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(71) Applicant(s)
Siemens Aktiengesellschaft

(72) Inventor(s)
Franz Schreib

(74) Agent/Attorney
SPRUSON and FERGUSON,GPO Box 3898,SYDNEY NSW 2001

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(71) Anmelder *(für alle Bestimmungsstaaten ausser US)*: SIEMENS AKTIENGESELLSCHAFT [DE/DE]; Wittelsbacherplatz 2, D-80333 München (DE).

(72) Erfinder; und
(75) Erfinder/Anmelder *(nur für US)*: SCHREIB, Franz [AT/DE]; Walliser Strasse 156, D-81475 München (DE).

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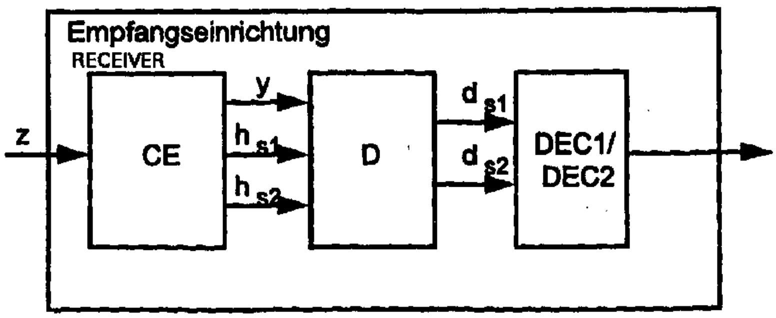
(54) Title: METHOD AND RECEIVER FOR TRANSMITTING DATA

(54) Bezeichnung: VERFAHREN UND EMPFANGSEINRICHTUNG ZUR DATENÜBERTRAGUNG



(57) Abstract

The invention relates to a method and receiver for transmitting data between radio stations in a radio communication system by means of a radio interface. According to the invention, the data which is to be transmitted is grouped into message blocks in the transmitter. Each message block contains additional symbols pertaining to a training sequence. At least two message blocks with varying training sequences are then transmitted simultaneously on a channel. The data contained in the at least two message blocks is detected in the receiver when the at least two training sequences are known.

GR 97 P 1709

Abstract

Method and receiver for data transmission

A method and a device are specified for data transmission via an air interface between radio stations in a radio communications system. According to the invention, data to be transmitted are grouped into message blocks at the transmitting end, the message blocks respectively containing additional symbols of a training sequence. Thereupon, at least two message blocks with different training sequences are simultaneously transmitted on a channel, whereupon the data of the at least two message blocks are detected at the receiving end with knowledge of the at least two training sequences.

Fig. 5

GR 97 P 1709

Description

Method and receiver for data transmission

The invention relates to a method and a device for data transmission via an air interface between radio stations in a radio communications system.

Radio communications systems serve to transmit data with the aid of electromagnetic waves via an air interface between a transmitting and a receiving radio station. An example of a radio communications system is the known GSM mobile radio network, in which a channel formed by a narrowband frequency band and a time slot is provided in each case for transmitting a subscriber signal. Since a subscriber signal is separated on a channel in frequency and time from remaining subscriber signals, the receiving radio station can detect the data of this subscriber signal.

It is known from the GSM mobile radio system to make use of training sequences embedded in the data of the subscriber signal which are known at the receiving end and serve to determine channel coefficients. The channel coefficients in this case simulate the radio transmission channel and facilitate the compensation of interference during subsequent data detection.

The frequency band available to the GSM mobile radio network is limited and leads increasingly to capacity bottlenecks, in particular in areas of high subscriber density. The capacity of the GSM mobile radio network is limited in this case by the number of the channels possible in a radio cell. A possibility of increasing this capacity is to introduce a so-called half rate transmission. This half rate transmission presupposes for voice an improved source coding so that only half of the previously required time slots suffice to transmit the same quantity of data.

however, this half-rate coding can be applied only to voice information.

It is therefore the object of the invention to specify a method of a receiver for data transmission which achieves an increase in capacity independently of the significance of the data to be transmitted.

According to one aspect of the present invention there is provided a method for data transmission via an air interface between radio stations in a radio communications system, said method comprising the steps of:

grouping data to be transmitted into message blocks at the transmitting end, the message blocks respectively containing additional symbols of a training sequence;

simultaneously transmitting at least two message blocks with different training sequences on a channel of the air interface designated by a frequency band and a time slot;

carrying out at least two channel estimates per channel at the receiving end with knowledge of the different training sequences; and

detecting at least two simultaneously transmitted message blocks per channel on the basis of the separate channel estimates.

According to another aspect of the present invention there is provided a receiver for data which are transmitted via an air interface between radio stations in a radio communications system, said receiver comprising:

channel estimator for simultaneous channel estimation of at least two message blocks simultaneously transmitted in the same channel of the air interface designated by a frequency band and a time slot, which channel estimator evaluates per channel at least two connection-specific training sequences transmitted within the message blocks in addition to the data, and determines channel coefficients in each case, and

a detector for respectively detecting data for the at least two message blocks with knowledge of the at least two separately determined channel coefficients.

By virtue of the fact that it is ensured when selecting the training sequences that the latter always differ from one another in conjunction with simultaneously transmitted message blocks, the subscriber signals can be separated at the receiving end by means of this characteristic of a message block. The data to be transmitted in the two message blocks can be arbitrary in this case. There is no need to heed any restrictions for these data and the ratio of the individual symbols to one another. Thus, when data of the two message blocks are evaluated the method according to the invention achieves an increase in capacity at least by a factor of 2 which is not limited only to voice information, but can also be applied to further services.

Alternatively, it can be provided that only the data of one message block is detected at the receiving end, use being made of knowledge of the further message block in order to improve the detection. An improvement in the interference immunity of the connection is thereby achieved. The interference from neighboring cells can thus also be compensated. Consequently, it is possible to permit relatively severe interference in the system, as a result of which either an improved reuse of frequency or a higher subscriber density becomes possible.

According to a development of the invention, the received data which are simultaneously transmitted in the same channel are synchronized. Different propagation paths of the transcriber signals lead to different instants of arrival at the receiving radio station, so that it is particularly important to use synchronization to tune the arrival of the two message blocks to one another, and thus to facilitate the following steps for channel estimation and data detection. The synchronization is prepared by signaling to the transmitting radio stations, which can thereupon set the transmission instant. The synchronization can also be performed at the receiving end; in this case, there is no need to signal to the transmitting radio stations.

A temporal deviation in the arrival of the at least two message blocks at the radio station at the receiving end which is smaller than a symbol length is advantageously set by the synchronization. Thus, if the transmission instants of the transmitting radio station are set in each case of signaling in such a way that there are a slight deviation between the instants of the occurrence of the at least two message blocks, it is possible to keep a bit error rate of the data transmission low by improved detection.

According to a further characterization of the invention, at least two training sequences are allocated to a transmitting radio station. A doubled data rate is rendered possible for this radio station by this measure. There is no need for additional outlay on hardware for this radio station, all that is required is to adapt the signal processing as appropriate in the receiving radio station. This can be performed, as the case may be, by reprogramming the appropriate signal processor.

If the radio stations are designed as mobile stations or base stations of a digital mobile radio network, the direction of transmission from the mobile station to the base station is designated as upward direction, and the direction of transmission from the base station to the mobile station is designated as downward direction. In accordance with a development of the invention, different transmission rates are used in the upward direction and downward direction. Consequently, asymmetrical services are possible which do better justice to the particular features of the requirements placed on the data to be transmitted. It is advantageous for message blocks of higher data rates to be used in the upward direction than the downward direction. That is to say, the mobile stations receive as previously, but they transmit simultaneously with other mobile stations on one channel, and thereby increase the data rate in the upward direction. Consequently, there is no need to change the circuit engineering of mobile stations; it is possible to achieve a doubling of the capacity of a data transmission in the upward direction in the base station by appropriate adaptation of the signal processing.

The method according to the invention exhibits particular advantages when the transmitted data are transmitted in accordance with a packet data service (GPRS General Packet Radio Services). In the case of this service, the data rates must be easily changeable, and flexible utilization of the radio resources of the air interface must be possible. This can be implemented by means of the method according to the invention.

The invention is explained in more detail below with the aid of an exemplary embodiment with reference to the figures, in which:

FIG 1 shows a block diagram of a radio communications system,

FIGS 2 to 4 show different variants of data rates for the data transmission according to the invention,

FIG 5 shows a block diagram of a receiver,

FIG 6 shows a block diagram of a channel estimator, and

FIG 7 shows a state diagram for the data detection.

A radio communications system represented in FIG 1 corresponds in its structure to a known GSM mobile radio network which comprises a multiplicity of mobile switching centers MSC which are networked and/or provide access to a fixed network PSTN. Furthermore, these mobile switching centers MSC are connected to in each case at least one base station controller BSC. Each base station controller BSC in turn permits connection to at least one base station BS, and undertakes to manage the radio resources of the connected base station BS. Such a base station BS is a radio station which can establish a communication link to mobile stations MS via an air interface.

FIG 1 shows by way of example three links for transmitting data, which can constitute useful information and signaling information, between three mobile stations MS and a base station BS. An operating and maintenance center OMC implements control and maintenance functions for the mobile radio network or for parts thereof. The functionality of this structure can also be transferred to other radio communications systems in which the invention can be used.

FIGS 2 to 4 show different applications of a method for data transmission via an air interface between mobile stations MS and a base station BS. The applications differ in the data rates which are used for data transmission in the upward or downward directions.

FIG 2 shows the data transmission between a base station BS and two mobile stations MS. Data rates of 24700 bits per s and channel are used both in the upward direction and in the downward direction. In this case, a channel is characterized by a frequency band and a time slot. Here, 24700 bit/s is the usual data rate for a channel of a GSM mobile radio network which has previously been used only by one mobile station MS. The total data rate transmitted via this channel is doubled by virtue of the fact that in this channel the data transmission of this data rate is possible to two mobile stations MS. Appropriate changes to the signal processing must be introduced for this purpose both in mobile stations MS and in the base station BS.

Double the data rate at 49400 bits per s and channel is allocated to a single mobile station in FIG 3. This means that, as shown later, two training sequences are allocated to the link between the mobile station MS and base station BS both in the upward direction and in the downward direction. Adaptations of the signal processing are also to be undertaken in this case at the receiving end and at the transmitting end.

FIG 4 shows a further application of the data transmission between a base station BS and two mobile stations MS, the mobile stations MS possibly being customary mobile stations previously used. Half the data rate at 12350 bit/s and channel is used in the downward direction. This means, for example, that only each second time slot of the channel is evaluated by one mobile station in each case. The two mobile stations MS thus share a channel. However, in the upward direction the two mobile stations MS simultaneously transmit on a channel with the usual bit rate. Only an adaptation of the base station BS need be performed in the case of this application.

A receiver for carrying out the data transmission method is shown in FIG 5. The receiver includes a channel estimator CE and a detector D. The channel estimator receives antenna data z from an analog high-frequency unit - not represented - which generates the antenna data as a complex base band signal. The channel estimator CE undertakes to synchronize the input data stream, with the result that a synchronized output data stream y is emitted.

Furthermore, for the purpose of simultaneous channel estimation for at least two message blocks transmitted simultaneously on the same channel, an evaluation of connection-specific training sequences tc1, tc2 transmitted in the message blocks in addition to the data d is evaluated in the channel estimator CE. This evaluation is used to determine the channel pulse responses of the two connections, which are likewise emitted by the channel estimator CE as channel coefficients h_{s1}, h_{s2}.

The detector D picks off the synchronized data y and the channel coefficients h, and carries out the data detection for both connections. The detected data d_{s1}, d_{s2} for the two connections are present as a result of the data detection. The detected data d_{s1}, d_{s2} are fed the further devices of the receiving radio station which thereupon carry out decoding and, if appropriate, further processing operations, for example decoding in decoders DEC1, DEC2, decryption, deinterleaving. The symbols of the data d_{s1}, d_{s2} represent the transmitted data d reconstructed by equalization and error correction.

The channel estimator CE is shown in FIG 6. It includes two channel models KM which are intended to simulate the transmission conditions for the two connections. The channel models KM model delay elements Z^{-1} which are arranged in the shape of a chain. Test data which correspond to the training sequences tc1, tc2 known at the receiving end are fed into the channel model and traverse these delay elements Z^{-1}. The non-delayed test data and the delayed test data present at the output of each delay element Z^{-1} are respectively evaluated with a channel coefficient h (h1, h2, ...hn) in an evaluation unit BE and subsequently summed to form model data r.

Multipath propagation is simulated in the channel models KM, signal components arriving sequentially being superimposed to form a common signal. Three to four delay elements Z^{-1} suffice to balance out this multipath propagation. The channel model KM is therefore implemented by a filter with a finite pulse response.

In order to set up the channel model, the data d of the two connections are grouped in a Töpliz matrix in each case, the data of a first message block being part of the matrix D_{s1}, and the data of a second message block being part of the matrix D_{s2}.

$$\tilde{D}_{s1} = \begin{bmatrix} d_5^{(s1)} & d_4^{(s1)} & .. & d_1^{(s1)} \\ d_6^{(s1)} & d_5^{(s1)} & .. & d_2^{(s1)} \\ d_7^{(s1)} & d_6^{(s1)} & .. & d_3^{(s1)} \\ .. & .. & .. & .. \end{bmatrix} \quad (1) \qquad \tilde{D}_{s2} = \begin{bmatrix} d_5^{(s2)} & d_4^{(s2)} & .. & d_1^{(s2)} \\ d_6^{(s2)} & d_5^{(s2)} & .. & d_2^{(s2)} \\ d_7^{(s2)} & d_6^{(s2)} & .. & d_3^{(s2)} \\ .. & .. & .. & .. \end{bmatrix} \quad (2)$$

Each of the connections can be described by a channel pulse response, the channel coefficients h of the first connection being described with a vector h_{s1}, and the channel coefficients of the second connection h_{s2}.

$$\underline{h}_{s1} = \begin{bmatrix} h_1^{(s1)} \\ .. \\ h_5^{(s1)} \end{bmatrix} \quad (3) \qquad \underline{h}_{s2} = \begin{bmatrix} h_1^{(s2)} \\ .. \\ h_5^{(s2)} \end{bmatrix} \quad (4)$$

The synchronized received data y can therefore be described by means of:

$$\underline{y} = \bar{D}_{s1}\cdot\underline{h}_{s1} + \bar{D}_{s2}\cdot\underline{h}_{s2} = \left[\bar{D}_{s1}\quad \bar{D}_{s2}\right]\cdot\left[\frac{\underline{h}_{s1}}{\underline{h}_{s2}}\right] \qquad (5)$$

The task of the channel estimator CE is to solve the equation (5) for the training sequences tc1, tc2 of the received message blocks. Assuming the channel model KM with five channel coefficients h permits the received data to be represented in accordance with equations (6) and (7), the exponent tc1 or tc2 indicates that the corresponding data are part of the training sequences tc1, tc2.

$$\bar{D}_{s1} = \begin{bmatrix} d_5^{(tc1)} & d_4^{(tc1)} & .. & d_1^{(tc1)} \\ d_6^{(tc1)} & d_5^{(tc1)} & .. & d_2^{(tc1)} \\ .. & .. & .. & .. \\ d_{26}^{(tc1)} & d_{25}^{(tc1)} & .. & d_{22}^{(tc1)} \end{bmatrix} \quad (6) \qquad \bar{D}_{s2} = \begin{bmatrix} d_5^{(tc2)} & d_4^{(tc2)} & .. & d_1^{(tc2)} \\ d_6^{(tc2)} & d_5^{(tc2)} & .. & d_2^{(tc2)} \\ .. & .. & .. & .. \\ d_{26}^{(tc2)} & d_{25}^{(tc2)} & .. & d_{22}^{(tc2)} \end{bmatrix} \quad (7)$$

The following equation (8) is a representation of equation (5), solution being possible with the aid of the criterion of least squares. In this case, there are 22 equations for 10 unknown channel coefficients h.

$$\left\| \left[\bar{D}_{s1}\quad \bar{D}_{s2}\right]\cdot\left[\frac{h_{s1}}{h_{s2}}\right] - y \right\| = e = \min \qquad (8)$$

Since the matrices D_{s1} and D_{s2} are independent of the input data, it is not necessary for the criterion of least square to be solved individually for each message block. The solution can be replaced by multiplying by a pseudoinverse of the matrix (exponent P) in accordance with equation (9):

$$\left[\frac{h_{s1}}{h_{s2}}\right] = \left[\bar{D}_{s1}\quad \bar{D}_{s2}\right]^{-P}\cdot y \qquad (9)$$

In order to synchronize the system of equations, a solution is found for each possible synchronization position of the message block. The synchronization position is symbolized by the variable M. The synchronization is finally carried out by a synchronization element Z^{-M}. The calculations described above are carried out by an arithmetic unit RW. The solution of the problem of least squares corresponds to minimizing the deviation e of received training sequences tc1, tc2 in relation to reference data r generated in at least two channel models KM.

A Viterbi detector can be used as detector D. In the case when a channel model KM is based on five channel coefficients h, this filter with a finite pulse response has a memory of four data symbols. Thus, when digital data are transmitted there is a possibility of 16 possible states in the past. Since a data symbol can specify two values (0 or 1), 32 transitions are possible from the state t to the state t + Δt. These transitions are shown in FIG 7.

The states are represented as binary numbers, and the numbers of the transitions are specified next to the initial state. Continuous lines indicate that the last symbol had the value 0, and dashed lines indicate that the last symbol had the value 1. Lines drawn double lead to a decision for a symbol with the value 1, and lines drawn once lead to a decision for a symbol with the value 0.

The detector D takes account of two signals with in each case one channel model KM with five channel coefficients h. Consequently, there are 16 states in the past for signal 1 and 16 states for signal 2, that is to say the overall result is 256 possible states. If a further two new data symbols are received, this leads to 256 multiplied by four=1024 transitions.

Table 1 describes the relationship between the transmitted data symbol and a state number. The two signals have a memory of four symbols. X0 corresponds to the symbol of signal 1 last transmitted, and Y0 corresponds to the data symbol of signal 2 last transmitted. X3 and Y3 produce the reference to the data symbols received furthest back in the past. The values in the row above y_i and x_i must be added in order to obtain the state number.

The sequence 1000 1110 corresponds, for example, to the state 142. All the symbols x and all the symbols y are shifted to the left by one element in order to reach the next state. The data symbols x3 and y3 are not further taken into account, while x0 with y0 are filled up with the symbols last received.

The transition numbers can be derived from Table 2. The known add compare select operation of the Viterbi algorithm must be extended.

A local number is introduced in accordance with Table 3 and Fig. 8 for a local add compare select operation. Four transitions lead to a state. Each transition (Fig. 8: 00 01 10 11) starts with an initial state with the metric Γ_i. Γ' is derived in this case in accordance with the following equation:

$$\Gamma = \min(\Gamma_i + \Delta_i)\big|_{i=0..3} \qquad (10)$$

where

$$\Delta_i = |y_i - r_i|^2 \qquad (11)$$

The index i of the finally selected transition (minimum metric growth) is denoted by imin. In this case, Δ_i specifies the euclidean distance between the complex received value y_i and a complex reference value r_i. However, it is also possible for other distances to be used, for example a Hamming distance.

The reference value r_i with i=0..1023 results from an addition of two convolution results of the values of all possible state numbers in accordance with Table 2 (10 bit $\rightarrow 2^{10} = 1024$ possibilities), the values being transferred from the value range (0, 1) into the value range (-1, 1), with the corresponding values of the channel coefficients (2 × 5 bit) h_{s1}, h_{s2}.

The following remarks serve to determine the so-called soft outputs s'_1, s'_2 - decisions provided with an item of reliability information. The data symbols x4 and y4 are defined for the transition imin. In order to reach the soft output for x4 (s'_1), the decision for y4 is assumed to be correct and constant, and the difference between the decision with x4=0 and x4=1 is evaluated. Equation (12) describes this calculation. The logic opperators of the indices are derived from the programming language C.

$$s'_1 = (\Gamma_{imin\&2} + \Delta_{imin\&2}) - (\Gamma_{imin|1} + \Delta_{imin|1}) \quad (12)$$

The same procedure is applied for the data symbol y4. Equation (13) describes this:

$$s'_2 = (\Gamma_{imin\&1} + \Delta_{imin\&1}) - (\Gamma_{imin|2} + \Delta_{imin|2}) \quad (13)$$

For example, according to Table 4 "&2" means that the value for y4 is retained, and x4 is set to "0", and "|1" means that the value for y4 is retained and x4 is set to "1".

The soft outputs s'_1, s'_2 can be used in the decoder DEC1 or DEC2 to improve the the decisions made. In addition to Viterbi decoders, it is also possible to use decoders for block codes.

The claims defining the invention are as follows:

1. A method for data transmission via an air interface between radio stations in a radio communications system, said method comprising the steps of:

grouping data to be transmitted into message blocks at the transmitting end, the message blocks respectively containing additional symbols of a training sequence;

simultaneously transmitting at least two message blocks with different training sequences on a channel of the air interface designated by a frequency band and a time slot;

carrying out at least two channel estimates per channel at the receiving end with knowledge of the different training sequences; and

detecting at least two simultaneously transmitted message blocks per channel on the basis of the separate channel estimates.

2. The method as claimed in claim 1, wherein the data of the at least two message blocks are detected at the receiving end.

3. The method as claimed in claim 1, wherein the data of a message block are detected at the receiving end, the knowledge of the further message block being used to improve the detection.

4. The method as claimed in one of the preceding claims, wherein radio stations simultaneously transmitting on the same channel are synchronized.

5. The method as claimed in one of claims 1 to 3, wherein the received data are synchronized at the receiving end.

6. The method as claimed in one of claims 4 or 5, wherein a temporal deviation in the arrival of the at least two message blocks at the radio station at the receiving end which is smaller than a symbol length is set by the synchronization.

7. The method as claimed in one of the preceding claims, wherein at least two training sequences are allocated to a transmitting radio station.

8. The method as claimed in one of the preceding claims, wherein the radio stations are designed as mobile stations or base stations of a digital mobile radio network.

9. The method as claimed in claim 8, wherein different transmission rates are used in the upward direction and downward direction.

10. The method as claimed in claim 9, wherein a message block with a higher data rate is used in the upward direction than in the downward direction.

11. The method as claimed in one of the preceding claims, wherein the transmitted data are transmitted in accordance with a packet data service.

12. The method as claimed in one of the preceding claims, wherein the detection is carried out by evaluating the at least two training sequences, in order to obtain a channel estimation referred to message block.

13. A receiver for data which are transmitted via an air interface between radio stations in a radio communications system, said receiver comprising:

channel estimator for simultaneous channel estimation of at least two message blocks simultaneously transmitted in the same channel of the air interface designated by a frequency band and a time slot, which channel estimator evaluates per channel at least two connection-specific training sequences transmitted within the message blocks in addition to the data, and determines channel coefficients in each case, and

a detector for respectively detecting data for the at least two message blocks with knowledge of the at least two separately determined channel coefficients.

14. The receiver as claimed in claim 13, wherein the channel estimator is characterized in such a way that at least two sets of channel coefficients are determined simultaneously by undertaking for received training sequences a minimization of the deviation of received data relative to reference data elevated in at least two channel models with channel coefficients.

15. The receiver as claimed in claim 13 or 14, wherein the detector is characterized in such a way that in order to apply a Viterbi algorithm at least four transitions from previous detection states Γ_i to a new detection state Γ' are considered, and that the new detection state is determined in accordance with the equation $\Gamma' = \min(\Gamma_i + \Delta_i)|_{i=0.3}$, Δ_i specifying the euclidean distance between a received symbol and a reference symbol.

16. The receiver as claimed in claim 15, comprising at least one decoder which takes account of so-called soft outputs s'_1, s'_2 which are calculated using

$$s'_1 = (\Gamma_{imin\&2} + \Delta_{imin\&2}) - (\Gamma_{imin|1} + \Delta_{imin|1}) \quad \text{and} \quad s'_2 = (\Gamma_{imin\&1} + \Delta_{imin\&1}) - (\Gamma_{imin|2} + \Delta_{imin|2}).$$

17. The receiver as claimed in one of claims 13 to 16, which is characterized as part of a mobile station or a base station of a digital mobile radio network.

18. A method for data transmission via an air interface between radio stations in a radio communications systems, substantially as herein described with reference to the accompanying drawings.

19. A receiver for data which are transmitted via an air interface between radio stations in radio communications system, substantially as herein described with reference to the accompanying drawings.

DATED this Fourteenth Day of December, 1999

Siemens Aktiengesellschaft

Patent Attorneys for the Applicant

SPRUSON & FERGUSON

Fig.1

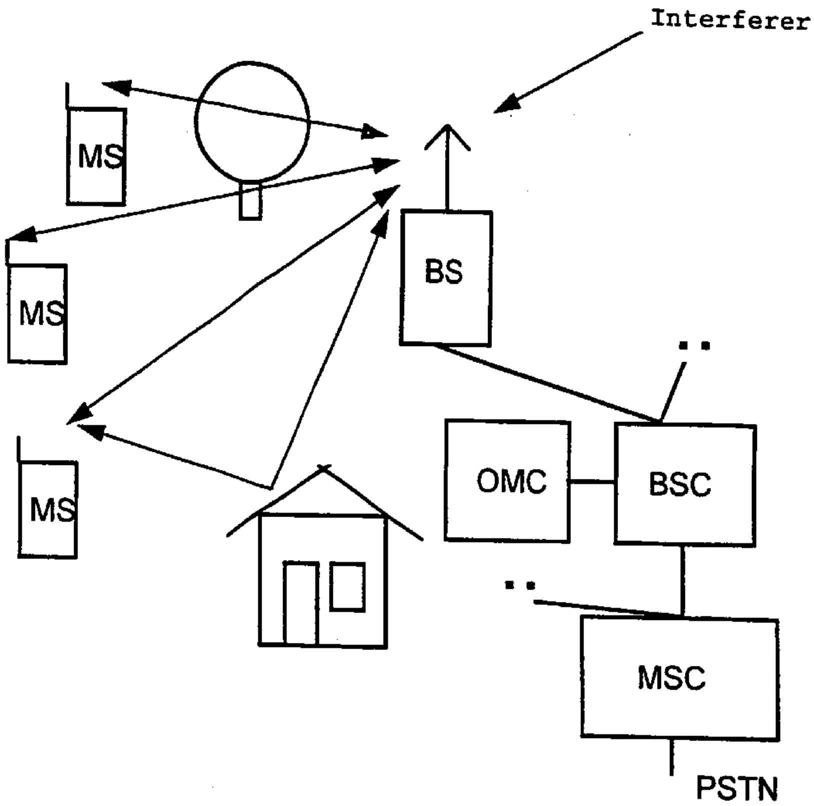


Fig.2

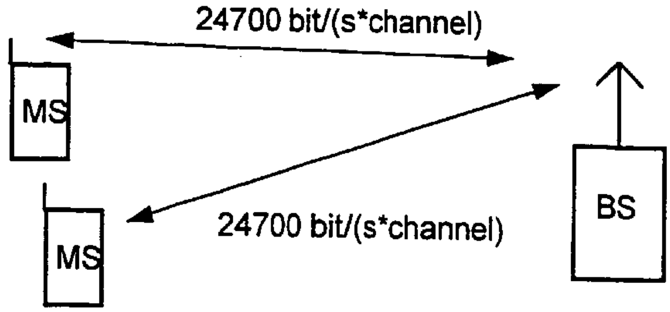


Fig.3

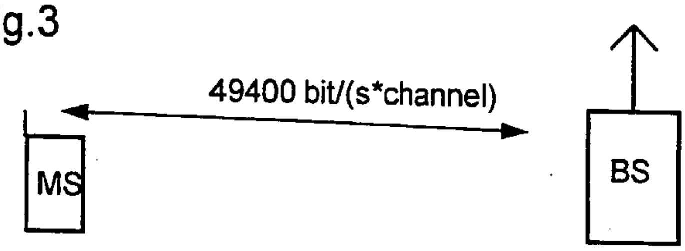


Fig.4

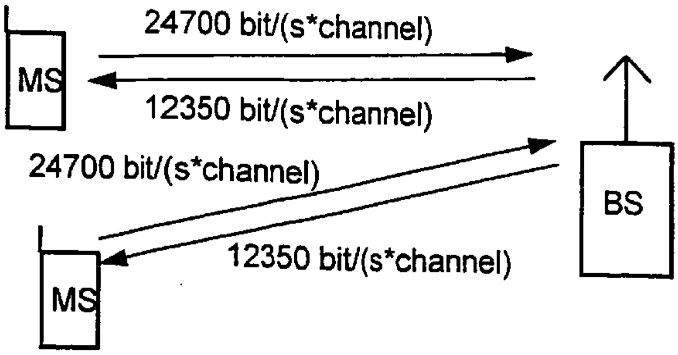


Fig.5

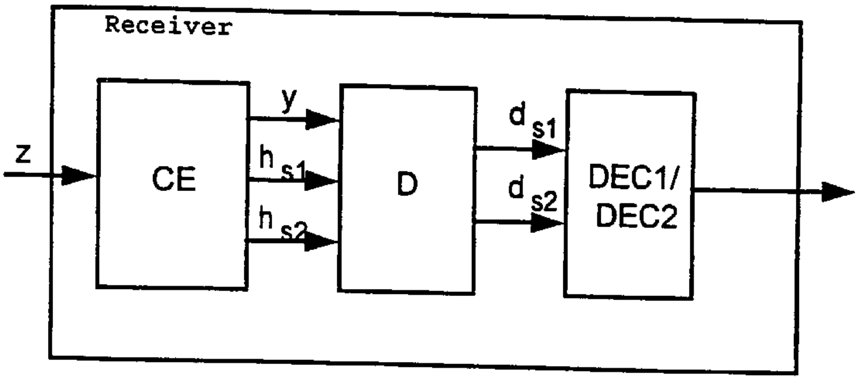
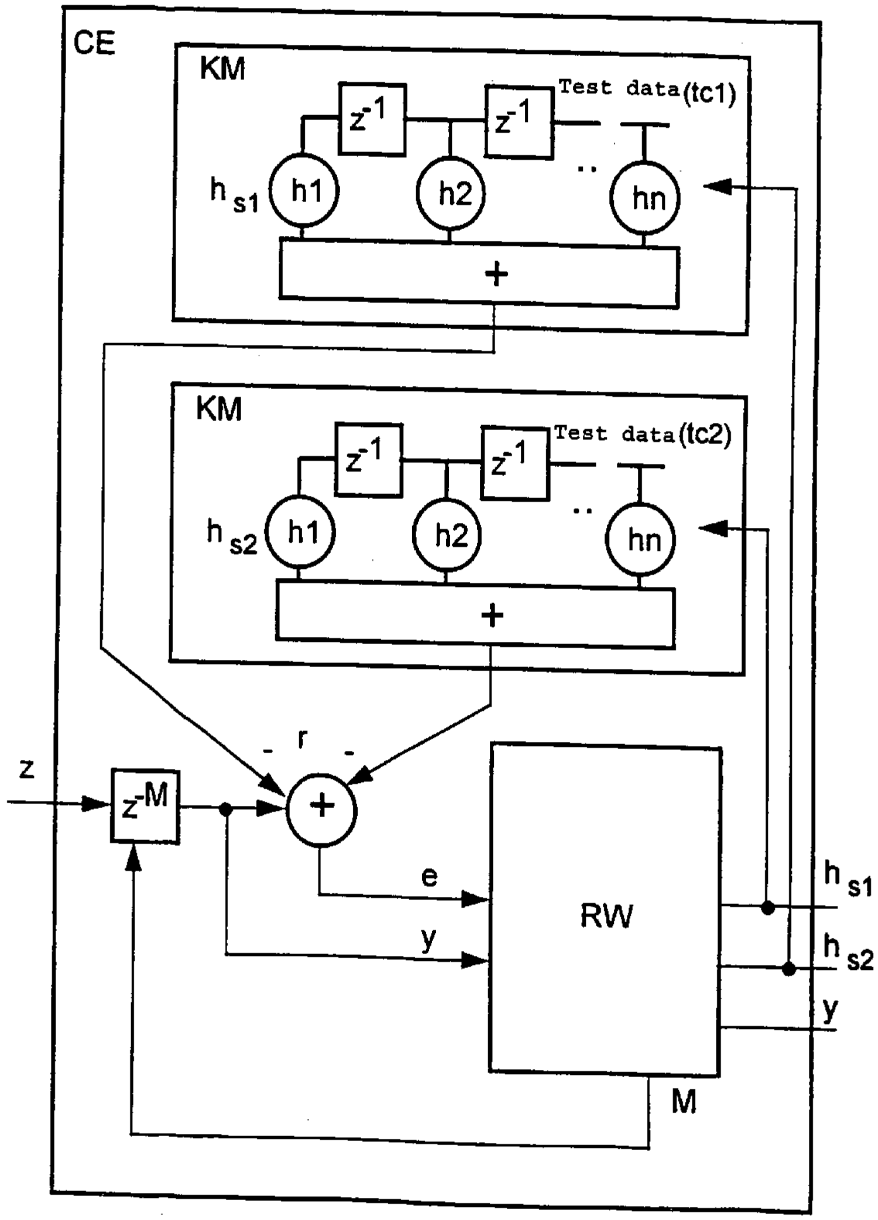


Fig.6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Test data(tc1)
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h s2
h1
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Fig.7

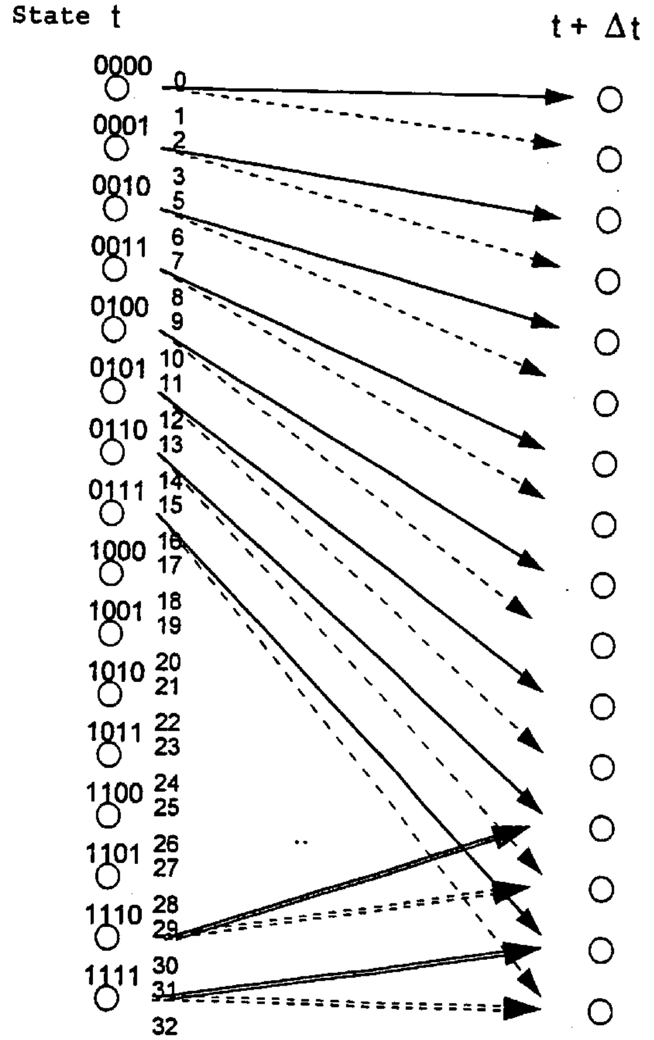
State t
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Fig.8

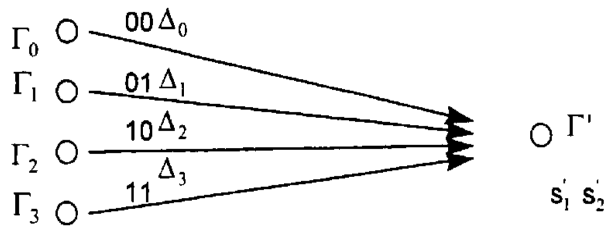

Fig 12

Tab 4

	&2	|1	&1	|2
00	00	01	01	10
01	00	01	01	11
10	10	11	11	10
11	10	11	11	11

Fig 9

Tab 1

Message block 1				Message block 2			
128	64	32	16	8	4	2	1
y3	y2	y1	y0	x3	x2	x1	x0

Fig 10

Tab 2

Message block 1					Message block 2				
256	128	64	32	16	16	8	4	2	1
y4	y3	y2	y1	y0	x4	x3	x2	x1	x0

Fig 11

Tab 3

y4	x4	Transition
0	0	0
0	1	1
1	0	2
1	1	3