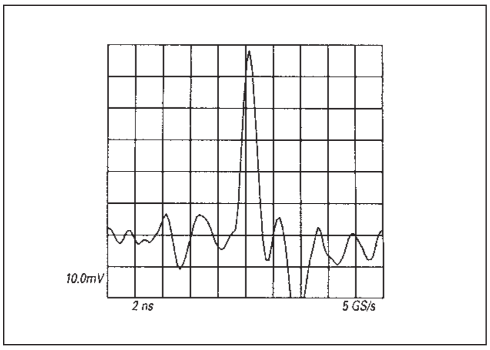
Picture 3: Signal directly close to the V_{CC} pin of a 74AC00.

In contrast to this picture 4 shows the same signal pick-off point, but now the IC is powered by a two-stage damped distribution system. The V_{CC} pin is connected to the V_{CC} layer via a large bandwidth filter choke, also this layer is damped by a layer of carbon. The reduction of amplitude is obvious. Just using this probe allows to determine the effect of the measure without the use of any further equipment.



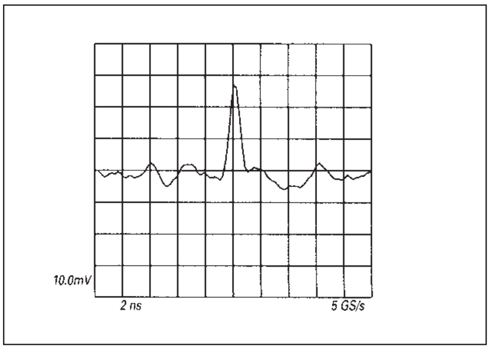
Picture 4: Comparable signal taken in a power distribution system with 2 stage damping.

The last example shows the signal taken from a clock distribution point on a "Europe" size EC board. The signal is taken directly from the output of the clock generator. Picture 5 shows the signal without any EMI damping measures, a very large amplitude signal of 60 mV is measured.



Picture 5: μH field probe signal taken from a circuit with no EMI prevention measures taken.

A popular means of improving the situation is the insertion of a series resistance directly at the output of the clock generator. In this case 82 Ω were used. Picture 6 shows the result: the signal amplitude is cut by half. The effect of the measure is visible immediately.



Picture 6: A series resistor at the output of the clock generator cuts the amplitude in half.