Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
Description

Background of the Invention

Field of the Invention

[0001] The present invention relates generally to communication systems. Specifically, the invention relates to a method and apparatus for facilitating the reliable transfer of short, bursty messages over a wireless communications link.

Description of the Related Art

[0002] The use of wireless communication systems for the transmission of digital data is becoming more and more pervasive. In a wireless system, the most precious resource in terms of cost and availability is typically the wireless link itself. Therefore, one major design goal in designing a communication system comprising a wireless link is to efficiently use the available capacity of the wireless link. In addition, it is also desirable to reduce the delay associated with use of the link.

[0003] In a digital data system, remote units tend to generate bursty data to a hub station. The bursty data is characterized in that it has a high peak-to-average traffic ratio, meaning that blocks of data are transferred during short periods of time interposed between significantly longer periods of idleness.

[0004] In a time division multiple-access (TDMA) communication system, a separate time slot channel is assigned or dedicated to each remote unit. The remote unit uses the assigned time slot channel to transmit data to a hub station. By limiting transmissions to fall within the assigned time slot, the remote units are able to share the communication resources provided by the hub station. A TDMA system is effectively utilized when the transmission times and time slots of the remote units are all properly synchronized with each other.

[0005] In a TDMA system in which units have a pattern of use that includes bursty data, dedication of an individual time slot channel to each active remote unit does not result in efficient use of system capacity. This is because during those times when a remote unit is not utilizing the system, the time slot channel remains idle.

[0006] In a communication system with a plurality of remote units and a hub station, the hub station may detect when a remote unit has sent a burst to the hub station, determine the data content of the burst, and generate commands, such as timing synchronization signals, to feed back to the remote unit.

[0007] For example, US-4649543 describes a method in which a set of multibit high autocorrelation, low cross-correlation synchronization words and their ones complement inverses are employed for message synchronization.

[0008] In present communication systems, the burst from a remote unit to the hub station typically includes a preamble which is used by the hub station to detect the burst. The added bits of the preamble increases the length of the burst and increases the duration of the time slot required by each remote unit. The more remote units in a system, the longer it takes the hub station to detect and process data bursts with their preambles. Furthermore, if the data bits in the burst are short, the preamble may be larger than the data bits. This results in an inefficient use of valuable system resources.

[0009] Thus, there is a need for a multiple-access system which provides advantageous use of system resources.

Summary

[0010] The present invention relates to a method and apparatus for facilitating the reliable transfer of short, bursty messages over a wireless communications link or channel according to the appended claims.

Brief Description of the Drawings

[0011] Figure 1 is a block diagram illustrating an exemplifying system in which the invention may be embodied. Figure 2 is a conceptual diagram illustrating one embodiment of an allocation of communication resources, in the exemplifying system of Figure 1, among a reserved block, a contention-type access block and a non-contention-type access block. Figure 3 is a block diagram illustrating a method of encoding data to be transmitted within the system of Figure 1. Figure 4 illustrates one configuration of a set of codewords used in relation to the reserved block of Figure 2. Figure 5 is a diagram of a method and apparatus which processes bursts of data received by the hub station of Figure 2.
Detailed Description of the Invention

Communication System

[0012] The present invention relates to an efficient method and apparatus for facilitating the reliable transfer of short, bursty messages over a wireless communications link or channel. The description below describes a communication system in which the invention may be embodied. Specifically, the invention may be embodied in a reservation channel of the communication system. Alternatively, the invention may be used in other types of systems and/or applications.

[0013] Figure 1 is a block diagram illustrating an exemplifying system in which the invention may be embodied. The system in Figure 1 provides high-speed, reliable Internet communication service over a satellite link.

[0014] In particular, in Figure 1, content servers 100 are coupled to an Internet 102 which is in turn coupled to a hub station 104. The hub station 104 also communicates via satellite 106 with a plurality of remote units 108A - 108N. For example, the hub station 104 transmits signals over a forward uplink 110 to the satellite 106. The satellite 106 receives the signals from the forward uplink 110 and re-transmits them on a forward downlink 112. Together, the forward uplink 110 and the forward downlink 112 are referred to as the forward link.

[0015] In a similar manner, the remote units 108A - 108N transmit signals over a reverse uplink 114 to the satellite 106. The satellite 106 receives the signals from the reverse uplink 114 and re-transmits them on a reverse downlink 116. Together, the reverse uplink 114 and the reverse downlink 116 are referred to as the reverse link. The hub station 104 monitors one or more channels which comprise the reverse link in order to extract messages from the remote units 108A - 108N.

[0016] In one embodiment of the exemplifying system, each remote unit 108A - 108N is coupled to a plurality of system users. For example, in Figure 1, the remote unit 108A is shown as coupled to a local area network 116 which in turn is coupled to a group of user terminals 118A - 118N. The user terminals 118A - 118N may be one of many types of local area network nodes such as a personal or network computer, a printer, digital meter reading equipment or the like. When a message is received over the forward hnk intended for one of the user terminals 118A - 118N, the remote unit 108A forwards it to the appropriate user terminal 118 over the local area network 116. Likewise, the user terminals 118A - 118N can transmit messages to the remote unit 108A over the local area network 116.

[0017] In one embodiment of the exemplifying system, the remote units 108A - 108N provide Internet service for a plurality of users. For example, assume that the user terminal 118A is a personal computer which executes browser software in order to access the World Wide Web. When the browser receives a request for a web page or embedded object from the user, the user terminal 118A creates a request message according to well-known techniques. The user terminal 118A forwards the request message over the local area network 116 to the remote unit 108A, also using well-known techniques. Based upon the request message, the remote unit 108A creates and transmits a wireless link request over a channel within the reverse uplink 114 and the reverse downlink 116. The hub station 104 receives the wireless link request over the reverse link. Based upon the wireless link request, the hub station 104 passes a request message to the appropriate content server 100 over the Internet 102.

[0018] In response, the content server 100 forwards the requested page or object to the hub station 104 over the Internet 102. The hub station 104 receives the requested page or object and creates a wireless link response. The hub station 104 transmits the wireless link response over a channel within the forward uplink 110 and forward downlink 112.

[0019] The remote unit 108A receives the wireless link response and forwards a corresponding response message to the user terminal 118A over the local area network 116. In this way, a bi-directional link between the user terminal 118A and the content servers 100 is established.

Allocation Of Communication Resources

[0020] Figure 2 is a conceptual diagram illustrating one embodiment of an allocation of communication resources, in the exemplifying system of Figure 1, among a reserved block or reservation channel 140, a contention-type access block 142 and a non-contention-type access block 144. Together, the reserved block 140, the contention-type access block 142 and the non-contention-type access block 144 make up the reverse link 114, 116 shown in Figure 1.

[0021] The reserved block 140 comprises a set of resources each of which is assigned and individually dedicated to an active remote unit 108 (Figure 1). The reserved block 140 may be implemented as any one of a variety of well-known non-contention access mechanisms in which the transmission from one remote unit 108 does not prevent another remote unit 108 from communicating. For example, the reserved block 140 may comprise a set of time multiplexed spread spectrum channels or a set of frequency division multiple-access (FDMA) or TDMA channels. The multiple access and communication format of the reserved block 140 may be different from the remaining resource allocation.
Functions of the Reservation Channel

[0022] The reserved block 140 is used to notify the hub station 104 whenever a remote unit 108 attempts to access the system over the contention-type access block 142. The notification of the hub station 104 allows the hub station 104 to accurately detect the occurrence of a collision (or other failure mode) on the contention-type access block 142 and to identify the remote units 108 that were involved in the collision. In addition, the reserved block 140 can be used to request resources for the transmission of user data or notify the hub station 104 of the amount of user data currently available for transmission, as well as other tasks.

[0023] In one embodiment, the communication format used on the reserved block 140 results in a high probability of successful reception by the hub station 104. For example, the notification message should arrive at the hub station 104 with a relatively high signal-to-interference ratio.

[0024] In addition, the reserved block transmissions may be used to derive time alignment (synchronization), carrier frequency adjustment and power control information for the remote units 108A-108N, whether or not the reservation block transmission indicates the transmission of a block of data over a contention-type resource. For example, by examining the transmission received over the reserved block 140, the hub station 104 may generate a time, carrier frequency, power adjustment command or other information for transmission to the remote unit 108.

[0025] Use of the reserved block 140 for these functions may be advantageous because the remote unit 108 can transmit actual or dummy messages over the reserved block 140 without expending any additional system resources and without the risk of collision. By using the reserved block 140 to implement these overhead functions, the loading on the contention-type access block 142 and non-contention access block 144 may be further decreased.

[0026] In one embodiment, the reserved block transmissions reflect an amount of data transmitted over a contention-type resource 142. For example, in one embodiment, the reserved block transmission is a payload message which indicates the number of packets transmitted over the contention-type resource 142. If the hub station 104 detects less than the indicated amount of data on the contention-type resource 142, the hub station 104 assigns a non-contention resource 144 of sufficient size to support transmission of the amount of data which was not received and notifies the remote unit 108. The remote unit 108 responds by re-transmitting data over the non-contention resource 144.

[0027] In such an embodiment, if a remote unit 108 is transmitting an isochronous data or another type of data where the need for communication resources can be predicted by the remote unit 108, the remote unit 108 can transmit a payload message over the reserved block 140 indicating the transmission of the predicted amount of resources before the data is available for transmission. However, the remote unit 108 does not transmit a corresponding message on the contention-type resource 142 Therefore, the hub station 104 receives the reserved block transmission but not a corresponding contention-type resource transmission and responds with a non-contention resource allocation. The remote unit 108 transmits the data over the non-contention resource 144 when the data is available without incurring the delay of scheduling or the probability of collision on the contention-type resource 142. In addition, because the remote unit 108 does not transmit a message over the contention-type resource 142, the loading and number of collisions on the contention-type resource 142 is reduced.

[0028] In some cases, a remote unit 108 transmits predictable data as well as a more unpredictable stream of data. For example, a remote unit 108 may transmit concurrently both a predictable rate voice signal and an unpredictable data signal. In such a case, the remote unit 108 can add the amount of predicted resources to the payload indication sent over the reserved block transmission. For example, if the remote unit 108 has five data packets to transmit and can predict that it will have two additional voice packets to transmit, the remote unit 108 transmits the five data packets over the contention-type resource 142 and transmits a corresponding message over the reserved block 140 indicating that seven data packets are being transmitted. The hub station 104 receives the reserved block transmission and the five data packets and schedules a sufficient non-contention resource 144 to transmit the remaining two packets.

[0029] In yet another embodiment, the remote unit 108 transmits a message over the reserved block 140 which indicates the amount of data queued for transmission. For example, the remote unit 108 indicates that a message has been sent over the contention-type resource 142 and that a certain amount of data remains available for transmission. The information concerning queue length can be used by the hub station 104 to allocate appropriate system resources. In practice, this embodiment is a special case of the embodiment described above in which the remote unit 108 transmits a reserved block message which indicates that a greater amount of data is transmitted than is actually received and in which when the hub station 104 assigns a non-contention resource 144 of sufficient size to support transmission of the amount of data which was not received. In effect, the difference between the amount of data transferred and the amount of data indicated in the message is equal to the queue size.

[0030] The transmission over the reserved block 140 need not be concurrent with the transmission over the contention-type access block 142. A transmission over the reserved block 140 may indicate that a transmission has been recently made over the contention-type access block 142, that a transmission is concurrently made over the contention-
type access block 142 or that a transmission will soon follow over the contention-type access block 142.

[0031] In yet another embodiment, the resources of the reserved block 140 can be non-uniformly allocated among the remote units 108A-108N. For example, the resources can be allocated based upon a set of active and quiescent remote units. The active remote units are those remote units which are more likely to transmit data. The quiescent remote units are those remote units which are less likely to transmit data. If no transmissions are received from an active remote unit for an extended period of time, the hub station 104 can re-categorize the remote unit as a quiescent remote unit. If a transmission from a quiescent remote unit is received, the hub station 104 can re-categorize the remote unit as an active remote unit. The active remote units are allocated more frequent access to the reserved block 140 than the quiescent remote units.

[0032] Likewise, the resources of the reserved block 140 may be allocated among the remote units 108A-108N according to a quality of service allocated to the user, the data transmission capability of the remote unit 108, the past usage pattern of the remote unit 108 or the length of time since the last transmission was received from the remote unit 108. Non-uniform allocation of the reserved block resources can aid in reducing the overall latency introduced in the system by the use of the reserved block 140.

[0033] Likewise, the total amount of system resources dedicated to the reserved block 140 can be varied during system operation. For example, the rigid separation of reserved block 140 and the contention-type access block 142 and the non-contention access block 144 in Figure 2 can be replaced with a movable separation. By increasing the amount of resources allocated to the reserved block 140, the overall latency of the system due to the use of the reserved block 140 can be reduced. However, increasing the amount of resources allocated to the reserved block 140 reduces the amount of resources which can be allocated to the other access resources. Thus, when sufficient resources are available on the contention-type resource 142 and the non-contention resource 144, additional resources can be allocated to the reserved block 140. As the loading on the contention-type resource 142 and the non-contention resource 144 increases, the amount of resources allocated to the reserved block 140 can be reduced.

[0034] As noted above, the communication format used on the reserved block 140, the contention-type access block 142 and the non-contention access block 144 need not be the same. A myriad of well known and later developed communication formats may be directly applied to the teachings of the invention. Typically, the non-contention access and the contention-type access blocks 142-144 use a common communication format and channelization for ease of implementation. In one embodiment, the reserved block 140 operates according to some different communication format. An important characteristic of the reserved block 140 is that it comprises a sufficient number of discrete resources so that each active remote unit 108 may be assigned a unique resource. The use of uniquely assigned resources allows one remote unit 108 to communicate with the hub station 104 without preventing other remote units from communicating with the hub station 104. In a system with a large number of remote units 108A-108N and a limited time slot allotted to each remote unit 108, it is important to keep the data bursts across the reservation channel 140 short.

[0035] It is also important that the transmission delay associated with sending a signal over the reserved resource 140 be limited to some reasonable value. If the time delay associated with successive transmissions from a single remote unit 108 over the reserved block 140 becomes too large, the delay may become significant in determining the delay associated with a retransmission over the non-contention access block 144. Thus, a short data burst across the reserved block 140 allows more frequent data bursts to be sent at a specified rate, and thereby advantageously limits the transmission delay.

Reservation Channel Coding

[0036] In Figure 2, the reserved block 140 of resources comprises a highly efficient narrowband communication channel (referred hereinafter as the "reservation channel 140"). In general, the remote units 108A-108N (Figure 1) preferably encode the messages before they are sent via the reservation channel 140 to the hub station 104. The hub station 104, in turn, decodes the messages. In one embodiment, the messages are encoded into a non-coherent, quadrature phase shift keying (QPSK) symbol sequence set. Use of a non coherent code advantageously does not require the determination of a carrier phase associated with the encoded burst during demodulation.

[0037] The QPSK symbol sequence set comprises a plurality of possible codewords or code patterns. Each codeword consists of a plurality of 'I' values and plurality of 'Q' values. The individual I and Q digit values are binary, e.g., either +1 or -1. Each QPSK modulated symbol consists of a single I value and a single Q value. The binary I and binary Q values of a symbol taken together effectively generate the four-phase modulation known as QPSK.

[0038] Figure 3 is a block diagram illustrating a method of encoding data to be transmitted via the reserved block 140 of Figure 2 within the system of Figure 1. In Figure 3, the initial length of each message intended for the reservation channel 140 is six bits. Alternatively, other message lengths greater than six or less than six may be used in accordance with the invention. In an encoder 150, the remote unit 108 encodes a 6-bit message into an 18-bit codeword by using a look-up table. Specifically, the remote unit 108 refers to a codeword set as shown in Figure 4 and finds a codeword which corresponds to the 6-bit message.
be encoded to any suitable number of bits, symbols or combination of bits and symbols, such as 12, 16, 18, 24, etc. Other message lengths may be used instead of six, such as 4, 5, 8, 10, 12, etc. In addition, the six message bits may be convolutionally encoded into 18-bits, which are then modulated. Also, instead of QPSK, other forms of modulation, such as 8PSK, 16PSK, etc. As mentioned above, other message lengths may be used instead of six, such as 4, 5, 8, 10, 12, etc. In addition, the six message bits may be encoded to any suitable number of bits, symbols or combination of bits and symbols, such as 12, 16, 18, 24, etc.

Reservation Channel Demodulation

In alternative embodiments, the remote units 108A-108N may apply other coding techniques or transformations to the messages in addition to or instead of the coding described above. For example, the remote units 108A-108N may convolutionally encode the 6-bit messages into 18-bits, which are then modulated. Also, instead of QPSK, the remote units 108A-108N may use other forms of modulation, such as 8PSK, 16PSK, etc. As mentioned above, other message lengths may be used instead of six, such as 4, 5, 8, 10, 12, etc. In addition, the six message bits may be encoded to any suitable number of bits, symbols or combination of bits and symbols, such as 12, 16, 18, 24, etc.

In other configurations, another positive symbol timing offset may be selected and used by the hub station 104. In other configurations, another negative symbol timing offset may be selected and used by the hub station 104. In other configurations, another positive symbol timing offset may be selected and used by the hub station 104. In other configurations, another negative symbol timing offset may be selected and used by the hub station 104. In other configurations, another positive symbol timing offset may be selected and used by the hub station 104.

In other configurations, another negative symbol timing offset may be selected and used by the hub station 104. In other configurations, another positive symbol timing offset may be selected and used by the hub station 104. In other configurations, another negative symbol timing offset may be selected and used by the hub station 104. In other configurations, another positive symbol timing offset may be selected and used by the hub station 104. In other configurations, another negative symbol timing offset may be selected and used by the hub station 104. In other configurations, another positive symbol timing offset may be selected and used by the hub station 104.
[0052] The correlator 226 of the hub station 104 assumes that the data burst that is resampled at the 'on-time' hypothesis is correct. The correlator 226 correlates the resampled data (9-symbol burst) at the 'on-time' hypothesis (stored in memory space 210) with all 64 possible 9 symbol (18-bit) reservation channel codewords, each of which is stored in the memory space 224 at the hub station 104.

[0053] In one embodiment, the 64 complex correlations are performed by deriving a correlation magnitude as follows:

\[
(magnitude)^2 = (\langle I_{\text{received}} \cdot I_{\text{code}} \rangle + \langle Q_{\text{received}} \cdot Q_{\text{code}} \rangle)^2 + (\langle I_{\text{received}} \cdot Q_{\text{code}} \rangle - \langle Q_{\text{received}} \cdot I_{\text{code}} \rangle)^2
\]

where \( I_{\text{received}} \) is 9-sample vector from the received reservation channel burst, \( Q_{\text{received}} \) is a 9 sample vector from the received reservation channel burst, \( I_{\text{code}} \) is a 9 bit vector from a codeword of the 64-codeword set shown in Figure 4, and \( Q_{\text{code}} \) is a 9 bit vector from a codeword of the 64-codeword set shown in Figure 4. The symbol ‘•’ in the equation above symbolizes a dot product of two vectors. Each codeword of the 64-codeword set is correlated with the received reservation channel burst. In one configuration, the output of correlator 226 is a set of 64 energy or power levels (magnitudes).

[0054] The results of the 64 complex correlations from correlator 226 are transferred to a detector 228, which finds the 18-bit codeword index (symbol sequence set member) with the maximum/highest correlation to the received reservation burst stored in memory space 210. The 18-bit codeword index with the highest correlation magnitude is associated with the most likely 6-bit reservation channel message that was transmitted by the remote unit 108. The detector 228 outputs the 6-bit output data 236 to other components of the hub station 104 for further processing.

[0055] The hub station 104 may further process the output data 236 to determine one or more characteristics or events of the remote unit 108 which sent the reservation burst 200. For example, as described above, the hub station 104 may use the output data 236 to determine whether a remote unit 108 has sent a data burst or the size of the queue at the remote unit 108. The hub station 104 may also use the output data 236 to determine the identity of the remote unit 108, the length of the data burst being sent (or to be sent) across the contention channel, the number of data bursts being sent, as well as other information.

Timing Synchronization

[0056] In one embodiment, the hub station 104 maintains accurate timing information or synchronization for the reservation channel 140, such as within +/- 1/32 symbol time offset. The hub station 104 preferably extracts timing information during the demodulation process shown in Figure 5 in the converter 222, a symbol index (6-bit output) 242 from detector 228 is converted into its corresponding symbol sequence (9-symbol codeword) by referring to the reservation symbol table as shown in Figure 4. Essentially, converter 222 acts as an encoder.

[0057] In correlators 214-218, the symbol sequence from selector 222 is complex correlated with each of the three data bursts stored in memory spaces 208-212 resulting from the early, on-time, and late resampling by the polyphase filter 202-206. In one configuration, the outputs of correlators 214-218 are energy or power levels.

[0058] The correlation performed by correlator 216 is the same as the correlation of the samples from the memory space 210 and the chosen codeword value performed by the correlator 226. Therefore, in one embodiment, the corresponding magnitude calculation result is forwarded from the correlator 226 to the selector 220, and the correlator 216 is no longer needed.

[0059] The outputs of correlators 214-218 are fed into the selector 220, where the correlations are compared to determine whether the timing of the burst 200 transmitted across the reservation channel 140 was early, late or on-time. Based on the maximum correlation, the selector 220 outputs an early, on-time or late feedback signal 238. The hub station 104 uses the feedback signal 238 to inform the remote unit 108 which sent the reservation burst to advance forward or retard backward in time for its next reservation burst transmission. In one configuration, the hub station 104 sends a 'timing error signal' to the remote unit 108 if the burst 200 transmitted across the reservation channel 140 was early or late. In one embodiment, if the hub station 104 determines that the burst 200 was on-time, the hub station 104 does not send a timing synchronization signal back to the remote unit 108.

[0060] For example, if the selector 220 finds that the complex correlation with the data set 212 resulting from the late sampling 206 has the highest magnitude, then the hub station 104 sends a feedback signal 238 to the remote unit 108 instructing the remote unit 108 to advance its next reservation burst transmission forward in time. In other words, the hub station 104 instructs the remote unit 108 to transmit its next reservation burst at an earlier time. This improves the timing of the reservation channel 140 for the remote unit 108.

[0061] In one embodiment, the hub station 104 sends a feedback signal 238 to the remote unit 108 after the hub...
station 104 processes a plurality of reservation channel bursts. In one configuration, the hub station 104 averages a number of maximum correlations before sending a feedback signal 238. In a specific implementation, the hub station 104 averages 10 maximum correlations (based on 10 received bursts 200) to derive a timing feedback signal 238.

5  

Carrier Frequency Adjustment

[0062] In one embodiment, the phase rotator 244 and the correlation module 246 of Figure 5 derive a carrier frequency adjustment signal 248 for the hub station 104 to send back to the remote unit 108. The carrier frequency adjustment signal 248 informs the remote unit 108 to adjust its carrier frequency (rate of change of the carrier phase) for subsequent transmissions. Specifically, the phase rotator 244 receives the ‘on-time’ resampled reservation burst from the second timing phase 204 and rotates the carrier phase of the burst to create three separate frequency sample sequences: a ‘slow’ frequency sample sequence, a ‘fast’ frequency sample sequence and an ‘on-frequency’ (unaltered frequency) sample sequence. Alternatively, in other embodiments, more than three or less than three frequency sample sequences may be created. The phase rotator 244 outputs the frequency sample sequences to the correlation module 246.

[0063] The operation of the correlation module 246 is substantially similar to the operation performed by the memory spaces 208, 210, 212, the correlators 214, 216, 218 and the selector 220 shown in Figure 5 and described above. The correlation module 246 correlates the symbol sequence from the converter 222 with the three frequency sample sequences (slow, fast and unaltered frequency sample sequences) The correlation module 246 then determines which frequency sample sequence out of the three frequency sample sequences provides the maximum correlation with the symbol sequence from the converter 222. After the correlation module 246 determines if the carrier frequency is too slow, too fast or substantially correct, the correlation module 246 provides a carrier frequency adjustment signal 248 for the hub station 104 to send back to the remote unit 108 to adjust the remote unit’s transmission carrier frequency, if needed.

[0064] In one embodiment, the hub station 104 sends a carrier frequency adjustment signal 246 to the remote unit 108 after the hub station 104 processes a plurality of reservation channel bursts. In one configuration, the hub station 104 averages a number of maximum correlations before sending a carrier frequency adjustment signal 246. In a specific implementation, the hub station 104 averages 10 maximum correlations (based on 10 received bursts 200) to derive a carrier frequency adjustment signal 246.

Estimating a Signal to Noise Ratio

[0065] In a preferred embodiment, an output from the correlator 226 and an output from the detector 228 are input into the process element 230. The process element 230 uses the inputs from the correlator 226 and the detector 228 to derive a real component (I_max_correlation) and an imaginary component (Q_max_correlation), which are associated with the complex correlation for the selected codeword found by detector 228. Specifically, the codeword with the maximum complex correlation magnitude found in detector 228 has an associated (I_max_correlation, Q_max_correlation) value pair:

\[
I_{\text{max correlation}} = (I_{\text{selected}} \cdot L_{\text{selected}}) + (Q_{\text{received}} \cdot Q_{\text{selected}})
\]

\[
Q_{\text{max correlation}} = (I_{\text{received}} \cdot Q_{\text{selected}}) \cdot (I_{\text{selected}} \cdot Q_{\text{received}})
\]

where \(I_{\text{selected}}\) and \(Q_{\text{selected}}\) are the I and Q vectors of the selected received codeword. In the process element 230 of Figure 5, the \((I_{\text{max correlation}}, Q_{\text{max correlation}})\) value pair is used to determine a phase rotation or phase estimate of the received data by using the equation:

\[
\text{phase} = \text{ArcTan2}(I_{\text{max correlation}}, Q_{\text{max correlation}})
\]

where \(\text{ArcTan2}\) is a four-quadrant arctangent function.

[0066] In the phase remover 232, the phase estimate derived in process element 230 is removed from the on-time resampled data by derotating the on-time resampled reservation data 210 by the derived phase estimate. In other words, the phase remover 232 rotates the on-time resampled reservation data by -1 multiplied by the derived phase estimate.

[0067] In the estimator 234, the derotated on-time resampled reservation data from the phase remover 232 is used to estimate a signal-to-noise ratio (SNR) at which the burst 200 is received. There are a number of methods to estimate a signal-to-noise ratio in the estimator 234 of Figure 5. In one embodiment, the method involves forming two sums:
where \( \overrightarrow{l}_{\text{derotated}} \) and \( \overrightarrow{q}_{\text{derotated}} \) are the I and Q vectors of the derotated on-time resampled reservation data (from the phase remover 232), and \( \overrightarrow{l}_{\text{selected}} \) and \( \overrightarrow{q}_{\text{selected}} \) are the I and Q vectors of the selected received codeword (from the detector 228). \( \text{SUM ABS} \) represents the sum of absolute values, and \( \text{SUM SQR} \) represents the sum of squared values. \( \text{SUM ABS} \) and \( \text{SUM SQR} \) are accumulated over an N number of reservation bursts to produce \( \text{SUM ABS}_N \) and \( \text{SUM SQR}_N \). The signal-to-noise ratio is estimated to be:

\[
\text{SNR} = 10 \log_{10} \left( \frac{\text{SUM ABS}_N}{(N)(B)(\text{SUM SQR}_N) \cdot \text{SUM ABS}_N} \right)
\]

where B represents the number of code bits per reservation burst. In one of the embodiments described above, B is equal to 18. Alternatively, in other embodiments, some other method may be used to estimate a signal-to-noise ratio by using the complex correlation results.

The hub station 104 uses the estimated signal-to-noise ratio from the estimator 234 to determine whether the reservation channel 140 is active, e.g., whether a reservation burst was actually received or not. If the estimated SNR is below a first predetermined threshold, then the hub station 104 does not process the output data 236 generated from detector 228.

In one embodiment, if the estimated signal-to-noise ratio is below a second predetermined threshold, then the hub station 104 does not use the timing feedback signal 238 to adjust the timing of the remote unit’s next transmission across the reservation channel 140. This can be implemented as an enable/disable line from estimator 234 to the selector 220. In one embodiment, this second predetermined threshold is the same as the first predetermined threshold. Alternatively, in other embodiments, the second predetermined threshold is greater than or less than the first predetermined threshold.

In one embodiment, the estimated signal-to-noise ratio is used by the hub station 104 to maintain transmit power for the remote unit 108 across the reservation channel 140. Specifically, based on the estimated signal-to-noise ratio, the hub station 104 sends one or more control messages to the remote unit 108 which instruct the remote unit 108 to increase or decrease power.

The present invention may be embodied in a variety of systems in which multiple units compete for access to a finite resource. Such systems include wireless terrestrial systems and wireline systems.

The invention may be embodied in other specific forms without departing from the scope of the appended claims. The described embodiment is to be considered in all respects only as illustrative and not restrictive and the scope of the invention is, therefore, indicated by the appended claims.

Claims

1. A method for a communication system in which a plurality of remote units (108A, ..., N) transmit data to a hub station (104), said method of communicating comprising:

   receiving a data burst from a remote unit, the data burst being encoded using a predetermined codeword set;

   sampling the data burst received by the hub station at a plurality of different timing offsets;

   correlating the data burst received by the hub station with the codeword set to find a codeword with maximum correlation;

   correlating the codeword having the maximum correlation with the plurality of different timing offset samples; and

   deriving a timing synchronization signal to be sent back to the remote unit, the timing synchronization signal providing information to the remote unit to synchronize its timing for transmitting subsequent data bursts.

2. The method of Claim 1, further comprising:
encoding a data burst at a remote unit using a predetermined codeword set; and

transmitting the encoded data burst from the remote unit to the hub station over a multiple-access channel.

3. The method of Claim 1, further comprising sending the timing synchronization signal back to the remote unit after the data burst from the remote unit has been received and processed by the hub station.

4. The method of Claim 1, further comprising sending the timing synchronization signal back to the remote unit after a plurality of data bursts from the remote unit have been received and processed by the hub station, the timing synchronization signal being based on a plurality of correlations of the data bursts with the codeword set.

5. The method of Claim 1, further comprising deriving a carrier frequency adjustment signal to be sent back to the remote unit, the carrier frequency adjustment signal providing information to the remote unit to adjust a carrier frequency for transmitting subsequent data bursts.

6. The method of Claim 5, further comprising rotating a carrier phase of the data burst to create three separate frequency sample sequences comprising:

- a slow frequency sample sequence;
- a fast frequency sample sequence; and
- an on-frequency sample sequence.

7. The method of Claim 5, further comprising sending the carrier frequency adjustment signal back to the remote unit after a plurality of data bursts from the remote unit have been received and processed by the hub station, the carrier frequency adjustment signal being based on a plurality of correlations of the data bursts with the codeword set.

8. The method of Claim 1, wherein the plurality of different timing offsets comprises an early offset resample, an on-time sample and a late offset sample.

9. The method of Claim 1, wherein the data burst is encoded using a predetermined, non-coherent QPSK codeword set.

10. The method of Claim 9, wherein the QPSK codeword set comprises 64 9-symbol codewords in which each codeword has equal noise immunity.

11. The method of Claim 9, further comprising demodulating the encoded data burst using noncoherent demodulation.

12. The method of Claim 1, wherein the data burst does not have a preamble.

13. A method for a communication system in which a plurality of remote units transmit data to a hub station, said method of communicating comprising:

- receiving a data burst from a remote unit, the data burst encoded using a predetermined codeword set;
- sampling the data burst received by the hub station at a plurality of different timing offsets;
- correlating the data burst received by the hub station with the codeword set to find a codeword with maximum correlation;
- correlating the codeword having the maximum correlation with the plurality of different timing offset samples; and
- deriving a carrier frequency adjustment signal to be sent back to the remote unit, the carrier frequency adjustment signal providing information to the remote unit to adjust a carrier frequency for transmitting subsequent data bursts.
14. A hub station for a system in which multiple remote units (108A, ..., N) compete for limited communication resources to access a hub station, said hub station (104) comprising:

   a receiver adapted to receive a data burst from a remote unit;

   characterized in that it further comprises
   a matched filter adapted to sample the received data burst at a plurality of different timing offsets (202,204,206),
   a microprocessor (226) adapted to correlate the received data burst with a plurality of codewords from a codeword set to find a codeword with maximum correlation; and
   a timing synchronization circuit adapted to send a signal back to the remote unit, the signal providing information to the remote unit to synchronize its timing for transmitting subsequent data bursts (288).

15. The hub station of Claim 14, further comprising a carrier frequency adjustment circuit adapted to correlate the codeword having the maximum correlation found by the microprocessor with a plurality of different carrier frequency offset samples (246) the carrier frequency adjustment circuit being adapted to send a carrier frequency adjustment signal (248) to the remote unit, the carrier frequency adjustment signal providing information to the remote unit to adjust a carrier frequency for transmitting subsequent data bursts.

Patentansprüche

1. Verfahren für ein Kommunikationssystem, bei dem eine Vielzahl von fern befindlichen Einheiten (108 A, ..., N) Daten an eine Unterstation (104) übertragen, wobei das Kommunikationsverfahren umfasst:

   Empfangen eines Datenbündels aus einer fern befindlichen Einheit, wobei das Datenbündel unter Verwendung eines vorbestimmten Codewortsatzes codiert ist;

   Abtasten des durch die Unterstation empfangenen Datenbündels zu einer Vielzahl unterschiedlicher Zeitabstände;

   Korrelieren des durch die Unterstation empfangenen Datenbündels mit dem Codewortsatz, um ein Codewort mit einer Hochstkorrelation zu finden,

   Ableiten eines Zeitsynchronisationssignals, das die Hochstkorrelation aufweist, mit der Vielzahl unterschiedlicher Zeitabstandsproben; und

   Ableiten eines Zeitsynchronisationssignals, das an die fern befindliche Einheit zurückgeschickt werden soll, wobei das Zeitsynchronisationssignal der fern befindlichen Einheit Information bereitstellt, damit sie ihre Zeitstellung zum Übertragen nachfolgender Datenbündel synchronisiert.

2. Verfahren nach Anspruch 1, darüber hinaus umfassend.
   Codieren eines Datenbündels an einer fern befindlichen Einheit unter Verwendung eines vorbestimmten Codewortsatzes; und
   Senden des codierten Datenbündels von der fern befindlichen Einheit zur Unterstation über einen Vielfachzugriffskanal


5. Verfahren nach Anspruch 1, darüber hinaus ein Ableiten eines Trägerfrequenzeinstellungssignals umfassend, das an die fern befindliche Einheit zurückgeschickt werden soll, wobei das Trägerfrequenzeinstellungssignal der fern befindlichen Einheit Information bereitstellt, damit sie eine Trägerfrequenz zum Übertragen nachfolgender Daten-
bündel einstellt.

6. Verfahren nach Anspruch 5, darüber hinaus das Drehen einer Trägerphase des Datenbündels umfassend, um drei separate Frequenzprobensequenzen zu schaffen, die umfassen:

   eine langsame Frequenzprobensequenz;

   eine schnelle Frequenzprobensequenz; und

   eine Einschaltfrequenzprobensequenz.


8. Verfahren nach Anspruch 1, wobei die Vielzahl unterschiedlicher Zeitabstände eine zeitlich vorversetzte erneute Probe, eine zeitgerechte Probe und eine zeitlich nachversetzte Probe umfasst.

9. Verfahren nach Anspruch 1, wobei das Datenbündel unter Verwendung eines vorbestimmten, nicht kohärenten QPSK-Codewortsatzes codiert wird.

10. Verfahren nach Anspruch 9, wobei der QPSK-Codewortsatz 64 Codewörter mit 9 Zeichen umfasst, bei dem jedes Codewort dieselbe Rauschfestigkeit hat.

11. Verfahren nach Anspruch 9, darüber hinaus ein Demodulieren des codierten Datenbündels unter Verwendung einer nicht kohärenten Demodulation umfassend.

12. Verfahren nach Anspruch 1, wobei das Datenbündel keinen Zeichenvorlauf hat.

13. Verfahren für ein Kommunikationssystem, bei dem eine Vielzahl von fern befindlichen Einheiten Daten an eine Unterstation übertragen, wobei das Kommunikationsverfahren umfasst:

   Empfangen eines Datenbündels aus einer fern befindlichen Einheit, wobei das Datenbündel unter Verwendung eines vorbestimmten Codewortsatzes codiert ist;

   Abtasten des durch die Unterstation empfangenen Datenbündels zu einer Vielzahl unterschiedlicher Zeitabstände;

   Korrelieren des durch die Unterstation empfangenen Datenbündels mit dem Codewortsatz, um ein Codewort mit einer Höchstkorrelation zu finden;

   Korrelieren des Codeworts, das die Höchstkorrelation aufweist, mit der Vielzahl unterschiedlicher Zeitabstandsproben; und

   Ableiten eines Trägerfrequenzeinstellungssignals, das an die fern befindliche Einheit zurückgeschickt werden soll, wobei das Trägerfrequenzeinstellungssignal der fern befindlichen Einheit Information bereitstellt, damit sie ihre Trägerfrequenz zum Senden nachfolgender Datenbündel einstellt.

14. Unterstation für ein System, bei dem viele fern befindliche Einheiten (108 A, ... , N) um eingeschränkte Kommunikationsbetriebsmittel konkurrieren, um auf eine Unterstation zugreifen, wobei die Unterstation (104) umfasst:

   einen Empfänger, der dazu ausgelegt ist, ein Datenbündel aus einer fern befindlichen Einheit zu empfangen;

   dadurch gekennzeichnet, dass sie darüber hinaus umfasst:

   ein angepasstes Filter, das dazu ausgelegt ist, empfangene Datenbündel zu einer Vielzahl unterschiedlicher Zeitabstände (202, 204, 206) abzutasten,
einen Mikroprozessor (226), der dazu ausgelegt ist, das empfangene Datenbündel mit einer Vielzahl von Codewörtern aus einem Codewortsatz zu korrelieren, um ein Codewort mit einer Höchstkorrelation zu finden; und

eine Zeitsynchronisationsschaltung, die dazu ausgelegt ist, ein Signal zurück zur fern befindlichen Einheit zu schicken, wobei das Signal der fern befindlichen Einheit Information bereitstellt, damit sie ihre Zeiteinstellung zum Übertragen nachfolgender Datenbündel (288) synchronisiert.

15. Unterstation nach Anspruch 14, darüber hinaus eine Tragerfrequenzeinstellungsschaltung umfassend, die dazu ausgelegt ist, das vom Mikroprozessor aufgefundene Codewort, das die Höchstkortelation aufweist, mit einer Vielzahl unterschiedlicher Tragerfrequenzversatzproben (246) zu korrelieren, wobei die Tragerfrequenzumstellungs schaltung dazu ausgelegt ist, ein Tragerfrequenzeinstellungssignal (248) an die fern befindliche Einheit zu schicken, wobei das Tragerfrequenzeinstellungssignal der fern befindlichen Einheit Information bereitstellt, damit sie eine Tragerfrequenz zum Übertragen nachfolgender Datenbündel einstellt.

Revendications

1. Méthode de système de communication dans laquelle une pluralité d’unités distantes (108 A, .. N) transmet des données à une station de concentrateur (104), ladite méthode de communication comprenant :

   la réception d’une salve de données d’une unité distante, la salve de données étant codée en employant un jeu de mots de code prédéterminé ;

   l’échantillonnage de la salve de données reçue par la station de concentrateur selon une pluralité de décalages de temporisation différents ;

   la corrélation de la salve de données reçue par la station de concentrateur avec le jeu de mots de code pour trouver un mot de code ayant une corrélation maximale ;

   la corrélation du mot de code ayant la corrélation maximale avec la pluralité d’échantillonnages de décalages de temporisation différents, et

   la dérivation d’un signal de synchronisation de temporisation à renvoyer à l’unité distante, le signal de synchronisation de temporisation fournissant des informations à l’unité distante pour synchroniser sa temporisation pour la transmission des salves de données suivantes.

2. Méthode selon la revendication 1, comprenant en outre
   le codage d’une salve de données à une unité distante utilisant un jeu de mots de code prédéterminé ; et
   la transmission de la salve de données codées de l’unité distante à la station de concentrateur par un canal à accès multiples

3. Méthode selon la revendication 1, comprenant en outre le retour du signal de synchronisation de temporisation à l’unité distante après que la salve de données de l’unité distante a été reçue et traitée par la station de concentrateur.

4. Méthode selon la revendication 1, comprenant en outre le retour du signal de synchronisation de temporisation à l’unité distante après qu’une pluralité de salves de données de l’unité distante a été reçue et traitée par la station de concentrateur, le signal de synchronisation de temporisation étant basé sur une pluralité de corrélations des salves de données avec le jeu de mots de code.

5. Méthode selon la revendication 1, comprenant en outre la dérivation d’un signal d’ajustement de fréquence de portée à retourner à l’unité distante, le signal d’ajustement de fréquence de portée fournissant à l’unité distante des informations pour ajuster la fréquence de portée pour transmettre des salves de données suivantes.

6. Méthode selon la revendication 5, comprenant en outre la rotation d’une phase de portée de la salve de données pour créer trois séquences d’échantillonnage de fréquence séparées comprenant une séquence d’échantillonnage de fréquence lente ;
une séquence d’échantillonnage de fréquence rapide ; et
une séquence d’échantillonnage de la fréquence momentanée.

7. Méthode selon la revendication 5, comprenant en outre le retour du signal d’ajustement de fréquence de porteuse à l’unité distante après qu’une pluralité de salves de données de l’unité distante a été reçue et traitée par la station de concentrateur, le signal d’ajustement de fréquence de porteuse étant basé sur une pluralité de corrélations des salves de données avec le jeu de mots de code.

8. Méthode selon la revendication 1, dans laquelle la pluralité de décalages de temporisation différents comprend un rééchantillonnage de décalage hâtif, un échantillonnage à temps et un échantillonnage de décalage tardif.

9. Méthode selon la revendication 1, dans laquelle la salve de données est codée en utilisant un jeu de mots de code QPSK non-cohérent, prédéterminé.

10. Méthode selon la revendication 9, dans laquelle le jeu de mots de code QPSK comprend 64 mots de code de 9 symboles dans lesquels chaque mot de code possède la même immunité au bruit.

11. Méthode selon la revendication 9, comprenant en outre la démodulation de la salve de données codées en utilisant une démodulation non-cohérente.

12. Méthode selon la revendication 1, dans laquelle la salve de données ne possède pas de préambule.

13. Méthode de système de communication dans laquelle une pluralité d’unités distantes transmettent des données à une station de concentrateur, ladite méthode de communication comprenant :

la réception d’une salve de données d’une unité distante, la salve de données étant codée en employant un jeu de mots de code prédéterminé ;

l’échantillonnage de la salve de données reçue par la station de concentrateur selon une pluralité de décalages de temporisation différents ;

la corrélation de la salve de données reçue par la station de concentrateur avec le jeu de mots de code pour trouver un mot de code ayant une corrélation maximale ;

la corrélation du mot de code ayant la corrélation maximale avec la pluralité d’échantillonnages de décalages de temporisation différents ; et

la dérivation d’un signal d’ajustement de fréquence de porteuse à renvoyer à l’unité distante, le signal d’ajustement de fréquence de porteuse fournissant des informations à l’unité distante pour ajuster une fréquence de porteuse pour la transmission des données suivantes.

14. Station de concentrateur pour un système dans lequel de multiples unités distantes (108 A, ... N) sont en compétition pour des ressources de communication limitées pour accéder à une station de concentrateur, ladite station de concentrateur (104) comprenant :

un récepteur adapté à la réception d’une salve de données d’une unité distante ;

caractérisée en ce qu’elle comprend en outre

un filtre appairé adapté pour échantillonner la salve de données reçue selon une pluralité de décalages de temporisation différents (202, 204, 206),

un microprocesseur (226) adapté pour corréler la salve de données reçue avec une pluralité de mots de code d’un jeu de mots de code pour trouver un mot ayant une corrélation maximale ; et

un circuit de synchronisation de temporisation adapté pour renvoyer un signal à l’unité distante, le signal fournissant des informations à l’unité distante pour resynchroniser sa temporisation pour transmettre des salves de données suivantes (288).
15. Station de concentrateur selon la revendication 14, comprenant en outre un circuit d'ajustement de fréquence de porteuse adapté pour corrérer le mot de code ayant la corréléation maximale trouvé par le microprocesseur avec une pluralité d'échantillons de décalage de fréquence de porteuse différents (246), le circuit d'ajustement de fréquence de porteuse étant adapté pour envoyer un signal d'ajustement de fréquence de porteuse (248) à l'unité distante, le signal d'ajustement de fréquence de porteuse fournissant des informations à l'unité distante pour ajuster une fréquence de porteuse pour transmettre des salves de données suivantes.