The Importance of Overload Revealing in EMI Receivers

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***Abstract*—The designing of instruments aimed to measure electromagnetic interference (EMI) is particularly challenging. The most critical aspect is the high dynamic range, which is required to avoid overload conditions and thus to guarantee reliable measurements. Unfortunately, also adhering to today's standards (*i.e.*, CISPR 16-1-1) is not sufficient to avert overload phenomena. With three simple experiments, we show that it is crucial for an EMI receiver to incorporate an overload revealer to guarantee that overload conditions are detected correctly. Only then, can a receiver be set correctly in its linear range by using specific hardware inserted at the front end of the receiving path, *i.e.*, a preselector and an attenuator. The combination of these three mechanisms - overload revealer, preselector and attenuator - turns out to be indispensable to avoid unnoticed overload conditions and guarantee reliable measurements.**

***Index Terms*—Dynamic Range, Preselector, CISPR 16-1-1, Pulse Signal, Compression**

I. Introduction

Today, electromagnetic interference (EMI) can be measured with two types of instruments: spectrum analysers or specialised instruments called EMI receivers. Spectrum analysers measure the amplitude of a signal across the entire frequency range of the instrument and display it graphically. Their primary use is to visualise and characterise the spectrum of typically known signals in the frequency domain (*e.g.*, bandwidth, dominant frequency, harmonics, distortions, etc.) [1]. EMI receivers can be defined as specialised, high-performing spectrum analysers.

The design of EMI receivers is particularly challenging. Indeed, in EMI measurements (i) there is no *a-priori* knowledge about the measured signal (interference), (ii) the interference amplitude covers a wide dynamic range, (iii) the interference frequency spectrum spans over a wide band, and (iv) the interference repetition rate can be as low as a few Hz or can even be non repetitive. Since decades, there exist specific standards (*e.g.*, CISPR 16-1-1 or MIL-STD 461 in the civilian and military contexts, respectively) that define the requirements for EMI receivers in order to benchmark these instruments in different setups and environments.[1] For example, EMI receivers must use specific resolution bandwidths (RBW, *e.g.*, 200 Hz, 9 kHz, 120 kHz, 1 MHz) and detectors (*e.g.*, peak, quasi-peak, average, RMS), as defined in [2]. Furthermore, to be able to comply with all requirements of CISPR 16-1-1, EMI receivers need to have a high dynamic range. For example, the prescriptions on the pulse response of the QP detector for isolated impulses (see Tab. 2 in [2]) are particularly challenging.

Overload phenomena, which may easily arise when the dynamic range is not sufficient, lead to a wrong, usually underestimated, EMI characterisation of the equipment under test (EUT). For this reason, it is indispensable to have specific hardware to notify and control overload conditions. EMI receivers should incorporate an overload revealer[2] that detects overload phenomena prior to the first compression sensitive component of the receiving path (either the pre-amplifier, mixer or ADC). Further, they should have a preselector and an internal attenuator (still at the front end of the receiving path) in order to set the receiver in its linear range. Unfortunately, EMI receivers are often evaluated based on characteristics such as RBW filters and detectors rather than on the presence of specific hardware to notify and control overload conditions.

The remainder of this paper is structured as follows. In Sect. II, we first distinguish between three different types of EMI receivers. In Sect. III, we discuss the required dynamic range of EMI receivers. In Sect. IV, we describe what happens when a receiver is overloaded and explain what hardware is required to prevent this. In Sect. V, we shortly discuss overload phenomena in the different types of EMI receivers. We corroborate our claims with three simple experiments, explained in Sect. VI and discussed in Sect. VII. Finally, we conclude this paper in Sect. VIII.

II. CISPR 16-1-1 Full-Compliant, Compliant, and Pre-Compliant EMI Receivers

CISPR 16-1-1 defines the characteristics and performance of EMI measurement instruments [2]. Specifically, it regulates radio disturbances in the frequency range from 9 Hz to 18 GHz, divided into the so-called CISPR Bands A, B, C, D and E. Amongst others, critical aspects for compliance are the prescriptions on the use of a quasi-peak (QP) detector and the handling of pulse signals. The QP detector gives a weighted peak value of the envelope of the input signal and makes that

[1] In this paper, we focus on the civilian context only and thus solely refer to CISPR 16-1-1 standard.

[2] In this paper, we use the term "revealer" instead of "detector" to avoid confusion with the actual detector of the receiver.

pulses with lower repetition rates exhibit lower levels than pulses with higher repetition rates (with equal amplitude and duration), see [3], [4] for details on the QP detector response. According to CISPR 16-1-1, EMI receivers must be able to correctly weight pulses with slow repetition rates (down to 1 Hz) and even isolated impulses. The prescribed relative pulse response of QP detectors varies according to the different bands (see Tab. 2 and Tab. 7 in [2]).

Measuring receivers (EMI receivers and spectrum analysers) without preselection, may only fulfill the requirements in [2], Tab. 2 for pulse repetition frequencies (PRF) of 20 Hz and higher. In this case, the user must demonstrate that the EUT does not emit broadband signals with PRF of 20 Hz or lower. To do this, CISPR defines a simple method that verifies the validity of the QP measurement. It basically consists in a comparison of measurement results obtained with the peak and QP detectors. If the difference in amplitude between peak and QP measurement is smaller than the maximum allowed value (see Tab. E.1 in [5]), it is implied that the pulse signal has at least a PRF of 20 Hz and thus the QP measurement is valid. Hence, for that particular EUT, the measuring receiver complies with CISPR 16-1-1 and can be used to demonstrate compliance of the EUT. Otherwise, a measuring receiver that fully complies with all PRF requirements of CISPR 16-1-1 (*i.e.*, low frequencies down to 1 Hz and even isolated impulses) has to be used.

There exists an informal (*i.e.*, not specifically defined in CISPR 16-1-1 standard) and mostly commercially used distinction between the two discussed types of measuring receivers. A *full-compliant* measuring receiver, is an instrument that fully complies with all PRF requirements in CISPR 16-1-1. On the other hand, measuring receivers which only comply with CISPR 16-1-1 requirements for PRFs of 20 Hz or higher are called *compliant*.

Another class of EMI receivers are the so called *pre-compliant* EMI receivers, although this term is neither formally nor informally defined and does not imply any specific characteristics. Basically, any instrument could be called pre-compliant. Pre-compliant EMI receivers are low-cost instruments which do not comply with CISPR 16-1-1, but have detectors and RBW filters as defined in [2]. For certain signals and measurement setups, such pre-compliant EMI receivers may give similar results to compliant EMI receivers and could thus represent a cheap tool to get first insights on the electromagnetic behaviour of a new product during its development. However, pre-compliant EMI receivers cannot guarantee that the EUT will pass the certification, and they can also not guarantee reliable results in all measurement setups.

The most critical aspects that distinguish among different EMI receivers are their dynamic range and the presence of specific hardware to notify and control overload conditions.

III. Dynamic Range in EMI Receivers

The dynamic range defines the capability of a receiver to correctly and simultaneously measure concurrent signals with (very) different amplitudes. Specifically, the dynamic range is defined as the logarithmic difference (or the linear ratio) between the maximum and the minimum signal level that a receiver can measure in one shot. This parameter is also called instantaneous dynamic range [6]. The minimum level is the lowest input signal level a receiver can detect. Signals with a lower level fall below the noise floor of the receiver and therefore cannot be detected. Instead, the maximum level is the highest input signal level a receiver can handle without compressing the signal. Signals with a higher level are distorted by one or more components in the receiving path of the receiver.

Since the dynamic range is limited by the noise floor of the instrument, it depends on the type of detector used and on the RBW value. Indeed, the use of different detector types leads to different noise floors. In standard conditions, the noise displayed with a peak detector is roughly 4 to 5 dB higher than with a QP detector (depending on the band), about 12 dB higher than with an RMS detector and approximately 13 dB higher than with an AVG detector [7]. This is due to the different nature of the detectors. While the peak detector captures the maximum value of the input signal, the QP detector gives a weighted peak value of the input signal, the RMS detector measures the quadratic mean of the signal, and the AVG detector determines the signal average value.

The noise floor is also proportional to the bandwidth which enters the system: the narrower the bandwidth, the lower the noise. Specifically, every time the input bandwidth becomes ten times narrower, the noise floor decreases by 10 dB [8].

The maximum measurable signal level depends on the energy that a receiver is able to handle, and it is thus dictated by the signal type and amplitude, and may depend on the receiver's RBW. When a single sinusoidal signal enters the system, the input energy is fully concentrated in a single frequency component. For example, suppose that the circuitry of an EMI receiver, with a band-pass filter of 30 MHz, starts compressing at a level of 107 dBμV (namely 0 dBm). Such a receiver is capable of correctly measuring a single sinusoidal signal of maximum 107 dBμV.

In multiple-tone signals the signal energy is spread over the different frequency components. Further, the crests of the tones may sum up in phase. Hence, to guarantee that a receiver does not compress the signal, the maximum amplitude of the single tones is reduced to make sure that their peak amplitude does not exceed the maximum measurable level. More specifically, for a multiple-tone signal made of many sinusoidal components of equal amplitude, the maximum amplitude of the single components decreases by 6 dB for every doubling in the number of sinusoidal components (see Fig. 1). For example, our EMI receiver would be able to correctly measure two sinusoidal signals of 101 dBμV each.

The worst case scenario is when the input energy spreads over the whole input bandwidth, namely with a pulse signal [4], [9]. As mentioned before, the maximum measurable level must be reduced in order to avoid compression phenomena. By reducing the input bandwidth through a filter, the energy can be limited before the signal arrives to the first compression

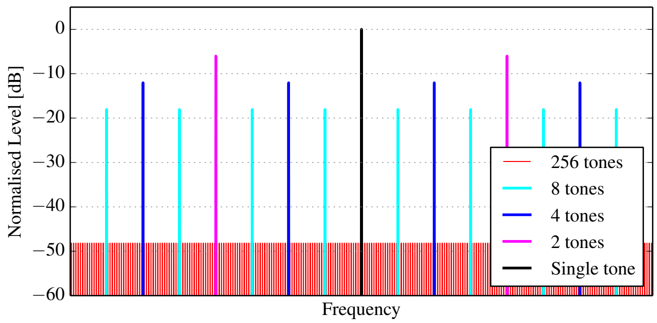

Fig. 1. Non-compressing level of multiple-tone signals normalised to a single-tone signal (full scale). The represented signals are made of either a single tone, two tones, four tones, eight tones or 256 tones.

sensitive component: the narrower the bandwidth, the lower the energy and thus the higher the maximum measurable level [10]. Obviously, in case of a pulse signal, this level depends on the RBW. For example, suppose we want to measure a pulse signal using again our EMI receiver with a band-pass filter of 30 MHz and which starts compressing at 107 dBμV. The spectral density, normalised to 1 MHz, should not exceed 77.5 dBμV/MHz ($=$ 107 dBμV $-$ $20\lg(30$ MHz$/1$ MHz$)$), otherwise the pulse signal would be compressed. If the RBW of the receiver is set to 100 kHz, the reading will be 77.5 dBμV $- 20\lg(1$ MHz$/100$ kHz$) = 57.5$ dBμV. By using instead an RBW of 9 kHz (RBW value required for band B, see Tab. 6 in [2]), the reading will be 36.6 dBμV. Thus, the maximum level that for a sinusoidal signal was 107 dBμV, for an impulse is merely 36.6 dBμV, seen with a 9 kHz RBW. This corresponds to a drastic dynamic reduction of 107 dBμV $-$ 36.6 dBμV $\approx$ 70 dB (see also the lab test in [11]). On the other hand, if we reduce the input bandwidth to 10 MHz, the maximum spectral density will increase to 87 dBμV/MHz, which means a reading of 46.1 dBμV with an RBW of 9 kHz. We have gained 10 dB in dynamic range.

An EMI receiver must always be capable of correctly working with all types of signals, first of all impulses. As mentioned in the introduction, in EMI measurements there is no *a-priori* knowledge about the nature of the interference under investigation. This means that the receiver must be able to deal with very high and very low level signals at the same time. Thus, a high dynamic range is essential.

The lack of dynamic range in EMI measurements is a very critical aspect because it can easily pass unnoticed. The reading of a high energy signal (such as an impulse) may be far below the maximum reading (instrument's Ref-Level) while the band is entirely occupied by the impulse. Thus, the user may erroneously think to still have a lot of dynamic range available while instead, the instrument may have already started compressing. Specifically for the latter phenomenon, it is crucial that receivers embed specific hardware that monitors sensitive components and notifies overload conditions.

IV. Hardware for Overload Conditions

Both, high level narrowband signals (*i.e.*, narrower than the receiver's RBW) and broadband signals (*i.e.*, broader than the receiver's RBW) with a certain spectral density can overload the first saturating component of EMI receivers. This component is usually either the pre-amplifier, the first mixer or the ADC. In overload conditions, any of these components may cause amplitude changes in the reading of input signals. Basically, for any change in the input there will no longer be a correspondent change in the output, as the signal is compressed. Further, because the components no longer work in their linear range, they may cause harmonic distortions and generate spurious responses. Thus, overload conditions lead to erroneous, usually underestimated, measurement results [12].

It is essential to know when a receiver works in overload conditions. Unfortunately, not all EMI receivers are able to directly notify the user of such non-linear phenomena. Moreover, many instruments that do have a mechanism to reveal and indicate overload conditions, have this mechanism too far down in the receiving path (where the signal is already compressed) and thus, cannot guarantee correct measurements. Indeed, an overload revealer is often placed within the detecting circuitry, *i.e.*, the last component in the receiving path. This may work, for example, with a high-level, single-tone signal, provided that the detecting circuitry has the same or a lower compression point than the previous components in the receiving path. In this case, the overload revealed at the last component corresponds to the maximum amplitude of the single-tone signal. In order that overload conditions are still correctly revealed, for example with a two-tone signal of equal amplitudes, the components preceding the detecting circuitry should exhibit at least a 6 dB higher compression point. Indeed, in this case, if the overload revealer placed within the detecting circuitry did not signal an overload condition, we can be sure that the previous components have not experienced an overload condition (due to this two-tone signal). Instead, in the case where all components have the same compression point, the first component in the receiving path could compress the two-tone signal and consequently, the signal would arrive at the detecting circuitry with a reduced amplitude. This reduced-amplitude signal would then not trigger the overload signalling at the detector circuitry stage, despite the first component being overloaded.

It is crucial that specific, valuable hardware is placed *at the front end* of EMI receivers, prior to the first saturating component (pre-amplifier, mixer or ADC) to avoid unnoticed overload conditions at the detector circuitry stage. Placing mere software or firmware after the first saturating component is not effective. In fact, also in the latest release of CISPR 16-1-1, Ed. 4.0 it is suggested to incorporate a *broadband* overload revealer in the receiver.

Without an indication of overload conditions, it is difficult to know if an EMI receiver works in its linear range. In fact, the user must have specific knowledge to correctly set the instrument in its linear range prior to the measurement.

Basically, the user must perform two measurements on two different levels and control if the difference in (dB-) readings given by the EMI receiver corresponds to the difference in input signal levels. Since the emission level of the EUT is not controllable, the only possible option to control the input signal level is to insert an attenuator at the front end of the receiver. If the difference in readings is smaller than the inserted attenuation level, the EMI receiver is overloaded. Such a non-automatic mechanism has of course intrinsic difficulties (it depends on the skills of the user, needs time to repeat the measurement, etc.) and is prone to errors.

EMI receivers with an overload revealer often also have a mechanism incorporated that automatically sets the instrument in its linear range by adjusting an internal input attenuator. This mechanism is called autoranging and relieves users of finding ideal settings. Basically, the attenuation level is adjusted step by step until the highest possible input signal level is found that does not overload the receiver. Autoranging brings also another advantage. Most limits for continuous disturbances are not flat but change with the frequency. Some limits show differences from highest to lowest of $\Delta L = 10$ dB (see for example Tab. 1, [13]). If there is no autoranging, when analysing an EUT, the EMI receiver must be adjusted such that at the highest limit the signal can still be measured correctly in its linear range. This means that for the lower limit values there is a further lack of dynamic range of up to 10 dB.[3]

For narrowband signals, such as continuous wave signals, using an internal attenuator is the only solution to avoid overload conditions. However, the use of an attenuator does not improve the dynamic range of the receiver. Indeed, increasing the attenuation level reduces also the amplitude of potentially concurring low level signals and thus reduces the receiver's sensitivity. If the amplitude of such low level signals falls below the noise floor level, the receiver will not be able to measure those signals anymore. Additionally, some attenuators may have a very coarse granularity. This may even lead to a reduction in dynamic range. Consider for example the following situation. To ensure that a receiver can measure the input signal correctly, its level should be reduced by 2 dB. However, the attenuator has only steps of 10 dB. By increasing the attenuation level we unnecessarily waste 8 dB of dynamic range.

For broadband signals such as impulses, where the energy is spread over the entire spectrum, using a preselector is a much better option as it effectively increases the dynamic range [12]. By placing a filter at the front end of the receiver, only a portion of the energy passes through and reaches the sensitive components further down in the receiving path. In the time domain, this corresponds to reducing the peak amplitude and extending the duration of the impulse. In this way, the area and therefore the spectral density of the input signal remain unvaried.

[3] Alternatively, one could also manually adjust the receiver for each frequency separately, but this would involve multiple, time consuming measurements.

A good EMI receiver should include both mechanisms, an attenuator (possibly with a fine granularity) and a preselector. However, the most important component remains the overload revealer. Only when overload conditions are detected correctly, can a receiver be adjusted accordingly. Note that, for some signals, it may not be possible to set a receiver in its linear range. In such cases, the use of a preselector and attenuator may not resolve the problem. Still, the overload revealer should notify that the receiver is not able to detect the signal correctly.

V. Overload in the Different EMI Receiver Types

The prescriptions for measuring receivers in [2] and [5] cannot guarantee that receivers are never overloaded, *i.e.*, overload conditions cannot fully be avoided. CISPR 16-1-1 requirements include an *absolute* calibration measurement that controls a correct relationship between peak and QP readings (see Tab. 7 in [2]). This calibration measurement has to be performed under specific conditions for each band. For example, in band B the receiver must use a RBW of 9 kHz and the generated pulse must have a PRF of 100 Hz. All other CISPR 16-1-1 requirements are based on this reference measurement and are thus only *relative* measurements. For instance, Tab. 2 in [2] prescribes the relative QP pulse response of measuring receivers for different PRFs compared to the previously obtained reference value. Hence, the receiver is calibrated to measure peak values under certain conditions but not for other conditions where only relative QP values are observed. As the QP detector gives a weighted peak value of the envelope of the input signal, any underestimation of peak values is necessarily also reflected in the QP measurement. Thus, it can happen that the relative values as prescribed in [2] and [5] may be correct, while the absolute reading is wrong, since the receiver is overloaded. Paradoxically, the more a receiver is overloaded, the more it is able to satisfy the requirements of low PRFs and hence, the better it may seem to work. However, these relative measurements based on compressed absolute values are, of course, completely unreliable and such EMI receivers cannot be used to make accurate characterisations of EUTs. After all, limits for EUT's emissions refer to absolute values, independently of the detectors.

Full-compliant EMI receivers do not have this problem, as they have a sufficiently high dynamic range thanks to their preselector. On the other hand, in EMI receivers without preselector and that exhibit a low dynamic range (compliant and, most of all, pre-compliant EMI receivers), this problem may easily arise. Indeed, also CISPR 16-1-1 distinguishes between these two classes of receivers and prescribes different tests for receivers with and without preselector. Unfortunately, when the quality/compliance of an EMI receiver is evaluated, the focus usually lies on the capability to correctly report the relative QP pulse response at different PRFs, whereas the correctness of the absolute reading is neglected.

TABLE I
READINGS OF A CONTINUOUS WAVE SIGNAL WITH AND WITHOUT EXTERNAL ATTENUATION FOR DIFFERENT INTERNAL ATTENUATIONS

Int. Att.	Reading	Reading with 3 dB ext. att. inserted	ΔReading
0 dB	112.9 dBμV	112.3 dBμV	0.6 dB
10 dB	118.8 dBμV	116.4 dBμV	2.4 dB
20 dB	119.8 dBμV	116.8 dBμV	3.0 dB

TABLE II
PEAK READINGS (BAND C) OF A PULSE SIGNAL WITH AND WITHOUT EXTERNAL ATTENUATION FOR DIFFERENT INTERNAL ATTENUATIONS

Int. Att.	Peak reading	Peak reading 3 dB ext. att. inserted	ΔPeak
0 dB	50.5 dBμV	49.8 dBμV	0.7 dB
10 dB	60.8 dBμV	60.3 dBμV	0.5 dB
20 dB	68.8 dBμV	68.0 dBμV	0.8 dB
30 dB	72.0 dBμV	71.0 dBμV	1.0 dB

TABLE III
PEAK READINGS (BAND B) OF A PULSE SIGNAL WITH AND WITHOUT EXTERNAL ATTENUATION FOR DIFFERENT INTERNAL ATTENUATIONS

Int. Att.	Peak reading	Peak reading 3 dB ext. att. inserted	ΔPeak
0 dB	40.0 dBμV	39.3 dBμV	0.7 dB
10 dB	48.3 dBμV	47.5 dBμV	0.8 dB
20 dB	55.2 dBμV	53.0 dBμV	2.2 dB
30 dB	58.1 dBμV	56.0 dBμV	2.1 dB

TABLE IV
QP PULSE RESPONSE OF THE RECEIVER COMPARED TO CISPR 16-1-1 REQUIREMENTS FOR DIFFERENT PRFS

PRF	QP reading	rel. QP value ref at 100 Hz	CISPR requirement for band B
100 Hz	47.2 dBμV	0 dB	0 dB
20 Hz	39.8 dBμV	7.4 dB	$+6.5 \pm 1.0$ dB
10 Hz	37.7 dBμV	9.5 dB	$+10.0 \pm 1.5$ dB

VI. EXPERIMENTS

In this section, we report on our investigation on overload conditions in a pre-compliant EMI receiver (we used a Rhode & Schwarz HAMEG HMS-X spectrum analyzer with the HMS-EMC option used in EMI receiver mode). We performed three different experiments; the first one dealing with a single-tone signal, and the second and third ones dealing with a pulse signal measured in band C and band B, respectively. In the third experiment, we also checked the relative pulse response of the QP detector, which represents the most-commonly used feature to classify EMI receivers. Throughout the experiments, to reproduce "real" EMI measurements where the input level is out of the control of operators/users, we kept fixed the level of the input signal and changed instead the receiver's setting.

In the first experiment, using a Rhode & Schwarz SMY Generator, we generated a continuous wave, single-tone, sinusoidal signal with a level of 120 dBμV (level well within the amplitude measurement range indicated in the specifications of the receiver) and a frequency of 50 MHz. We set the RBW of the receiver to 120 kHz (band C) and measured the level of the signal. We verified that the receiver was able to correctly measure the signal by inserting an external input attenuator of 3 dB and checking if the reading decreased by 3 dB as well. If the reading decreased by less than 3 dB, it meant that the receiver was compressing the signal. In that case, we increased the receiver's internal input attenuator until the receiver was able to measure correctly. This was achieved by using 20 dB internal attenuation. The results are reported in Tab. I. By simply removing the signal from the input, we also measured the noise floor level (of the QP detector), which was 29.1 dBμV without attenuation and 49.8 dBμV with 20 dB internal attenuation. As expected, by inserting an attenuator the dynamic range did not change, but we simply adjusted the receiver's working range.

In the second experiment, using an Electro-Metrics CIG 25 Impulse Generator, we generated a pulse signal with 100 Hz PRF, a spectral density of 90 dBμV/MHz and a flatness of 2 dB within 1 GHz (as prescribed in §B.1.2 in [2]). In this experiment, we measured the peak level tuned at 100 MHz, setting the RBW to 120 kHz (band C). For such an impulse, we would expect a peak reading of 71.6 dBμV/MHz ($= 90$ dBμV/MHz $- 20\lg(1$ MHz$/120$ kHz$)$), independently of the PRF.[4] In Tab. II, we report the peak readings with and without 3 dB external attenuation for different internal attenuation levels. Even with 30 dB internal attenuation the receiver did not measure the peak correctly (there was no 3 dB decrease in peak reading when inserting the 3 dB external attenuation). However, the receiver has no option to insert more than 30 dB internal attenuation. Nonetheless, even when we reduced the input level, the receiver was still not able to measure the pulse signal correctly.

To allow more headroom in the dynamic range of the receiver and see if a linear working range can be found, we repeated the previous experiment in band B, deliberately generating a pulse signal with a lower spectral density than the one prescribed in [2]. Specifically, in this third experiment, we generated a pulse signal with 100 Hz PRF, a spectral density of 95 dBμV/MHz (instead of the prescribed 107 dBμV/MHz) and a flatness of 1 dB for band B, using an EM C1611 EMI Receiver Tester. For this impulse, we would expect a peak reading of 95 dBμV/MHz$-20\lg(1\text{MHz}/9\text{kHz}) = 54.1$ dBμV. In Tab. III, we report the peak readings of the receiver tuned at 15 MHz and setting the RBW to 9 kHz (band B) with and without 3 dB external attenuation for different internal attenuation levels. Once again, even with 30 dB internal attenuation the receiver could not measure the peak correctly.

In the same setting, with 20 dB and 30 dB internal attenuation inserted, the receiver's QP readings were 47.2 dBμV and 49.9 dBμV, respectively. Thus, there was a difference between

[4]In this and the third experiment, to evaluate if the receiver measures correctly, we do not only focus on the theoretically calculated absolute value, since, when all tolerances are considered, this value may vary significantly. Rather, as in the first experiment, we verify the absence of compression by inserting an external input attenuator of 3 dB and checking if the peak reading decreased by 3 dB as well.

peak and QP readings of 8 dB and 8.2 dB, respectively, for 20 dB and 30 dB attenuation, which just complies with the requirements in Tab. 7, [2] for band B and a PRF of 100 Hz (including the 1.5 dB tolerance). For 20 dB internal attenuation we further measured the QP for different PRFs, see Tab. IV. The obtained results are in line with the requirements in Tab. 2, [2] for band B. Hence, when only focusing on relative QP readings, a user may think that the receiver measures correctly and even complies fully with CISPR 16-1-1 prescriptions, although the QP readings are based on completely wrong absolute measurements.

VII. Discussion

In the first experiment, we have seen that a single-tone sinusoidal signal may overload a receiver. This can usually be resolved by increasing the attenuation. However, an attenuator also decreases the sensitivity of the receiver.

With the second and third experiment, we have demonstrated that when the energy of the input signal is too high (compared to the dynamic range of the receiver), by simply adjusting the attenuation level it can even be impossible to set the receiver in a linear, not overloaded range above the noise floor level. Specifically, by increasing the attenuation to avoid compression, the signal level may be reduced below the noise floor level, and would thus not be detected anymore. For such high-energy, broadband signals another solution is needed. As we have discussed in Sect. IV, preselection effectively increases a receiver's dynamic range. EMI receivers, namely instruments that *per definition* need a high dynamic range, should therefore embed a preselector at the front end of the receiving path to guarantee correct measurements.

Further with the third experiment, we have shown that by only focusing on QP readings, a user may think that a receiver measures correctly and even complies (fully) with CISPR 16-1-1 prescriptions. However, when the QP readings are based on wrong (compressed) absolute peak measurements, the measurements are completely unreliable and such EMI receivers cannot be used to make accurate characterisations of EUTs.

In all three experiments, the receiver did not signal any overload conditions. If we had not checked the difference in readings with and without the external attenuation inserted, we would not have noticed that the signal measurement (peak and QP) was compressed. When dealing with a single sinusoidal signal (first experiment), although there was no overload signalling, it was possible to find a setting for which the receiver showed a correct value (when inserting an external attenuation, the reading changed accordingly). Instead, for pulse signals (second and third experiment) it was impossible to find such a setting. Although the receiver was able to measure a single sinusoidal signal of 120 dBμV, it could not give a reliable reading for a much lower broadband signal of 54 dBμV. Hence, all further inquiries, for example regarding QP weighting, are inconsistent. For this reason (as explained also in Sect. IV), it is essential that a receiver incorporates an overload revealer and that the specific hardware to control overload conditions is placed *at the front end* of EMI receivers, prior to the first saturating component to avoid unnoticed overload conditions at the detector circuitry stage.

VIII. Conclusion

Designing electromagnetic interference (EMI) receivers is particularly challenging. As we have demonstrated in this paper, high energy signals can easily overload instruments that do not have an internal attenuator and/or a preselector at the front end of the receiving path. The attenuator reduces the input level and thus represents the only solution for narrowband signals. Instead, the preselector reduces the input bandwidth and thus should be used for broadband signals, such as impulses. Yet, it is essential to first recognise overload phenomena. The receiver should have an overload revealer placed prior to the first saturating component (pre-amplifier, mixer or ADC). Unfortunately, EMI receivers are often evaluated based on characteristics such as RBW filters and detectors rather than on the presence of specific hardware to notify and control overload conditions.

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