

APPARATUS AND METHOD FOR SYNCHRONIZING A PLURALITY OF REMOTE TRANSMISSION AND RECEIVING STATIONS

This invention relates to methods of and apparatus for synchronising a plurality of rf circuits included at a plurality of remote transceiver stations.

- 5 Increasing the capacity and improving cell radiation in a wireless and/or cellular radiotelephone system has traditionally required a splitting of the cell in which a new pattern of a greater number of smaller cells replaces the previously existing cell pattern. This arrangement requires the creation of many new cell sites which in turn requires the acquisition of real estate to locate the new cell sites and
10 the replication of expensive cell site radio and switching equipment.

- The need for new cell sites may be avoided by the use of remote transceiver stations all connected to an existing cell site or base station and distributed throughout the existing cell. These remote transceiver stations function as 'repeaters' or 'radiators' in interconnecting mobile units and the cell sites or base
15 stations. These remote stations handle rf signals sent to and from mobile radiotelephone units which they retransmit for communication with the base stations via fiber optics or other transmission media. In order to optimize the operation of the system it is necessary to provide system synchronization for the multiplicity of rf circuits of the remote stations.

- 20 According to one aspect of this invention there is provided a method of synchronizing a plurality of rf circuits included at a plurality of remote transceiver stations to a reference frequency provided at a common base station in a cellular radiotelephone system, including (a) combining a reference frequency signal with rf signals at the base station to create a composite signal, (b) driving a base station
25 frequency synthesizer with the reference frequency signal, (c) transmitting the composite signal to the plurality of rf circuits at the plurality of remote transceiver stations, (d) extracting the reference frequency signal from the received composite signal in each of the plurality of remote transceiver stations, (e) driving a remote station frequency synthesizer with the reference frequency signal extracted from the
30 composite signal in each of the plurality of remote transceiver stations, (f) combining the reference frequency signal extracted from the composite signal with received radiotelephone signals at each of the plurality of remote stations to create a received composite signal, (g) transmitting the composite signal to the base station, and (h) extracting the received radiotelephone signals from the composite signals.

According to another aspect of this invention there is provided a cellular radiotelephone system including apparatus for synchronizing a plurality of rf circuits included at a plurality of remote transceiver stations to a reference frequency at a common base station, the apparatus including, at a base station, an input for
5 accepting rf signals; an input for a reference frequency signal; and a combiner for receiving the rf signals and the reference frequency signals and combining them into a first composite signal; a remote transceiver station; transmission means connecting the base station to the remote transceiver station and connected to transmit the first composite signal to the remote transceiver station; a receiver at the remote
10 transceiver station operative for separating the reference frequency signal from the first composite signal; rf signal reception apparatus for receiving radio signals, including a first diversity antenna and a second diversity antenna; a frequency synthesizer connected to accept the reference frequency signal of the first composite signal from the receiver and generate a down converted rf signal from a received rf
15 signal received at the first diversity antenna and apply the down converted rf signal to a signal combiner; the rf signal reception apparatus serving to connect a received signal from the second diversity antenna to the signal combiner for generating a return composite signal from the received rf signal and the down converted rf signal; an output of the signal combiner being connected to a signal transmission means
20 connected to a transmission link coupling the remote transceiver station to the base station; and a receiver at the base station connected to the transmission link and circuitry for separating the rf signals from the return composite signal.

System synchronization may thus be achieved in a system of remote transceiver stations serving a particular cell site or base station by combining rf
25 signals transmitted to the remote station from the cell site with a reference signal, obtained from a highly stable reference signal source, to form a composite signal. In an illustrative embodiment this composite signal is used to modulate the output of a base station laser transmitter. The composite signal is transmitted to the remote station where the reference frequency is extracted and used to synchronize the rf
30 circuits of the remote station. Special diagnostic features of the remote station transceivers are synchronized by the synchronizing signal so that proper transceiver equipment functioning may be monitored at the base station.

The invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a system schematic of a plurality of cellular radiotelephone cells each with a system of remote transceiver stations;

5 FIG. 2 is a block schematic of a base station including the optical transmission links to the remote transceiver stations;

FIG. 3 is a block schematic of the optical interface circuits at the base station and the remote transceiver stations;

FIG. 4 is a schematic of transceiver circuitry included at a base station
10 for communicating with a remote transceiver station; and

FIG. 5 is a schematic of transceiver circuitry included in the remote transceiver station.

A cellular radiotelephone system utilizing a plurality of remote
15 transmitting and receiving stations within cells of the cellular system is shown in FIG. 1. A plurality of base stations 101, 102 and 103, each servicing a particular cell (i.e. geographical area) 111, 112 and 113 are shown connected to a common mobile telephone switching center 105, via the trunks 121, 122 and 123. The mobile telephone switching center 105 connects the base stations through switching
20 circuitry to the public switched telephone network 109. It therefore interconnects the individual mobiles in the cells to a public switched telephone network 109.

Each cell 111, 112 and 113 includes a plurality of remote transmitting and receiving stations 101-1 through 103-2. The remote stations 101-1 through 101-9 of cell 111 may be added to serve increased traffic or to improve radiation and
25 reception in selected cell areas. In cell 113 two remote stations 103-1 and 103-2 are included to serve what would otherwise be RF deadspots in the cell. Cell 112 may include the added remote stations 102-1 to 102-10 for a variety of these purposes.

A detailed block diagram of the base station to remote station connections is shown in FIG. 2. The base station 201 includes an air interface frame
30 202 connected to an antenna 203. The air interface frame 202 which includes rf filter and amplifier circuits is connected to the antenna 203 to transmit radiotelephone signals. It is also connected to the receive line 206 coupling it to a radio channel frame 207 which includes the radio transceivers dedicated to each of the individual channels. A transmit line 208 connects the radio channel frame 207 to the air
35 interface frame 202. The radio channel frame 207 is connected, via voice and data trunks, to the mobile telephone switching office 210.

An RF transmission link 211 connects the radio channel frame 207 to an optical interface frame 212 which is connected to optical fiber transmission links 213 coupling it to a plurality of remote transceiver station 214 located within the cell. The fiber optic transmission and reception circuitry is shown in FIG. 3 and includes an optical transceiver unit 301 included at the base station. Optical transceiver unit 301 is connected to the radio channel units 305, via the rf combiner/splitter 307. The input signals supplied from the radio channel units 305 proceed through an attenuator 311 which applies the radio signal to a laser transmitter 313. The output of the laser transmitter 313 is applied through an optical isolator 315 to an optical fiber link 319 coupling it to the remote transceiver station 320. The optical fiber link 319 is connected to a photo detector 321 at the remote transceiver station 320 which recovers the rf signal from the light signal and applies the detected signal to a linear amplifier 322. The received amplified rf signal is coupled through a bandpass filter 323 to a transmitting antenna 325.

Signals (rf) received at the receiving antenna 335 at the remote transceiver station 320 are coupled via a band pass filter 333 to the linear amplifier 336. The amplified rf signals are applied to the laser transmitter 332 and applied, via an optical isolator 331, to the fiber link 338 connecting the remote station 320 to the base station. The light signal, received at the base station, is applied to a photo detector 341 and an rf signal is recovered. This signal is connected, via linear amplifier 342 and combiner/splitter 307, to the radio channel units 305.

A detailed schematic of the optical transceiver unit included at the base station is shown in FIG. 4. Rf signals from the radio channel units of the base station are applied to the input lead 401. A reference frequency signal is applied to the lead 402. Lead 402 is connected to the splitter 403 which splits the reference frequency signal into two paths. One path 405 is connected to the combiner 406. Here the reference frequency signal is combined with the rf signals from the radio channel units, supplied on lead 401. This combined or composite signal is transmitted, via the automatic gain control amplifier 408 to the optical transmitter 410. The optical transmitter converts the composite rf signal to a composite light signal and applies this composite light signal to the optical fiber link 412 which transmits the composite light signal to the remote stations. The optical transmitter includes a back-face monitor 415 which includes a photo detector to measure light intensity. A feedback loop including a filter 413 tuned to the reference frequency and a detector 414 feeds signals from the optical transmitter's back-face monitor 415 to the agc amplifier 408 in order to maintain the proper laser modulation level.

Signals received from the remote transceiver stations are coupled by the optical fiber link 422 to an optical receiver 423 which converts the composite light signal to a composite rf signal. This composite rf signal comprising a combined rf reference frequency signal and an rf signal is applied to the agc amplifier 425. A parallel loop path including a detector circuit 426 and a filter 427 tuned to the reference frequency connects an amplitude control of the agc amplifier 425 to a coupler 421 which samples the agc amplifier output level. The output of the agc amplifier 425 is applied to the splitter 428 which divides the signal into two paths. One path on lead 431 is applied to the bandpass filter 432. The signal passed by the bandpass filter 432 is applied to the output amplifier 433 of the rf diversity "0" output on lead 434.

A second output of the splitter 428 is applied to the bandpass filter 435, tuned to the rf signal frequency band, whose output is in turn applied to the mixer 436. The other input to mixer 436 is supplied by the frequency synthesizer 438 responsive to the reference frequency signal output of the splitter 403. The output of mixer 436 is a signal having a sum and difference frequencies of these two signals. The sum frequency signal is passed by the bandpass filter 439. Its output is applied to the amplifier 440 to provide the rf diversity "1" output on lead 442.

The details of the optical transceiver unit at the remote station are shown in the FIG. 5. An optical fiber link 501 is connected to an optical receiver 503. The optical receiver 503 recovers the rf signal and the reference frequency signal. An rf signal output of the optical receiver 503 is connected, via lead 504, to the amplifier 505 which is connected in turn, via lead 506, to the transmitting antenna. The reference frequency signal output of the optical receiver 503 is applied to a four way splitter 507. One output on lead 511 is applied to an rf receiver 514 operative for demodulating maintenance messages received from the base station. It is connected to the coupler 515. A second output on lead 513 is connected to a frequency synthesizer 517 for supplying signals to be used as a carrier for maintenance data generated at the remote transceiver station which is to be transmitted to the base station. The output of frequency synthesizer 517 is also directly applied to the combiner circuit 520. The third output of splitter 507 on lead 512 is applied to a local oscillator frequency synthesizer 522 whose controlled frequency signal output is in turn applied to a mixer 523. The fourth output on lead 514 is applied to the combiner circuit 520 and is combined with the rf signal for modulation control of the optical transmitter 550.

6

Received signals are received at the diversity "0" and diversity "1" receiving antennas on leads 530 and 531, respectively. The diversity "1" signal on lead 531 is applied to a filter 533, and coupled, via amplifier 534, to the mixer 523. The mixer 523 combines the diversity "1" signal with the output of local oscillator
5 frequency synthesizer 522 and applies the resultant difference signal to the bandpass filter 538 tuned to pass the difference signal. The output of the bandpass filter 538 is applied to the combiner circuit 520.

The received diversity "0" signal is applied to the filter 541 and the filtered output is coupled by an amplifier 543 to the combiner circuit 520. The
10 output of combiner circuit 520 is applied to the automatic gain control amplifier 545 whose output is in turn applied to an optical transmitter 550 connected by the optical fiber link 551 to the base station. A parallel connecting loop including detector 557 and filter 558 also connects the level control of the agc amplifier 545 to the back face monitor 546 of the optical transmitter 550.



7

Claims:

1. A method of synchronizing a plurality of rf circuits included at a plurality of remote transceiver stations to a reference frequency provided at a common base station in a cellular radiotelephone system, including (a) combining a
5 reference frequency signal with rf signals at the base station to create a composite signal, (b) driving a base station frequency synthesizer with the reference frequency signal, (c) transmitting the composite signal to the plurality of rf circuits at the plurality of remote transceiver stations, (d) extracting the reference frequency signal from the received composite signal in each of the plurality of remote transceiver
10 stations, (e) driving a remote station frequency synthesizer with the reference frequency signal extracted from the composite signal in each of the plurality of remote transceiver stations, (f) combining the reference frequency signal extracted from the composite signal with received radiotelephone signals at each of the plurality of remote stations to create a received composite signal, (g) transmitting the
15 composite signal to the base station, and (h) extracting the received radiotelephone signals from the composite signals.
2. A method as claimed in claim 1 including (i) applying the composite signal to a laser to generate a composite light signal in the light spectra, and wherein (c) includes transmitting the composite light signal over light fiber cable to the
20 plurality of rf circuits at the plurality of remote transceiver stations.
3. A method as claimed in claim 2 wherein (d) includes extracting the reference frequency signal from the composite light signal in each of the plurality of remote transceiver stations, (f) includes combining the reference frequency signal extracted from the composite light signal with received radiotelephone signals at
25 each of the plurality of remote stations to create a received composite signal, and the received composite signal is applied to a laser to generate a received composite light signal in the light spectra.
4. A cellular radiotelephone system including apparatus for synchronizing a plurality of rf circuits included at a plurality of remote transceiver
30 stations to a reference frequency at a common base station, the apparatus including, at a base station, an input for accepting rf signals; an input for a reference frequency signal; and a combiner for receiving the rf signals and the reference frequency signals and combining them into a first composite signal; a remote transceiver



station; transmission means connecting the base station to the remote transceiver station and connected to transmit the first composite signal to the remote transceiver station; a receiver at the remote transceiver station operative for separating the reference frequency signal from the first composite signal; rf signal reception

5 apparatus for receiving radio signals, including a first diversity antenna and a second diversity antenna; a frequency synthesizer connected to accept the reference frequency signal of the first composite signal from the receiver and generate a down converted rf signal from a received rf signal received at the first diversity antenna and apply the down converted rf signal to a signal combiner; the rf signal reception

10 apparatus serving to connect a received signal from the second diversity antenna to the signal combiner for generating a return composite signal from the received rf signal and the down converted rf signal; an output of the signal combiner being connected to a signal transmission means connected to a transmission link coupling the remote transceiver station to the base station; and a receiver at the base station

15 connected to the transmission link and circuitry for separating the rf signals from the return composite signal.

5. A system as claimed in claim 4 including a laser device connected to the combiner and operative for converting the first composite signal into a composite light signal.

20 6. A system as claimed in claim 5 wherein the transmission means includes light fiber cables connecting the base station to the remote transceiver station and connected to transmit an output of the laser device to the remote transceiver station, and the receiver at the remote transceiver station includes an optical signal receiver at the remote transceiver station operative for separating the

25 reference frequency signal from the composite light signal.

7. A system as claimed in claim 6 wherein an output of the signal combiner is connected to an optical transmitter connected to an optical fiber link coupling the remote station to the base station, and there is provided an optical receiver at the base station connected to the optical link and circuitry for separating

30 the rf signals from the return composite signal.

8. A method of synchronizing a plurality of rf circuits included at a plurality of remote transceiver stations to a reference frequency provided at a



9

common base station in a cellular radiotelephone system, substantially as herein described with reference to the accompanying drawings.

9. A cellular radiotelephone system substantially as herein described with reference to the accompanying drawings.