Pitfalls in Measuring Discontinuous Disturbances with Latest Click Analysers

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***Abstract*—The recent advancing in click analyser technology aims at reducing costs and time required to perform a full CISPR 14-1 compliant click measurement. The two relevant approaches to achieve costs and time reductions are, respectively, the use of Fast Fourier Transform (FFT) EMI receivers and performing the threshold calculation and actual measurement in a single run (single-run systems). However, there are some critical aspects related to these approaches. (i) The reduced dynamic range, emphasized in FFT receivers and single-run systems, can lead to underestimated measurements. (ii) The partial consideration of the disturbance (i.e., only its amplitude but not its shape in time) can make single-run systems susceptible to an erroneous calculation of clicks. Still, both approaches can be pursued with certain precautions: a specific circuitry to notify an overload condition of click anaysers in general and the recording of both IF and quasi-peak channels in single-run systems.**

By thoroughly discussing the two issues and the related proposed precautions, we undermine popular claims of click analyser manufacturers and reconsider common beliefs about click analysers. We report on important technical aspects and scarcely known details, supporting our claims with simple lab tests and examples.

Keywords*—*dynamic range, FFT receiver, clicks, second run

I. Introduction

Since the first wireless transmissions, design engineers have been concerned about the electromagnetic interference (EMI) level. International regulatory agencies arose to define allowed EMI levels and measurement methods for compliance testing. For example, the CISPR committee internationally defines allowed radio-frequency disturbance levels. Particularly, CISPR 14-1 describes the precise measuring procedure for discontinuous disturbances (clicks) [1]. Clicks are broadband disturbances which are usually produced by switching operations and have a maximum spectral characteristic below 2 MHz [1]. Since the beginning, the classic CISPR 14-1 compliant measuring procedure is divided into two runs. The first run serves to obtain threshold parameters that are later used in the second run. The second run is the actual measurement phase that, based on the calculated *relaxed limits*, establishes if the appliance under test has passed the test. This measurement must be performed at four frequencies. Nowadays, to perform the click measurement commonly a click analyser is used, which is made of a specialised EMI receiver. Such an EMI receiver must fully comply with CISPR 16-1-1 [2].

Since the beginning, to reduce the time required to perform the whole click measurement, manufacturers introduced the so-called four-channel click analysers. These analysers were practically made of four parallel EMI receivers, each tuned to one of the four frequencies. They thus allowed measuring all four frequencies at once, which led to a significant time reduction. However, four receivers imply higher costs. With the advancement of technology, i.e. by using Fast Fourier Transform (FFT) EMI receivers, it became possible to measure the four frequencies at once using a single receiver only. This reduced by far the costs of a click analyser.

To further reduce the time needed to perform the click measurement, manufacturers started to produce click analysers that merge the two runs into one single run only. Practically in such *single-run systems*, the data is stored during the 'first run' and is then used afterwards for two processing steps: first the threshold parameters are calculated and then the same data is re-evaluated based on the new thresholds (relaxed limits). In this way, the measurement is based only on a data post-processing and not anymore on a second measurement.

However, there are some risks related to the use of FFT receivers and single-run systems for the click measurement. The main concerns regard the limited dynamic range that EMI receivers may present. The baseline concept is that EMI receivers can only process a certain amount of energy at a given time, otherwise they are overloaded (they start compressing) and are unable to measure linearly. In fact, the dynamic range represents the most critical aspect of an EMI receiver [3]. Unfortunately, FFT receivers and, even more, single-run systems require quite a high dynamic range. It may thus happen that clicks are not measured correctly any more, due to EMI receivers working in overloaded conditions. To be sure of a correct test outcome, click analysers should prove that the EMI receiver was not overloaded.

The need for a high dynamic range of click analysers derives from the following aspects.

1) The EMI receiver must be adjusted such that the CISPR 14-1 limit is sufficiently above the background noise.
2) Although click analysers must use a *quasi-peak (QP)* detector, the dynamic range of the EMI receiver must be sufficient to deal with *peaks* of input signals.
3) To be able to cover the entire frequency range (when using an FFT receiver), a wider bandwidth is necessary (i.e., 30 MHz as opposed to 9 kHz when measuring the frequencies separately).
4) Depending on the frequency, the CISPR 14-1 limit

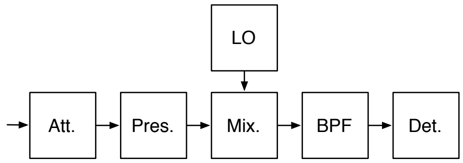

Fig. 1. Simplified block scheme of a traditional heterodyne EMI receiver, made of attenuator (Att.), preselector (Pres.), local oscillator (LO), mixer (Mix.), band pass filter (BPF) and detector (Det.)

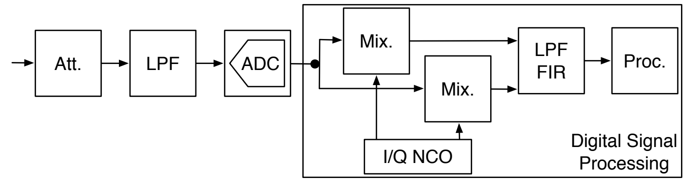

Fig. 2. Simplified block scheme of a Fast Fourier Transform (FFT) EMI receiver, made of attenuator (Att.), low pass filter (LPF), analog-to-digital converter (ADC), complex numerically controlled oscillator (I/Q NCO), mixers (Mix.), digital low pass filter (LPF FIR) and final processing (Proc.)

changes (the limit is not flat). To measure all four frequencies at once with an FFT receiver, the entire range of limits must be considered when setting the EMI receiver.

5) The relaxed limit in the second run may be much higher than the limit in the first run. To do both runs at once, a single-run system must cover the entire range of limits.

A further concern regarding single-run systems is that merging two runs in one during the click measurement can be done only if both the input signal (IF channel) and the QP channel shapes are recorded and analysed. Any simplified approach (e.g., simple evaluation of QP amplitudes over limits) may result in a wrong measurement result.

In this paper, we first generally introduce EMI receivers in Sect. II. Then in Sect. III, we focus on the receivers' dynamic range and illustrate the importance of this feature in a simple lab test. Next in Sect. IV, we report on the dynamic range required to successfully perform click measurements, specifically discussing traditional four-channel click analysers and click analysers with FFT receivers. Finally, in Sect. V, we point out possible pitfalls of single-run systems. We end the paper with a short conclusion in Sect. VI.

II. EMI Receivers

EMI receivers are specialised instruments for measuring radio-frequency disturbances. Historically, EMI receivers were (super-) heterodyne receivers, whose basic block scheme is shown in Fig. 1. The attenuator serves to align the input level with the dynamics of the successive blocks. The preselector (i.e., a band pass filter) limits the input band to the successive stages. The preselector can be a bank of filters or a tunable filter (tracking) that covers the entire measured frequency range. The band pass filter (BPF), placed after the down converter stage (mixer and local oscillator), defines the resolution bandwidth (RBW) of the receiver. Finally, the detector reveals readings (e.g., peak, average, weighted) of the input component.

In traditional receivers, a measurement is done by consecutively tuning the receiver over the different frequencies such that the whole frequency span is covered. With this type of receivers, the time required to measure wide bands can be very long. For example, more than three hours are needed to measure band B of 150 kHz - 30 MHz with a RBW value of 9 kHz, assuming that the observation time of the detector is 2 s (given the equation B / $\frac{\text{RBW}}{2} \times$ observation time).[1] [2]

[1]These values are realistic and are aligned with Band B CISPR 16-1-1 full compliant measurements [2].

[2]A minimum overlap of half RBW is required.

With the advancement of technology (advancement in A/D conversion and digital signal processing), FFT receivers have been introduced (the related basic block scheme is shown in Fig. 2). In FFT receivers the whole bandwidth under measurement (limited by a low pass filter, LPF) is given to an analog-to-digital converter (ADC), which is placed at the very front of the reception path. After digital conversion, time-domain samples are windowed, thus obtaining the needed RBW, and Fast Fourier Transform algorithms are used to convert data into the frequency domain. Finally, data is processed to apply the required detection.

FFT receivers may reduce the time required to perform a measurement by a factor of hundred or even thousand times. Instead of scanning the required band step by step, FFT receivers measure the entire band at once by making first a time-domain acquisition and then the processing in the frequency domain. In case of the aforementioned example, the measurement time reduces to the observation time only, namely 2 s for a QP detector. However, FFT receivers may present a major drawback: their limited dynamic range. An input signal which has a level out of the instrument's dynamic range is not measured correctly due to non-linear phenomena, often even without the user noticing that.

III. Dynamic Range in EMI Receivers

The dynamic range is defined as the logarithmic difference (or the linear ratio) between the maximum and minimum signals that a receiver can correctly and simultaneously handle.[3] Obviously, 'simultaneously' implies a single shot measurement and thus no adjustments can be done in the meanwhile. 'Simultaneously' also implies that no effective methods exist to increase the dynamic range other than using a hardware with better intrinsic performance.[4] The minimum level is the lowest detectable level that lies just barely above the noise. Conversely, the maximum level normally coincides with the highest level before compression phenomena happen. The RBW value and the detector-type always affect the minimum level and they may also influence the maximum level, depending on the type of input.

Different detectors have different noise floor levels. For example, an *average* detector, because of its averaging nature, shows a lower noise than a *peak* detector. For the same reason, a peak detector displays a higher floor noise than an *RMS* detector. For example, in standard conditions, peak detector

[3]This parameter is also known as instantaneous dynamic range [4].

[4]E.g., techniques varying the attenuation at run-time or more advanced techniques using scaled ADCs [5] fail when dealing with high-dynamics simultaneous signals; an ADC with higher resolution is instead required.

noise is roughly 12 dB higher than RMS detector noise [6]. The noise level is also related to the bandwidth which enters the system: the narrower the bandwidth, the lower the noise. The change in noise between two different bandwidths BW_1 and BW_2 is $\Delta N = 10\lg(BW_1/BW_2)$ [7], which means that for every decade there is a 10 dB change.

For a single sinusoidal signal, where the energy is fully concentrated in the single frequency component, the maximum level corresponds to the signal magnitude and depends neither on the RBW value nor on the type of detector used. If we introduce a second sinusoidal signal, still keeping the full scale, to avoid compression when the two crests sum up in phase, we must reduce the amplitude of both signals by 6 dB. Therefore, the maximum measurable level for each signal is 6 dB below the full scale value. If we now add further two signals, we have to further reduce the level by 6 dB so that, once more, when all the summits of the four signals are in phase no compression occurs. Hence, the maximum measurable level for each signal is now 12 dB below the full scale value, which leads to a lower dynamic range available for each signal.

In case of an impulse, a receiver has to deal with a much worse condition where numerous spectral lines add up to fully occupy the band [3]. Still, the level must be reduced in order to avoid compression phenomena. Indeed, the energy is solely limited by the band of the filter before the impulse arrives to the first compression-sensitive component. As a consequence, the wider the bandwidth, the higher the energy and thus the lower the maximum measurable single signal. For example, suppose that the circuitry of a simple receiver, which has a band-pass filter of 30 MHz, starts compressing at a level of 107 dBμV (namely 0 dBm). This level can be (i) just a single sinusoidal signal of 107 dBμV or (ii) the (peak-)sum of all signals arriving to the input, such as in case of multiple signals or (iii) an impulse whose area is 0.011 μVs (this value is calculated according to 'terms and definitions' §3.5 and §3.6 in [2] and considering a filter bandwidth $B_{\text{imp}} = 30$ MHz).[5] In case of such an impulse, the spectral density, normalised to 1 MHz, must be limited to 107 dBμV $- 20\lg(30$ MHz/1 MHz$) = 77.5$ dBμV/MHz. If the RBW of the receiver is set to 100 kHz, the measured peak will be 77.5 dBμV $- 20\lg(1$ MHz/100 kHz$) = 57.5$ dBμV. This means that the maximum level that for a sinusoidal signal was 107 dBμV, for an impulse is merely 57.5 dBμV, seen with a 100 kHz RBW. That means a dynamic reduction of 107 dBμV $-$ 57.5 dBμV $\approx$ 50 dB. If the RBW of the receiver is reduced to 9 kHz (a realistic value aligned with the requirements of [2] in Table 6, for band B), the measured peak will be 36.6 dBμV. This results in a drastic dynamic reduction of 107 dBμV $-$ 36.6 dBμV $\approx$ 70 dB!

The worst aspect of the lack of dynamic range is that the user will not notice any problems when simply reading the receiver. Indeed, the reading of the single signal may be far below the full scale level. One may thus think to still have a lot of dynamic range available, ignoring that the whole band is fully occupied by the spectrum produced by the input signal (e.g., an impulse). Only by means of specific tests, can the user realise if the dynamic range is sufficient to correctly measure the signal. Specific tests that however need (i) time to be performed, (ii) the ability and the experience of the user, (iii) the rough knowledge of the signal under test, and, most importantly, (iv) the repeatability of the signal. For these reasons, receivers need to embed specific hardware circuitry that monitors the sensitive components and notifies the user of the non-linearity and, even better, corrects the problem when possible through a different setting (e.g., a different attenuator value). Still today, many on-the-market receivers do not embed circuitry that handles over-range conditions.

A. Simple Lab Test With a CISPR 16-1-1 EMI receiver

We now validate the concepts expressed in the previous section through a simple lab test by using a UKAS certified CISPR 16-1-1 full compliant EMI receiver. The setup is for a Band B EMI measurement, therefore 9 kHz RBW (Table 6, [2]). In this band, we deliberately do not use preselection thus a full 30 MHz bandwidth arrives to the input. The attenuator is set to 10 dB. Then, CISPR 16-1-1 Band B impulses (with 100 Hz pulse repetition rate) are generated, increasing the level up to the point where the compression starts. The reading shows compression for peak level values above 46 dBμV which says that this is the maximum level. In this setup, after removing the signal, the noise is around 11 dBμV and 6 dBμV, respectively, for the Peak and the QP detector. Leaving the same setup and attenuation, we then put a sinusoidal signal increasing the level up to the point where it starts compressing: this point is reached approximately at 115 dBμV. Thus, the difference in maximum levels is 115 dBμV $-$ 46 dBμV $= 69$ dB, which is very close to the theoretical value. The QP dynamic range has been drastically reduced from 115 dBμV $-$ 6 dBμV $= 109$ dB with a single sinusoidal signal, to a mere 46 dBμV $-$ 6 dBμV $= 40$ dB when impulses are present.

With this background, we are now able to discuss the dynamic range of CISPR 16-1-1 full compliant EMI receivers when doing the CISPR 14-1 click measurement. We consider roughly 110 dB as reference value for the dynamic range of a full compliant receiver (with ideal preselector).

IV. Dynamic Range in Click Analysers

Clicks (discontinuous disturbances) are measured following the CISPR 14-1 standard. As already mentioned, the common way to perform the click measurement is to use a click analyser, which is made of a specialised EMI receiver. Specifically, the CISPR 14-1 click measurement relies on the QP detector of a CISPR 16-1-1 full compliant EMI receiver [1]. This special detector gives a weighted peak value of the envelope of the input signal. The slow-decay response of the QP detector implies that impulses with slower repetition rates result exhibiting lower levels than impulses with higher repetition rates (with equal amplitude and duration) [8].

According to [2], the full compliant EMI receiver must be able to correctly weight impulses with slow repetition rates and even single impulses. Specifically, Table 2 in [2] cites impulses with 1 kHz to 1 Hz repetition frequency and isolated pulses. After all, clicks are broadband disturbances which are usually produced by switching operations and can hence be compared to impulses. The use of the QP detector when measuring a

[5]In this paper, we neglect the difference between impulsive bandwidth (B_{imp}) and 6-dB bandwidth (B_6) because it is not appreciable in our approximated calculations.

single impulse represents a critical aspect which makes larger the dynamic range required by a (CISPR 16-1-1 full compliant) EMI receiver. For this reason, since CISPR 14-1 was first issued, this normative prescribes the use of an attenuator to tailor the input dynamics according to the receiver dynamic range: '*The receiver attenuator is to be set such that an input signal equal in amplitude to the relevant limit L for continuous disturbance produces a mid-scale deflection on the meter*' [1]. This prescription, which may seem old fashioned, wants to ensure that the linearity of the receiver is set at its optimum point to guarantee the full linearity, especially in the lower level, namely when the receiver measures signals with an amplitude comparable with the noise level. Indeed, to fulfil the requirements of tests 11 and 12 reported in Table 17, [2], a noise far below the amplitude equivalent to the relevant limit L for continuous disturbance is essential. According to [2], for Band B, the difference of QP weighting for isolated impulses with respect to continuous wave is 23.5 ± 2 dB (Table 2) plus 6.6 dB (Table 7). Further, to guarantee that the response to slow repetition rates of the QP detector matches the time constraints defined in [2], roughly a 10 dB margin must be considered (for details on the QP response please refer to [8]). Hence, the receiver must be set to have a sufficient margin above the noise M_N: the noise should be at least $M_N = 23.5\text{ dB} + 6.6\text{ dB} + 10\text{ dB} \approx 40$ dB below L in order to guarantee CISPR compliant measuring and full linearity.

A. Dynamic Range in Traditional EMI Receivers

Historically, a click counter was made of a (super-) heterodyne EMI receiver, which measured on a single frequency, out of four, at a time. The so-called four-channel click analysers were made of four parallel receivers, each tuned to one of the four frequencies. Because each receiver had to measure only at one particular frequency they could, and in fact they did, use a preselector. Thanks to the reduced input bandwidth, as a result of the preselection, the analyser had to deal with a lower energy and thus exhibited a better dynamic range. In fact, the ideal condition is when the input bandwidth matches the resolution bandwidth, which is 9 kHz according to [2].

In four-channel click analysers, because of the four separate receivers, every single input level could be tailored for the specific limit value. This is important because normally the limits for continuous disturbances are not flat and thus each frequency has its own reference level (Table 1, [1]). By using a different attenuation for each frequency, namely flattening the limits, the dynamic range of the receiver can be optimised based on each reference level.

A four-channel click analyser, which uses an ideal preselector of 9 kHz and has a different attenuation for each frequency optimised for the specific limits, needs a minimum dynamic range equal to the margin M_N:

$$\text{MDR}_1 = M_N \approx 40\text{ dB}. \tag{1}$$

This figure represents a minimum ideal value that does not take into account margins for the granularity of the attenuator and other minor compensations.

B. Dynamic Range in Fast Fourier Transform EMI Receivers

In the last decade, click analysers with FFT receivers were introduced [9]. Like four-channel click analysers, click analysers using FFT receivers have some benefits in terms of time spent as, instead of measuring a single frequency at a time, an entire band is measured in the same time span [10]. However, these benefits are limited by the click measurement procedure itself, as defined by CISPR 14-1: The time for the test is the time needed to count 40 clicks or 120 minutes. Thus, the advantage of FFT receivers over traditional receivers when performing click measurements is purely economic: one receiver, capable of measuring the four frequencies at the same time, instead of four receivers. However, when using FFT receivers for click measurements, the dynamic range becomes an important issue. Paradoxically, modern FFT receivers used as click analysers may have worse performances than the traditional four-channel stepped receiver: no improvement in measuring time (since it cannot be reduced as it is fixed by the normative) but less dynamic range.

In FFT receivers, the full band must arrive flat at the input. If the measurement over Band B is done in one shot, this necessarily means that there is no preselection in front of the first-saturating component, which normally is the ADC. In other words, the full 30 MHz band is presented to the input along with its full energy. Being that the RBW required by the normative for Band B is 9 kHz and that 30 MHz is the band at the input of the measuring component, the loss of dynamic range is $M_{30\text{MHz}} = 20\lg(30\text{ MHz}/9\text{ kHz}) \approx 70$ dB. This figure, as already explained in Sect. III, is irremediably lost and cannot be recovered.

The use of FFT receivers for the full band click analysis has another drawback in terms of loss of dynamic range related to non-flat limits of CISPR 14-1. Limits for continuous disturbances show differences from highest to lowest of $\Delta L = 10$ dB (see Table 1, [1]). Because all four frequencies arrive at the input unconditioned, the input shall be adjusted for the lowest limit value to make sure that the noise is low enough to correctly weight the QP detector for that lower reference value. However, this generates a further lack of dynamic range at the frequencies with higher limit values (up to 10 dB).

Summing up the mentioned aspects, we can calculate the minimum dynamic range MDR_2 required by a click analyser using FFT receivers in the worst case scenario: The first figure is the previously defined margin above the noise $M_N \approx 40$ dB. The second figure comes from non-flat limits, i.e., $\Delta L = 10$ dB. Last, and unfortunately the biggest, is the loss due to the wide band presented at the input $M_{30\text{MHz}} \approx 70$ dB.

$$\text{MDR}_2 = M_N + M_{30\text{MHz}} + \Delta L \approx 120\text{ dB} \tag{2}$$

Obviously, this big figure (order of magnitudes higher than values discussed in [9]) does not include margins for the granularity of the attenuator, the receiver flatness, and other minor compensations.

It is likely that such a receiver saturates and thus does not give linear readings. As mentioned, unless there is a specific circuitry to notify the overload or saturation, the phenomenon will occur unnoticed. Saturation will always lead to have an underestimation because of compression. Obviously, this dynamic range issue could be improved by adding a preselector in front of the input (a preselector placed after the ADC, as in [9], does not improve the linear dynamic range). The preselection, in this case, should be tailored for the click measurement, cutting out the unneeded energy. This means that FFT receivers that merely use additional software without adding hardware (i.e., four pass-band filters tuned to the four frequencies) may not comply with the CISPR standards.

V. Single-run Click Analysers

Some manufacturers claim that they can make the full click measurement merging the first run (new threshold calculation) and the second run (actual measurement) in one single run. The theory behind this is that all data is recorded during the first run. Then the data is re-used, applying the relaxed limits and thus finding new clicks, as if they were re-measured a second time. The advantage of such single-run systems is the drastic reduction of the measurement time.

Contrary to common beliefs, single-run click analysers are *not* bound to the modern FFT receiver technology but can also be realised with traditional stepped receivers. Indeed, it is a pure record-and-calculate process and has nothing to do with the way signals are received. Actually, since many years, there are traditional click analysers on the market that have the option to skip the second run according to the user's will.

Undoubtedly, although it is debatable whether the current edition (Ed. 5.2) of CISPR 14-1 allows single-run click analysers [11], single-run click analysers can be designed. However, click analyser designers and manufacturers should take into account two main critical aspects: the dynamic range of the embedded receiver and the role of the input signal shape (data shape) on the click measurement outcome.

A. Concerns About the Dynamic Range

Merging first and second runs in one single run worsens the requirements in terms of dynamic range. This is due to the relaxation of the relevant limit L in the second run. According to [1] the maximum possible relaxation is 44 dB. Therefore, there is the possibility that the initial value of the limit for continuous disturbances is increased by as much as $\Delta Lq = 44$ dB.[6] This figure is an additional 'room' needed at the top of the dynamic range if the single-run approach is applied. Indeed, only by correctly measuring the clicks with no compression, can the stored values be used for re-evaluating and matching them to the relaxed (i.e. higher) limit. Therefore, in a single-run four-channel click analyser with an ideal preselector, the minimum dynamic range required is

$$\mathrm{MDR}_3 = M_N + \Delta Lq \approx 84 \text{ dB}. \quad (3)$$

This means that when using traditional receivers, the single-run approach could still be done quite safely.

FFT receivers, instead, pose some additional concerns. We have already analysed that a full band FFT receiver needs an enormous dynamic range that, with today's technology, can hardly be achieved. Much harsher is the picture if the second run is skipped using the previously recorded data. The minimum dynamic range required turns out to be

$$\mathrm{MDR}_4 = M_N + M_{30\mathrm{MHz}} + \Delta L + \Delta Lq \approx 164 \text{ dB} \quad (4)$$

[6]The relaxed limit L_q is the value used in the measurement run (second run) above which disturbances, with specific characteristics, are counted as clicks. L_q value is calculated based on the click rate N obtained during the first run [1].

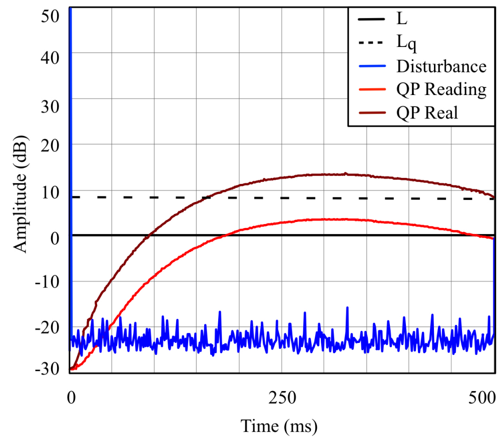

Fig. 3. Click measurement with a high-amplitude, short-duration pulse. This disturbance (blue) leads to a saturated QP reading (red), which underestimates the real QP value (brown) by ≈10 dB. The black continuous line represents the continuous disturbance limit L, whereas the black dashed line represents the relaxed limit L_q, here 8 dB above L.

This is a huge number that, as per today, is not feasible.

For an FFT receiver that uses a preselector, depending on the bandwidth of it, the dynamic range required could be much lower. The ideal case would be a receiver with a preselector having four pass-band filters with a bandwidth of 9 kHz (in total 36 kHz) where the $M_{30\mathrm{MHz}} \approx 70$ dB loss calculated in Sect. IV-B becomes $M_{36\mathrm{kHz}} = 20\,\lg(36\text{ kHz}/9\text{ kHz}) \approx 12$ dB. Yet, even in this ideal condition, the minimum dynamic range required to deal with the worst situation is

$$\mathrm{MDR}_5 = M_N + M_{36\mathrm{kHz}} + \Delta L + \Delta Lq \approx 106 \text{ dB} \quad (5)$$

This is still a remarkable figure for a full compliant receiver.

In case of a single-run system, saturation due to a limited dynamic range can lead to an underestimation of click occurrence. This is because, in single-run systems, the attenuator level is not adjusted for the second run. Especially with pulses of high amplitude and short duration, saturation easily occurs (see Fig. 3). This leads to a compressed QP reading, which underestimates the actual QP level (in our example of roughly 10 dB). While this poses no consequences during the first run (QP reading still exceeds the limit L), the readings cannot be used for comparing with Lq. In our example (Fig. 3) we clearly show that a single-run system would miss the click.

B. Concerns About the Data Shape

When re-evaluating the data recorded during the 'first run' for the pseudo-second run, it is not sufficient to have only the amplitude of the QP channel and of the actual signal (also called IF-channel) for each click; also their temporal evolution (shape) is necessary. To prove this, we consider the situation depicted in Fig. 4, which in parts comes from the performance-check test 6, table 17 in [2]. Before discussing this example, we must summarise three CISPR 16-1-1 rules that are important to understand the example.

1) A 'click' has the following characteristics:
    a) the QP amplitude exceeds the QP limit L of continuous disturbance,

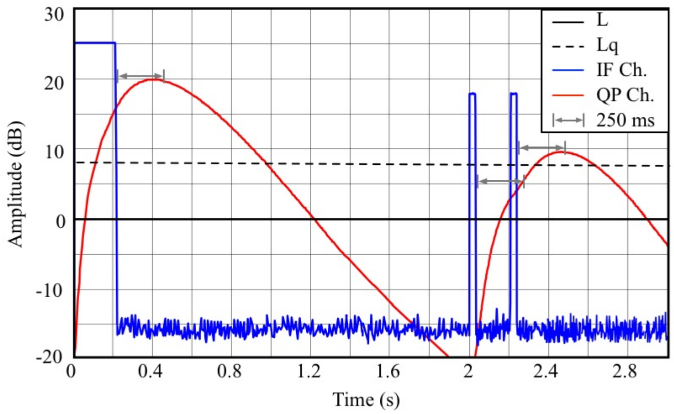

Fig. 4. Signal measured in the IF-channel (blue) and the associated QP channel (red). The relaxed limit L_q (black dashed line) is 8 dB above the continuous disturbance limit L (black continuous line). The arrows represent 250 ms, which is the time after which the QP channel shall be measured. The amplitudes of impulses are adjusted such that, individually taken, they would generate a QP reading of 20 dB, 5 dB and 5 dB, respectively, above L. The duration of impulses is 205 ms, 30 ms and 30 ms, respectively, while the separation of impulses is 1795 ms and 180 ms, respectively.

  b) the duration is shorter than 200 ms, and
  c) the spacing from a preceding or subsequent disturbance is equal to or more than 200 ms.
2) When the spacing between clicks is less than 200 ms, a combination of clicks in a time frame less than 600 ms is allowed (exception E2, [2]). The combination forms the so-defined 'other than click'.
3) The amplitude in the QP channel has to be measured 250 ms after the last falling edge in the IF channel.

Suppose that the situation depicted in Fig. 4 occurs during a click measurement. During the first run, a click analyser should measure one 'other than click', which counts as one click. Indeed, the first disturbance is longer than 200 ms and thus counts as an 'other than click' (of duration 205 ms). The following two disturbances, being their separation time lower than 200 ms, are added to make a 'long' click (240 ms) whose duration is summed up to the 'other than click'-time. Hence, the total duration of the 'other than click' is 445 ms. Suppose now that the relaxed limit L_q is 8 dB higher than the value used during the first run. In an actual second run, the first disturbance remains the same, i.e., an 'other than click' of duration 205 ms. Instead, the second disturbance would no longer be measured because, after 250 ms, the QP has not yet exceeded the new limit. Therefore, the third disturbance will be counted as a normal click and no longer added to the 'other than click'-time. Thus, the final result would be an additional standard click and still a (shorter) 'other than click', counting in total as two clicks.

In single-run systems, by applying the L_q value to the recorded click amplitudes, the outcome of the click measurement in Fig. 4 would drastically change. Indeed, since both QP amplitudes are still above the L_q limit, the result would be interpreted as it was during the first run, i.e., one (445 ms long) 'other than click', which counts as one click only. Thus one click less than when re-measuring clicks during a proper second run.

Single-run systems are possible. However, we have shown that it is not sufficient to simply compare the QP value with the relaxed limit. Instead, it is crucial that both the IF channel and the QP channel are recorded during the first run (with a time resolution at least equal to the minimum compulsory 500 μs) and are then re-evaluated level-by-level as well as time-by-time.

VI. Conclusion

With this paper, we pointed out weaknesses in common beliefs about click analysers. We have analysed some hidden aspects of click (discontinuous disturbance) measurements that could pass unnoticed without a sound knowledge of the measurement procedure, the involved instruments, and the related normative. Hidden aspects that may undermine the claimed advantages of new advertised approaches or, even worse, can lead to erroneous, underestimated measurements. The limited dynamic range in the EMI receiver represents the main concern for the validity of measurements. For this reason, we recommend to have the information about the compression of the input signal (IF channel), which alerts a user if the click has not been detected correctly with the needed linearity. This is important in Fast Fourier Transform EMI receivers, which particularly suffer from a limited dynamic range. An additional concern regards click analysers that perform the assessment (first run) and the actual measurement (second run) in a single shot. Indeed, such a single-run approach may be adopted as long as the linearity, for every single click, is proven and details of IF and QP channels are recorded.

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