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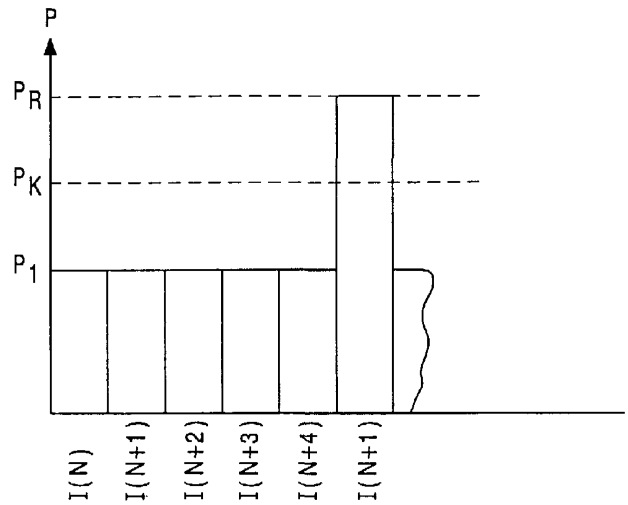

(57) Abstract: A method and apparatus for transferring information over a communications link includes transmitting information at a first power level, monitoring for correct reception of the transmitted information and transmitting further information at a second, power level other than that used for the original transmission if correct reception did not occur. The further information allows the content of the originally transmitted information to be established and in one embodiment constitutes a retransmission of the originally transmitted information. By retransmitting at a different power level the probability of correct reception may be enhanced, especially when the communications link is wireless. The first and second transmission power levels are governed using closed loop power control such that transmission power level is controlled to achieve a required quality of reception parameter at the receiving end of the link. In one arrangement the quality or reception parameter is the signal-to-interference ratio.

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DESCRIPTION

METHOD FOR THE COMMUNICATION OF INFORMATION AND APPARATUS EMPLOYING THE METHOD

The present invention relates to digital communication systems and more particularly to the exchange of information over wireless digital communication links of varying quality. In comparison to links which are wired, a greater variation in quality is usually observed in wireless links, for example the radio links found in a cellular mobile radio telephone system between mobile telephones and basestations. The present invention relates in particular, but not exclusively, to code division multiple access (CDMA) systems as used in so called third generation mobile telecommunications systems such as the Universal Mobile Telecommunications System (UMTS).

Communication systems, including mobile telecommunication systems and networks are making increasing use of digital technology. Such networks require a wireless radio communication link to be established between a mobile terminal and a basestation (or fixed terminal). Second and third generation mobile telephone systems exchange digital signals over the wireless radio communications link.

Digital systems can be exploited to provide greater spectral efficiency of a radio communications link than is offered by an analogue system and digital processing can often minimise the effects of interference.

In communication systems that rely on wireless links, such as mobile communications systems, the quality of these links can vary considerably. A number of factors influence the quality of the link and the system must be tolerant of any such variation. In systems employing an analogue link, a reduction in link quality may merely result in a noisy but tolerable link being established. However, in systems employing a digital link, it is important that the information sent over the link can be faithfully recovered at the receiving end, even when the link quality is poor. The effect of incorrectly received information depends on the application. For example, in the case of a digital cellular mobile radio telephone system employing a wireless radio link, during a telephone conversation, incorrect reception and loss of information over the link may just result in a temporary muting of sound. However, with the advent of mobile computing, mobile telephone cellular networks are increasingly used for the communication of data and in this situation any loss of data is unacceptable.

Various techniques are known for assisting with correct communication of digital information over a range of media and some of these techniques fall into the category of error detection and correction. One technique is forward error correction (FEC) which involves encoding information prior to transmission in such a way that any errors occurring during communication may be identified and corrected on reception. Another technique is to employ an automatic repeat request (ARQ) error control scheme which involves the retransmission of information that is deemed to have been erroneously received or not received at all. There are various derivatives of the basic ARQ scheme and these are employed depending on the feasibility of providing buffer space at the transmit/receive ends of the link and the requirement to utilise the link efficiently. Indeed some ARQ schemes do not merely retransmit the same information. In the case of these schemes retransmission involves the (re)transmission of only a portion of the information, transmission of appropriate FEC information or any combination thereof. Various ARQ schemes are well known to the person skilled in the art, as is the fact that retransmission may be initiated in the absence of an acknowledgement that information has been received correctly or even incorrectly. This is in contrast to the situation where an explicit request for retransmission is sent to the transmitter. When FEC and ARQ techniques are combined they can provide a powerful error detection and correction mechanism and in certain implementations ARQ operation only becomes active if FEC fails to recover information. However both techniques are most effective when the quality of the link is more predictable and consistent as may be provided, for example, by a co-axial cable, although wired twisted pair links are susceptible to noise and interference. In contrast, wireless radio communication links, such as those employed between mobile terminals and fixed terminals have a link quality which is constantly changing due to, for example movement (should the terminal be mobile), obstructions caused by buildings, the geography of the area, weather conditions and the distance of the wireless link. The onset of interference can also affect the link quality. In particularly poor conditions ARQ techniques will result in multiple retransmissions occurring which may cause a delay in data communication and an overall increase in system power consumption. Where components of the system, for example mobile terminals, rely on battery power this is particularly undesirable.

Where the radio link quality deteriorates because of large signal fluctuations, for example at the onset of a deep fade, various prior art remedies have been proposed to deal with reception failure, including the measures of shifting down of transmission rates and increasing the overall transmission power.

In a radio system such as UMTS the main aim of providing an ARQ scheme is to maximise throughput, while minimising the use of system radio frequency (RF) resources such as power and duration of transmission. It is also desirable to minimise parameters such as interference caused to other users, end-to-end delay of transmissions, implementation complexity and additional consumption of network transmission capacity. These are all long-standing issues.

Published international patent application WO-A-00/19634 filed in the name of Koninklijke Philips Electronics N. V. describes an ARQ scheme where the transmission power level of re-transmitted information packets may be increased with respect to the transmission power level used for corresponding earlier (original) packet transmissions. The motivation for doing this is to reduce the probability of unsuccessful reception of the re-transmitted information packets. This allows information packets to be sent initially with a lower power level than would be the case in an arrangement not benefiting from this scheme, whilst still maintaining a given probability of packet reception failure overall. For this reason, it is also possible to reduce the total transmitted energy, that is, the sum of energy arising from the first transmission and any retransmissions. In certain cases this can mean a reduction of interference caused to other users. This scheme also reduces the probability of a large number of repeat transmissions occurring, which would constitute a sub-optimal manner of communication for a number of reasons, including delays in information transfer.

While the above scheme goes some way to providing an increase in the probability of correct data reception on retransmission whilst simultaneously seeking to regulate the interference caused to other users, it is an object of the present invention to improve on such operation, particularly with respect to CDMA systems such as UMTS.

In accordance with a first aspect of the present invention there is provided a method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, on a carrier modulated in accordance with a second modulation scheme, the second information units allowing the content of the first information units to be established.

The second modulation scheme may be of a lower order modulation than the first modulation scheme.

The method may further include the step of selecting the second modulation scheme for the second information unit transmissions on the basis of a predefined allowable bit error rate or block error rate in the information received at the receiving station by virtue of the second information unit transmissions.

In this case, the allowable bit error rate or block error rate for received second information unit transmissions may be lower than the allowable bit error rate or block error rate for the received first information unit transmissions.

The communications link may be established by equipment operating in accordance with a communications protocol based on the Universal Mobile

Telecommunication System. This communications link may be established on at least one physical channel.

The receiving station can send modulation scheme selection commands to the transmitting station in the transport format combination indicator (TFCI) field carried on a control channel set up in the communications link.

The modulation schemes may include those members of the set n-QAM or n-PSK where n is a positive integer.

Optionally the first modulation scheme order is selected to be the highest possible order while maintaining a maximum allowable probability of failed first information units transmission and consequent second information units transmission.

The received first information units transmitted with the first modulation scheme can be combined with received second information units transmitted with the second modulation scheme.

In accordance with a second aspect of the present invention there is provided a method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units comprising of data having a first spreading factor applied thereto;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, the second information units comprising of data having a second spreading factor applied thereto, the second information units allowing the content of the first information units to be established.

The second spreading factor may be greater than the first spreading factor.

The method may further include the step of selecting the second spreading factor for the second information unit transmissions on the basis of a predefined allowable bit error rate or block error rate in the information received at the receiving station by virtue of the second information unit transmissions.

In this case the allowable bit error rate or block error rate for received second information unit transmissions may be lower than the allowable bit error rate or block error rate for the received first information unit transmissions.

The communications link may be established by equipment operating in accordance with a communications protocol based on the Universal Mobile Telecommunication System. This communications link may be established on at least one physical channel.

The receiving station can send spreading factor selection commands to the transmitting station in the transport format combination indicator (TFCI) field carried on a control channel set up in the communications link.

Optionally, the first spreading factor is selected to be the lowest possible while maintaining a maximum allowable probability of failed first information units transmission and consequent second information units transmission.

The received first information units transmitted with the first spreading factor can be combined with received second information units transmitted with the second spreading factor.

In accordance with a third aspect of the present invention there is provided a method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units on the communications link using a first bandwidth;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, on the communications link using a second bandwidth, the second information units allowing the content of the first information units to be established.

The second bandwidth may be lower than the first bandwidth.

The method may further include the step of selecting the second bandwidth for the second information unit transmissions on the basis of a predefined allowable bit error rate or block error rate in the information received at the receiving station by virtue of the second information unit transmissions.

In this case the allowable bit error rate or block error rate for received second information unit transmissions may be lower than the allowable bit error rate or block error rate for the received first information unit transmissions.

The communications link may be established by equipment operating in accordance with a communications protocol based on the Universal Mobile Telecommunication System.

The communications link may be established on at least one physical channel.

The receiving station can send link bandwidth selection commands to the transmitting station in the transport format combination indicator (TFCI) field carried on a control channel set up in the communications link.

The received first information units transmitted using the first bandwidth may be combined with received second information units transmitted using the second bandwidth.

In each of the above mentioned aspects of the present invention, optionally the transmission of second information units is at a power level which is controlled on the basis of the disparity between target and actual quality of reception parameters for said second information units, wherein the target quality of reception parameter for said second information units is different to the target quality of reception parameter for said first information units, the second information units allowing the content of the first information units to be established. The target quality of reception parameter for the second information units may be greater than the target quality of reception parameter for the first information units.

In the method of the present invention, received first information units and received second information units may be combined.

The modulation scheme, data spreading factor or link bandwidth may be directed by the receiving station.

The content of the second information units can be the same as the content of the first information units.

The units may be data frames or packets of data.

The step of monitoring may be performed by the transmitting station based on information provided by the receiving station.

In accordance with a further aspect of the present invention there is provided a digital wireless communications system comprising at least one transmitter having means for transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

at least one receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme; and wherein the second information units allow the content of the first information units to be established.

The control means may be responsive to control information originating from the receiver.

In accordance with a yet further aspect of the present invention there is provided a transmitter station for digital wireless transmission of traffic information to a receiver, said transmitter station having:

a transmitter for transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver, wherein the transmitter transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme, the second information units allowing the content of the first information units to be established.

The control means may be responsive to control information originating from the receiver.

In accordance with a yet further aspect of the present invention there is provided a receiver for use in a digital wireless communications system comprising at least one transmitter having means for transmitting first information units on a carrier modulated in accordance with a first modulation scheme, the receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme; and wherein the second information units allow the content of the first information units to be established.

The control means may be responsive to control information originating from the receiver.

Other aspects and optional features of the present invention appear in the appended claims to which reference should now be made and the disclosure of which is incorporated herein by reference.

The invention will now be described by way of example only with reference to the accompanying drawings, wherein

Figure 1 is a schematic representation of a typical cellular mobile radio telephone communications system employing at least one wireless radio communications link;

Figure 2 is a schematic representation of components in a transmitter stage from the system of Figure 1;

Figure 3 illustrates the operation of a typical known automatic repeat request (ARQ) error control scheme;

Figure 4 illustrates the operation of an implementation of an error control scheme employing power control; and

Figure 5 shows transmission power with respect to time of apparatus employing power control.

Referring to Figure 1, a communications system 1 in the form of a cellular mobile radio telephone system includes a switching centre 10, which is connected to the public switched telephone network (PSTN) and to other data networks if required. The switching centre is typically one of a number of switching centres and a number of basestations 20 are connected to each switching centre. The main function of the basestations 20 is to establish a radio link 30 with a terminal 40, such as a mobile telephone, (or in the case of UMTS, the so-called user equipment (UE)), and therefore allow communication between the mobile terminal 40 and the rest of the system. Each basestation 20 is usually capable of supporting a plurality of such links 30 and therefore a plurality of mobile terminals 40. While the base stations 30 and the switching centre 10 are shown as separate components, this is for illustrative purposes only and various functions may be performed by the switching centre and / or base station depending on the implementation of the system, as will be appreciated by the person skilled in the art. A base station 20 is sometimes referred to as a fixed terminal, and in certain cases this terminology may be taken to include components such as the switching centre 10 or at least such functional components associated with the switching centre and other fixed infrastructure components. The basestation 20 and the terminals 40 are each provided with radio transmitting and receiving means for establishing the links 30. It is assumed that the radio link 30 is digital and furthermore may employ techniques such as Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) or Code Division Multiple Access (CDMA).

In use, the quality of a link 30 established between the basestation 20 and the terminal 40 will vary considerably and the system must be tolerant of fluctuating link quality. Where digital information is being exchanged, as in the present example, this may result in the incorrect reception of digital information. Error correction techniques such as forward error correction (FEC) may be employed which can allow recovery of the correct information from the incorrectly received information. As the quality of the link 30 deteriorates further FEC techniques may not be adequate to recover the correct information and in this case there is no alternative but to initiate further transmissions for any incorrectly received information. These further transmissions may take a variety of forms although one practice is to employ ARQ schemes as mentioned earlier. In each case, regardless of the scheme chosen the further transmissions may be considered as the transmission of second information units that are associated in some way to (failed) previously transmitted first information units. As also mentioned above the further transmissions (of second information units) can involve a straightforward retransmission of information, (re)transmission of only a portion of the information, transmission of appropriate FEC information, transmission of enhanced FEC information or any reasonable combination thereof. However, for the purpose of illustrating the present invention, and by way of example only, the following specific description relates to a typical ARQ scheme where the transmission of second information units actually constitutes a repeat transmission of (failed) first transmission units.

The retransmission of information occurs without the intervention of a user and is therefore called an automatic repeat request (ARQ). By way of example only, a typical ARQ scheme may be understood by reference to Figure 3 which shows the frame sequence of a so called selective RQ scheme ARQ implementation (where a frame is a unit of information transferred across the data link 30 of this example). This known scheme is discussed in more detail in the publication “Data Communications, Computer Networks and OSI” (second edition) at page 126 – 127 by Fred Halsall and published by the Addison-Wesley Publishing Company. Although information often flows in both directions across a link, Figure 3 shows a situation where information is being sent from a sender (S) to a receiver (R) in the form of a number N of information frames I. Each transmitted frame contains a unique identifier which allows the sender S and the receiver R to keep track of individual frames. Both the sender and the receiver are provided with buffer storage space C_s and C_R respectively to record the frames that have been sent or received. When, for example, the frame I (N) denoted as 101 is transmitted by the sender S, this is recorded in the buffer C_s. Frames are sent continuously and the contents of C_s form a (provisional) retransmission list. The receiver R returns an acknowledgement ACK to S for each correctly received frame and also records a list of correctly received frames in the buffer C_R. When the sender S receives acknowledgement ACK from the receiver R that a particular frame has been received correctly, sender S removes from the buffer C_s the entry that corresponds to that acknowledged frame. Each I frame is coded to permit the receiver R to establish that the I frame is not corrupted. Various ways of doing this include the use of cyclic redundancy check (CRC) error checking. Now with further reference to Figure 3, it is assumed that frame I (N+1) which is denoted as 102 becomes corrupted during transmission which is shown as a crossed line. This results in the absence of an acknowledgement for the I frame N+1 while acknowledgement ACK of the other illustrated frames N, N+2, N+3 ... occurs normally. The sender S detects frame N+1 has not been acknowledged causing sender S to retransmit the frame as is denoted at 103. Depending upon the particular implementation of the ARQ scheme, subsequent retransmission may occur until correct receipt of a frame is acknowledged.

Where multiple retransmissions occur this can cause problems in certain systems. Firstly, multiple retransmissions may cause a significant delay. A second problem occurs in systems where large messages are transferred which are required to be broken into a number of frames. Because the frames must be reassembled in the correct order before the message can be recovered, this can require the use of large buffer storage space for temporary storage of frames received out of sequence. This is illustrated in the above example where frame (N+1) is retransmitted after transmission of frame (N+4). In order to recover the original message it is necessary for the receiver R to buffer the frames N+2, N+3 and N+4 which have been received out of sequence. Alternatively, or in addition to this buffering, the transmitter may buffer frames ready for retransmission.

In data communication systems employing a physical link, such as a coaxial cable, incorrect transfer of information is frequently caused by spurious noise or collision of data, in which case simple retransmission of data is likely to be successful on the first attempt. However, in the case of a wireless communication link, such as that employed between a mobile terminal 40 and a basestation 20, incorrect transmission of information is often caused by a weak signal reaching the receiving end of the link. Furthermore this signal strength may be constantly varying due to a changing operating environment and in these situations a simple retransmission of incorrectly received information may be unsatisfactory. In this case, information that needs to be retransmitted may be sent over the link 30 with a transmission power that is greater than the transmission power used to transmit that information originally. This is illustrated in Figure 4, which shows the same frame transmission sequence of Figure 3 along the x-axis and transmission power on the y-axis. Frames are normally transmitted at power P_1 whereas retransmitted frames are transmitted at power P_R. This increases the probability of repeated information being successfully received on retransmission, especially under conditions where signal strength is weak or fading occurs. Furthermore the increased likelihood of successful communication resulting on the first retransmission allows a smaller buffer space to be employed in the transmitter and/or receiver for storing frames or a list of frames. The increased likelihood of successful communication resulting on the first retransmission can also result in reduced delay when sending the information, which is advantageous when carrying real time information such as video or audio. Benefits may also result when transmitting other types of information for which a transmission delay beyond a predetermined period is unacceptable. In the case that the first information units are discarded in the event of incorrect reception, the power amplitude of the retransmitted frames (second information units) may, for example, be in the order of 3dB higher than the power amplitude used for the initial transmission of the frames (first information units) although other amplitudes may be chosen to give different relative powers and the above value is not intended to limit the scope of the present invention.

Alternatively, if the first information units are not discarded, but are combined with any re-transmitted information, then the required quality target might be reached with a lower power for the re-transmissions. The re-transmitted information in this case would only be required to make up the difference between the received quality of the first transmission and the quality needed for correct reception.

Figure 2 shows components of the transmitter stage in a basestation 20 of the telecommunications system 1. A transmitter 50 transmits units of information as frames with a power that is governed by control means 60. In this example control means 60 is responsive to monitoring means 70. As stated above the transmitter 50 may output retransmitted information with a different (usually greater transmission power in the case of discarded first transmissions) transmission power than the transmission power used to transmit that information originally. Although the transmitter 50, control means 60 and monitoring means 70 are shown together as components of the transmitter stage in the base station 20, this does not indicate a limitation. For example the monitoring means may be located away from the transmitter stage. In some cases the monitoring means may be located at the receiving end of the wireless link.

The above scheme allows retransmitted data to be successfully communicated with an increased level of confidence and this may be exploited in those applications where it is preferable that information should be successfully communicated by the first retransmission attempt. The transmission power levels for the first transmission attempt may be variable. For example it may be desirable to select this initial transmission power level P_1 such that a particular proportion of initial transmissions are likely to require retransmission (at the higher power level). Selection of the transmission power levels for the first transmission attempt will influence the proportion of retransmissions and thereby influence the average transmission power level. Lowering the initial transmission power will reduce the probability of information being successfully received. However, by using a low transmission power the power consumption of the transmitter will be reduced. The transmission power for the first attempt may in this way be used to control the average power consumption (which of course must take into account the transmissions at the higher power) of the transmitting circuitry, and preferably maintain a minimum average power consumption. Obviously, certain applications will be more tolerant than others to the occurrence of retransmissions and a balance needs to be established based on the relative importance of power saving versus the occurrence of retransmission. Indeed, excessive retransmission may give rise to a greater average power consumption than would occur if choosing to initially transmit at a higher power level thus reducing the number of retransmissions. The present arrangement is primarily intended for use in the transmission of traffic, which may for example be user video, voice, or file data and the requirements for transmitting various types of traffic will be known to the person skilled in the art. An overall reduction in transmission power reduces power consumption. This is of particular benefit when an exhaustible power source, such as a battery is being used. In certain implementations it may be desirable to impose a limitation on the number of retransmissions that are permitted in the interest of power saving and/or limiting transmission delay.

This power saving feature is also illustrated in Figure 4. Information is initially transmitted at power P_I which is below the power P_K that would be used for transmission and retransmission in a system not benefiting from the present scheme. As will be noted, the re-transmitted information, in this case I frame (N+1), is re-transmitted at power P_R which is greater than P_1. In this case, P_R is also greater than P_K although this is not mandatory. The reduction in overall power consumption may be exploited to provide a number of benefits such as extended operating time in the case of battery powered equipment, the use of smaller lighter batteries or the use of more economical battery technology.

Now that the basic concept of using a different transmission power for repeat transmissions has been explained, operation where transmission power is governed by the use of a closed loop power control will be described. In a system with closed loop power control, such as UMTS when operating in the frequency division duplex (FDD) mode, it is proposed that transmission power, for the retransmissions at least, should be governed with reference to at least one parameter indicative of the quality of received transmissions at the receiving end of the link. One such parameter is the signal to interference (SIR) ratio. Transmission power may be adjusted as necessary such that the required SIR ratio (the 'target' SIR ratio) is achieved in transmissions detected by the receiver. In order to bring about a change in transmission power for repeat transmissions in comparison with original transmissions, it is possible to lower or raise the target SIR ratio at the receiver for any re-transmissions in comparison with the target SIR set at the receiver for the original transmissions. This change in target SIR setting may be done by explicit signalling between the fixed terminal and mobile terminal or under control of the physical layer. One procedure for setting the target SIR already exists, and is defined in the current version of the UMTS specification 3G TS25.433v3.2.0 "UTRAN Iub Interface NBAP signalling" section 8.2.17 the teaching of which is incorporated herein by reference.

In the case of a UMTS uplink (UL), a closed-loop power control procedure is employed for uplink Dedicated Channels (DCH). This procedure is specified in the current version of the UMTS specification 3GTS25.214v3.3.0 "Physical Layer Procedures (FDD)" section 5.1.2 the teaching of which is incorporated herein by reference. The procedure can be further subdivided into two processes which operate in parallel: outer-loop power control and inner-loop power control.

The outer-loop power control for the uplink operates within the base station (BS), and is responsible for setting a target SIR of transmissions as received at the BS from each UE. This target is set on an individual basis for each UE, according to the required BLock Error Rate (BLER) of the decoded data received from that UE. Generally, if it is required that the error rate of received, decoded data should be low, then it will be necessary for the SIR of received undecoded transmissions to be relatively high. In applications where a higher error rate in decoded data is permissible, it will be acceptable to receive transmissions having a lower SIR. The required BLER will depend on the particular service which is being carried, and therefore could, for example, be higher for a data service than for a voice service. The outer-loop power control will adjust the SIR target until the required BLER is matched. The SIR can be calculated by the reception of known pilot information.

The inner-loop power control mechanism controls the transmitted power of the UE in order to counteract the fading of the radio channel and meet the SIR target at the BS set by the outer-loop.

If the inner-loop power control fails to counteract adequately the fades in the channel, the BLER will increase and the outer-loop power control will increase the SIR target, so that the average received SIR from the UE is increased.

The BS compares the received SIR from the UE with the target once every time-slot (0.666ms). If the received SIR is greater than the target SIR, the BS transmits a TPC ("Transmit Power Control") command "0" to the UE via the downlink dedicated control channel. Such a command instructs the transmitter to reduce transmitting power. If the received SIR is below the target, the BS transmits a TPC command "1" to the UE. Such a command instructs the transmitter to increase transmitting power.

In the case of a UMTS downlink, inner and outer loop power control acts on dedicated channels in a similar way to the uplink.

Further information on uplink and downlink power control system employed in UMTS may be found in the paper entitled "Power control in UMTS release '99" M P J Baker, T J Moulsley IEE 3G2000 Mobile Communication Technologies Conference 27th-29th March 2000 (London), published as International Conference on 3G 2000 "Mobile Communication Technologies", 27-29 March 2000 London UK, pp 36-40, the teaching of which is incorporated herein by way of reference.

In a specific arrangement proposed here, the DSCH (Downlink Shared Channel) can be used to send packet data on the downlink. A pair of DCH (Dedicated Channels) would be used in uplink and downlink to support functions such as signalling and power control. If a packet is received in error by the UE, then the target SIR at the UE used by the downlink power control loop can be changed. The new SIR has the effect that the UE requests that the network (via closed loop inner power control) should transmit with a different power. The target SIR could be restored to its original values when the packet has been received correctly.

Such operation is illustrated in Figure 5 which shows SIR on the y-axis versus time on the x-axis. The solid line 150 shows the received SIR value. For the first transmission of information units, the target SIR is set at value A. The actual received SIR value can fluctuate (for a number of reasons as have already been discussed above). In order to compensate for such fluctuations, the inner loop power control adjusts the transmission power in order to achieve the required SIR ratio A. In order to compensate for such fluctuations the closed loop power control is employed such that the receiver sends transmit power 'up' or power 'down' TPC commands to the transmitter such that the received SIR will be centred on the target SIR value A.

Now assuming that reception of first transmission units has failed, the receiver sends such an indication to the transmitter, which may be in the form of a negative acknowledgement command (NACK) or the lack of a positive acknowledgement command (ACK) depending on the form of ARQ scheme being used, as will be appreciated by the person skilled in the art. Consider the example scheme where the received first information units are discarded if received in error. The receiver also now raises the target SIR to a value B which is higher than the target SIR value A. This is denoted in Figure 5 at 151. The SIR value of received transmissions is below the target SIR B which causes the receiver to send power 'up' commands to the transmitter, which commands are sent until the new target SIR B is reached. This is shown in Figure 5 at 152. The higher target SIR B is maintained until the retransmission successfully communicates the failed data to the receiver. On acknowledgement of correct reception of the information units, the receiver sets the target SIR to the lower value A, as is denoted at 153. Since the SIR value of received transmissions is now above the target SIR, the receiver will send power 'down' commands to the transmitter, which commands are sent until the target SIR A is reached by the actual SIR value of received signals. This is shown in Figure 5 at 154.

The same principle may be employed on the uplink communications. The change in SIR target may also be instructed or requested by the transmitting station.

Operation becomes be more complex if additional packets are sent before the erroneous one is re-transmitted, requiring the use of buffers and means for correctly sorting received packets of data. One way to simplify operation is to fix or restrict the delay of any re-transmissions, so that the target SIR could be raised at the correct time (or approximately the correct time).

In addition to the above mechanism of setting the target SIR and relying solely on the inner loop power control to cause a variation in transmission power, it may be possible to also apply an initial power change at the onset of re-transmissions, so that the new target SIR is reached more quickly. This is denoted in Figure 5 as 155, which shows the new SIR value B being reached more quickly, relying on fewer inner loop power control cycles to reach the required SIR.

The above principle may also be applied to communications performed using other channels of the UMTS system, with appropriate modifications where necessary, as will be appreciated by the person skilled in the art.

In the case of the present invention we exploit the fact that other parameters of the re-transmission can be altered, either individually or in combination with the above described power control techniques. For example, it is already known that the coding scheme applied to re-transmitted data may be different to the coding scheme applied to data during the original transmission. More particularly, in accordance with an aspect of the present invention, the modulation scheme used for modulation of the carrier for the re-transmissions is chosen to be different to the modulation scheme used for modulation of the carrier during the original transmissions. For example, the modulation scheme used for the re-transmissions may be chosen to be more robust than the modulation scheme employed in the original transmissions. For example, if the first transmission is sent with a higher order modulation (e.g. 64-QAM (quadrature amplitude modulation), 16-QAM or 8-PSK), then in the event of erroneous reception, any re-transmissions may be sent using a more robust lower order modulation (e.g. QPSK). Types of modulation include n-QAM and n-PSK where n is a positive integer.

High order modulation schemes are favoured because the use of higher order modulation can be used to increase system throughput in comparison with lower order modulation scheme use, but only when the SIR is high.

Alternatively, a higher order modulation might be used for the re-transmissions. This would be appropriate if the re-transmitted information can be combined with the first information units. The re-transmitted information in this case would only be required to make up the difference between the received quality of the first transmission and the quality needed for correct reception, and using a less robust modulation scheme might be appropriate.

The choice of modulation scheme for re-transmissions may also take into account any changes in the channel following the first transmission. For example, if the SIR has improved due to lower path loss or lower interference, then a higher order modulation might be used. Conversely, a lower order modulation might be used if the SIR has decreased.

Also in accordance with the present invention, the transmission can be made more robust by increasing the spreading factor which would be particularly applicable in the case of a CDMA system. The change of spreading factor may be performed instead of or in addition to the change of modulation order.

Alternatively, a greater spreading factor might be used for the re-transmissions. This would be appropriate if the re-transmitted information can be combined with the first information units. The re-transmitted information in this case would only be required to make up the difference between the received quality of the first transmission and the quality needed for correct reception, and using a less robust spreading factor might be appropriate.

The choice of spreading factor for re-transmissions may also take into account any changes in the channel following the first transmission. For example, if the SIR has improved due to lower path loss or lower interference, then a greater spreading factor might be used. Conversely, a lower spreading factor might be used if the SIR has decreased.

Also in accordance with the invention, the transmission bandwidth used for re-transmissions may be chosen to be different to that transmission bandwidth used for the original transmissions. By choosing a narrower bandwidth for re-transmission, the channel is likely to contain less noise and interference, although it may take a longer time to transmit a given amount of information. However, in the case of a frequency dispersive channel, it may be preferable to use a wider bandwidth for the re-transmissions.

In one arrangement, a wider bandwidth might be used for the re-transmissions. This would be appropriate if the re-transmitted information can be combined with the first information units. The re-transmitted information in this case would only be required to make up the difference between the received quality of the first transmission and the quality needed for correct reception, and using a less robust bandwidth might be appropriate.

The choice of bandwidth for re-transmissions may also take into account any changes in the channel following the first transmission. For example, if the SIR has improved due to lower path loss or lower interference, then a wider bandwidth might be used. Conversely, a narrow bandwidth might be used if the SIR has decreased.

In accordance with known techniques the information in the second and subsequent transmissions may be combined with that in the first transmission to allow the information in the first transmission to be determined. The second transmission may contain additional redundant information, which can be used for error correction.

Measuring a quality of reception parameter at the receiver, such as the SIR may be used to select the modulation and/or coding and/or spreading factor. Techniques for measuring SIR will be known to the person skilled in the art.

Under some circumstances there may be errors in measuring SIR, and hence in choosing the correct modulation. If the packet fails for this or any other reason and if re-transmission power cannot be increased, or it is not desirable to do so, the modulation (and / or coding / spreading factor / bandwidth use) may be changed on re-transmission. In UMTS, modulation or other parameters could be indicated in the Transport format combination indicator (TFCI) signalling field in the Dedicated physical control channel (DPCCH), or could be determined by virtue of the fact that the first transmission had failed.

The present invention may be implemented having regard to the requirements of the particular application. In applications where occasional transmission errors are tolerable it may be possible to reduce significantly the initial transmission power or quality of reception parameter (for example SIR target) causing a large reduction in the power consumption, placing reliance on the fact that successful transmission is likely on repeat transmission. In applications where a saving in power consumption needs to be balanced with the avoidance of unnecessary re-transmission, the initial transmission power is not reduced to the same extent. Likewise, the order of the modulation scheme may not be increased to the same extent, the spreading factor may not be increased to the same extent and so forth.

Although the present invention is described with reference to a mobile cellular radio telephone system and so-called third generation mobile telecommunications systems, other applications include other cordless telephone systems and wireless LANs (for example Hiperlan), et cetera.

Variations on the basic scheme may include increasing the retransmission power or quality of reception parameter (for example SIR target) only after the first or a plurality of initial retransmission attempts have failed, thus providing greater scope for a reduction in power consumption.

Another variation on the basic scheme is to provide a progressive power increase for information that is retransmitted more than once. For example, the target SIR could be increased progressively until the information is successfully received. This further reduces the probability of unsuccessfully transmitted information being further delayed as a result of multiple retransmissions. In the general case there could be a pre-determined sequence of SIR values depending on the number of re-transmissions. In some cases it may be desirable to limit the maximum allowable number of retransmission attempts for a given initial transmission.

The present invention may be used in conjunction with the concept of transmitting second transmission units at a different power level to the first transmission units, as is the subject of our co-pending UK patent applications entitled "Method for the communication of information and apparatus employing the method" GB0020599.7 filed on 21st August 2000, and GB0024699.1 filed on 9th October 2000, each in the name of Koninklijke Philips Electronics NV, with applicants references PHGB000113 and PHGB000139 respectively.

Whilst the present invention offers direct advantages in terms of reliable communication of information and a reduction in power consumption, other indirect advantages may be enjoyed through the correct implementation of the present invention. A lower initial (hence average) transmission power can result in reduced interference with other transmissions. An example of this in a cellular system would be observed as a reduction in overall co-channel interference (and a possible reduction in other types of interference) since the duration of the high power transmissions is relatively short. This can result in less interference to other users.

Although the present invention has been described with reference to a known ARQ scheme this is not intended to indicate any limitation. As described the present invention may be primarily considered as a special ARQ scheme in which case the information is generally digital data organised into frames or packets. In this case the invention may be considered as an automatic repeat request error control scheme wherein transmitted data frames or packets which are deemed to have been unsuccessfully communicated are complemented with further transmissions at a power level different to the power used to transmit the data frames or packets originally, or aiming to achieve a quality of reception parameter (for example SIR ratio) different to that achieved for the transmission of the data frames or packets originally. The present invention is also in keeping with techniques where first and subsequent transmissions or retransmissions may be combined to recover information. This principle extends to combining first and subsequent transmissions having differing modulation schemes, spreading factors or link bandwidths. In such techniques it may be preferable to employ some type of averaging, and in this case may also be preferable to give more "weight" to information transmitted at a higher power or received with a higher quality of reception parameter. While the present invention will be of greatest use over a wireless radio link, it may also in principle be implemented in systems employing links of other mediums, for example co-axial cable, twisted pairs and so on, although the issue of power consumption is normally of minor importance in wired communication links. Furthermore, although the present invention has been described with reference to an example employing transmission between a fixed terminal and a portable terminal, it will be apparent to the person skilled in the art that the present invention is not so limited in application. That is the present invention may be employed in the transfer of information in either direction over a communications link or in both directions, irrespective of the fact that the transmitting station and/or receiving station is fixed or mobile. It will also be apparent to the person skilled in the art that in a two way communications system a transmitting station may be combined with a receiving station.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of systems and devices and component parts thereof and which may be used instead of or in addition to features already described herein.

CLAIMS

1. A method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, on a carrier modulated in accordance with a second modulation scheme, the second information units allowing the content of the first information units to be established.

2. A method in accordance with claim 1 wherein the second modulation scheme is of a lower order modulation than the first modulation scheme.

3. A method in accordance with claim 1 or 2 wherein received first information units transmitted with the first modulation scheme are combined with received second information units transmitted with the second modulation scheme.

4. A method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units comprising of data having a first spreading factor applied thereto;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, the second information units comprising of data having a second spreading factor applied thereto, the second information units allowing the content of the first information units to be established.

5. A method in accordance with claim 4 wherein the second spreading factor is greater than the first spreading factor.

6. A method in accordance with claim 4 or 5 wherein received first information units transmitted with the first spreading factor are combined with received second information units transmitted with the second spreading factor.

7. A method of transferring information in units over a wireless digital communications link between a transmitting station and a receiving station comprising the steps of:

transmitting first information units on the communications link using a first bandwidth;

monitoring if correct reception of the transmitted units occurred;

and

transmitting second information units associated with the first information units, for which first information units the monitoring did not indicate correct reception occurred, on the communications link using a second bandwidth, the second information units allowing the content of the first information units to be established.

8. A method in accordance with claim 7 wherein the second bandwidth is lower than the first bandwidth.

9. A method in accordance with claim 7 or 8 wherein received first information units transmitted using the first bandwidth are combined with received second information units transmitted using the second bandwidth.

10. A method in accordance with any one or more of claims 1 to 9 wherein the communications link is established by equipment operating in accordance with a communications protocol based on the Universal Mobile Telecommunication System.

11. A method in accordance with claim 10 when appended to claim 1, 2 or 3, wherein the receiving station sends modulation scheme selection commands to the transmitting station in the transport format combination indicator (TFCI) field carried on a control channel set up in the communications link.

12. A method in accordance with any one or more of claims 1, 2, 3 or 11 wherein the modulation schemes include those members of the set n-QAM or n-PSK where n is a positive integer.

13. A method in accordance with any one or more of claims 1, 2, 3, 11 or 12, wherein the first modulation scheme order is selected to be the highest possible order while maintaining a maximum allowable probability of failed first information units transmission and consequent second information units transmission.

14. A method in accordance with claim 4, 5 or 6, wherein the first spreading factor is selected to be the lowest possible while maintaining a maximum allowable probability of failed first information units transmission and consequent second information units transmission.

15. A method in accordance with any one or more of claims 1 to 14, wherein the transmission of second information units is at a power level which is controlled on the basis of the disparity between target and actual quality of reception parameters for said second information units, wherein the target quality of reception parameter for said second information units is different to the target

quality of reception parameter for said first information units, the second information units allowing the content of the first information units to be established.

16. A method in accordance with claim 15, wherein the target quality of reception parameter for the second information units is greater than the target quality of reception parameter for the first information units.

17. A digital wireless communications system comprising at least one transmitter having means for transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

at least one receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme; and wherein the second information units allow the content of the first information units to be established.

18. A transmitter station for digital wireless transmission of traffic information to a receiver, said transmitter station having:

a transmitter for transmitting first information units on a carrier modulated in accordance with a first modulation scheme;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitter transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme, the second information units allowing the content of the first information units to be established.

19. A receiver for use in a digital wireless communications system comprising at least one transmitter having means for transmitting first information units on a carrier modulated in accordance with a first modulation scheme, the receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a carrier modulated in accordance with a second modulation scheme; and wherein the second information units allow the content of the first information units to be established.

20. A digital wireless communications system comprising at least one transmitter having means for transmitting first information units comprising of data having a first spreading factor applied thereto;

at least one receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units comprising of data having a second spreading factor applied thereto; and wherein the second information units allow the content of the first information units to be established.

21. A transmitter station for digital wireless transmission of traffic information to a receiver, said transmitter station having:

a transmitter for transmitting first information units comprising of data having a first spreading factor applied thereto;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitter transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units comprising of data having a second spreading factor applied thereto, the second information units allowing the content of the first information units to be established.

22. A receiver for use in a digital wireless communications system comprising at least one transmitter having means for transmitting first information units comprising of data having a first spreading factor applied thereto, the receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units comprising of data having a second spreading factor applied thereto; and wherein the second information units allow the content of the first information units to be established.

23. A digital wireless communications system comprising at least one transmitter having means for transmitting first information units on a communications link using a first bandwidth;

at least one receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a communications link using a second bandwidth; and wherein the second information units allow the content of the first information units to be established.

24. A transmitter station for digital wireless transmission of traffic information to a receiver, said transmitter station having:

a transmitter for transmitting first information units on a communications link using a first bandwidth;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitter transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a communications link using a second bandwidth, the second information units allowing the content of the first information units to be established.

25. A receiver for use in a digital wireless communications system comprising at least one transmitter having means for transmitting first information

units on a communications link using a first bandwidth, the receiver having means for receiving the transmitted information units;

control means; and

monitoring means for monitoring if correct reception of the transmitted units occurred at the receiver,

wherein the transmitting means transmits second information units associated with the first information units for which first information units the monitoring means does not indicate correct reception has occurred, the second information units being transmitted on a communications link using a second bandwidth; and wherein the second information units allow the content of the first information units to be established.

26. The method, system, transmitting station or receiver of the preceding claims wherein received first information units and received second information units are combined.

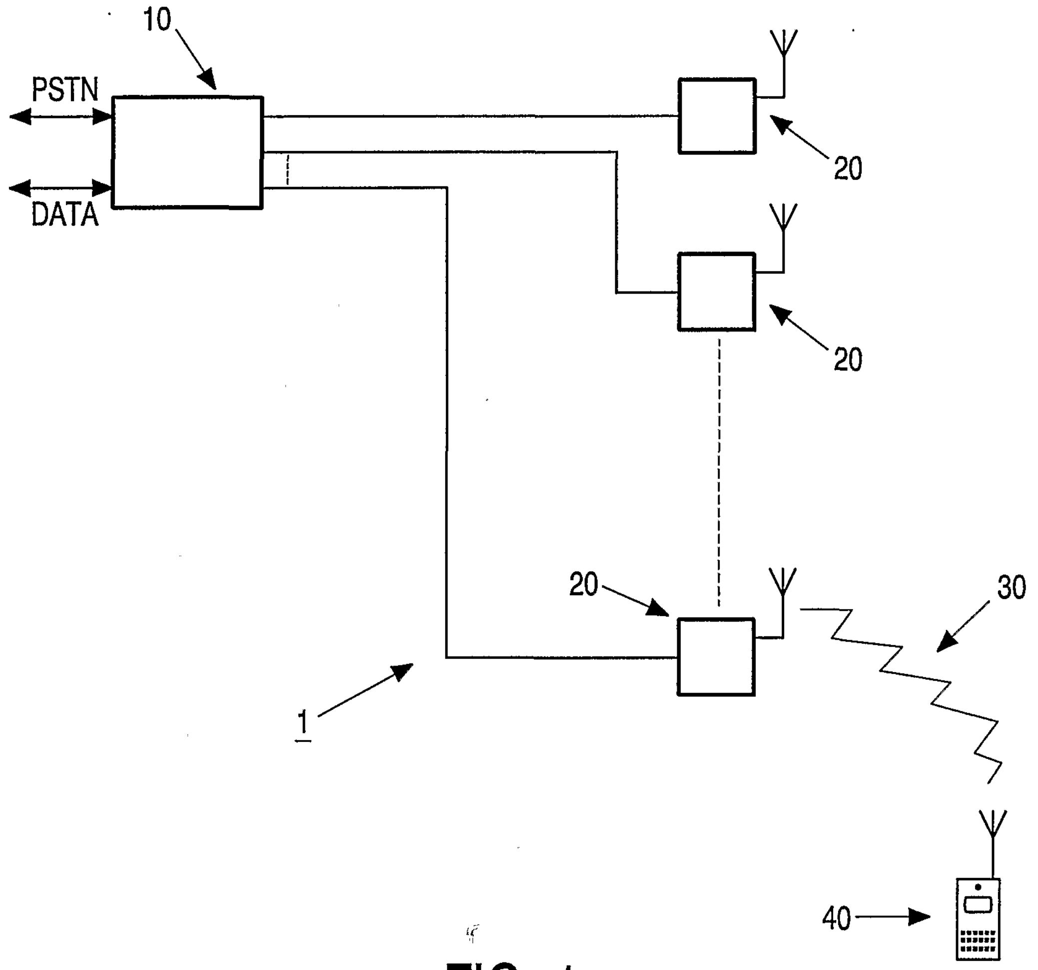


FIG. 1

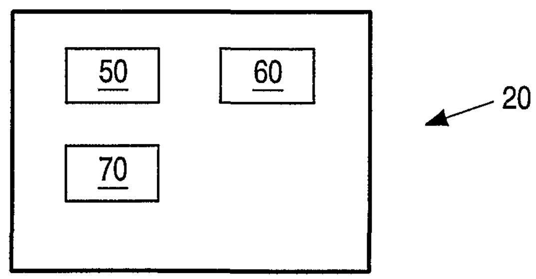
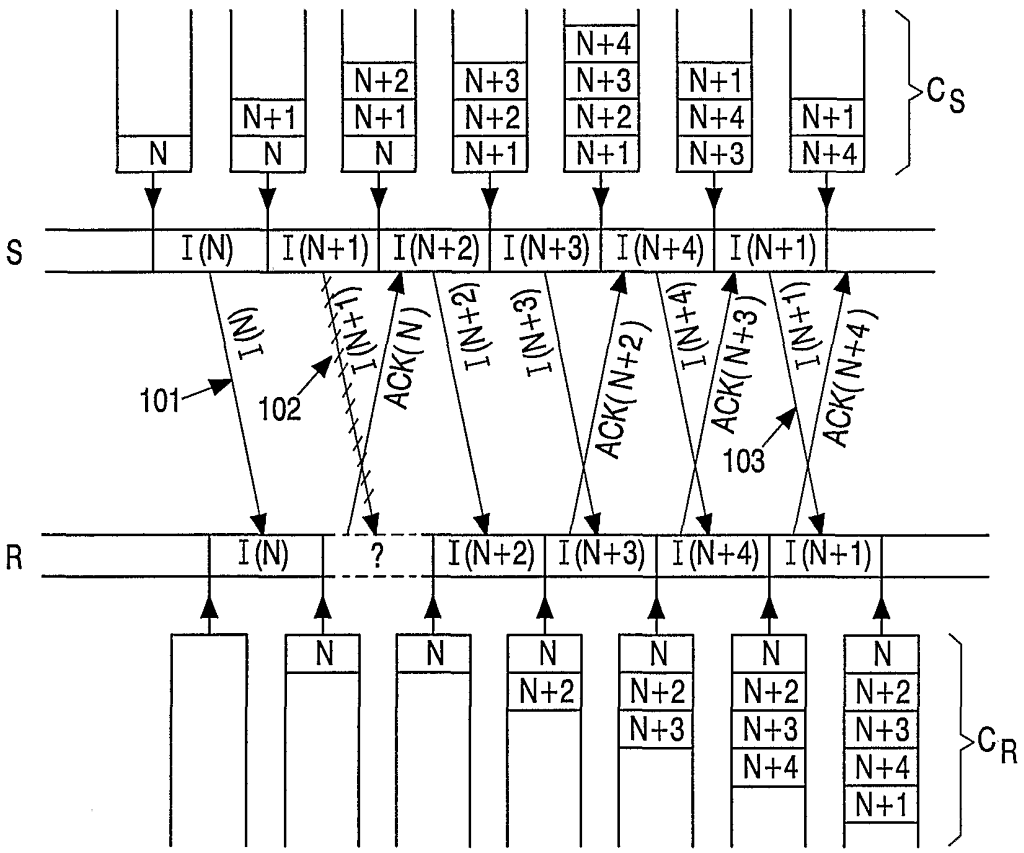


FIG. 2



N
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N
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N+1
N
N+3
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N+1
N+4
N+3
N+1
N+4
C_S
S
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I(N+1)
I(N+2)
I(N+3)
I(N+4)
I(N+1)
I(N)
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ACK(N+2)
I(N+4)
ACK(N+3)
I(N+1)
ACK(N+4)
101
102
103
R
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?
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I(N+3)
I(N+4)
I(N+1)
N
N
N
N+2
N
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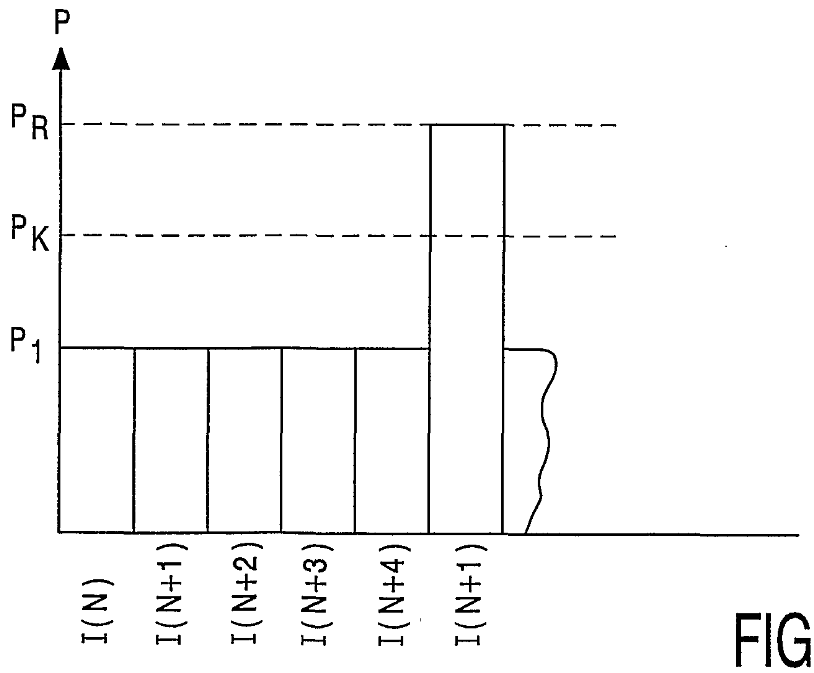
N+1
C_R

FIG. 3



P
P_R
P_K
P_1
I(N)
I(N+1)
I(N+2)
I(N+3)
I(N+4)
I(N+1)

FIG. 4

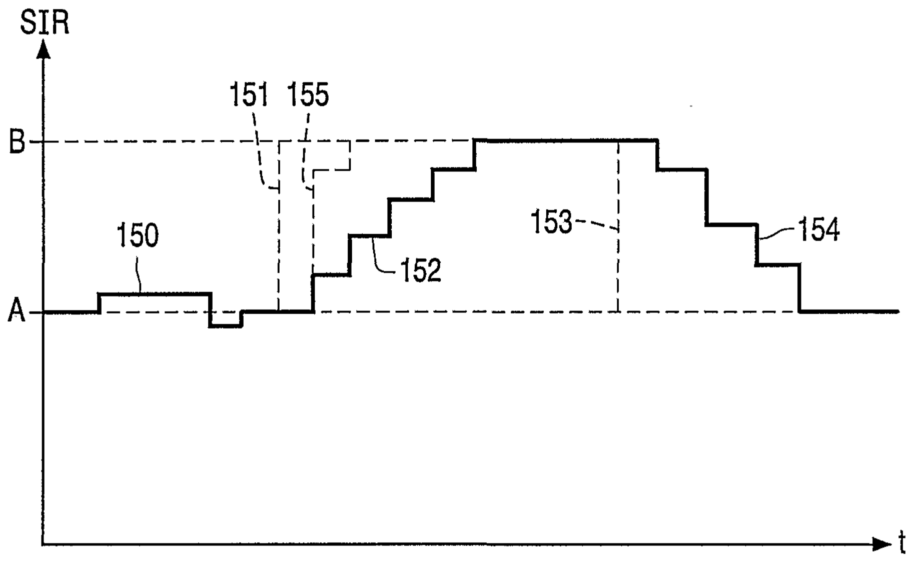


FIG. 5

INTERNATIONAL SEARCH REPORT

Intei al Application No
PCT/EP 01/09615

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/00 H04B7/005 H04L1/18

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)
IPC 7 H04L H04B

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FALAHATI S ET AL: "Hybrid type-II ARQ schemes with adaptive modulation systems for wireless channels" VEHICULAR TECHNOLOGY CONFERENCE, 1999. VTC 1999 - FALL. IEEE VTS 50TH AMSTERDAM, NETHERLANDS 19-22 SEPT. 1999, PISCATAWAY, NJ, USA,IEEE, US, 19 September 1999 (1999-09-19), pages 2691-2695, XP010353427 ISBN: 0-7803-5435-4 the whole document ---	1-14, 17-26

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2002	04/02/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Martínez Martínez, V

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 996 248 A (ERICSSON TELEFON AB L M) 26 April 2000 (2000-04-26) abstract column 5, line 45 -column 6, line 3 column 11, line 14 - line 35; figure 9 claim 2 -----	1,2,4,5, 7,8, 10-14, 17-25

INTERNATIONAL SEARCH REPORT

Inter al Application No
PCT/EP 01/09615

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0996248	A	26-04-2000	EP	0996248 A1	26-04-2000
			AU	6469899 A	08-05-2000
			WO	0024152 A1	27-04-2000
			EP	1123601 A1	16-08-2001