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5 **DATA TRANSMISSION SYSTEM WITH RELAY STATIONS BETWEEN A**
 SOURCE STATION AND A TARGET STATION

The invention relates to a data transmission system for the digital transmission of data, including voice data.

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A decentralised data transmission network with numerous distributed stations is known from DE 33 37 648 C2, in which direct data communication takes place only between neighbouring stations. The transmission path from a source station to
15 a target station is defined by a special routing system and the data are then transmitted from station to station in both directions on different channels. In this context, each of the stations transmits on a single channel, which is used only for linking exactly two stations. This, however, requires a correspondingly adapted data rate.
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Packet-oriented data transmission between the stations of a data transmission network is also known from the Internet. In this case, data are grouped in packets and these packets are
25 transmitted separately via the most favourable transmission path in each case. This kind of packet transmission causes considerable delays, which are at least equivalent to the time required to transmit one packet. Due to the associated delays, packet transmission of this kind is unfavourable for a telephone system. The delays would accumulate in accordance with
30 the number of stations involved in transmission, particularly in a decentralised data transmission network which uses station-to-station transmission.

35 The object of the invention is to design a decentralised digital data transmission system which enables the use of different transmission channels between two stations and greatly minimises delays at the same time.

According to the invention, the object is solved by the features specified in Patent Claim 1.

The data transmission system according to the invention is characterised in that the signals received at each station are converted symbol-by-symbol from the reception channels to at least one different transmission channel. This means that each symbol flow coming in on a reception channel is converted to the transmission channels. This process is similar to forming information packets consisting of a single symbol. In the simplest case, a symbol is one bit. However, it can also consist of a number of related bits, such as the eight bits representing a letter symbol. During a transmission, the number of bits per symbol position is constant within a sub-channel. The number of bits per symbol is defined at the beginning of transmission, depending on the required or desired degree of transmission quality. Symbol-by-symbol conversion means that only a delay equivalent to one symbol position of the symbol flow is required at each station. This delay is related to the fact that the symbol string on the incoming channels and the outgoing channels is normally not synchronised, meaning that a certain waiting time is required before the outgoing signal can be transmitted in synchrony with the transmission channels. This delay, however, is minimal. In practice, it amounts to roughly one to two symbol positions. The delays of the individual stations accumulate. As a result of the minimal delay at each individual station, the resulting total delay of the transmission path is still acceptable.

According to a preferred configuration of the invention, the transmission channels are divided into sub-channels, each of which is suitable for transmitting a symbol flow and where the symbols of all sub-channels of a transmission channel are transmitted synchronously. This means that each station can receive incoming signals on all channels. The outgoing sub-channels can be transmitted in concentrated fashion on a single channel or a few selected ones. The symbol positions of all sub-channels are transmitted synchronously on each channel,

which consists of a pre-defined number of sub-channels. Each sub-channel supports unidirectional data flow. The data arrive at the station on each sub-channel of the entire channel system in a continuous data flow, without being divided into "frames" or "packets". Consequently, the data flow does not require headers or any other defining elements. Rather, each symbol of the data flow is converted to the sub-channel selected for transmission within a very short time after reception and transmitted synchronously with the transmission channel.

The sub-channels are allocated to a transmission channel between two stations such that the transmission frequency range is dynamically adapted to the information content to be transmitted. This means that the number of sub-channels per channel is variable.

Preferably, allocation for transmitting envisaged channels occurs at a station in such a way that all transmitting sub-channels of this station are located within just a few channels. This considerably reduces the number of channels to be used. In this context, it must be borne in mind that, if a station is transmitting on a channel, this channel cannot be used by neighbouring stations, in order to avoid interference or other disturbances. Even if a station uses only one sub-channel of a channel, the entire channel is reserved for this station. Therefore, all connections which run through a specific station are preferably distributed over sub-channels all contained in the same channel.

In a preferred configuration of the invention, appropriate error correction bits are added to the contents of the synchronously transmitted symbol positions of the sub-channels of a channel, and error correction is carried out at the receiving station, in order to reduce the probability of error in the data link. Known methods can be used for error correction, such as the FEC method (Forward Error Correction) or the ARQ method (Automatic Re-transmission Request). The special feature in the present case is that the contents of the synchro-

nously transmitted symbol positions of the sub-channels of a channel are used for error correction, where completely independent information contents flow in the sub-channels. This means that error correction is carried out on the basis of bits which are associated with different information and which merely happen to be located at the synchronous positions of the channel.

The use of an error correction method is only sensible if a bit error ratio of less than roughly 10^{-3} is to be achieved. Simple error detection is adequate for higher bit error ratios, in order to at least obtain information on the quality of the connection between the two participating stations. Error detection of this kind can be provided by a redundant error control element (e.g. parity bit), this error control element being added to the synchronously transmitted symbol positions of all sub-channels of a channel. It is alternatively or additionally possible, after each transmission of a pre-defined number of symbol positions of a sub-channel, to generate an error detection bit for each sub-channel, which corresponds to the consecutive information contents of this sub-channel, error detection being carried out at the receiving station.

A practical example of the invention is described in more detail below based on the drawings.

The drawings show the following:

Fig. 1 A diagram of part of the data transmission system showing the distributed stations,

Fig. 2 An example of a connection from a source station to a target station,

Fig. 3 A coupling matrix for frequency conversion at each station,

Fig. 4 An example of data flows running through the coupling matrix shown in Fig. 3, and

Fig. 5 A diagram of the consecutive symbol positions in a channel with error correction bits and error detection bits.

The data transmission system consists of numerous distributed stations S, where each station represents a subscriber position. Each station contains transmitting and receiving equipment. Two frequency bands of 12.8 MHz each are available for radio transmission of the data. The two frequency bands are separated from one another by duplex spacing. One frequency band is designated as the uplink and the other as the downlink. In order to establish a connection, a channel in the uplink is used for the connection in the one direction and a channel in the downlink for the connection in the other direction, so that the two directions are completely decoupled from one another in terms of frequency.

In this practical example, the two frequency bands of 12.8 MHz bandwidth each are divided into a total of 1,280 channels with a width of 20 kHz. Some of these channels are used as information channels for establishing a connection and for other purposes. Each station can receive on any of the available channels and transmit on any of the available channels.

In Fig. 1, it is assumed that a connection is to be established between a source station S61 and a target station S65. This connection runs via stations S60 and S63, which act as relay stations. In addition, a connection from station S62 to Station S64 is relayed by station S60.

In the example of an established connection shown in Fig. 2, data transmission from S61 takes place on channel C1, data transmission from S60 to S63 on channel C25 and data transmission from S63 to target station S65 on channel C12. Station S60, which is given special consideration in this example,

also transmits on channel C25 for stations S61 and S64.

5 Routing, i.e. selection of the stations through which the connection is to be established, and selection of the channels are handled by way of a dialogue conducted between the participating stations. Routing (path-finding) and establishment of the connection are not the object of the present invention.

10 Figure 3 shows a coupling matrix KM, which is contained in each station. For reasons of simplicity, each symbol position represented by a box is assumed to consist of one bit in this practical example.

15 Each station contains a channel register CR-1...CR-n for every channel C1...Cn. Channel register CR-1 contains eight information symbol positions 1...8, where each of the symbol positions corresponds to one sub-channel SC. Thus, channel C1 is divided into eight sub-channels 1...8. Each sub-channel has a bandwidth of 20 kHz, where the frequencies of all sub-channels 1-8 are consecutive. A unidirectional data link can be established over one sub-channel SC.

25 Figure 3 shows the time-slot patterns for sub-channels 4 and 5 of channel C1, in which symbols are transmitted to channel register 1. Transmission takes place at a frequency of 20 kHz in a continuous symbol flow.

30 The synchronously received symbols (in this case: bits) of the sub-channels of a channel enter a receiving register ER1...ERn and are transmitted from there to the respective channel register CR-1...CR-n with a delay of two symbol durations. Channel registers CR-1 ...CR-n are each associated with the columns of the coupling matrix. The coupling matrix has n rows and m columns, where each row and each column is assigned to a different sub-channel and a different frequency. The rows of coupling matrix KM each correspond to one sub-channel or transmitting frequency. Each channel has one channel register CR-1...CR-n, which contains one symbol position for each sub-

channel 1...8. The symbol positions of all transmission-side channel registers are associated with the rows of coupling matrix KM. Each transmission-side channel register CR-1...CR-n is assigned a transmission register SR1...SRn.

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Coupling matrix KM is of integrated circuit design, where corresponding control signals can connect the nodes to the intersections of a row and a column. The associated node remains connected during connection.

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In the practical example shown, it is assumed that the information received on sub-channel No. 1 of channel C1 is to be relayed on sub-channel No. 2 of channel 25. There is a connected node KP at the associated intersection of the coupling matrix, so that the bit located in position No. 1 of receiving channel register CR-1 is transmitted to position No. 2 of transmitting channel register CR-25 for channel C25.

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In the same way, the signals received on sub-channel No. 4 of channel C2 are transmitted to sub-channel No. 6 of channel C25 and sent out on this channel.

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Figure 4 shows an example of the timing of signals received on the sub-channels of channels C1, C2 and C3. At the associated station, such as station S60 in Figs. 1 and 2, the signals received there and intended for relaying are converted to channel C25. For station S60, a dialogue with the neighbouring stations previously determined that channel C25 is available for data transmission.

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As Fig. 2 shows for the selected practical example, station S60 receives the data from station S61 on channel C1 which it is supposed to relay to station S63. Consequently, these data are converted to channel C25 at station S60. At station S63, the same data are converted to another channel, such as C12, and transmitted to target station S65.

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In the selected example, station S60 considered here receives

signals from station S62 on channel C2. These signals are to be relayed to station S64. Channel C25 is again selected for this purpose. Finally, signals are also to be transmitted from station S60 to station S61, for which purpose another sub-channel of channel C25 is selected. Everything station S60 transmits is on channel C25, but on different sub-channels.

Figure 4 shows the conversion of the data at station S60, which were received by stations S61 and S62 on channels C1 and C2. These data are converted to channel C25, but to different sub-channels. In this context, the time axis is designated as "t" in each case. The top line of Fig. 4 shows that the symbol positions transmitted on channels C1, C2 and C3 are delayed relative to one another by a maximum of the duration of one symbol position. For this reason, the data are retained in channel register CR-1...CR-n (Fig. 3) until the associated symbol position has been received for all channels. Conversion to the outgoing channels is then carried out simultaneously in coupling matrix KM.

In addition to the symbol positions of sub-channels 1...8, which transmit the information, three other bit positions have been added to each channel for error correction bits A, B, C. The contents of these additional bit positions are analysed in receiving register ER1...ERn and used to correct errors in the information bits received simultaneously on one channel. Only the corrected information bits are entered in the corresponding channel register CR-1...CR-n.

In transmission registers SR1...SRn, error detection bits A, B, C are added to the eight information symbols of a channel, before the entire bit volume is transmitted. These error detection bits are generated by an error detection algorithm in accordance with the contents of the information symbol positions. After receiving the entire signal, error correction is performed in the same way using the algorithm.

Figure 5 shows a channel's individual symbol positions in relation to their timing, where the numbers 1...8 refer to the information symbol positions and represent sub-channels. These sub-channels have different frequencies. In Fig. 5, frequency f increases from left to right with increasing ordinal number. The three error correction bit positions A, B, C have been added to the last sub-channel (channel "8").

In the practical example shown in Fig. 5, a total of eight consecutive symbols in the channel is followed by an additional symbol position P, which contains a parity bit for each sub-channel that also serves the purpose of error detection. The addition of the error detection bits and the error correction bits, and the analysis of these bits on the basis of the information content, are carried out separately for each transmission link. These additional bits are not involved in frequency conversion.

As an alternative to the practical example described above, in which the assignment of the sub-channels to the frequencies is fixed, the assignment of the sub-channels to the frequencies can be changed after each symbol step. This makes it possible to ensure that a disturbance cannot permanently interfere with a sub-channel.

PATENT CLAIMS

1. Data transmission system with distributed stations (S) which can only engage in direct data communication with neighbouring stations on selectable transmission channels, where a symbol flow consisting of consecutive symbols is transmitted via the channel and where stations located between a source station and a target station function as relay stations,

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the signals received at each station (S) are converted from the respective reception channel to a different transmission channel, the conversion of the symbol flow arriving on the reception channel to the transmission channel taking place symbol-by-symbol.

2. Data transmission system as per Claim 1, characterised in that the transmission channels are divided into sub-channels (SC), each of which is suitable for transmitting a symbol flow, and that the symbols of all sub-channels (SC1...SC8) of a transmission channel are transmitted synchronously.

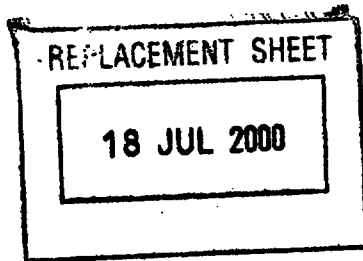
3. Data transmission system as per Claim 2, characterised in that bits (A, B, C) are added to the synchronously transmitted symbol positions of the sub-channels (SC1...SC8) of a channel based on the information contents of these symbol positions, where error detection and/or error correction is carried out at the receiving station.

4. Data transmission system as per Claim 2 or 3, characterised in that error detection and/or error correction is carried out on each individual sub-channel via a pre-defined number of symbol positions.

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PATENT CLAIMS

1. Data transmission system with distributed stations (S) which can only engage in direct data communication with neighbouring stations on selectable transmission channels, where a symbol flow consisting of consecutive symbols is transmitted via the channel and where stations located between a source station and a target station function as relay stations and where the signals received at each station (S) are converted from the respective reception channel to a different transmission channel,

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the conversion of the symbol flow arriving on the reception channel to the transmission channel taking place symbol-by-symbol.

2. Data transmission channel as per Claim 1, characterised in that the symbol positions received with time shift on the individual reception channels are retained before the conversion as long as the associated symbol position has been received for all reception channels.

3. Data transmission system as per Claim 1 or 2, characterised in that the transmission channels are divided into sub-channels (SC), each of which is suitable for transmitting a symbol flow, and that the symbols of all sub-channels (SC1...SC8) of a transmission channel are transmitted synchronously and are transmitted in a station parallel, symbol-by-symbol from one or several reception channels to one or several transmission channels.

4. Data transmission system as per Claim 3, characterised in that bits (A, B, C) are added to the synchronously transmitted symbol positions of the sub-channels (SC1...SC8) of a channel based on the information contents of these symbol positions, where error detection and/or error



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correction is carried out at the receiving station.

5. Data transmission system as per Claim 3 or 4, characterised in that error detection and/or error correction is carried out on each individual sub-channel via a pre-defined number of symbol positions.

