An apparatus transmits an analog data signal over a wireless communication link. The apparatus includes a base unit having a wired connection to a telephone line. The base unit transmits data to and from the telephone line via the wired connection. The apparatus also includes a remote unit having a wired connection to a modem. The remote unit transmits data to and from the modem via the wired connection. The remote unit and the base unit communicate with each other over the wireless communication link. The base unit includes a radio frequency transmitter to transmit the analog data signal to the remote unit and an automatic gain control circuit that keeps a peak amplitude of the analog data signal substantially constant and within a linear amplification range of the radio frequency transmitter.
CIRCUITRY TO ESTABLISH A WIRELESS COMMUNICATION LINK

TECHNICAL FIELD

[0001] This application relates to establishing a wireless communication link between a modem and a telephone line.

BACKGROUND

[0002] Computers with built-in dial-up modems often connect to networks, such as the Internet, via a wired connection. One example of a wired connection is a two-wire telephone cord that connects a personal computer (PC) modem port to a wall jack. There, the two-wire telephone cord meets a twisted pair telephone line from the telephone company’s central office (referred to as the “local loop”).

[0003] There are numerous limitations associated with the use of wired connections. For example, computers that require wired connections have limited portability, since their operation is dependent upon proximity to a nearby telephone jack or outlet. Wireless links have therefore been developed to reduce the need for wired connections.

[0004] A cordless telephone provides a wireless link. Devices exist that use an analog cordless telephone to provide an analog wireless link for connecting a modem to a telephone line. Such devices use an additional digital echo canceller in the telephone’s base unit, in addition to the echo canceller that is part of any standard modem. The additional echo canceller requires expensive high-bit digital-to-analog and analog-to-digital converters to reduce quantization errors. Furthermore, the echo cancellers in the base unit and the modem may interfere with each other, resulting in overall signal degradation.

[0005] Commercial products have recently been introduced that use digital radio frequency (RF) modulation to provide a wireless link for use by a modem. Such products require a digital data format that uses 200 kHz channels to transmit data over the wireless link. This format is incompatible with conventional digital cordless telephones, which operate using 100 kHz channels, and with conventional analog cordless telephones, which operate using 30 kHz channels.

SUMMARY

[0006] In general, in one aspect, the invention is directed to circuitry for transmitting an analog data signal over a wireless communication link. The circuitry includes an automatic gain control circuit that receives the analog data signal and that keeps a peak amplitude of the analog data signal substantially constant and within a predetermined linear amplification range. The circuitry also includes a transmitter, which has the predetermined linear amplification range, that receives the analog data signal from the automatic gain control circuit and that modulates a radio frequency (RF) carrier. This aspect may include one or more of the following features.

[0007] The circuitry may include a hybrid circuit that isolates an incoming data signal from an outgoing data signal. The hybrid circuit may produce the analog data signal based on the incoming data signal and output the analog data signal to the automatic gain control circuit. The analog data signal produced by the hybrid circuit may exceed a linear amplification range of the transmitter. The automatic gain control circuit may limit a voltage of the analog data signal.

[0008] The circuitry may include a duplexer that maintains separation between transmitted and received signals. The transmitter may include a radio frequency (RF) transmitter. The RF transmitter may include a frequency modulation (FM) deviator which performs FM modulation of an RF carrier of the analog data signal. The circuitry may reduce a signal voltage of the analog data signal prior to input to the FM deviator. The circuitry may include a microprocessor which sends and receives control signals to a remote unit that communicates with the circuitry over the wireless communication link.

[0009] In general, in another aspect, the invention is directed to an apparatus for transmitting an analog data signal over a wireless communication link. The apparatus includes a base unit having a wired connection to a telephone line, which transmits data to and from the telephone line via the wired connection, and a remote unit having a wired connection to a modem, which transmits data to and from the modem via the wired connection. The remote unit and the base unit communicate with each other over the wireless communication link.

[0010] The base unit in the foregoing apparatus includes a radio frequency transmitter to transmit the analog data signal to the remote unit and an automatic gain control circuit that keeps a peak amplitude of the analog data signal substantially constant and within a linear amplification range of the radio frequency transmitter. This aspect may include one or more of the following features.

[0011] The base unit may include a radio frequency receiver to receive data from the remote unit and/or a hybrid circuit that isolates an incoming data signal from an outgoing data signal. The hybrid circuit may produce the analog data signal based on the incoming data signal and output the analog data signal to the automatic gain control circuit. The analog data signal output by the hybrid circuit may exceed a linear amplification range of the transmitter. The automatic gain control circuit may limit a voltage of the analog data signal.

[0012] The base unit may include a duplexer that maintains separation between RF transmitted and received signals. The RF transmitter may include a frequency modulation (FM) deviator which performs FM modulation on the analog data signal. The base unit may include circuitry to reduce a signal voltage of the analog data signal prior to input to the FM deviator and/or a microprocessor which sends and receives control signals to the remote unit over the wireless communication link.

[0013] The remote unit may include a hybrid circuit that isolates an incoming data signal from an outgoing data signal. The hybrid circuit may produce an output analog data signal based on the incoming data signal. The remote unit may also include an automatic gain control circuit to reduce echoes produced by the hybrid circuit in the output analog data signal.

[0014] In general, in another aspect, the invention is directed to an apparatus for transmitting data or voice over a wireless communication link. The apparatus includes means for operating the apparatus as a wireless data link and
means for operating the apparatus as an analog cordless telephone. This aspect of the invention may include one or more of the following features.

[0015] An analog data signal may be transmitted over the wireless data link and/or an analog voice signal may be transmitted over the wireless link. The apparatus may include a cordless telephone, a base unit comprising a cordless telephone base unit and a remote unit comprising a handset for a cordless telephone. The remote unit may include a speaker, a microphone, and a dialing pad.

[0016] Other features and advantages of the invention will become apparent from the following description, including the claims and drawings.

DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a block diagram of a wireless link.

[0018] FIG. 2 is a block diagram of a base unit for use in establishing the wireless link.

[0019] FIG. 3 is a block diagram of a remote unit for use in establishing the wireless link.

DESCRIPTION

[0020] Described herein is circuitry for establishing a short-range wireless communication link between a dial-up modem and a twisted pair telephone line. The circuitry reduces the need for the two-wire telephone cord customarily required for a dial-up Internet connection without affecting performance significantly. The modem circuitry may operate according to the latest standards for dial-up connections, such as V.90 or V.92, providing a data speed of 56 kilobits/second (kb/s) or better.

[0021] The circuitry described herein uses an analog architecture, as opposed to a digital architecture. The circuitry thus avoids the analog-to-digital and digital-to-analog conversions that degrade the performance of a V.90 or V.92 modem, and higher bandwidths associated with digital RF modulation. The circuitry uses a novel and cost-effective automatic gain control (AGC) circuit to address the problem of echoes from the telephone lines adversely affecting the data.

[0022] The wireless link established by the circuitry described herein is produced using two components: a base unit and a remote unit. The arrangement of these components is as follows.

[0023] A short length of two-wire telephone cord connects the modem port of a computer to the remote unit. This remote, battery operated (or charger-powered) unit may be housed in a small box with an attached antenna. The two-wire telephone cord simultaneously carries modem data signals in both directions of transmission, from the modem and to the modem, for full duplex operation. The modem data signals may be of the V.90 type, comprised of highly complex amplitude and phase-modulated signals with a spectral width of less than 4 kHz that can be transmitted over the classical voice frequency channel. Data transmitted in this "voiceband" frequency channel is referred to as voiceband data.

[0024] The remote unit contains a radio transmitter and receiver, which may operate in the 900 MHz or 2.4 GHz cordless telephone radio band, to carry modem data signals traveling in opposite directions. Unlike conventional digital approaches, modifications to the wireless frequency channels are not required. Transmission over the wireless channel is "four-wire," as opposed to two-wire transmission on a telephone cord.

[0025] Wireless transmission may be performed via analog frequency modulation (FM). FM has the advantage of avoiding distortions associated with quantizing noise that would otherwise result from digital modulation. The FM channel can also meet the stringent linearity requirements needed for the transmission of V.90-type signals.

[0026] The remote unit communicates via the wireless link with the base unit, which is located near a wall telephone jack. The remote unit communicates using slightly different carrier frequencies for the two directions of transmission. The base unit contains a corresponding radio transmitter and receiver, along with circuitry needed to transmit the two (duplex) voiceband V.90 signals to and from the wall jack and the telephone line.

[0027] The base unit includes circuitry that limits the amount of nonlinear distortion in the data signal that is transmitted to the modem. This circuitry employs an AGC circuit that limits the peak amplitude that can be transmitted over the analog FM radio channel and keeps distortions within the stringent requirements of the V.90 modem specification. By using automatic gain control in the base unit, the wireless link becomes substantially linear and, thus, essentially invisible to the transmitted V.90 data signal. This means that the function of canceling echoes on the telephone line can be performed by the standard echo canceller built into the modem located in the computer at the other end of the wireless link.

[0028] Circuitry for establishing the wireless link may leverage chip sets developed for existing analog cordless telephones, in addition to the AGC in the base unit and additional circuitry, described below, in the remote unit. This circuitry provides a virtually seamless connection with a computer modem, without requiring significant modifications to either hardware or software in the modem (e.g., protocols, etc.).

[0029] The remote unit may be battery-operated and can be recharged by placing it in the base unit. This will also reset a security code, in accordance with standard cordless telephone operation. There are sixty channels available at 900 MHz. Radio channel selection can be either automatic or via a button on the remote unit.

[0030] FIG. 1 shows a wireless communication system. Wireless communication system 10 includes base unit 11 and remote unit 12. Parts of these two units may be similar to standard 900 MHz cordless telephone circuitry.

[0031] Remote unit 12 interfaces with computer 13, allowing computer 13, with its built-in modem 14, to transmit/receive data over a two-wire telephone cord 18 and a radio frequency (RF) link 17. Computer 13 may be any type of processing device, such as a laptop or desktop PC, with a built-in dial-up modem 14 operating at speeds up to 56 kb/s according to ITU specification V.90, for instance. It is noted that other types of modems may be used in addition to the V.90 modem operating at 56 kb/s.
[0032] Wireless Link Interface

[0033] Base unit 11 connects to the telephone company central office and to the Public Switched Telephone Network (PSTN) through a two-wire telephone cord 15, which is plugged into telephone wall jack 16. Telephone wall jack 16 is typically an RJ11 type connector.

[0034] Communication between base unit 11 and remote unit 12 is via RF link 17. RF link 17 transmits standard voiceband frequencies contained in the three-kilohertz (kHz) baseband spectrum extending from 0.3 kHz to 3.4 kHz. This is also the spectrum occupied by the voiceband data signal (V.90 modem data, for instance).

[0035] Thus, data signals are transmitted from base unit 11 to remote unit 12 (and vice versa) via the RF portion of the wireless communication system. The range of this RF link may vary, but it is typically several hundred feet or longer. After demodulation, the data signals are transmitted between the remote unit 12 and computer 13 via a two-wire telephone cord 18 with standard RJ11 telephone plugs at each end.

[0036] Base Unit

[0037] FIG. 2 shows a block diagram of base unit 11. The two circuits of base unit 11 that are nearest to the telephone central office are telephone line interface 20 and hybrid circuit 21. Telephone line interface 20, also called a Data Access Arrangement (DAA), connects through cord 15, wall outlet 16, and a twisted-pair telephone line to equipment (not shown) in the telephone central office.

[0038] Telephone interface 20 includes a ring detector, a hook switch, a DC (Direct Current) loop holding circuit, and an isolation transformer (none shown). A description of circuitry that may be included in telephone interface 20 is found in U.S. patent application Ser. No. 09/658,049, entitled “Wireless Modem”, filed on Sep. 8, 2000, the contents of which are incorporated herein by reference.

[0039] Hybrid circuit 21, which includes a resistive hybrid and operational amplifiers (not shown), converts two-wire to four-wire telephone operation. More specifically, one function of hybrid circuit 21 is to separate two signals simultaneously flowing in opposite directions in the two-wire telephone line (so-called “full-duplex operation”) and make the signals available at two distinct terminals (four wires) 22 and 23. An incoming (from a central office) analog data signal appears at hybrid terminal 22 and an outgoing analog data signal is applied to hybrid terminal 23.

[0040] Hybrid circuit 21 is a bridge circuit; therefore, isolation of the two signals at terminals 22 and 23 may be achieved if all of the impedances connected to the bridge circuit are well-matched. A considerable impedance mismatch can exist, which can cause the signal applied to terminal 23 to be at least partially reflected from the telephone central office and appear at terminal 22. This “echo” may be added to the incoming signal, causing the amplitude of the resulting signal 24 to be, e.g., several times the amplitude of the desired signal.

[0041] The resulting signal 24 (with echo) can cause overload and nonlinear distortion in radio transmitter 25. Echoes, embedded in signal 24, after having been corrupted by nonlinear distortion, cannot be effectively eliminated by the echo canceller in modem 14 of computer 13. Therefore, to reduce overload and nonlinear distortion, AGC circuit 26 is included in base unit 11 between hybrid circuit 21 and radio transmitter 25. AGC circuit 26 includes a peak amplitude detector with a sufficiently long time constant that keeps the peak amplitude of the combined output signal 27 substantially constant and within the linear amplification range of radio transmitter 25. Since AGC circuit 26 reduces nonlinear distortions, RF link 17 essentially becomes invisible to the modem data signal. Thus, an echo canceller in modem 14 will be able to cancel substantially all of, and in some cases all of, the echo appearing at hybrid terminal 22.

[0042] Imperfect echo cancellation, thermal noise, and interference are sources of transmission errors. These factors may cause modem 14 to revert to half duplex operation, to reduce data transmission speed (e.g., from 56 kbps) and/or to initiate an automatic request for retransmission of the data signal.

[0043] Radio transmitter 25 converts an analog data signal into a modulated RF signal and radio receiver 38 converts a modulated RF signal to an analog data signal. Radio transmitters 25 and radio receiver 38 operate on different frequencies and are connected to common antenna 29 through duplexer 60. Antenna 29 transmits/receives modulated RF signals to/from remote unit 12.

[0044] A variety of techniques can be used to modulate the RF signal in radio transmitter 25, including analog frequency modulation (FM), which is also used widely in cordless telephones operating at 900 MHz. With analog FM, a V.90 data signal, for instance, is directly applied to an FM deviator in radio transmitter 25. The FM deviator performs FM modulation on the data signal. It is relatively easy to obtain good modulation linearity, and consequently low distortion, in an FM deviator circuit. If necessary, distortion can be further reduced by simply adding circuitry to reduce the signal voltage applied to the deviator. Also, the FM channel is a relatively stable transmission medium whose baseband gain is essentially unaffected by varying RF signal levels (i.e., fading).

[0045] Microprocessor 61 controls the functions of base unit 11 and interacts with telephone line interface 20, radio transmitter 25, and radio receiver 38. Microprocessor 61 is also responsible for sending/receiving control signals to/from remote unit 12. In operation, an external caller (an incoming call) operates a ring detector in telephone line interface 20 resulting in a ring indicator signal 62. Microprocessor 61 transmits ring indicator signal 62 over the wireless link to remote unit 12, where its ringer switch 39 operates in response thereeto. In the other direction of transmission, a call initiated by computer 13 will cause a hook switch control signal to be transmitted from remote unit 12 to base unit 11. Microprocessor 61 then generates an off-hook condition in line interface 20 through hook switch control signal 63.

[0046] Microprocessor 61 is also responsible for automatically selecting a relatively quiet, substantially interference free, radio channel from the total of sixty available channels at 900 MHz.

[0047] Remote Unit

[0048] FIG. 3 shows a block diagram of circuitry in remote unit 12. This circuitry includes an antenna 30 for receiving analog data signals over RF link 17 from base unit 11 and for transmitting analog data signals to base unit 11.
over RF link 17. A duplexer 31 separates RF signals traveling in opposite directions (to/from base unit 11) by virtue of their different channel frequencies and connects to either a radio receiver 32 or a radio transmitter 33.

Remote unit 12 includes a microprocessor 34 that controls its general operation. In addition, microprocessor 34 receives a signal 35 from hook switch trigger circuit 36, and emits a ring indicator signal 37 to control ringer driver 38 and ringer switch 39. Microprocessor 34 also communicates with microprocessor 61 in base unit 11 (FIG. 2) over RF link 17.

Radio receiver 32 sends demodulated modem data signal 40 (from the telephone central office) into hybrid circuit 41. Radio transmitter 33 receives modem data signal 42 (originating in modem 14) from hybrid circuit 41.

Hybrid circuit 41 operates as a four-wire to two-wire converter, combining signals 40 and 42 (4-wires) so that they can be transmitted onto two-wire telephone cord 18. Hybrid circuit 41, like hybrid circuit 21 in base unit 11, has a balance impedance Rb and two operational amplifiers 43 and 44. The balance impedance Rb approximately matches the line terminating impedance Rl of modem 14. Since different modems may have somewhat different terminating impedances Rb, a fixed value of Rb may not sufficiently balance the hybrid. This will lead to echoes being generated in the hybrid circuit. These echoes are typically smaller than those in hybrid circuit 21 of base unit 11. If the echoes cause circuit overload in radio transmitter 33, an AGC circuit 45, similar to circuit 26 in the base unit, may be added to remote unit 12.

The triggering voltage 46 for hook switch trigger circuit 36 will be zero volts as long as the hook switch in modem 14 is open (“on hook”). After modem 14 goes off-hook (starts communicating), the hook switch in modem 14 closes and a DC current starts flowing from battery voltage Vb in remote unit 12 through resistors R1, R2, and R3 of remote unit 12 and the resistance provided by the DC loop holding circuit (identical to the circuit in telephone line interface 20) in modem 14. Voltage 46 thus becomes positive and hook switch trigger circuit 36 initiates hook switch control voltage 45. Hook switch control voltage 45 operates the hook switch (going “off hook”) in telephone line interface 20 of base unit 11.

An incoming call from the telephone central office generates ring indicator voltage 37, as described above, which operates ring driver 38. To produce an audible ring, the ring driver 38 normally operates, through voltage 48, a piezoelectric transducer (not shown). An audible ring is not necessary in the remote unit 12 of wireless communication system 10. The drive signal 48 is used here to operate the ringer circuit in modem 14 of computer 13, after first being transformed to a high voltage in ringer transformer 49, and is then applied to line 18 through ringer switch 39. Ringer signal 48 is of much higher frequency (as high as several kHz) than the ordinary ringer signal (16 to 60 Hz) coming from a central office and a normally-operating ringer circuit in modem 14. Since the ringer circuit in modem 14 is quite frequency-insensitive, there is no disadvantage in using higher ringer frequencies. Higher frequencies actually make the design of transformer 49 much simpler.

Remote unit 12 (FIG. 3) obtains power from a battery (not shown). This battery can be recharged by putting remote unit 12 into a cradle provided on base unit 11. Following standard cordless telephone practice, every time the remote unit is put into the cradle, a security code can be changed. This will prevent unauthorized over-the-air access of the base unit by foreign remote units.

Wireless Link with Telephone Features

Wireless communication system 10 may include the same functions as a regular cordless telephone if a handset with speaker and microphone, a dialing pad, a ringer, and other sundry items are provided. These items may be included in wireless communication system 10, thereby allowing wireless communication system 10 to have dual functionality, i.e., to operate as a cordless telephone for transmitting analog voice signals and as an RF link for transmitting analog data signals between a telephone line and a modem.

More specifically, a regular cordless telephone will also serve as a wireless communication link 10 for data communication if the circuits shown in FIGS. 2 and 3 are added. The handset may be equipped with a telephone jack (RJ11) for interconnecting the handset with a computer modem. Provisions are also made to disconnect the speaker and microphone of the cordless telephone if the cordless telephone is used as a wireless link for data communication as described herein.

The invention is not limited to the hardware and software configurations shown in FIGS. 1 to 3. The invention is also not limited to transmitting data over the RF frequency bands described above, or to the specific modulation techniques described herein.

Other embodiments not described herein are also within the scope of the following claims.

What is claimed is:

1. Circuitry to transmit an analog data signal over a wireless communication link, comprising:
   - an automatic gain control circuit that receives the analog data signal and that keeps a peak amplitude of the analog data signal substantially constant and within a predetermined linear amplification range; and
   - a transmitter that receives the analog data signal from the automatic gain control circuit and that outputs the analog data signal, the transmitter having the predetermined linear amplification range.

2. The circuitry of claim 1, further comprising:
   - a hybrid circuit that isolates an incoming data signal from an outgoing data signal, the hybrid circuit producing the analog data signal based on the incoming data signal and outputting the analog data signal to the automatic gain control circuit.
   - The circuitry of claim 2, wherein the analog data signal produced by the hybrid circuit exceeds a linear amplification range of the transmitter, and the automatic gain control circuit limits a voltage of the analog data signal.

4. The circuitry of claim 1, further comprising:
   - a duplexer that maintains separation between transmitted and received signals.

5. The circuitry of claim 1, wherein the transmitter comprises a radio frequency (RF) transmitter.
6. The circuitry of claim 5, wherein the RF transmitter includes a frequency modulation (FM) deviator which performs FM modulation of an RF carrier of the analog data signal.

7. The circuitry of claim 6, further comprising:

circuitry to reduce a signal voltage of the analog data signal prior to input to the FM deviator.

8. The circuitry of claim 1, further comprising:

a microprocessor which sends and receives control signals to a remote unit that communicates with the circuitry over the wireless communication link.

9. An apparatus for transmitting an analog data signal over a wireless communication link, comprising:

a base unit having a wired connection to a telephone line, the base unit transmitting data to and from the telephone line via the wired connection; and

a remote unit having a wired connection to a modem, the remote unit transmitting data to and from the modem via the wired connection, the remote unit and the base unit communicating with each other over the wireless communication link;

wherein the base unit comprises:

a radio frequency transmitter to transmit the analog data signal to the remote unit; and

an automatic gain control circuit that keeps a peak amplitude of the analog data signal substantially constant and within a linear amplification range of the radio frequency transmitter.

10. The apparatus of claim 9, wherein the base unit further comprises:

a radio frequency receiver to receive data from the remote unit.

11. The apparatus of claim 9, wherein the base unit further comprises:

a hybrid circuit that isolates an incoming data signal from an outgoing data signal, the hybrid circuit producing the analog data signal based on the incoming data signal and outputting the analog data signal to the automatic gain control circuit.

12. The apparatus of claim 9, wherein the analog data signal output by the hybrid circuit exceeds a linear amplification range of the transmitter, and the automatic gain control circuit limits a voltage of the analog data signal.

13. The apparatus of claim 9, wherein the base unit further comprises:

a duplexer that maintains separation between RF transmitted and received signals.

14. The apparatus of claim 9, wherein the RF transmitter includes a frequency modulation (FM) deviator which performs FM modulation on the analog data signal.

15. The apparatus of claim 14, wherein the base unit further comprises:

circuitry to reduce a signal voltage of the analog data signal prior to input to the FM deviator.

16. The apparatus of claim 9, wherein the base unit further comprises:

a microprocessor which sends and receives control signals to the remote unit over the wireless communication link.

17. The apparatus of claim 9, wherein the remote unit further comprises:

a hybrid circuit that isolates an incoming data signal from an outgoing data signal, the hybrid circuit producing an output analog data signal based on the incoming data signal; and

an automatic gain control circuit to reduce echoes produced by the hybrid circuit in the output analog data signal.

18. An apparatus for transmitting data or voice over a wireless communication link, comprising:

means for operating the apparatus as a wireless data link; and

means for operating the apparatus as an analog cordless telephone.

19. The apparatus of claim 18, wherein an analog data signal is transmitted over the wireless data link.

20. The apparatus of claim 18, wherein an analog voice signal is transmitted over the wireless link.

21. The apparatus of claim 18, wherein the apparatus comprises a cordless telephone, a base unit comprising a cordless telephone base unit, and a remote unit comprising a handset for a cordless telephone.

22. The apparatus of claim 21, wherein the remote unit further comprises a speaker, a microphone, and a dialing pad.