



AU9334480

(12) PATENT ABRIDGMENT (11) Document No. AU-B-34480/93
 (19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 671977

- (54) Title
TESTING OF A DATA-TRANSMISSION LINE USING DUAL CROSS-CORRELATION TO ASSESS THE NUMBER OF DEFECTIVE BITS
- International Patent Classification(s)
 (51)⁵ **H04L 001/24**
- (21) Application No. : **34480/93** (22) Application Date : **03.02.93**
- (87) PCT Publication Number : **WO93/17511**
- (30) Priority Data
- | | | |
|----------------|-----------------|-------------------|
| (31) Number | (32) Date | (33) Country |
| 4205776 | 21.02.92 | DE GERMANY |
- (43) Publication Date : **13.09.93**
- (44) Publication Date of Accepted Application : **19.09.96**
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- (57) Claim

1. A method for determining the number of digital data communicated in error via a data transmission link to be tested (number of bit errors BF), in which a test sequence (A) comprising digital data (bits) is transmitted at the link input terminal, and an output sequence (AS) is received at said link output end, is cross-correlated with a referenced sequence (R; $\bar{R}$) corresponding to the test sequence (A) or to the inverted test sequence ($\bar{A}$), and in which the number of bit errors BF is determined by analysing the extreme value (EX) of the cross-correlation function (KKF) thus formed, wherein said output sequence is cross-correlated with said reference sequence (R) by respective exclusive-or logic operation (EXOR), followed by a checksum formation, thus creating a dual cross-correlation function ($KKF_d(n)$) in accordance with the rule:

$$KKF_d(n) = \sum_{m=0}^{N-1} f(m) \diamond h(n+m)$$

it being the case that

$$0 \leq n \leq N-1$$

where: ♦ : exclusive-or logic operation
 $f(m)$: reference sequence R; $\bar{R}$
 $h(n+m)$: output sequence AS
 N : number of the bits in the test
sequence A

 n : number of the bit positions by which
the output sequence is shifted relative to the original
output sequence, and in that the number of bit errors (BF)
is specified immediately by specifying the low-order
positions of the extreme value (EX) of the dual cross-
correlation function (KKF).

5. A device for carrying out the method as claimed
in one of claims 1 to 4, having a transmitter (SE) for
outputting a test sequence (A) composed of digital data, or
an inverse test sequence ($\bar{A}$) formed by inverting the
digital data into a data transmission link (DS) to be
tested, having a receiver (EM) for receiving an output
sequence (AS) at the link output end, and having a
correlator (K) to which the output sequence (AS) and a
reference sequence (R) are applied at the input end for the
purpose of forming a cross-correlation function (KKF),
wherein:

 the correlator (K) includes an exclusive-or (EXOR) or
an exclusive-not-or logic operation circuit (EXNOR)
downstream of which a summer for checksum formation is
arranged, in that a comparator compares the checksum (Q)
with an upper (OS) and a lower threshold value (US), the
threshold values (OS, US) being set at prescribed intervals
to test-sequence typical limits to the range of values, and
in that as a function of an established threshold value
overshoot a selector module (S) feeds at least the low-order
positions of the checksum (Q), which has been fed, to a
reprocessing device or a display ~~(AZ)~~.



(51) Internationale Patentklassifikation ⁵ : H04L 1/24		A1	(11) Internationale Veröffentlichungsnummer: WO 93/17511
			(43) Internationales Veröffentlichungsdatum: 2. September 1993 (02.09.93)
(21) Internationales Aktenzeichen: PCT DE93 00108 (22) Internationales Anmeldedatum: 3. Februar 1993 (03.02.93) (30) Prioritätsdaten: P 42 05 776.0 21. Februar 1992 (21.02.92) DE (71) Anmelder (für alle Bestimmungsstaaten ausser US): SIEMENS AKTIENGESELLSCHAFT [DE DE]; Wittelsbacherplatz 2, D-8000 München 2 (DE). (72) Erfinder; und (75) Erfinder/Anmelder (nur für US) : WOLF, Andreas [DE/DE]; Menzelstraße 23-24, D-1000 Berlin 41 (DE).		(81) Bestimmungsstaaten: AU, CA, CZ, JP, NO, US, europäisches Patent (AT, BF, CH, DL, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Veröffentlicht Mit internationalem Recherchenbericht.	

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(54) Title: TESTING OF A DATA-TRANSMISSION LINE USING DUAL CROSS-CORRELATION TO ASSESS THE NUMBER OF DEFECTIVE BITS

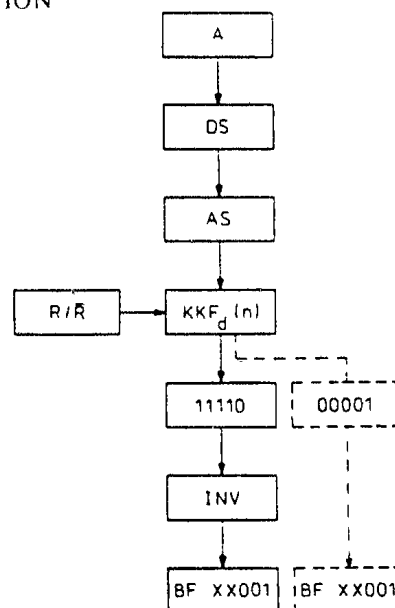
(54) Bezeichnung: DATENÜBERTRAGUNGSSTRECKENUNTERSUCHUNG DURCH BITFEHLERANZAHLWERTUNG MITTELS DUALER KREUZKORRELATION

(57) Abstract

The data-transmission line (DS) has a digital test-sequence (a) fed into it at the input end. An output sequence received is correlated, by means of a cyclically bitwise shifted exclusive-OR function (EXOR) followed by check-sum formation to form a dual cross-correlation (KKF_d), with a reference sequence (R) corresponding to the test sequence. The number of defective bits (BF) is immediately apparent from the low-order positions of the extreme value (EX) of the cross-correlation function (KKF_d).

(57) Zusammenfassung

Verfahren zum Ermitteln der Anzahl fehlerhaft über eine zu untersuchende Daten-Übertragungsstrecke übertragener digitaler Daten (Bitfehleranzahl) und Vorrichtung zur Durchführung des Verfahrens. Eine zu untersuchende Datenübertragungsstrecke (DS) wird eingangsseitig mit einer digitalen Testsequenz (A) beaufschlagt. Eine empfangene Ausgangssequenz wird mit einer der Testsequenz (A) entsprechenden Referenzsequenz (R) durch zyklisch bitweise verschobene Exklusiv-Oder-Verknüpfung (EXOR) mit anschließender Quersummenbildung (Q) zur Bildung einer dualen Kreuzkorrelation (KKF_d) korreliert; die niederwertigen Stellen des Extremwertes (EX) der Kreuzkorrelationsfunktion (KKF_d) geben die Bitfehleranzahl (BF) unmittelbar an.



TESTING OF A DATA-TRANSMISSION LINE USING DUAL
CROSS-CORRELATION TO ~~ASSESS~~ THE NUMBER OF
DEFECTIVE BITS

5 The invention relates to a method for determining the
number of digital data bits communicated in error over a
data transmission link to be tested (number of bit errors),
in which a test sequence comprising digital data (bits) is
transmitted from the link input terminal, in which an output
10 sequence received at the link output terminal is cross-
correlated with a reference sequence corresponding to the
test sequence or to the inverted test sequence, and in which
the number of bit errors is determined by analysing the
extreme value of the cross-correlation function formed.

15 In such a known (DE-A1-40 12 850) method, a test
sequence formed from a sequence of digital data is
transmitted from the link input end. It is preferable to
use as a test sequence, digital data whose autocorrelation
function has a pronounced extreme value, for example in the
20 form of a Dirac pulse (for the definition of the Dirac
pulse, refer Otto Mildenerger "Fundamentals of System
Theory for Telecommunication Engineers", Hansa-Verlag, 1981,
pages 48-50, (Grundlagen der Systemtheorie für
Nachrichtentechniker)). In the known method, the output
25 sequence received at the link output terminal is related to
the transmitted test sequence. The output sequence is
cyclically cross-correlated bit-by-bit over its length, with
a reference sequence corresponding to the test sequence or
to the inverted test sequence in order to form a cross-
30 correlation function. An inverted test sequence is to be
understood as a sequence comprising the respective



complementary digital data of the test sequence.

The extreme value, that is to say the maximum or minimum, of the cross-correlation function is analysed to determine the number of data bits communicated in error (number of bit errors). In principle, within a relatively wide range there exists an inverse relationship between the absolute value of the extreme value and the number of bit errors.

In the known method, for the purpose of specifying the number of bit errors, the extreme value must be subjected to further arithmetic operations in the form of a subtraction and a division. Specifically, if, for example, starting from a binary number sequence in the form of a 2^5 -m-sequence

10 $C_0(n) = 0000100101100111110001101110101$ (Equ. 1)

15 with a period of $N=31$ as test sequence and reference sequence after converting the latter - by assigning the binary values of 0 and 1 to the bipolar values of -1 and +1 - into a bipolar number sequence of the form

20 $C_{obi}(n) = (-1)(-1)(-1)(-1)(+1)(-1)(-1)(+1)(-1)(+1)(+1)(-1)$
 $(-1)(+1)(+1)(+1)(+1)(+1)(-1)(-1)(-1)(+1)(+1)(-1)$
 $(+1)(+1)(+1)(-1)(+1)(-1)(+1)$ (Equ. 2)

with an output sequence h_{bi} which is falsified, for example, in one position (bit) the cross-correlation function ($KKF(n)$) is formed in accordance with the rule

25

$$KKF(n) = \sum_{m=0}^{30} C_{obi}(m) \cdot h_{bi}(n+m), \quad (\text{Equ. 3})$$



the result is an extreme value of $KKF_{Ext} = 29$. The arithmetic operations of

$$BF = (N - KKF_{Ext}) / 2 = (31 - 29) / 2 = 1 \quad (\text{Equ. 4})$$

5 must be performed.

These arithmetic operations necessary for specifying the number of bit errors require a substantial outlay on circuitry, since they cannot be realised by simple logic elements. The effect of the necessary arithmetic operations
10 is to reduce the speed of execution of the known method.

Preferably, the invention provides a method for determining the number of digital data communicated in error via a data transmission link to be tested, which is distinguished by a high method speed and a simple
15 possibility for specifying the number of bit errors determined.

In accordance with one aspect of the invention, when the output sequence is cross-correlated with the reference sequence by respective exclusive-or logic operation,
20 followed by checksum formation, thus creating a dual cross-correlation function in accordance with the rule:

$$KKF(n) = \sum_{m=0}^{N-1} f(m) \diamond h(n+m)$$

it being the case that $0 \leq n \leq N-1$

where: $\diamond$: exclusive-or logic operation

25 $f(m)$: reference sequence R; $\bar{R}$



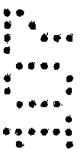
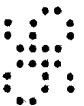
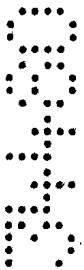
$h(n+m)$: output sequence AS

N : number of the bits in the test sequence A

5 n : number of the bit positions by which the output sequence is shifted relative to the original output sequence, and when the number of bit errors is specified immediately by specifying the low-order positions of
10 the extreme value of the dual cross-correlation function.

For the purpose of obtaining a general electrical signal, it is known from DE-A1-40 14 767 firstly to read two binary unipolar data streams respectively into a register,
15 and to combine the data with one another in respectively mutually assigned memory locations of the two registers, by means of an exclusive-or function. The intermediate data simultaneously produced from the respective combinations are summed, accompanied by the formation of an electric signal
20 corresponding to the dual cross-correlation function between the two incoming binary data streams. The summing device used for this purpose can comprise a cascade-type structure of a plurality of adders.

25 An advantage of the method according to an aspect of the invention consists in that subtraction of the extreme value and division for the purpose of specifying the number of bit errors are eliminated in principle by the use of the dual cross-correlation function. The binary cross-correlation function has
30 a positive value range which - after inversion of the extreme value, as the case may be - permits immediate specification of bit errors via the low-order positions of the extreme value. The method according to an aspect of the invention is distinguished by a rapid specification of the number of bit errors, which
35 permits it to be used for measurements in real time. The number



of the low-order positions of the extreme value which can still be used for the purpose of a reliable specification of the number of bit errors in determined in principle in accordance with the number of bit errors for which the dual cross-correlation function still has a reliably detectable extreme value (error tolerance). The error tolerance is test-sequence specific and reaches comparatively high values in the case of test sequences having a significant extreme value of autocorrelation function, and whereby an advantage is that the error distribution within the output sequence is not important. It is preferred to provide test-sequence specific threshold values, so that a value of the dual cross-correlation function greater than the threshold value can be detected reliably as the extreme value.

A configuration of the method according to an aspect of the invention which is advantageous with respect to the detectability of faults in the processing of the output sequence, (for example, failure of a memory containing the reference sequence), consists in that the exclusive-or logic operation is carried out in the form of the dual cross-correlation function inversely as an exclusive-not-or logic operation, and in that when using the test sequence as reference sequence the low-order positions of the inverted extreme value are used to specify the number of bit errors, while when the inverted test sequence is used as reference sequence, the low-order positions of the extreme value are used for directly specifying the number of bit errors. It is particularly advantageous in this case, to use the inverted test sequence as reference sequence, which permits direct utilisation of the low-order positions without inverting the extreme value.



As will be explained in further detail below, an inversion at least of the low-order digit positions of the extreme value which is to be undertaken, as the case may be, before the specification of the number of bit errors is
5 determined by the relationship between test sequence and reference sequence with respect to equality or inverting, and by the selected logic operation (exclusive-or or exclusive-not-or logic operation).

An advantageous development of the method according to
10 an aspect of the invention provides that a 2^n -m sequence (cf description in "Semi-conductor Circuit Engineering" ["Halbleiterschaltungstechnik"] Tietze/Schenk, 1980, pages 509 - 512) a Barker code (cf. description in "Pulse engineering", ["Pulstechnik"] Hölzer/Holzwarth, 1982, pages
15 170 - 174), a Gordon-Mills-Welch sequence (cf. "Sequences", Scholz/Welch, 1984, IEEE, Vol. IT-30, No. 3, May 1984, pages 548 - 553) or a Gold code (cf. "Binary Sequence with a High Cross-correlation with each Member of a Subset of Gold Codes" Yates, Electronics Letters, 28.08.1986, Vol. 22, No.
20 18, pages 930 to 932) is used as test sequence. The use of such special random number sequences as test sequences is particularly advantageous because the autocorrelation function of these test sequences have exceptionally significant extreme values, approximately in the form of a
25 Dirac pulse. As a result, the dual cross-correlation function forms a coding method which is as error-tolerant as possible, that is to say the highest possible number of bit errors in conjunction with a reliably detectable extreme value of the cross-correlation function. The error
30 tolerance can be substantially raised by using long sequences.

An advantage of the method according to an aspect of the invention is that, apart from the test sequence there is



additionally transmitted at the link input and, an inverse test sequence which is formed by inverting the test sequence, and in that the relative type of the extreme value of the dual cross-correlation function is also additionally
5 evaluated. Relative type is understood to mean the relative position of the extreme value with reference to the remaining course of the function; an extreme value which is less than the remaining function values is also referred to below as a lower extreme value or minimum. An extreme value
10 which is greater than the remaining function values is referred to below in an analogous way as upper extreme value or maximum. The additional use of the inverse test sequence doubles the number of test sequences (code words) which is available for test purposes. Moreover, this is advantageous
15 with respect to the reliability of the extreme value detection in conjunction with a low outlay on circuitry. It is possible, for example, to specify the number of bit errors directly, given the use of the exclusive-not-or logic operation to form the dual cross-correlation function, and
20 the test sequence as reference sequence given a negative extreme value (minimum) via the low-order positions of the latter, while given a positive extreme value (maximum) the number of bit errors is specified via the inverted low-order positions of the latter.

25 An apparatus according to an aspect of the invention, having a transmitter for outputting a test sequence composed of digital data, or an inverse test sequence formed by inverting the digital data into a data transmission link to be tested, having a receiver for receiving an output
30 sequence at the link output end, and having a correlator to which the output sequence and



a reference sequence are applied at the input terminal for the purpose of forming a cross-correlation function, is configured according to an aspect of the invention such that the correlator includes an exclusive-or or an exclusive-not-
5 or logic operation circuit downstream of which a summer for checksum formation is arranged, that a comparator compares the checksum with an upper and a lower threshold value, the threshold values being set at prescribed intervals to the test-sequence typical range of values, and that as a
10 function of an established threshold value, overshoots a selector module and feeds at least the low-order positions of the checksum, which has been fed to a reprocessing device or a display. The device according to an aspect of the invention is distinguished by an extremely low requirement
15 for circuit components in order to be able to represent the determined number of bit errors directly in a simple way. The device according to an aspect of the invention is exceptionally robust and insensitive to faults, since the evaluation of the received output sequences can be performed
20 without an arithmetic unit merely by means of cost-effective and reliably operating logic elements.

The invention is explained in more detail with reference to the drawings in which:

Fig. 1 shows the sequence of the method according to
25 an aspect of the invention, diagrammatically, and

Fig. 2 shows an apparatus for carrying out the method according to an aspect of the invention, and

Fig. 3 shows the relationship between the extreme value of a dual cross-correlation function and a selected
30 test sequence, a reference sequence and a logic operation; and

Fig. 4 shows a representation of the specification of



a number of bit errors obtained immediately in accordance with the method according to an aspect of the invention.

The method according to an aspect of the invention is described below, using a test sequence A which comprises a sequence of unipolar, digital data (binary number sequence) in the form of a 2^5 -m sequence in accordance with equation (Equ. 1). The test sequence is taken, for example, from a digital memory or generated from a feedback shift register and then coupled at the input end into a data transmission link DS to be tested. An output sequence AS received at the link output end as a consequence of this coupling in is subsequently correlated in accordance with the rule

$$KKF_d(n) = \sum_{m=0}^{30} f(m) \diamond h(n+m) \quad (\text{Equ. 5})$$

it being the case that

$$0 \leq n \leq 30$$

and $\diamond$ means exclusive-not-or function or exclusive-or logic operation

$f(m)$ means reference sequence R (2^5 -m sequence)

$h(n+m)$ means output sequence AS with the period (number of bits in the test sequence) $N=30$, with a reference sequence R, to form a dual cross-correlation function $KKF_d(n)$. The correlation is performed using an exclusive-or logic operation EXNOR or an exclusive-or logic operation EXOR. The reference sequence R corresponds to the test sequence, that is to say the 2^5 -m sequence in accordance with (Equ. 1). The reference sequence R can, however, also be inverted relative thereto, resulting in a reference sequence.

$$\bar{R} = \bar{A} = (1111011010011000001110010001010) \quad (\text{Equ. 6})$$



It is assumed below that the received output sequence AS contains a single bit error (4th bit), and thus has binary number sequence of

5 AS = (0001100101100111110001101110101) (Equ. 7)

The cross-correlation function KKF_a has an extreme value EX (maximum) of 30 (decimal) or 11110 (binary) in the case of the use of the reference sequence R corresponding to the test sequence A, and in the case of an exclusive-not-or logic operation EXNOR and subsequent checksum formation. In order to display the number of bit errors BF directly in this example, there is a need for inversion INV before the number of bit errors BF is represented by specifying the three low-order positions "001". The use of the inverted test sequence $\bar{A}$ as reference sequence $\bar{R}$ immediately produces an extreme value EX (minimum) of the dual cross-correlation function KKF of 1 (decimal) or 00001 (binary), which directly represents the number of bit errors BF (shown by dashes in Figure 1). The use of a 2^5 -m sequence produces an error tolerance of up to 7 bit errors, with the result that the last three low-order positions of the extreme value EX preferably serve the purpose of representing the number of bit errors BF.

25 The relationship between the decimal or binary extreme value EX of the dual cross-correlation function KKF_a and the number of bit errors BF is represented in a table in Fig. 2 for further examples. In the upper part of the table, the low-order positions of the dual cross-correlation function KKF_a directly represent the number of bit errors BF. As explained above, in the lower part of the table, by



contrast, the binary value is inverted before specification, at least the low-order positions of the extreme value EX of the cross-correlation function KKF_a .

Fig. 3 shows possible combinations of a to h of test sequences A or $\bar{A}$ and reference sequences R or $\bar{R}$ employed and the type of logic operation and the effect thereof on the type of the extreme value EX (maximum/minimum checksum Q) of the dual cross-correlation function KKF_a and an inversion preferably to be undertaken. In the case of the description of Figure 3, as well, the presence of a single bit error BF is assumed. In accordance with column a of Fig. 3, test sequence A and reference sequence R are identical; an exclusive-or logic operation EXOR is selected as the logic operation. Given the occurrence of a single bit error BF, the cross-correlation function KKF_a formed in accordance with (Equ. 5) between the output sequence AS and reference sequence R has a lower extreme value EX (minimum) of 1 determined by the formation of the checksum Q. This extreme value is specified immediately by outputting the low-order positions of the extreme value EX (checksum Q).

By contrast, in accordance with column b the reference sequence R comprises the inverted used test sequence A, with the result that in the case of the exclusive-or logic operation EXOR the checksum A corresponds to the maximum possible checksum MAX reduced by 1. In the case of the use of a 2^5 -m sequence, in accordance with (Equ. 1) and (Equ. 5) the maximum checksum is $MAX = 31$; the actual checksum Q is in this case

$$Q = MAX - 1 = 30 \quad (\text{Equ. 8})$$

After inversion INV (cf. in Fig. 1), the inverted low-



order positions of the extreme value EX (maximum) - that is to say the inverted checksum Q - are used for immediate specification of the number of bit errors. The conditions are correspondingly reversed in the case of the use of an
5 exclusive-not-or logic operation EXNOR as columns c and d in Fig. 3 show.

If, in addition to the test sequence A use is also made of an inverse test sequence $\bar{A}$ to increase the supply of test sequences, in accordance with columns e to h of Fig.
10 3 the relationship is correspondingly reversed in each case with reference to columns a to d. If both the test sequence A and the inverse test sequence $\bar{A}$ are used during testing of a data transmission link DS, it is possible - as explained below - depending on the configuration with regard
15 to the reference sequence used and the logic operation to use the type (maximum or minimum) of the extreme value EX in order, if required, to invert at least the low-order positions of the extreme value EX before specification.

Fig. 4 shows a device for carrying out the method
20 according to an aspect of the invention, in which a transmitter SE transmits both the test sequence A and the inverted test sequence $\bar{A}$ into a data transmission link DS to be tested. A receiver EM arranged at the output terminal receives the output sequence AS and feeds the latter to a
25 correlator K. A reference sequence R from a memory RS is applied further at the input terminal to the correlator K and corresponds to the test sequence A. The correlator K carries out a cross-correlation with the reference sequence R cyclically in a bitwise fashion over the length of the
30 output sequence AS. This is performed in each case by an exclusive-not-or logic operation EXNOR and subsequent



formation of the checksum Q. If the respectively formed checksum Q is within a range of values which is formed by a lower threshold value $US = 8$ and an upper threshold value $OS = 23$, the next exclusive-not-or logic operation EXNOR with
5 subsequent checksum formation is undertaken after a relative bitwise shift between the output sequence AS and reference sequence R. If the checksum Q overshoots the upper threshold value OS, a switch S is brought into a switch position S1 which passes on the checksum Q directly to a display AZ or a
10 reprocessing device, for example, in the form of a memory. The display AZ displays at least the three low order positions of the checksum Q and thus directly the number of bit errors BF.

If the checksum Q undershoots the lower threshold
15 value US, the switch S is brought into a switch position S2 in which the checksum Q is fed to the display AZ in an inverted fashion via an inverter INV.

If, after cyclic scanning of the entire output sequence AS, the checksum Q has overshoot neither the lower
20 threshold value US, nor the upper threshold value OS, the switch S is brought into a switch position S3 via which the value 8 is fed to the display AZ. Instead of the value 8, it is also possible to output a signal which displays overshooting of the number of bit errors BF in the selected
25 example of 7.

It becomes clear from Figure 3 that in the case of use of the inverted test sequence $\bar{A}$ as reference sequence $\bar{R}$ or in the case of use of the exclusive-or logic operation EXOR



the inverter INV is to be brought into the branch line for the switch position S1, while in the switch position S2 a direct specification of the checksum Q would be performed.

According to an aspect of the invention, it is
5 possible to form and evaluate a dual cross-correlation function KKF_d between an output sequence AS, and a reference sequence R, in an extremely simple and very rapid fashion. The method according to an aspect of the invention is therefore eminently suitable for testing digital
10 transmission links in real-time.



The claims defining the invention are as follows:

1. A method for determining the number of digital data communicated in error via a data transmission link to be tested (number of bit errors BF), in which a test sequence (A) comprising digital data (bits) is transmitted at the link input terminal, and an output sequence (AS) is received at said link output end, is cross-correlated with a referenced sequence (R; $\bar{R}$) corresponding to the test sequence (A) or to the inverted test sequence ($\bar{A}$), and in which the number of bit errors BF is determined by analysing the extreme value (EX) of the cross-correlation function (KKF) thus formed, wherein said output sequence is cross-correlated with said reference sequence (R) by respective exclusive-or logic operation (EXOR), followed by a checksum formation, thus creating a dual cross-correlation function ($KKF_d(n)$) in accordance with the rule:

$$KKF_d(n) = \sum_{m=0}^{N-1} f(m) \diamond h(n+m)$$

it being the case that

$$0 \leq n \leq N-1$$

where: $\diamond$: exclusive-or logic operation

$f(m)$: reference sequence R; $\bar{R}$

$h(n+m)$: output sequence AS

N : number of the bits in the test sequence A

n : number of the bit positions by which the output sequence is shifted relative to the original output sequence, and in that the number of bit errors (BF) is specified immediately by specifying the low-order positions of the extreme value (EX) of the dual cross-correlation function (KKF).

2. The method as claimed in claim 1, wherein the



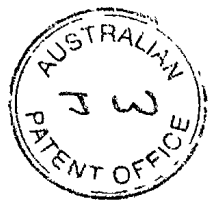
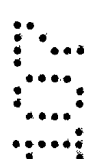
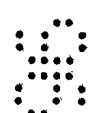
exclusive-or logic operation (EXOR) is carried out in the formation of the dual cross-correlation function (KKF_d) inversely as an exclusive-not-or logic operation (EXNOR), and in that when using the test sequence (A) as reference sequence (R) the low-order positions of the inverted extreme value (EX) are used to specify the number of bit errors, while when the inverted test sequence ($\bar{A}$) is used as reference sequence ($\bar{R}$), the low-order positions of the extreme value (EX) are used for directly specifying the number of bit errors (BF).

3. The method as claimed in claim 1 or 2, wherein a 2^n -m-sequence, a Barker code, a Gordon-Mills-Welch (GMW) sequence or a Gold code is used as said test sequence.

4. The method as claimed in any one of the preceding claims, wherein:

apart from the test sequence (A), there is additionally transmitted at the link input terminal, an inverse test sequence ($\bar{A}$) which is formed by inverting the test sequence (A), and in that the relative type (maximum, minimum) of the extreme value (EX) of the dual cross-correlation function (KKF_d) is also evaluated.

5. A device for carrying out the method as claimed in one of claims 1 to 4, having a transmitter (SE) for outputting a test sequence (A) composed of digital data, or an inverse test sequence ($\bar{A}$) formed by inverting the digital data into a data transmission link (DS) to be tested, having a receiver (EM) for receiving an output sequence (AS) at the link output end, and having a



correlator (K) to which the output sequence (AS) and a reference sequence (R) are applied at the input end for the purpose of forming a cross-correlation function (KKF), wherein:

5 the correlator (K) includes an exclusive-or (EXOR) or an exclusive-not-or logic operation circuit (EXNOR) downstream of which a summer for checksum formation is arranged, in that a comparator compares the checksum (Q) with an upper (OS) and a lower threshold value (US), the
10 threshold values (OS, US) being set at prescribed intervals to test-sequence typical limits to the range of values, and in that as a function of an established threshold value overshoot a selector module (S) feeds at least the low-order positions of the checksum (Q), which has been fed, to a
15 reprocessing device or a display (AZ).

6. A method for determining the number of digital data communicated in error via a data transmission link to be tested substantially as herein described with reference to Fig. 1.

20 7. A method for determining the number of digital data communicated in error via a data transmission link to be tested substantially as herein described with reference to Fig. 4.

25 8. A device for determining the number of digital data communicated in error via a data transmission link to be tested substantially as herein described with reference to Fig. 2.

DATED this Ninth Day of July 1996

Siemens Aktiengesellschaft

Patent Attorneys for the Applicant

SPRUSON & FERGUSON



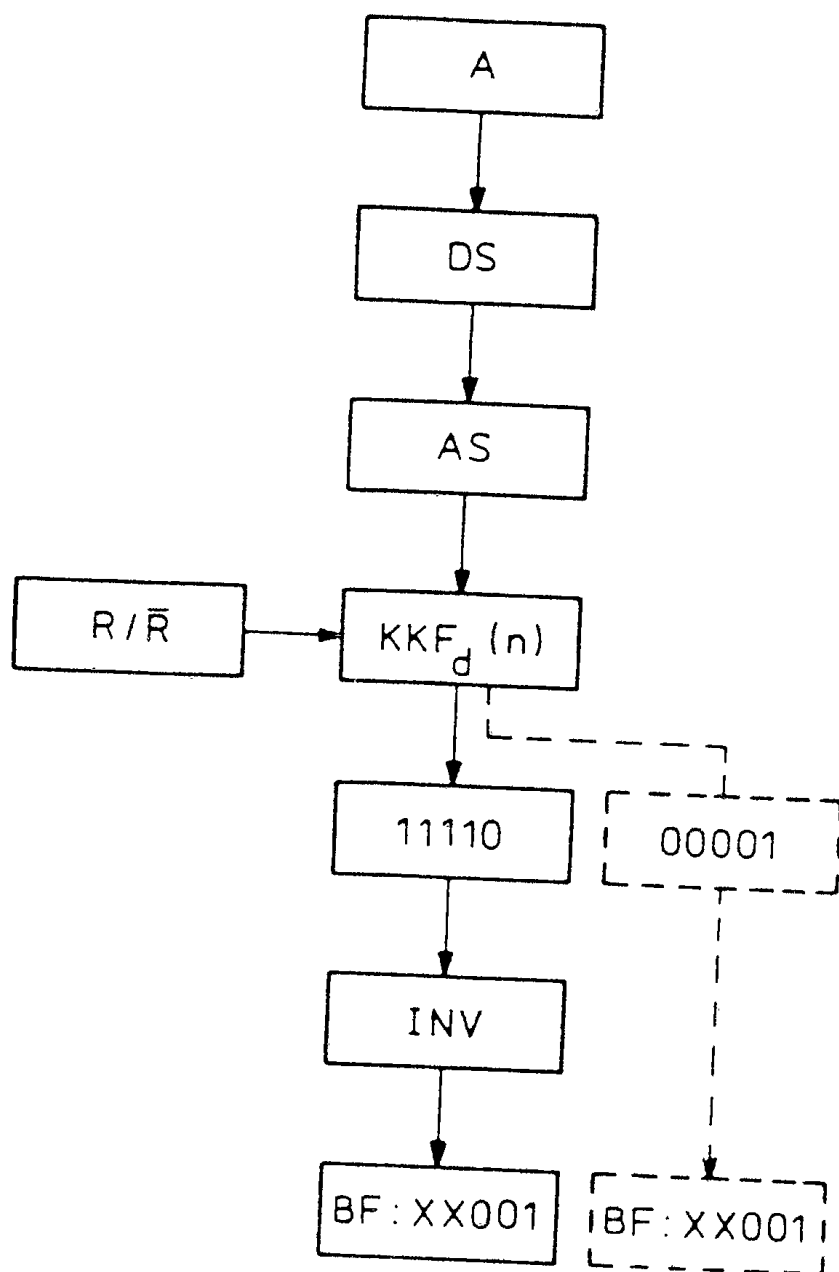
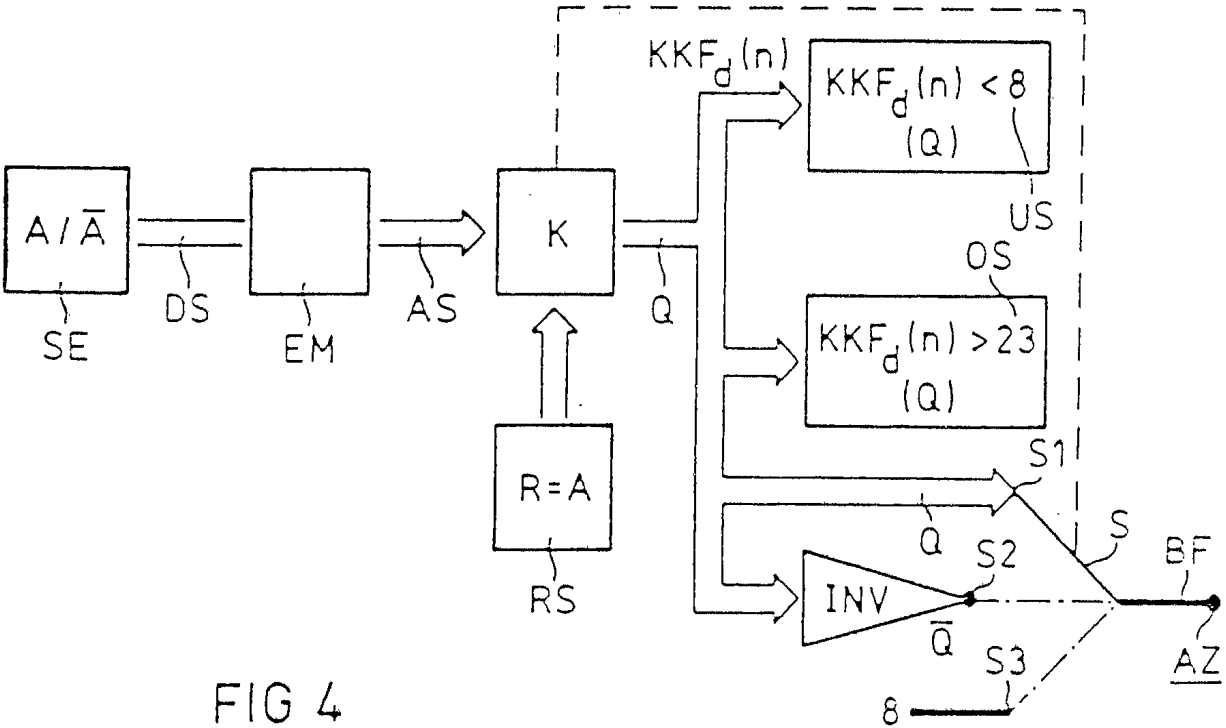


FIG 1

decimal $KKF_d(n)$ value	binary $KKF_d(n)$ value	inverted digital value	number of bit errors BF
0	00000 =		0
1	00001 =		1
2	00010 =		2
3	00011 =		3
4	00100 =		4
.			
.			
.			
27	11011	00100 =	4
28	11100	00011 =	3
29	11101	00010 =	2
30	11110	00001 =	1
31	11111	00000 =	0

FIG 2



	a	b	c	d	e	f	g	h
Test sequence	A	A	A	A	$\bar{A}$	$\bar{A}$	$\bar{A}$	$\bar{A}$
Reference sequence	R(A)	R($\bar{A}$)	R(A)	R($\bar{A}$)	R(A)	R($\bar{A}$)	R(A)	R($\bar{A}$)
Logic operation	EXOR	EXOR	EXNOR	EXNOR	EXOR	EXOR	EXNOR	EXNOR
Extreme value/ maximum/minimum	1	MAX-1	MAX-1	1	MAX-1	1	1	MAX-1
sum Q of digits in the case of one bit error								
Inverting	/	YES	YES	/	YES	/	/	YES
Display (low-order of the extreme value)	Q	Q	Q	Q	Q	Q	Q	Q

3/3

FIG 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/DE 93/00108

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. 5 H04L1/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. 5 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	NTZ Vol. 44, No. 8, 1991, BERLIN, DE; pages 548 - 557 WOLF ET AL 'BITFEHLER-STRUKTURANALYSE IN DER BREITBAND-ISND-MESSTECHNIK' see page 555, right-hand column, line 39 - page 557, left-hand column, line 7 see figures 7-11	1
A	TELCOM REPORT Vol. 14, No. 2, 1991, pages 104 - 107 WOLF 'MESSPRÄZISION AUF BREITEM BAND' see page 104, right-hand column, line 11 - page 105, left-hand column, line 59; figures 2,3,6	1

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of the international search

14 May 1993 (14.05.93)

Date of mailing of the international search report

28 May 1993 (28.05.93)

Name and mailing address of the ISA/

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Authorized officer

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INTERNATIONAL SEARCH REPORT

-2-

International application No

PCT/DE 93/00108

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	TELCOM REPORT Vol. 10, 1987, ERLANGEN,DE; pages 166 - 172 SEITEL 'DER ISDN-BASISANSCHLUSS' see page 169, right-hand column, line 1 - line 9; figure 7	1,3
A	INTERNATIONAL JOURNAL OF ELECTRONICS Vol. 50, No. 6, 1981, LONDON,GB; pages 429 - 436 EL-KHAMY 'ON GENERATION AND MEASUREMENT OF COMBINED BARKER CODES' see paragraph 2; figures 1-3	3
A	INTERNATIONAL JOURNAL OF ELECTRONICS Vol. 64, No. 3, 1988, LONDON,DE; pages 481 - 492 EL-KHANY 'ON THE GENERATION AND CORRELATION MEASUREMENT OF GOLD CODES' see paragraph 5; figures 8-10	3
A	IEEE MILITARY COMMUNICATIONS CONFERENCE Vol. 2, 1987, WASHINGTON,US; pages 738 - 741 KUMAR ET AL 'ON THE PARTIAL-PERIOD CORRELATION MOMENTS OF GMW SEQUENCES' see abstract	3

I. KLASSEFIZIKATION DES ANMELDUNGSGEGENSTANDS (bei mehreren Klassifikationssymbolen sind alle anzugeben) ⁶		
Nach der Internationalen Patentklassifikation (IPC) oder nach der nationalen Klassifikation und der IPC		
Int.Kl. 5 H04L1/24		
II. RECHERCHIERTE SACHGEBIETE		
Recherchierter Mindestprüfstoff ⁷		
Klassifikationssystem	Klassifikationssymbole	
Int.Kl. 5	H04L	
Recherchierte nicht zum Mindestprüfstoff gehorende Veröffentlichungen, soweit diese unter die recherchierten Sachgebiete fallen ⁸		
III. EINSCHLAGIGE VERÖFFENTLICHUNGEN ⁹		
Art. ^o	Kennzeichnung der Veröffentlichung ¹¹ , soweit erforderlich unter Angabe der maßgeblichen Teile ¹²	Betr. Anspruch Nr. ¹³
A	NTZ Bd. 44, Nr. 8, 1991, BERLIN, DE; Seiten 548 - 557 WOLF ET AL 'BITFEHLER-STRUKTURANALYSE IN DER BREITBAND-ISDN-MESSTECHNIK' siehe Seite 555, rechte Spalte, Zeile 39 - Seite 557, linke Spalte, Zeile 7 siehe Abbildungen 7-11 ---	1
A	TELCOM REPORT Bd. 14, Nr. 2, 1991, Seiten 104 - 107 WOLF 'MESSPRÄZISION AUF BREITEM BAND' siehe Seite 104, rechte Spalte, Zeile 11 - Seite 105, rechte Spalte, Zeile 59; Abbildungen 2,3,6 ---	1
-/-		
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Datum des Abschlusses der internationalen Recherche		Absenddatum des internationalen Recherchenberichts
14. MAI 1993		28. 05. 93
Internationale Recherchenbehörde		Unterschrift des bevollmächtigten Bediensteten
EUROPAISCHES PATENTAMT		BISCHOF J.L.A.

III. EINSCHLAGIGE VERÖFFENTLICHUNGEN (Fortsetzung von Blatt 2)		
Art °	Kennzeichnung der Veröffentlichung, soweit erforderlich unter Angabe der maßgeblichen Teile	Betr. Anspruch Nr.
A	TELCOM REPORT Bd. 10, 1987, ERLANGEN, DE; Seiten 166 - 172 SEIDEL 'DER ISDN-BASISANSCHLUSS' siehe Seite 169, rechte Spalte, Zeile 1 - Zeile 9; Abbildung 7 ---	1,3
A	INTERNATIONAL JOURNAL OF ELECTRONICS Bd. 50, Nr. 6, 1981, LONDON, GB; Seiten 429 - 436 EL-KHAMY 'ON GENERATION AND MEASUREMENT OF COMBINED BARKER CODES' siehe Absatz 2; Abbildungen 1-3 ---	3
A	INTERNATIONAL JOURNAL OF ELECTRONICS Bd. 64, Nr. 3, 1988, LONDON, DE; Seiten 481 - 492 EL-KHANY 'ON THE GENERATION AND CORRELATION MEASUREMENT OF GOLD CODES' siehe Absatz 5; Abbildungen 8-10 ---	3
A	IEEE MILITARY COMMUNICATIONS CONFERENCE Bd. 2, 1987, WASHINGTON, US; Seiten 738 - 741 KUMAR ET AL 'ON THE PARTIAL-PERIOD CORRELATION MOMENTS OF GMW SEQUENCES' siehe Zusammenfassung -----	3