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Translation of PCT/EP02/14158

Method and arrangement for the graphic representation of
5 the I and/or Q components of digitally modulated high-
frequency signals

The invention relates to a method for the graphic
representation of the I and/or Q components of digitally
10 modulated high-frequency signals such as quadrature
amplitude modulated (QAM) signals or vestigial sideband
modulated (VSB) signals, and an arrangement for the
implementation of this method.

15 To evaluate and monitor modern communication systems, the
digitally modulated high-frequency signals used in this
context must be registered using measurement technology.
Digitally modulated high-frequency signals of this kind
are described by the I/Q configuration diagram. It is
20 already known, for example, from DE 195 47 896 A1, that
the configuration diagram for relatively high-order
digital modulations of this kind, such as 64 QAM, can be
presented to the observer in a direct graphic manner on a
screen.

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It is also already known, that the I/Q components
measured in temporal succession in the I/Q-demodulator of
a receiver can be represented graphically on screen
either separately or optionally also superimposed
30 simultaneously in such a manner that the spacing of the
value clouds representing the individual symbols in the
configuration diagram appears on screen as a so-called
"eye-diagram". The so-called "eye-opening" displayed in



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this manner provides a measure for the quality of the digital modulation and the signal transmission.

One disadvantage of these known methods of representation
5 is that they fail to provide adequate information about the temporal course of any interference which may be present, for example, any periodically-occurring interfering pulses. Moreover, with the known method of representation, only a fraction of the I/Q data actually
10 present, which are registered within a short time window, are displayed and presented on screen. A large number of measured values are not registered at all, and the representation therefore contains considerable gaps.

15 The object of the present invention is to provide a method for graphic representation of the I/Q components of digitally modulated high-frequency signals, which avoids these disadvantages and also provides information about the temporal course of the signal represented. The
20 further object of the invention is to provide an arrangement, with which such I/Q components of digitally modulated high-frequency signals can be represented in a seamless manner.

25 This object is achieved according to the present invention by a method with the features of claim 1 and an arrangement with the features of claim 5. Advantageous further embodiments are defined in the dependent claims.

30 With the method according to the invention, the I and/or Q components measured in temporal succession are represented side by side on a graphic display. Accordingly, time is also graphically represented as a further dimension. As a result, a periodic interference

of the signal, for example, which cannot be registered reliably in any other manner or which cannot be registered because of the rarity of its occurrence, can be identified with certainty. However, the so-called
5 minimum eye-opening, of which the temporal course is represented graphically via the distance between the graphically represented I/Q components, can be measured in exactly the same manner as in the above-mentioned eye-diagram. The method according to the invention is
10 suitable for the graphic representation of all conventional digitally modulated high-frequency signals, which are determined with reference to I components or Q components or combined I/Q components, for example, conventional quadrature amplitude modulated (QAM) signals
15 or vestigial sideband modulation (e.g. 8VSB), which is conventional in the USA.

The invention will now be explained in greater detail with reference to drawings of exemplary embodiments. The
20 drawings are as follows:

- Figure 1 shows an outline circuit diagram of the arrangement according to the invention;
- 25 Figure 2 shows an outline diagram of the method according to the invention;
- Figure 3 shows a first example of a measured result and
- 30 Figure 4 shows a second example of a measured result.

Figure 1 shows the outline circuit diagram for an arrangement for the implementation of a method according

to the invention, for example, with a 64 QAM signal. The QAM-modulated high-frequency signal is demodulated in an I/Q demodulator of a receiver 1. The I/Q components seamlessly demodulated in temporal succession are
5 provided in parallel for further processing at the output of the demodulator. In the exemplary embodiment shown, both the I and Q components are to be evaluated. I and Q components arriving in parallel are therefore converted in a converter 2 into serial I/Q components and supplied
10 to a detector device 3, which consists of a large number n of amplitude-threshold detectors 4 arranged in parallel, each of which is tuned to a different threshold value 0 to n within the representational range of the relevant configuration diagram, for example, with 64 QAM,
15 within the range -8 to $+8$. The outputs of these detectors 4 are connected to a scanner 5, by means of which the relevant status of the n detectors 4 is scanned at regular time intervals, for example, 100 ms. The scanning result is placed into intermediate storage as a digital
20 result value in a buffer memory 6, from which it is read out at regular time intervals by a reader 7 and displayed graphically on the screen of a calculation and display device 8 (display and digital signal processor).

25 Figure 2 shows schematically the principle of the method according to the invention in the context of a QAM signal, of which the I and Q components are to be evaluated. The I and Q components provided in parallel in temporal succession at the output of the I/Q demodulator
30 are collated to form configuration-diagram packets P, for example, 100 ms in length. As shown in Figure 2, the I-component is rotated through 90° and is therefore orientated in the same vertical direction as the Q-component. This provides a one dimensional representation

of the configuration diagram. In this context, no information is lost. These one dimensional I/Q representations of configuration diagram packets P generated in temporal succession are now graphically
5 represented side by side, and time is therefore included in the display as an additional dimension.

In terms of memory technology, this is achieved with an arrangement according to Figure 1, in that the parallel
10 I/Q components are converted into serial components in the converter 2 and supplied to the detector device 3 as equivalent components. Each of the n detectors 4 establishes which of the I and Q components supplied in series corresponds to the value (for example, 0 to 255)
15 relevant to it. If an I or Q component corresponds to the relevant threshold value of a detector, the detector is activated, and its output is set from 0 to 1. After a given measuring time of, for example, 100 ms, the scanner
5 then determines which of the detectors 0 to n have been
20 activated during this measuring time. The result is placed into intermediate storage as a digital result value in the buffer memory 6. The results from all n detectors are therefore collated in this result value, which occurred in the measured signal during the period
25 since the last scanning of the detectors. Accordingly, each digital result value has as many binary digits as there are detectors. Each of these digits therefore accurately characterises one of the possible I or Q components.

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Another possibility is for the result values to be multi-digit numbers, which can be interpreted as the address of an array. Each of these digits again characterises an I or a Q value. The value of these digits (content of the

addresses) is determined by the number of allocated measured values occurring since the resetting of the detectors. Accordingly, each individual event increments the content of the addresses. In this manner, the
5 frequency of a measured value is known in addition to its mere occurrence. This possibility can be used particularly advantageously, for example, in order to represent the frequency distribution of the I/Q components occurring, graphically, for example, by means
10 of a colour scale.

The result values stored in the buffer memory 6 are read out by the reader 7 and represented horizontally side by side in the graphic display 8. In this manner, the eye-
15 opening of the digitally modulated high-frequency signal is obtained, and indeed, in dependence upon time. Since the maximum time-representation range of the display is exhausted after a short time, the time axis must then be re-scaled. For this purpose, the various result values
20 are collated in an appropriate manner for the graphic representation, so that, in this case also, all of the I/Q components occurring since the beginning of the measurement are registered and represented.

25 The collation of result values can take place in two different ways.

The result values are collated, stored and then graphically represented. This method is very memory-
30 efficient, but does not allow a retrospectively extended representation (magnification in the time range). The maximum number of result values to be stored overall is constant, that is, independent of the currently represented time range.

Another possibility is to store all the result values separately, collating them only for the graphic display, without changing the result values themselves in this context. This method, which is very memory-intensive especially with long measurements, does allow a subsequent magnified representation of any positions along the measured curve. However, considerably more space is required in the memory.

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Figure 3 shows the measured results for a 64 QAM signal with 20 second display time. The signal was subjected to interference every 2 seconds with 25 ns wide pulses. All of the pulses were registered by the device (seamless registration). For each pulse, at least two disturbed measuring points (I and Q components) are visible, depending on whether only one symbol was disturbed or two symbols. In the display diagram according to Figure 3, the vertical decision-field boundaries of the configuration diagram (-8 to +8) are shown as horizontal lines. The I and Q components collated to form a result value are represented as block strips within the 20 seconds between these decision fields boundaries; in this context, the intervening spacing corresponds to the eye-height defined in the eye-diagram. The measured points generated by the interfering pulses are marked in each case by the arrows drawn in dotted lines. In Figure 3, the associated number n of detectors (e.g. $n = 255$) according to Figure 1 used in this context is allocated to the vertical decision-field boundaries of the configuration diagram for 64 QAM shown on the right.

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Figure 4 shows a further measurement and representation with four days display time. Once again, a 64 QAM signal

is represented, which is subject to a periodicity of rising and falling interference, which is dependent upon the time of day. In this context, the causes may be, for example, EMV problems or temperature differences. The
5 spacing between two I or Q components represented as horizontally bulging lines again corresponds to the eye-height in the eye-diagram.

The time range to be represented can be configured by the
10 user within wide boundaries. A time range defined by the user (e.g. 1 hour) is initially started in the display within the smallest time range (20 seconds). Once this period has been reached, the device automatically switches into the next highest time range (in this case,
15 40 seconds, and so on) until finally, the desired time range is represented on the display.

Following this, the display switches to the so-called roll mode, that is, new measured values are appended at
20 the right-hand edge of the display, while the oldest measured values are deleted at the left-hand edge. Accordingly, the full time range specified by the user is visible in the display at all times with the current measured values. The maximum time range which can be
25 represented is 1000 days. A seamless registration of measured values can be achieved even in this operating mode.

In the exemplary embodiment described so far, which is
30 based on 64 QAM, both I and Q components were evaluated and represented in a superimposed manner. Graphic representation of only the I component or only the Q component is, of course, also possible. In this case, the parallel/serial conversion in the converter 2 is

dispensed with, and only the I components or the Q components are supplied to the parallel detectors 4. The evaluation and representation remains as described above. A separate, simultaneous representation of the I component and the Q component is also possible, in that the I component, for example, according to Figure 2, is not directly rotated upwards through 90° in the direction towards the Q component, but is, on the contrary, rotated downwards and then shifted, so that both components are graphically represented on the display as separate, horizontal measured strips.

The arrangement illustrated in Figure 1 with a large number of threshold detectors arranged in parallel is not only advantageous for the method according to the invention, but could also be advantageously used for the representation of classic configuration diagrams, because it allows a seamless evaluation of all I/Q measured values supplied from the demodulator. In the case of a representation of a classic configuration diagram, only a small fraction of the actually-occurring measured values were ever processed and represented. With the arrangement according to the invention, a 100%-seamless registration of measured values is possible, and interference with very short pulses can also be registered, even if only a single symbol in the transmission has been disturbed.

Claims

1. Method for the graphic representation of the I
5 component or Q component of digitally modulated
high-frequency signals,
characterised in that
the I or Q components measured in temporal
succession are graphically represented side by
10 side.
2. Method for the simultaneous graphic representation
of I and Q components of digitally modulated high-
frequency signals,
15 **characterised in that**
the I and Q components measured in temporal
succession are graphically represented side by
side, in one dimension.
- 20 3. Method according to claim 1 or 2,
characterised in that
the I/Q-components are measured seamlessly in
temporal succession and graphically represented
side by side.
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4. Method according to any one of claims 1 to 3,
characterised in that,
in each case, a large number of I/Q-components in
temporal succession are collated to provide result
30 values, and that these result values in temporal
succession are graphically represented side by side
on a display.

5. Arrangement for the graphic representation of the I/Q-components of digitally modulated signals, in particular, for the implementation of a method according to any one of the preceding claims 1 to 4,
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characterised by
an I/Q-demodulator (1) for determining successively the I and/or Q components of the digitally modulated high-frequency signal to be represented, of which the I-output and/or Q-output is connected to a large number of threshold detectors (4) arranged in parallel, which, in each case, are adjusted to different threshold values (0 to n) within the display range (-8 to +8 for 64 QAM) for the I/Q-components, and of which the statuses are scanned and collated at time intervals to form result values and graphically represented on a display device (8).
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- 20 6. Arrangement according to claim 5
characterised in that
the result values are graphically represented on the display device (8) side by side as vertical amplitude values together with the decision-field boundaries of the relevant I/Q-components.
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7. Arrangement according to claim 5 or 6
characterised in that
the result values collated at time intervals are stored in a buffer memory (6) and can be read out by means of a reader (7) for graphic representation.
30
8. Arrangement according to any one of claims 5 to 7,

characterised in that,
after the statuses of the detectors (4) have been
copied into the buffer memory (6), these can be
reset for the registration of a new measured value.

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9. **Arrangement according to any one of claims 5 to 8,**
characterised in that,

between the I/Q-demodulator (1) and the parallel
threshold detectors (4), a converter (2) is
10 arranged, by means of which, optionally, only the I
component or only the Q component is supplied to
the threshold detectors (4) successively in series.