

SYSTEMS AND METHODS FOR SYNCHRONIZATION OF CLOCK SIGNALS**BACKGROUND****1. Field of the Invention(s)**

[001] The present invention(s) generally relate to processing of data on a transceiver. More particularly, the invention(s) relate to systems and methods for synchronization of clock signals across a backplane of a transceiver.

2. Description of Related Art

[002] In microwave radio systems, a transceiver may include an indoor unit (IDU) and an outdoor unit (ODU) coupled to an antenna. In one example, the IDU may be coupled to a server or other computer over a wired network (e.g., LAN, WAN, or the Internet) or to a mobile network base-station. Information to be wirelessly transmitted may be prepared by both the IDU and the ODU before wireless transmission. Similarly, the outdoor unit may receive signals from the antenna to provide to the server, other computer, or mobile network node via the IDU.

[003] Unlike time-division multiplexing networks, standard Ethernet does not carry clock synchronization information. New standards, such as G8262/Y.1362 from the ITU-T, require a significantly greater precision and accuracy than previous standards. As a result, accurate synchronization of a customer's clock signal across a backplane of a transceiver unit is an increasing challenge. For example, traversing an asynchronous TDM backplane from a digital access card (DAC) to a radio access card (RAC) can cause clock signals to lose precision. Stuffing bits in a nonperiodic, low frequency manner typically adds jitter and/or wander to the clock signal as it traverses a microwave network. The egress clock signal may be used to synchronize a base-station which in turn is used to synchronize mobile devices.

SUMMARY OF THE INVENTION

[004] Systems and methods for synchronization of clocks signals are discussed herein. An exemplary system comprises a transmitting device and a receiving device. The transmitting device including a terminal, a first phase lock loop, and a transmitting data block interface. The terminal may be configured to receive an initial clock signal. The first phase lock loop may be configured to lock a phase of an initial periodic signal with a phase of the initial clock signal. The transmitting data block interface may be configured to construct a plurality of data blocks and provide the plurality of data blocks to a receiving device. Each of the plurality of data blocks may include at least one sample of the initial periodic signal. The receiving device includes a receiving data block interface, a second phase lock loop and a clock signal generator. The receiving data block interface may be configured to receive the plurality of data blocks. The second phase lock loop may be configured to recreate the initial periodic signal as a recreated periodic signal, lock a phase of the recreated signal with a phase of the samples of the initial periodic signal from the plurality of data blocks. The clock signal generator may be configured to recreate the initial clock signal as a recreated clock signal and to provide the recreated clock signal. The recreated clock may be signal synchronized to the initial clock signal based on the phase of the recreated periodic signal.

[005] The transmitting data block interface may be further configured to construct the plurality of data blocks to include data from the terminal. The receiving device may further comprise a timing module configured to receive data from the plurality of data blocks received by the receiving data block interface, to receive the recreated clock signal from the clock signal generator, and to provide the data and the recreated clock signal.

[006] In various embodiments, a frequency of the initial periodic signal may be equal to or less than half of a data rate of the plurality of data blocks provided by the transmitting data block interface. In some embodiments, a frequency of the initial periodic signal is greater than half of a data rate of the plurality of data blocks provided by the transmitting data block interface. Further, the phase of the samples of the initial periodic signal may appear to be at a lower frequency at the second phase lock loop due to aliasing.

[007] The transmitting device may further comprise a down sampling module configured to down-sample the initial clock signal to the frequency of the initial periodic signal. The system may further comprise a decimation module operating based on a first backplane clock

signal. The decimation module may be configured to provide a subset of samples of the initial periodic signal to the transmitting data block interface. The receiving data block interface may operate based on a first backplane clock signal. Alternately, the receiving data block interface may operate based on a different or second clock signal that is not the first backplane clock signal.

[008] The second phase lock loop may further comprise a second decimation module configured to generate a subset of samples of the recreated periodic signal to provide feedback and assist in locking the phase of the recreated periodic signal with the phase of the samples of the initial periodic signal.

[009] In various embodiments, the transmitting data block interface and the receiving data block interfaces are TDM interfaces. The plurality of data blocks may be a plurality of TDM frames. The transmitting data block interface may incorporate a plurality of bits based on the at least one sample of the periodic signal in each TDM frame.

[0010] An exemplary method for clock signaling may comprise receiving, by a transmitting device, an initial clock signal, locking, with a first phase lock loop, a phase of an initial periodic signal with a phase of the initial clock signal, constructing a plurality of data blocks to be provided to a receiving device, each of the plurality of data blocks including at least one sample of the initial periodic signal, providing the plurality of data blocks to the receiving device, recreating the initial periodic signal to create a recreated periodic signal, locking, with a second phase lock loop of the receiving device, a phase of the recreated periodic signal with a phase of the samples of the initial periodic signal from the plurality of data blocks, and recreating the initial clock signal as a recreated clock signal synchronized to the initial clock signal based on the locked phase of the recreated periodic signal.

[0011] Another exemplary system comprises a transmitting device on a TDM backplane bus and a receiving device on the TDM backplane bus. The transmitting device including a terminal, a first phase lock loop, and a transmitting TDM interface. The terminal may be configured to receive an initial clock signal and data. The transmitting data block interface may be configured to construct a plurality of frames, to store, within a control byte of each frame, at least one bit or more of a sample of the locked initial periodic signal, to store at least some of the data within one or more data bytes of each frame, and to provide the plurality of frames to the receiving device on the TDM backplane bus. The receiving device on the TDM

backplane bus includes a receiving TDM interface, a second phase lock loop, and a clock signal generator. The receiving TDM interface may be configured to receive the plurality of frames. The second phase lock loop may be configured to recreate the initial periodic signal as a recreated periodic signal and lock a phase of the recreated signal with a phase of the initial periodic signal based on the bits of the samples of the locked initial periodic signal from the plurality of frames received by the receiving TDM interface. The clock signal generator may be configured to recreate the initial clock signal as a recreated clock signal, to provide the recreated clock signal, and to provide data from the data bytes of the plurality of frames received by the receiving TDM interface. The recreated clock may be signal synchronized to the initial clock signal based on the phase of the recreated periodic signal.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0012] FIG. 1 is an environment including two transceiver units in some embodiments.
- [0013] FIG. 2 is a high level diagram regarding communication between two transceiver units in some embodiments.
- [0014] FIG. 3 is a block diagram of a transmitting DAC or RAC in some embodiments.
- [0015] FIG. 4 is a tone sample insertion diagram in some embodiments.
- [0016] FIG. 5 is another block diagram of a receiving DAC or RAC in some embodiments.
- [0017] FIG. 6 is a flow diagram for synchronizing a recreated clock signal based on a tone signal in some embodiments.
- [0018] FIG. 7 is a graph of a test utilizing an E1 backplane in some embodiments described herein.
- [0019] FIG. 8 is a graph of a test utilizing a DS1 backplane in some embodiments described herein.
- [0020] FIG. 9 is a graph of scope measurements in some embodiments described herein.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Various embodiments described herein enable synchronization timing of an asynchronous clock signal across a backplane (in some examples referred to as a TDM backplane) that allows passage of synchronous signals derived from E1, T1, or Synchronous Ethernet clock signals to minimize wander effects that would typically cause failure in meeting G8262 specifications.

[0022] FIG. 1 is an environment 100 including two transceiver units 102 and 104 in some embodiments. Each of the transceiver units 102 and 104 are split mount radios. A split-mount radio has a part of the electronics mounted outdoors with an antenna and part indoors. The outdoor unit (ODU) may be the RF transmitter/receiver. In various embodiments, the indoor unit (INU) contains a data access card (DAC) and a radio access card (RAC). The DAC and RAC may be configured, utilizing processes further described herein, to allow synchronous signals derived from E1, T1, or Synchronous Ethernet signals to minimize wander effects as described herein. The INU may contain the modulator/demodulator, multiplexer, control, and traffic interface elements. The INU and ODU may be coupled together using a cable or any other means.

[0023] By comparison, an all-indoor radio has all radio equipment installed inside and is connected to its antenna using a waveguide or coax feeder. A split-mount radio may be a point-to-point radio installation for licensed 6 to 38+ GHz frequency bands with the ODU direct-mounted to the rear of the antenna to provide an integral antenna feed. By having the ODU mounted with the antenna, split-mount may eliminate or reduce feeder losses, minimize or reduce rack occupancy, and/or lower installed costs compared to indoor radios.

[0024] For example, transceiver unit 102 may comprise an INU 108 in communication with a processor and/or a digital device, an ODU 110 in communication with the INU 108 over cables 118, a waveguide 112 in communication with the ODU 110, and an antenna 116. The INU 108 may comprise a modulator/demodulator and control circuitry for providing data from a digital device or a processor over line 114 to the antenna 116 via the ODU 110 and/or the waveguide 112. Similarly, the INU 108 may also be configured to receive information from the antenna 116 via the ODU 110 for providing to the digital device or processor via the line 114. The ODU 110 may comprise an RF transmitter/receiver and be coupled with the antenna 116. The waveguide 112 may or may not be a part of the ODU 110.

[0025] The INU 108 of the transceiver unit 102 may be coupled to the ODU 110 utilizing a coaxial cable 118. Although only one coaxial cable 118 is depicted in FIG. 1, any number of coaxial cables may provide signals between the INU 108 and the ODU 110. Further, those skilled in the art will appreciate that any number and/or type of cables may be configured to receive and transmit signals between the INU 108 and the ODU 110.

[0026] Similarly, transceiver unit 104 may comprise an INU 120 in communication with a processor and/or a digital device, an ODU 122 in communication with the INU 120 over cable 130, a waveguide 124 in communication with the ODU 122, and an antenna 128. The INU 120 may comprise a modulator/demodulator and control circuitry for providing data from a digital device or a processor over line 126 to the antenna 128 via the ODU 122 and/or the waveguide 124. Similarly, the INU 120 may also be configured to receive information from the antenna 128 via the ODU 122 for providing to the digital device or processor via the line 126. The ODU 122 may comprise an RF transmitter/receiver and be coupled with the antenna 128. The waveguide 124 may or may not be a part of the ODU 122.

[0027] The INU 120 of the transceiver unit 104 may be coupled to the ODU 122 utilizing a coaxial cable 130. Although only one coaxial cable 130 is depicted in FIG. 1, any number of coaxial cables may provide signals between the INU 108 and the ODU 110. Further, those skilled in the art will appreciate that any number and/or type of cables may be configured to receive and transmit signals between the INU 108 and the ODU 110.

[0028] Those skilled in the art will appreciate that the transceiver unit 104 may perform in a manner similar to the transceiver 102. In various embodiments, the two transceiver units 102 and 104 may be in communication with each other over a wireless communication tower 106. Those skilled in the art will appreciate that the transceiver units 102 and 104, individually or together, may communicate with any digital device or receiver.

[0029] The wireless communication tower 106 (e.g., cell tower or other microwave radio device) may be any device configured to receive and/or transmit wireless information.

[0030] FIG. 2 is a high level diagram 200 regarding communication between two transceiver units in some embodiments. The diagram 200 depicts data access card (DAC) 202 and NCC (TDM clock source) 204. The DAC time multiplexes E1, T1, or Synchronous Ethernet signals from a customer interface card (e.g., customer premises equipment or CPE)

onto an asynchronous (TDM) backplane 206. Timing transfer over the backplane 206 may use a byte stuffing design due to the nature of the asynchronous E1, T1, or Synchronous Ethernet clocks relative to the backplane clock. The RAC 208, containing a modulator/demodulator card, may be configured to recover the data from the asynchronous backplane 206 and respond to the stuffing opportunities on a TDM frame. Doing so may result in time gaps that are smoothed by FIFO circuits to generate and pass a synchronous clock. Unfortunately, the processing of signals from the asynchronous backplane 206 may cause wander buildup from hop to hop as the timing signal must pass through multiple radio nodes.

[0031] The resulting wander buildup due to backplane stuffing requirements may cause the system to fail G8262 synchronization requirements. G8262 is an ITU-T recommendation for synchronous Ethernet that defines “timing characteristics of synchronous Ethernet equipment slave clock (EEC).” A new version was published in 2010.

[0032] A similar effect may be found within the receiving transmitter. For example, the ODU 212 may receive a signal from the ODU 210 over a wireless link. The RAC 214 may receive a clock signal. In a manner similar to that discussed with regard to the DAC 202, the NCC 218 time multiplexes the clock signal on the asynchronous backplane 216. The DAC 220 may be configured to receive the data from the asynchronous backplane 216 in a manner similar to that discussed with regard to the RAC 208.

[0033] In various embodiments, stuffing and/or destuffing requirements may be loosened or eliminated in order to allow the modem to synchronize to a low jitter wander clock.

[0034] FIG. 3 is a block diagram of a DAC or RAC 300 in some embodiments. For the purpose of the following discussion, the block diagram of FIG. 3 will be referred to as a DAC 300. Those skilled in the art will appreciate that the block diagram of FIG. 3 may be a RAC configured to provide data and a timing signal to another RAC. Various embodiments described herein may be used to synchronize any clock signal across a link utilizing frames and/or other data packets between devices (e.g., between DAC 300 and a RAC). For purposes of this discussion, the DAC 300 may be termed a transmitting device and the RAC may be termed a receiving device.

[0035] The DAC 300 comprises a phase lock loop 302, a decimation module 312, a stuff module 314, and a TDM interface 316 configured to provide data and timing signals via the TDM interface 316 to a RAC (discussed with respect to FIG. 5).

[0036] At a high level, a DAC 300 receives customer applied E1, T1, or Synchronous Ethernet data, recovers the synchronous clock from the customer source (e.g., 2048KHz or 1544KHz), and synchronizes the PLL 302 to the recovered clock. The PLL module 302 comprises a divider module 304, a phase detector module 306, a filter module 308, and an oscillator module 310. The PLL 302 may be a digital PLL.

[0037] In various embodiments, the DAC 300 may receive an initial clock signal and a data signal. In one example, the initial clock signal and the data signal are received from customer equipment. The PLL module 302 may receive the initial clock signal and the stuff module 314 may receive the data. In some embodiments, a splitter or other module directs the initial clock signal to the PLL module 302 and directs the data to the stuff module 314.

[0038] The initial clock signal may be applied to the PLL module 302 via an internal divider by the divider module 304. In this example, the divider ratio of the divider module 304 is 1/64. Other divider ratios could be utilized depending upon the system requirements.

[0039] In various embodiments, in order to determine a divider ratio, a frame rate for TDM frames is determined. Here, the frame rate for TDM frames is 85.8kHz. An initial periodic signal generated by the PLL module 302 may be at a frequency that is equal to or less than half of the frame rate (for the Nyquist rate). Here, the frequency rate for the initial periodic signal is 32kHz. The divider module 304 may divide the initial clock signal received from the customer equipment to a frequency that is equal to the first periodic signal. Here, the initial clock signal is at 2.048MHz which is divided by the divider module 304 to a frequency of 32kHz.

[0040] The phase detector module 306 receives the divided clock signal from the divider module 304, receives the feedback signal (e.g., the initial periodic signal) from the oscillator module 310 (further described herein), and detects and/or adjusts the phase differences based on the two signals. The phase detector module 306 may be any kind of phase detector module. In one example, the phase detector 306 is a flip flop phase detector.

[0041] The filter module 308 may filter the signal from the phase detector module 306. The filter module 308 may comprise a loop filter, lowpass filter, and/or any kind of filter.

[0042] In various embodiments, the PLL 302 includes an oscillator module 310 (e.g., NCO) with a large enough word size to provide low jitter performance. The oscillator module 310 generates the initial periodic signal based on the filtered signal from the filter module 308. The initial periodic signal may represent a tone that will be used to regenerate and synchronize the initial clock signal in the receiving RAC. The output of the oscillator module 310 (i.e., the initial periodic signal) may be applied to the TDM frame. The output of the oscillator module 310 may also be provided to the phase detector module 306 as a feedback signal. The oscillator module 310 may comprise any number and any kind(s) of oscillator(s).

[0043] The PLL 302 is synchronized with the backplane clock 318 (shown as 36.4MHz) which is asynchronous to the initial clock that generated the initial clock signal received by the DAC 300.

[0044] The MSBs (most significant bits) output of the oscillator module 310 are decimated by the decimation module 312. In other words, the initial periodic signal (e.g., sin 32kHz) is oversampled. The decimation module 312 may sample the initial periodic signal at a fraction of the backplane clock 318 to provide samples to the TDM interface 316. In one example, the backplane clock 318 is 36.4MHz that operates the decimation module 312 for the desired frame rate. In this example, the decimation module 312 samples the initial periodic signal once every 424 backplane clock cycles for a frame rate of 85.8kHz (e.g., 36.4MHz of the backplane clock 318 rate divided by 424 is equal to 85.8kHz). The decimation module 312 may be any hardware, software, or combination of both configured to down-sample the first periodic signal. The decimation module 312 may sample the initial periodic signal at any rate.

[0045] The output of the oscillator module 310 may be any number of bits. In some embodiments, the output of the oscillator module 310 may be any number of bits including or between (but not limited to) three to eight (e.g., equal to the capacity of a control byte in a byte-based TDM frame). For example, plot 902 of FIG. 9 further discussed herein depicts the 32 kHz tone generated at 36.4MHz at high precision. Plot 904 depicts the 32 kHz tone generated at 36.4 MHz at 4b precision.

[0046] The number of bits of the output of the oscillator module 310 may be based on the unused capacity of a frame (e.g., TDM frame). TDM frames are further discussed herein.

[0047] The stuff module 314 may receive data that was provided with the initial clock signal. The stuff module 314 transfers data asynchronously to the TDM interface 316 without regard to the aforementioned periodic control signal using regular stuff control bits and opportunity bytes.

[0048] The TDM interface 316 operates on frames (e.g., TDM frames generated by a Node Control Card) utilizing 8 bit tributary data from the stuff module 314 and the samples of the first periodic signal. In various embodiments, the TDM interface 316 injects up to one 7 bit word per frame (e.g., 4 bit initial periodic signal sample) into the unused bits of one stuffing control byte of a TDM frame. For example, plot 906 of FIG. 9, discussed further herein, shows the 85.4 kHz sample points (2-3 samples per sinusoid). Plot 908 depicts sample values to be conveyed in the TDM bus. Although not appearing sinusoidal, the plot indicates that less bits per sample are likely sufficient (e.g., 1 or 2 bits).

[0049] Although the TDM interface 316 is identified as being TDM, those skilled in the art will appreciate that any interface configured to generate and/or process frames may be used. The data and the bit samples of the initial periodic signal may be included in the frames. In some embodiments, the initial clock signal may be recovered between any two devices such as, but not limited to, two RACs, two DACs, a RAC and a DAC, or any transmitter and receiver. In one example, various systems and methods described herein may be used to recover an initial clock signal across a wired link or air link (e.g., any wired or wireless network).

[0050] FIG. 4 is a tone sample insertion diagram 500 in some embodiments. In various embodiments, the TDM interface 316 applies each sample point word TDM frame by TDM frame. Samples of the 32kHz tone (i.e., samples of the initial periodic signal), locked to the initial clock signal, are passed onto the TDM backplane to be recovered by the RAC circuit (discussed further herein). Bits from the sampled initial periodic signal may be stored in the first control byte 410 of the TDM frame 402. Similarly, bits from the sampled initial periodic signal may be stored in the control bytes of the TDM frame 404 and/or 406.

[0051] In various embodiments, bits within control bytes 410 (as well as the control bytes of other TDM frames) may be unused. As a result, the storage of bits representative of

samples of the initial periodic signal may be stored within TDM frames without impacting data flow.

[0052] The second control byte 412 may be used to carry data. In one example, the first bit of the control byte 410 may indicate whether the control byte 412 contains data. Data (e.g., from the stuff module 314) may be carried by the data bytes 408 in TDM frame 402 as well as the other data bytes of the other TDM frames.

[0053] In some embodiments, the first and/or second control bytes 410 and 412 may store data and/or bits of the samples of the initial periodic signal. For example, the first control byte 410 may contain bits related to the sampled initial periodic signal while the second control byte 412 and/or the data bytes may contain data from the stuff module 314. The rest of the first control byte 410 may contain bits from the samples of the initial periodic signal. If the second control byte 412 does not carry any data or is only partially full, the second control byte 412 may carry bits related to the sampled initial periodic signal.

[0054] Although three TDM frames are depicted in FIG. 4, those skilled in the art will appreciate that there may be any number of TDM frames. Further, each TDM frame may comprise data representative of a sample point of the first periodic signal. For example, 7 bits (most significant bits or MSB) of the sampled first periodic signal may be stored in the first control byte of each TDM frame. In some embodiments, not all TDM frames include bits of the sampled first periodic signal (e.g., every second TDM frame could be used to convey the periodic signal).

[0055] Further, there may be any number of bits related to the sampled initial periodic signal. In one example, any number of bits (related to the sampled initial periodic signal) that fit within the first control byte may be used

[0056] FIG. 5 is another block diagram of a receiving DAC or RAC 500 in some embodiments. In various embodiments, a method and system is described herein for transferring a high quality timing reference between modules (e.g., an RAC and a DAC within an INU chassis). In one example, the method includes sending a 4-bit tone between two digital phase locked loops (DPLLs) which allows them to stay tightly synchronized together. The tone may be conveyed across a TDM bus. In one example, the tone is conveyed within justification control time slots to utilize otherwise unused backplane capacity.

[0057] In the RAC 500, recovered initial periodic signal samples (e.g., tone samples) are used to re-construct the initial periodic signal with a PLL 504 and synchronize the TDM clock which may be used to generate a symbol clock for the TX modulator. In various embodiments, the symbol clock is ultimately locked to the original timing signal without having timing gaps that are a result of stuffing and de-stuffing across the back plane.

[0058] As discussed herein, for the purpose of the following discussion, the block diagram of FIG. 5 will be referred to as a RAC 500. Those skilled in the art will appreciate that the block diagram of FIG. 5 may be a RAC configured to received data and a timing signal from another RAC. Further, The DAC or RAC 500 may be a DAC or any other receiving device. The RAC 500 comprises a TDM interface 502, a phase lock loop 504, an oscillator module 514, a destuff module 516, and a retiming module 518.

[0059] At a high level, the RAC 500 receives the frames from the transmitting DAC or RAC. The RAC 500 may lock a recreated tone or periodic signal utilizing the samples of the initial periodic signal. The RAC 500 may generate a recreated clock signal synchronized to the recreated tone or periodic signal. As a result, the recreated clock signal may be synchronized to the initial clock signal. The recreated clock signal and/or data from the DAC or RAC 300 may be provided to one or more other devices and/or units (e.g., an ODU for microwave transmission over a wireless link).

[0060] In various embodiments, the TDM interface 502 receives frames from the DAC or RAC 300. Data (e.g., 8 bit tributary data) may be provided to the destuff module 516 and the 4 bit tone samples of the initial periodic signal at 85.8kHz may be provided to the PLL 504. Although the TDM interface 502 is identified as “TDM,” those skilled in the art will appreciate that the interface may be any kind of interface configured to receive and/or process any periodic frames or groups of data.

[0061] The PLL module 504 comprises a phase detector module 506, a filter module 508, an oscillator module 510, and a decimation module 512. The PLL 504 may be a digital PLL.

[0062] The phase detector module 506 receives the samples of the initial periodic signal and a decimated recreated periodic signal discussed further herein. The phase detector module 506 detects and/or adjusts the phase differences based on the two signals. The phase detector module 506 and/or the filter module 508 may lock the recreated periodic signal to the initial

periodic signal. The phase detector module 506 may be any kind of phase detector module. In one example, the phase detector is a multiply phase detector.

[0063] The filter module 508 may filter the signal from the phase detector module 506. The filter module 508 may comprise a loop filter, bandpass filter, and/or any kind of filter.

[0064] In various embodiments, the PLL 504 includes an oscillator module 510 (e.g., NCO) which recreates the initial periodic signal based on the filtered signal from the filter module 508. The recreated periodic signal may represent a tone that will be used to regenerate and synchronize the recreated clock signal. The output of the oscillator module 510 (i.e., the recreated periodic signal) may be sampled by the decimation module 512

[0065] The PLL 504 may be synchronized with the backplane clock 318 (shown as 36.4MHz) which is asynchronous to the initial clock that generated the initial clock signal received by the DAC 300. In some embodiments, the PLL 504 and the PLL 302 using the same backplane clock 318. In various embodiments, the PLL 504 and the PLL 302 utilize different clocks.

[0066] In various embodiments, the recreated periodic signal from the oscillator module 510 is decimated by the decimation module 512. In one example, the backplane clock 318 is 36.4MHz that operates the decimation module 512 for the desired frame rate. In this example, the decimation module 512 samples the recreated periodic signal once every 424 backplane clock cycles for a frame rate of 85.8kHz (e.g., 36.4MHz of the backplane clock 318 rate divided by 424 is equal to 85.8kHz). The decimation module 510 may be any hardware, software, or combination of both configured to down-sample the recreated periodic signal. The decimation module 510 may sample the recreated periodic signal at any rate.

[0067] In a manner similar to the decimation module 312, the decimation module 510 may sample the recreated periodic signal at a fraction of the backplane clock 318 to provide the decimated recreated periodic signal to the phase detector module 506. The phase detector module 506 may lock the phase of the recreated periodic signal with the phase of the sampled initial periodic signal to synchronize the recreated clock signal of the oscillator module 514 discussed herein.

[0068] In some embodiments, the initial periodic signal generated by the PLL module 302 may be at a frequency that is greater than half of the frame rate. The initial periodic signal,

however, may be perceived by the PLL 504 at a lower frequency as a result of aliasing. In one example, if the frequency of the initial periodic signal is $\frac{3}{4}$ of the TDM frame rate, the PLL module 302 may lock the decimated recreated periodic signal to $\frac{1}{4}$ of the TDM frame rate. Those skilled in the art will appreciate that the initial periodic signal may be at any frequency.

[0069] The oscillator module 514 may be an NCO configured to recreate the initial clock signal. The recreated clock signal of the oscillator module 514 may be synchronized to the initial clock signal based on the locked tone signal (e.g., the locked periodic signal) of the PLL 504. In one example, the oscillator 514 generates a recreated clock signal at 2.048MHz. The oscillator module 514 may comprise any number or type of oscillator.

[0070] Although FIG. 5 depicts the filter module coupled to the oscillator module 514, any modules, interfaces, and clocks in FIGs 3 and 5 may be in any order. In one example, the filter module 508 is coupled to the oscillator module 510 which is, in turn, coupled to the oscillator module 514.

[0071] The destuff module 314 may receive the frames from the TDM interface 502 and retrieve data. The retiming module 518 may receive data from the destuff module 516 and the recreated clock signal. The retiming module 518 may provide the data and/or recreated clock signal (e.g., to the ODU and/or antenna). In some embodiments, the retiming module 518 comprises a FIFO.

[0072] FIG. 6 is a flow diagram for synchronizing a recreated clock signal based on a tone signal in some embodiments. In step 602, a RAC or DAC 300 receives an initial clock signal. In one example, the initial clock signal is 2.048MHz. The initial clock signal may be received from customer equipment (e.g., CPE) or any other source. The initial clock signal may be any signal at any frequency.

[0073] In step 604, the divider module 304 divides the initial clock signal to a frequency of an initial periodic signal. In some embodiments, a periodic signal frequency may be chosen that is equal to or less than half of a frame rate for transmission. In one example, the frame rate is 85.8kHz and the initial periodic signal (e.g., initial tone) is determined to be a sine wave of 32 kHz. As a result, the divider ratio of the divider module 304 may be determined to be $1/64$ (i.e., $2.048 \text{ MHz}/64 = 32 \text{ kHz}$). The divider module 304 may divide the initial clock signal frequency for phase detection and adjustment with the initial periodic signal by the PLL 302.

[0074] In step 606, the PLL 302 locks the phase of the initial periodic signal with the phase of the divided initial clock signal. The PLL 302 may filter the signal and provide the filtered comparison to the oscillator module 310 to recreate and lock the initial periodic signal. The oscillator module 310 may provide the initial periodic signal to the phase detector module 306 as a feedback loop.

[0075] In step 608, a decimation module 312 decimates sampling (e.g., down-samples) the phase-locked initial periodic signal to the frame rate of frames to be provided to the receiving device (e.g., DAC or RAC 500). In one example, the decimation module 312 operates at the clock rate provided by the backplane clock 318. The decimation module 312 may down-sample the phase-locked initial periodic signal to provide samples to individual frames to be provided. For example, the decimation module 312 may down sample the initial periodic signal at 1 of every 424 cycles of the backplane clock 318 (e.g., $36.4\text{MHz}/424=85.8\text{kHz}$).

[0076] In step 610, the TDM interface 316 may generate data blocks in frames to be provided to the receiving RAC or DAC 500. One or more data blocks may include samples of the phase-locked initial periodic signal. In one example, the TDM interface 316 may provide bits representing a sample of the phase-locked initial periodic signal. The bits may be MSB of the phase-locked initial periodic signal. In one example, the frame has a byte (e.g., control byte 410) that may be used to provide bits representing a sample of the phase-locked initial periodic signal. In this example, there may be up to eight bits representing the representing the sample of the phase-locked initial periodic signal. Those skilled in the art will appreciate that there may be any number of bits and/or any number of bytes of the frame that may be used to provide bits representing the sample of the phase-locked initial periodic signal.

[0077] In some embodiments, the frame may also include data from the customer equipment. The data may be stuffed or placed within data bytes of the frame and/or opportunity bytes such as an additional control byte 412. In some embodiments, there may be bits reserved for the first control byte 410 which indicates whether a second control byte 412 is used for data. In this example, the first control byte 410 may be limited to storing one to seven bits representing a sample of the phase-locked initial periodic signal.

[0078] Those skilled in the art will appreciate that there may be any kind of frame, packet, or other grouping of data blocks that may be provided by the DAC or RAC 300 to the DAC or RAC 500. In step 612, the TDM interface 316 provides the frames to the RAC or DAC 500.

[0079] In step 614, the RAC or DAC 500 recreates the initial periodic signal. In one example, the TDM interface 502 of the RAC or DAC 500 retrieves the samples of the bits representing the sample of the phase-locked initial periodic signal from the frames. The PLL 504 recreates the initial periodic signal with the oscillator module 510 and locks the recreated periodic signal with the initial periodic signal in step 616.

[0080] In some embodiments, the recreated periodic signal is down-sampled by decimation module 512 to allow for phase locking by the PLL 504. For example, the decimation module 512 may operate at the backplane clock 318. The decimation module 512 may provide samples of the recreated periodic clock at the frame rate for phase detection. In one example, the decimation module 512, like the decimation module 312, may down sample the recreated periodic signal at 1 of every 424 cycles of the backplane clock 318 (e.g., $36.4\text{MHz}/424=85.8\text{kHz}$).

[0081] Those skilled in the art will appreciate that the PLL 504 may, in some embodiments, operate at a different clock than the DAC or RAC 300. In one example, the backplane clock 318 of the DAC or RAC 300 may not be synchronized with a backplane clock of the DAC or RAC 500. The PLL 504 and the NCO 510 may be required to generate a clean clock at the same frequency as the periodic signal from the TDM interface.

[0082] In step 616, the PLL 504 locks the phase of the recreated periodic signal with the phase-locked initial periodic signal. For example, the PLL 504 may lock the phases of the samples of the initial periodic signal from the TDM interface 502 with the samples of the recreated periodic signal from the decimation module 512.

[0083] In step 618, the oscillator module 514 may recreate the initial clock signal synchronized to the phase-locked recreated periodic signal. As a result, the recreated signal may be locked to the initial clock signal. In one example, the oscillator module 514 generates a signal at the same frequency (e.g., 2.048MHz) as the initial clock signal. The generated signal (i.e., the recreated initial clock signal) is based on the phase-locked recreated tone and, as a result, may be synchronized with the initial clock signal.

[0084] In step 620, the destuff module 516 retrieves data from the frames provided by the DAC or RAC 300 via the TDM interface 502. The destuff module 516 may retrieve the data from one or more data bytes of any number of frames.

[0085] In step 622, the retiming module 518 may receive the data from the destuff module 516, receive the recreated clock signal from the oscillator module 514, and provide the data and/or recreated clock signal to another device or unit. In one example, the data and/or recreated clock signal is provided to the ODU or customer equipment.

[0086] FIG. 7 is a graph 700 of a test utilizing an E1 backplane in some embodiments described herein. Graph 700 depicts wander measurement between two modules (e.g., DAC and RAC) utilizing the tone conveyed across the TDM bus to synchronize the DPLLs in the respective module. The graph 700 measure observations along the x axis and MTIE (maximum time interval error) / TDEV (Time Deviation). The measurements in graph 700 show limited wander.

[0087] FIG. 8 is a graph 800 of a test utilizing a DS1 backplane in some embodiments described herein. The measurements depicted in Graph 800 are based on the same test hardware used with regard to FIG. 8. Like graph 700, graph 800 depicts wander measurement between two modules (e.g., DAC and RAC) utilizing the tone conveyed across the TDM bus to synchronize the DPLLs in the respective module. The measurements in graph 800 show limited wander.

[0088] FIG. 9 is a graph 900 of scope measurements in some embodiments described herein. Plot 902 of graph 900 depicts the 32 kHz tone generated at 36.4MHz at high precision. Plot 904 depicts the 32 kHz tone generated at 36.4 MHz at 4b precision. Plot 906 shows the 85.4 kHz sample points (2-3 samples per sinusoid). Plot 908 shows the sample values to be conveyed in the TDM bus. Although plot 908 does not appear to be sinusoidal, a spectrum plot shows the 32 kHz present which may indicate that even less bits per sample may likely sufficient (e.g., the 32 kHz tone generated at 36.4 MHz may be at 3b precision).

[0089] The above-described functions may be performed in hardware. In one example, the functions may be performed by one or more field-programmable gate arrays (FPGAs), discrete hardware, and/or one or more application-specific integrated circuits (ASICs).

[0090] Further, one or more functions may be stored on a storage medium such as a computer readable medium. The instructions can be retrieved and executed by a processor. Some examples of instructions are software, program code, and firmware. Some examples of storage medium are memory devices, tape, disks, integrated circuits, and servers. The

instructions are operational when executed by the processor to direct the processor to operate in accord with some embodiments. Those skilled in the art are familiar with instructions, processor(s), and storage medium.

[0091] Various embodiments are described herein as examples. It will be apparent to those skilled in the art that various modifications may be made and other embodiments can be used without departing from the broader scope of the present invention. Therefore, these and other variations upon the exemplary embodiments are intended to be covered by the present invention(s).

Claims

1. A system for clock signaling, the system comprising:
 - a transmitting device including:
 - a terminal configured to receive an initial clock signal;
 - a first phase lock loop configured to lock a phase of an initial periodic signal with a phase of the initial clock signal; and
 - a transmitting data block interface configured to construct a plurality of data blocks and provide the plurality of data blocks to a receiving device, each of the plurality of data blocks including at least one sample of the initial periodic signal; and
 - the receiving device including:
 - a receiving data block interface configured to receive the plurality of data blocks;
 - a second phase lock loop configured to recreate the initial periodic signal as a recreated periodic signal, lock a phase of the recreated periodic signal with a phase of the samples of the initial periodic signal from the plurality of data blocks; and
 - a clock signal generator configured to recreate the initial clock signal as a recreated clock signal and to provide the recreated clock signal, the recreated clock signal synchronized to the initial clock signal based on the phase of the recreated periodic signal.
2. The system of claim 1 wherein the transmitting data block interface is further configured to construct the plurality of data blocks to include data from the terminal.
3. The system of claim 2 wherein the receiving device further comprises a timing module configured to receive data from the plurality of data blocks received by the receiving data block interface, to receive the recreated clock signal from the clock signal generator, and to provide the data and the recreated clock signal.
4. The system of claim 1 wherein the transmitting device further comprises a down sampling module configured to down-sample the initial clock signal to the frequency of the initial periodic signal.

5. The system of claim 1 further comprising a decimation module operating based on a first backplane clock signal, the decimation module configured to provide a subset of samples of the initial periodic signal to the transmitting data block interface.
6. The system of claim 5 wherein the receiving data block interface operates based on a first backplane clock signal.
7. The system of claim 5 wherein the receiving data block interface operates based on a second clock signal that is not the first backplane clock signal.
8. The system of claim 1 wherein the second phase lock loop further comprises a second decimation module configured to generate a subset of samples of the recreated periodic signal to provide feedback and assist in locking the phase of the recreated periodic signal with the phase of the samples of the initial periodic signal.
9. The system of claim 1 wherein the transmitting data block interface and the receiving data block interfaces are TDM interfaces.
10. The system of claim 9 wherein the plurality of data blocks are a plurality of TDM frames.
11. The system of claim 9 wherein the transmitting data block interface incorporates a plurality of bits based on the at least one sample of the periodic signal in each TDM frame.
12. A method for clock signaling, the method comprising:
 - receiving, by a transmitting device, an initial clock signal;
 - locking, with a first phase lock loop, a phase of an initial periodic signal with a phase of the initial clock signal;
 - constructing a plurality of data blocks to be provided to a receiving device, each of the plurality of data blocks including at least one sample of the initial periodic signal;
 - providing the plurality of data blocks to the receiving device;
 - recreating the initial periodic signal to create a recreated periodic signal;
 - locking, with a second phase lock loop of the receiving device, a phase of the recreated periodic signal with a phase of the samples of the initial periodic signal from the plurality of data blocks; and
 - recreating the initial clock signal as a recreated clock signal synchronized to the initial clock signal based on the locked phase of the recreated periodic signal.

13. The method of claim 12 wherein the plurality of data blocks further include data received by the transmitting device.

14. The method of claim 13 further comprising providing the data and the recreated clock signal by a timing module of the receiving device.

15. The method of claim 12 further comprising down-sampling the initial clock signal to the frequency of the initial periodic signal.

16. The method of claim 12 further comprising decimating a first backplane clock signal to provide the samples of the initial periodic signal.

17. The method of claim 16 further comprising receiving, by the receiving device utilizing the first backplane clock signal, the plurality of data blocks.

18. The method of claim 16 further comprising receiving, by the receiving device utilizing a second clock signal, the plurality of data blocks, wherein the first backplane clock signal is not the second clock signal.

19. The method of claim 12 further comprising down-sampling the recreated periodic signal to provide feedback and assist in locking the phase of the recreated periodic signal with the phase of the samples of the initial periodic signal.

20. The method of claim 12 wherein the plurality of data blocks are a plurality of TDM frames.

21. The method of claim 20 wherein constructing the plurality of data blocks to be provided to the receiving device comprises incorporating a plurality of bits based on the at least one sample of the initial periodic signal in each TDM frame.

22. A system for clock signaling, the system comprising:

a transmitting device on a TDM backplane bus, the transmitting device including:

a terminal configured to receive an initial clock signal and data;

a first phase lock loop configured to lock a phase of an initial periodic signal with a phase of the initial clock signal; and

a transmitting TDM interface configured to construct a plurality of frames, the transmitting TDM interface further configured to store, within a control byte of each frame, at least one bit or more of a sample of the locked initial periodic signal, to store at least some of the data within one or more data bytes of each frame, and to provide the plurality of frames to a receiving device on the TDM backplane bus; and

the receiving device on the TDM backplane bus, the receiving device including:

a receiving TDM interface configured to receive the plurality of frames;

a second phase lock loop configured to recreate the initial periodic signal as a recreated periodic signal, lock a phase of the recreated periodic signal with a phase of the initial periodic signal based on the bits of the samples of the locked initial periodic signal from the plurality of frames received by the receiving TDM interface; and

a clock signal generator configured to recreate the initial clock signal as a recreated clock signal, to provide the recreated clock signal, and to provide the data from the data bytes of the plurality of frames received by the receiving TDM interface, the recreated clock signal being synchronized to the initial clock signal based on the phase of the recreated periodic signal.