EVALUATION OF STOCHASTIC SIGNALS FOR FAST EMISSION
MEASUREMENTS IN TIME DOMAIN
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Abstract. According to the standards, emission measurements are carried out in the frequency domain using
a test receiver. In this paper the set-up and procedures of a measuring system in the time domain is presented.
The advantage of this system is, that measurements can be done approximately 10 to 100 times faster. The
emphasis in this paper is set on a special procedure to measure stochastic signals.

Introduction

Emission measurements for the EMC check of a de-
vice must be carried out (according to the standard [4])
in the frequency domain with e.g. a test receiver. It is
necessary to execute a frequency sweep and to measure
the emission at each frequency. This method has the
disadvantage that the measurement lasts, depending on
the selection of the parameters, for a quite a long time
(typically 10 to 30 min). Since a long measurement al-
ways implies high costs, it is profitable to look up for
possibilities to shorten the measurements without a loss
of quality.

In particular, the measurement in the time domain
provides a good possibility to save time. Instead of
measuring in the frequency domain with a test receiver,
several single shots are recorded with an oscilloscope.
From these data a comparable spectrum can be calcu-
lated by using the discrete Fourier transform (DFT) and
several correction procedures. In this paper the time
domain measuring system FEMIT (Fast Emission
Measurement In Time Domain) is described.

Measurement set-up

When measuring in the frequency domain, the sig-
nal is recorded directly with the test receiver, which
executes a frequency sweep.

The central device for FEMIT is a digital oscillo-
scope. If the noise level has to be lower than approxi-
amately 10 dB below the limits (CISPR 16 [4], etc.), it is
necessary to use a preamplifier. To make sure, that the
sampling theorem is kept, an appropriate anti-aliasing
low-pass should be connected in series to the oscillo-
scope.

Time consumption and accuracy

The time consumption of one FEMIT measurement
is, depending on the parameters, 10 - 100 times lower
than the one of a test receiver measurement; one meas-
urement takes ≈ 5 - 20 s. The error is typically < 1 dB
for narrow-band signals and < 1 - 3 dB for broad-band
signals.

Typical applications

Typical applications for FEMIT are quick previews,
repeated emission checks and the measurement of short
or rare phenomena (e.g. switching impulse, flashover).
The height scan and the check of the direction of highest
emission can be performed fast. Furthermore, the emis-
sion of different modes of operation of a device can be
measured separately.

Basic procedure of evaluation

The basic FEMIT procedure consists of a DFT, a
smoothing procedure and a correction. The correction
takes all frequency characteristics (antenna factor, low-
pass, etc.) into account, so that narrow-band signals are
measured correctly. This basic procedure was already
described in detail [1].

Procedure for one pulse

Pulses with a repetition frequency less than the
bandwidth of the test receiver have to be measured by a
special procedure. The procedure was explained in detail
in [2]. First, the trigger of the oscilloscope is set to a
relatively high level in order to record a pulse. The
spectrum is calculated by applying the basic procedure
and is corrected for all frequencies according to the cor-
rection value given by the correction curve (Fig. 1) at
the repetition frequency $f_{\text{rep}}$ of the pulse.

![Correction curve](image)

**Fig. 1**: Correction curves for peak $PK(f_{\text{rep}})$, quasi-
peak $QP(f_{\text{rep}})$ and average detector $AV(f_{\text{rep}})$. Capture
time 10 µs, 120 kHz band-pass
Formula (1) describes this correction by the example of the quasi-peak detector as
\[ u' = u + QP(f_{\text{rep}}). \] (1)

Here, \( u \) is the level (at any measurement frequency) after the DFT, \( u' \) is the level after the correction. \( QP(f_{\text{rep}}) \) represents the correction value according to the correction function (Fig. 1).

**Superposition of several pulses**

The so far described procedure calculates the correct spectrum when the signal contains (apart from the narrow-band signals) one pulse with the repetition frequency \( f_{\text{rep}} \). Often, several pulses with different repetition frequencies are present in the signal. In [3] a procedure to measure and calculate the spectra of two pulses was presented. The interesting case of the quasi-peak detector (due to its non-linearity) can be described by
\[ S_{\text{spectra}} = u'_{1,2} - \Delta \] (2)

where \( u'_{1} \) and \( u'_{2} \) represent the separately attenuated spectra of the two pulses (according to (1)). Therefore, at each frequency a correction term \( \Delta \) depending on the difference between the two spectra \( \Delta = |u'_{1} - u'_{2}| \) is added to the higher of the two spectra (see Fig. 2).

**Pulses of irregular period**

So far, the considered pulses are regular pulses. One characteristic of a stochastic signal is the irregularity of the period. In a first step the difference between a pulse of regular and irregular period with the same number of pulses per second is determined.

The irregularity can be described (worst case) by a compression as indicated in Fig. 3. Here, the pulses are combined to longer pulses with a corresponding longer period (same number of pulses/s). The now resulting DC-value can be derived by replacing \( t_1 \leftrightarrow x t_1 \) and \( t_2 \leftrightarrow x t_2 \) in (3). Fig. 6 shows the obtained attenuation of the quasi-peak-result normalized on the result of a regular pulse (\( x = 1 \)) depending on the compression factor \( x \) and with the number of pulses/s as parameter.

As the peak detector does not react on these changes, only the behaviour of the quasi-peak detector has to be evaluated. The schematic of this detector is shown in Fig. 4. To get a simple analytical solution, a rectangular input pulse is regarded (see Fig. 5).

![Fig. 5: Charging and discharging of the capacitor of the quasi-peak-detector](image)

As \( \tau_2 \) is much greater than \( \tau_1 \) [4], the steady state can be described by simple exponential charge- and discharge-functions. Here, the time constants are \( \tau_1 = R_1 C \) respectively \( \tau_2 = R_2 C \). As the voltage is additionally filtered by a mechanical time constant, the final result equals the DC-part of the signal. The DC-part of the output signal can be described as (for space-saving reasons only the final result):
\[ u_{\text{DC}} = \tilde{u} \frac{\tau_1}{\tau_2} \frac{(1-e^{-\frac{\tau_2}{\tau_1}})}{(1-e^{-\frac{\tau_1}{\tau_2}})} \] (3)

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Two conclusions can be made: first, the result for irregular pulses is always lower. Second, for realistic compression factors and number of pulses/s the attenua-
tion is very low (< 1-2 dB). Therefore, irregular pulses can be regarded as regular pulses with the same number of pulses/s. This effect was additionally proved by a Pspice-simulation (see Fig. 7) and test receiver measurements.

Classification of the statistically distributed pulses

Typically, a stochastic signal consists of pulses of different amplitudes. As the higher pulses in the signal usually have a lower repetition frequency than the low ones and different repetition frequencies mean different attenuations due to the correction curves (Fig. 1), the pulses of signal have to be devided into groups of similar amplitudes. It is useful to define approximately 5 amplitude ranges respectively 5 trigger levels \( u_{tr} \) (Fig. 8 left).

![Fig. 8: Definition of the trigger-ranges and trigger-frequency over triggerlevel](image)

All pulses are arranged into groups according to their maximum amplitude (Fig. 8 left: pulse of group "range 2"). In the next step the average number of pulses/s for the pulses of each range is determined. Therefore, the time \( T_{u_{tr},100} \) for e.g. 100 trigger events is measured for each trigger level \( \mu \) (e.g. by using the "sequence mode" of the oscilloscope).

\[
T_{u_{tr},100} = \frac{n}{f_{u_{tr},\mu}}.
\]

(4)

\[
f_{u_{tr},\mu,1} = f_{u_{tr},\mu} - f_{u_{tr},\mu+1}.
\]

(5)

By evaluating (4) the average repetition frequency \( f_{u_{tr},\mu} \) for trigger level \( \mu \) can be determined. As in this value the pulses of higher ranges are also included, the repetition frequency \( f_{u_{tr},\mu+1} \) of the next higher trigger level has to be subtracted (5) to get the average number of pulses/s \( f_{u_{tr},range\mu} \) inside trigger range \( \mu \).

![Fig. 9: Procedure for the measurem. of stoch. signals](image)

Now, for each group, the attenuation \( QP_{u_{tr}} \) according to Fig. 1 can be determined. Table 1 illustrates this procedure by the example of a parting-off grinder.

**Table 1. Determination of the attenuation/range. Example: parting-off grinder**

<table>
<thead>
<tr>
<th>( \mu )</th>
<th>( u_{Tr,\mu} )</th>
<th>( T_{Tr,100} )</th>
<th>( T_{Tr,\mu} )</th>
<th>( f_{Tr,\mu} )</th>
<th>( f_{Tr,Range \mu} )</th>
<th>( QP_{u_{tr}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 mV</td>
<td>150 ms</td>
<td>1.5 ms</td>
<td>670 Hz</td>
<td>420 Hz</td>
<td>-5</td>
</tr>
<tr>
<td>2</td>
<td>30 mV</td>
<td>400 ms</td>
<td>4 ms</td>
<td>250 Hz</td>
<td>150 Hz</td>
<td>-8</td>
</tr>
<tr>
<td>3</td>
<td>50 mV</td>
<td>1 s</td>
<td>10 ms</td>
<td>100 Hz</td>
<td>67 Hz</td>
<td>-12</td>
</tr>
<tr>
<td>4</td>
<td>70 mV</td>
<td>3 s</td>
<td>30 ms</td>
<td>33 Hz</td>
<td>23 Hz</td>
<td>-19</td>
</tr>
<tr>
<td>5</td>
<td>90 mV</td>
<td>10 s</td>
<td>100 ms</td>
<td>10 Hz</td>
<td>10 Hz</td>
<td>-24</td>
</tr>
</tbody>
</table>

After these preinvestigations, the final procedure for measuring stochastic signals can be described. First, for each range, 1-3 pulse samples are recorded and transferred into the frequency domain. To get the worst case, the maximum of the spectra of each group is calculated.

Then, for each group the spectrum is attenuated according to the corresponding \( QP_{u_{tr}} \). Now, the superposition of these spectra is calculated (see equation (2)) and in a last step the antenna factor is corrected.
When the quasi-peak-corrected spectra (before the superposition) are regarded, the dominating pulse group can be found. Fig. 10 shows these spectra in comparison to the test receiver result by the example of a vacuum cleaner. In this example the dominating spectrum is the one of the pulses of the lowest range (trigger level 5 mV). This is surprising, but understandable, because these pulses have the highest repetition frequency and therefore the lowest attenuation.

Examples: Comparison FEMIT – test receiver

The following figures show the comparison of the FEMIT and test receiver result by the example of a electromagnetic bell (Fig. 11), a vacuum cleaner (Fig. 12) and a parting-off grinder (Fig. 13).

Errors and difficulties in measuring stoch. signals

When evaluating narrowband signals, the error of FEMIT (compared to the test receiver result) is < 1 dB, for regular pulses < 3 dB and for the here described stochastic signals < 5 dB. It has to be considered that these stochastic signals are generally difficult to measure. Fig. 14 illustrates this by the example of a test receiver measurement with the peak detector and different measurement times per step: 100 ms, 1 s and 5 s /step. The high differences between the results show the typical problem of the irregularity of stochastic signals.

Other detectors

In this paper, the measurement procedure was described by the example of the quasi-peak-detector, which is (due to its non-linearity) the most difficult case. The simulation of the other detectors, such as average and peak-detector, can be done the same way with the following changes: the corresponding attenuations are given by Fig. 1 and the equations for the superposition are described in [3].

Conclusion

In this paper, the time domain emission measurement system FEMIT was described. FEMIT is an adequate measuring system especially for quick previews, repeated checks of the emission of an EUT and short phenomena.

The central result of the here presented aspect is:

- An advanced procedure allows the measurement of stochastic signals by calculating the superposition of separately attenuated part-spectra.

References


