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(54) Title: MOBILE COMMUNICATIONS EQUIPMENT

(57) Abstract

Mobile telecommunications equipment comprising a vehicle mounted mobile base unit (2) and a number of portable units (1) which may comprise portable telephones. The first and second units (2) are interconnected by a communication link (4), the units including a microprocessor (8) which senses characteristics of the communication link (4), the equipment further including feedback and control means (5, 8) for adaptive control of the link in accordance with the communications environment.
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MOBILE COMMUNICATIONS EQUIPMENT

The present invention relates to mobile communications equipment and finds particular application in systems incorporating mobile or portable radio telephone units.

Mobile communications equipment is known which comprises a telephone switching system or network, for instance the public switched telephone network, by means of which mobile or portable radio telephone units can communicate. Each unit can usually communicate, via the switching system or network, either with another mobile unit or with a fixed conventional telephone unit such as a wired subscriber's telephone. To establish communication between the mobile unit and the network, a radio or similar link is generally provided between each mobile unit and the switching system or network.

A potential problem arises however in that if two or more mobile units are operative within communication range of each other, interference or
possibly "eavesdropping" can occur.

This problem has been overcome in particular environments in the past by various means. For instance, in cellular telephone systems, an area served by a telephone network is divided into cells and a fixed network transceiver is allotted to each cell. Mobile units within a cell access the network by communicating with the fixed transceiver by means of allotted frequency channels. Allotment of the channels is centrally controlled by the network.

The above solution is acceptable within the constraints of a cellular telephone system. Channel allotment within each cell, and the size of the cells, can be tailored to local conditions. Hence in crowded geographical areas, each cell will be relatively small and, if possible, will have a high number of channels allocated to it. Conversely, in a sparsely populated area, each cell will generally be substantially larger.

However, there are communication environments in which such central control of channel allotment, and the predetermined manner in which the cells are designed, are inappropriate.

As well as interference between mobile units, other problems have been recognised such as local variations in transmission conditions. Indeed, communications equipment may be required to operate in a communication environment which can be rendered hostile by any of the following:

i) initial interference between neighbouring RF links;

ii) interference from external sources;

iii) interference due to multipath transmission (which can occur for instance due to
reflections in the path of the RF link);

iv) signal fading (which can occur for instance due to obstructions moving into the path of the RF link).

Various solutions have been put forward, including the use of directional antennae or leaky transmission lines as variations of the transmission link. However, such solutions are limited to use in a relatively controlled or predictable environment, such as within a building or for generally small scale communication systems.

A further constraint on equipment employing mobile or portable units is that they may have to conform to stringent size, weight, power consumption and cost constraints, as well as offering the user a degree of communications privacy.

An object of the present invention is to provide mobile communications equipment in which the above problems are ameliorated, and which can be designed to meet the above constraint.

According to a first aspect of the present invention there is provided mobile communications equipment comprising a first, mobile unit incorporating transceiving means, and a second unit incorporating transceiving means and connection means for connecting the second unit to a telephone switching system or network, the transceiving means of the first and second units being adapted for establishing a communication link between them, wherein either the first, mobile unit or the second unit further incorporates a sensor for sensing characteristics of the communication link, and the equipment further comprises feedback and control means for controlling aspects of said link in
response to the sensed characteristics, such that the
link is adaptive in accordance with its
communications environment.

The link may comprise a radio communications
link.

Preferably the characteristics sensed by the
sensor include characteristics of the link after it
has been established, such that the link is
dynamically adaptive in accordance with its
communications environment.

The characteristics sensed by the sensor may
advantageously include the level of interference
associated with the link and/or the signal power
being received over the link.

Such communications equipment can be used in
a variety of environments and in particular it can be
used where the environment relevant to the
communication link is likely to vary. Thus it is
particularly useful where the second unit may be
connected to any of a variety of points in a
gerographically dispersed telephone switching system
or network, such as the public switched telephone
network, since the equipment can automatically and
immediately provide an acceptable quality of
communication link, within reasonable limits,
regardless of the local conditions under which the
link must be established.

Additionally, it is particularly useful
where the number and mobile nature of the units in a
mobile communications arrangement means that the
number of communication links established in a small
area can vary substantially. For instance, in any
area which attracts a crowd it is possible that a
large number of mobile units will be brought together
and operated at the same time and in the same locality. It is not necessarily convenient or possible to predict where such a crowd might gather and then to provide equipment according to a centrally organised system of known type, that will give acceptable facilities under widely varying conditions. However, equipment according to embodiments of the present invention can detect the effect of a change in local occupancy and adapt its manner of operation to avoid interference between competing communication links.

Preferably the communication link established between the transceiving means of the first and second units is coded according to a spread spectrum technique (SST) wherein transmission is based on a broadband frequency regime. Instead of employing tightly controlled, narrow frequency band carriers to provide separate channels for neighbouring communication links, as is known for instance in cellular telephone systems, each channel is differentiated by modulation of the carrier frequency according to a predetermined code. For instance, the modulation might comprise frequency hopping between two or more specified frequencies. Such techniques have an inherent advantage in that low signal power at any single frequency may be used, which significantly reduces interference with or by other equipment. Additionally, the number of channels available, defined by unique and distinguishable codes, is considerably greater than when channels are defined by narrow frequency bands.

Clearly, embodiments of the invention may include arrangements wherein the first and second units are both mobile and indeed the adaptive quality
of such embodiments is then of enhanced importance.

Both the first and second units may include a sensor for sensing characteristics of the communication link established between them, linked to the feedback and control means.

A particular aspect of an SST communication link which may be controlled by the control means is the SST code assigned to it. In the case where two established communication links move closer to one another as a result of movement of at least one of the associated units, and begin to interfere because their allocated codes are not sufficiently distinguishable, the control means may instigate a "back-off" procedure whereby the allocated codes are changed so as to eradicate the interference.

Communications equipment according to embodiments of the present invention will now be described, by way of example only, with reference to the accompanying Figures in which:

Figure 1 shows a schematic diagram of communications equipment according to an embodiment of the present invention, for use with a cellular telephone system;

Figure 2 shows a block diagram of elements of a transceiving unit for use in the equipment of Figure 1;

Figure 3 shows in more detail selected elements of the unit shown in Figure 2, including transmitting, receiving and correlating means;

Figure 4 shows a block diagram of steps performed under the control of a microprocessor in converting an audio voice signal for supply to the transmitting means of Figure 3;

Figure 5 shows in greater detail a switch
shown in block form in Figure 3;
Figure 6 shows in greater detail a single side band up-
converter shown in block form in Figure 3;
Figure 7 shows in greater detail an oscillator and
audio input shown in Figure 3;
Figure 8 shows schematically the control process of a
microprocessor shown in block form in Figure 2;
Figure 9 shows frequency responses of components of the
oscillator and audio input shown in Figure 7;
Figure 10 shows a modified system of the invention;
Figure 11 illustrates in more detail some of the
receiver components of Figure 10; and
Figure 12 shows still further detail of some of the
carrier detection and AGC components of Figure 11.

Referring to Figure 1, a particular form of the
communications equipment may comprise two mobile
transceiving units, one of which is a base unit 1 having
coupling means 3 for direct or indirect connection to a
telephone switching system or network, and the other of
which is a remote unit 2 carried by a user. The coupling
means 3 may for instance comprise an audio port for
communication via a cellular telephone with a fixed base
station of a cellular telephone network, or a plug for
direct connection into a PSTN.

Communication between the two mobile units 1, 2 takes
place over a radio frequency (RF) communication link 4
established under the control of either mobile unit 1, 2 and
monitored by both units 1, 2. The RF link 4 exploits SST
signalling and data is sent in packet format, time division
multiplexed, with identifying address information to alert
the remote unit 2.

In a particular embodiment, the overall manner in which
the communications equipment may be used is as a "pocket
radio" link for application as a
remote extension of a vehicle-based cellular telephone. The base unit 1 receives the audio output of the cellular telephone and converts it for retransmission by means of the RF link 4 to the remote unit 2 which may be a selected one of a plurality of remote units 2.

The RF link 4 can be described as a half duplex, spread spectrum link which relies on code diversity and time division multiplexing to permit communication between two mobile units 1, 2 regardless, with reason, of the proximity of other mobile units sharing the same spectrum. The base unit 1 is usually attached to a vehicle while the remote unit 2 is carried by a user. Both mobile units 1, 2 comprise substantially the same components and monitor the communications environment before and after an RF link 4 has been established. An RF link 4 is established using time slot and SST code assignment performed by consensus between the mobile units 1, 2 on a predetermined "protocol" or "supervisory" channel.

Referring to Figure 2, each mobile unit 1, 2 can be considered to comprise a transmitter 5 and a receiver 6 which both operate under the control of a microprocessor 8 with input/output control elements. A digitiser 9 and a digital/analogue conversion unit 95 interface the microprocessor 8 with a microphone (audio input) 10 and a loudspeaker (audio output) 11 respectively.

Referring to Figures 2 and 3, each unit 1, 2 is operated in transmit or receive mode under the control of a transmitter/receiver (T/R) switch 7 which in turn is controlled by the microprocessor 8 associated with that unit. The switch 7 is shown in
further detail in Figure 5. It is a standard component, based on a pair of PIN diodes 20, 21, with a control voltage input 100 from the microprocessor 8 which is high when transmit mode is selected and low when receive mode is selected.

Referring again to Figures 2 and 3, the transmitter 5 is provided with a pair of frequency modulated sources (oscillators) 12 operating 1 MHz apart. Each oscillator comprises a known surface acoustic wave (SAW) device designed to oscillate at a frequency of the order of 900 MHz. When the T/R switch 7 puts the relevant mobile unit 1 or 2 into transmit mode, the outputs of the two oscillators 12 are alternately connected to a transmitting antenna 15, via suitable amplifiers 16, 17, according to a predetermined pseudo-random sequence which can be reconstructed by the receiver 6. The selection process effectively impresses a high frequency, frequency modulation (FSK) on the signal FM carrier and spreads the transmitted spectrum in accordance with the speed and characteristics of the chosen pseudo-random sequence.

Referring to Figures 7 and 8, audio modulation is applied to each oscillator 12 via the summing input of an operational amplifier 84 in an oscillator arrangement 85 which also maintains the centre frequency of the oscillator. The arrangement provides a voltage controlled oscillator (VCO) and a phase detector which together provide a phase locked loop (PLL).

The VCO comprises a transistor 71, delay lines 72 and a varactor diode 73. The phase detector comprises a prescaler 74, which operates on the frequency of a crystal oscillator 75 to multiply it
by 256 via an exclusive OR gate 76, and a low pass filter, or op-amp, 77. The phase detector detects the difference in phase between the VCO output and the crystal oscillator 75 and a resultant error voltage drives the loop via the low pass filter 77.

The low pass filter 77 of the loop is designed to have a cut-off frequency 78 of 100 Hz, whilst the audio modulation has a bandwidth 79 in the range from 5 KHz to 50 KHz. This provides mutually exclusive filtering such that the loop response is not fast enough to affect the audio input, and the audio modulation applied to the summing input of the operational amplifier 84 does not interfere with the basic loop operation. This allows the centre frequency of the oscillator to be maintained during the application of the modulation.

When the relevant mobile unit 1 or 2 is put into receive mode, the same pair of oscillators 12 are used as local oscillators for the receiver 6, but offset in frequency by means of a single side band (SSB) up-converter 18 to permit the use of a moderately high first intermediate frequency (IF). The receiver 6 otherwise comprises the elements of a standard heterodyne receiver, supplemented by components 6A for use in synchronisation, and connections to the microprocessor 8 for use in monitoring the communications environment.

Referring to Figure 6, the SSB up-converter 18 comprises a standard component based on a 35 MHz crystal oscillator 22 and configured to eradicate all but a single sideband. Two buffers 23, 24 prevent unwanted reflections of the up-converter output, for instance into the transmitter 5. The crystal oscillator 22 is gated to operate when the unit 1 or
2 is in receive mode only, by means of a control input 25 from the microprocessor 8.

Referring to Figures 2, 3 and 4, when the mobile unit 1 or 2 is in transmit mode, the digitiser 9, microprocessor and input/output control elements 8 convert a speech signal input to the microphone 10 to the signal FM carrier on which the oscillators 12 impress the SST pseudo-random sequence. The conversion is performed in a series of steps (80 to 83) under the control of the microprocessor 8. These steps comprise:

i) digitising the speech signal from the microphone 10;
ii) formatting and storing data packets from the digitised speech signal, each packet having framing and synchronisation bits added;
iii) high speed playback of the stored packets so that each one is time-compressed relative to the directly digitised speech signal; and
iv) conversion of the data packets to an 8 bit (256 level) "analogue" form for frequency modulation of the input to the oscillators 12.

When the mobile unit 1 or 2 is in receive mode, the same steps are effectively reversed at the audio output 19 of the receiver 6.

Overall, the operation of the communications equipment is as follows.

When a mobile base unit 1 is operated by a user to establish a communication link 4 with a mobile remote unit 2, it alerts the remote unit 2 by transmitting on a fixed supervisory channel. Both units 1, 2 select by consensus a free channel for voice transmission and subsequent transmission takes
place via the selected channel. Channels, including the supervisory channel, are distinguished by the SST pseudo-random sequence associated with them.

In more detail, during voice transmission from the base unit 1, a speech signal at the microphone 10 is operated on according to steps i) to iv) described above. Thus it is acquired in real time, digitised and stored in a "frame" in a buffer allocated to the transmitter 5, with added framing and synchronisation bits. When a transmission command is activated, the prepared packet of data is read out of the buffer at approximately 16 times the acquisition rate, converted back to an 8 bit (256 level) "analogue" form and output to frequency modulate the two RF oscillators 12 at rates in the range of 5 KHz to 50 KHz, with a maximum deviation of approximately 50 KHz.

The 256 level "analogue" form used to modulate the oscillator is a known signalling technique in which the signal value is allowed to take one of 256 levels during a sampling interval.

The above arrangement permits the use of 8 rather than 16 system time slots since each channel selected must have two time slots assigned to it to achieve two-way communications. Typical packet length may be selected to be 10 m sec, corresponding to 160 m sec of acquired audio, so as to maintain conversation continuity without allowing synchronisation and propagation delay overheads (up to 10 micro sec.) to become significant.

The frequency modulated RF output from the oscillators 12 would be capable of being transmitted through a channel 300 KHz wide. However, this spectral occupancy is spread by the imposing of the
SST pseudo-random frequency hopping sequence to a channel as wide as relevant authorities may make available. In Australia, this means a channel 13 MHz wide while in the United States, this means a channel 26 MHz wide.

The frequency hopping can occur at clocking rates of up to approximately 6 MHz in Australia and 12 MHz in the United States. It has the effect of spreading the transmission spectrum in two ways, firstly because two frequencies are applied but more significantly because the frequency hopping itself generates a series of sidebands representing harmonics. The receiver, on receiving such a signal and being synchronised thereto will then reconstruct the original audio RF modulation but will further spread any interference effects or noise which is not frequency hopped according to the selected sequence.

There are known code sets for use as pseudo-random sequences in signalling which offer a range of codes sufficiently orthogonal to be clearly distinguished. One such set of codes are known as Gold codes and it is proposed to use Gold code sequences of 127 clock periods in communications equipment according to the present invention. There are 129 such distinguishable Gold code sequences and one of these is reserved for the supervisory channel, leaving 128 channel codes. The code repetition period (127 clock periods at 6 MHz or 12 MHz clocking rate) is thus 21 micro sec. in Australia and 10.56 micro sec. in the United States.

The selection of Gold code sequences of 127 clock periods represents a compromise between the number of channels this makes available in addition to the supervisory channel (128 x 8 time slots = 1024
channels), and the maximum acquisition time necessary for the receiver to establish synchronisation. In order to establish synchronisation from a cold start, the receiver code sequence is time shifted and correlated through 1/2 clock period increments, that is at 2 x 127 = 254 locations in the code sequence. These operations can be performed sequentially by hardware, using a synchronisation detector having a rise time commensurate with the code repetition period, and hence total synchronisation time is of the order of 254 x 21 micro sec = 5.3 m sec in Australia and 254 x 10.56 microsec = 2.7 m sec in the United States. Thus the synchronisation time of the receiver 6 is less than the time taken to transmit a single data packet.

The SST coded packet is amplified and applied to the antenna 15 for transmission as an RF signal. Output power is controlled by the microprocessor 8 to provide an adequate signal to noise ratio at the receiver 6, so as to use the minimum power commensurate with an acceptable standard of communication.

At the receiver 6 of the remote unit 2, receiving the above RF signal, the local oscillation is frequency hopped using the same Gold code as that impressed on the RF signal by the base unit 1. The local oscillation is provided by the oscillators 12 of the remote unit transmitter 5, up-converted by 35 MHz to give a first IF of 35 MHz. The RF signal received at the antenna 15 is applied to a preamplifier 30 through the T/R switch 7 and mixed at a DBM 142 Vari L mixer 31 with the frequency hopped local oscillation which is hopped in synchronisation with the oscillators at the base unit 1 which has
generated the RF signal.

The output of the mixer 31 is thus a despread IF signal at 35 MHz and can be demodulated by a standard IF discriminator 32.

The power output of the IF filter/amplifier 33, 34 is indicative of the signal to noise ratio of the incoming RF signal, and of the degree of synchronisation between the two units 1, 2, and can therefore be used for diagnostic purposes. Additionally, if the modulating sequence is deliberately dithered in the time domain (shifted repeatedly to and fro in time), synchronisation can be maintained by monitoring the effect of the dither.

As mentioned above synchronisation from a cold start is achieved by the known technique of sweeping the receiver code sequence and looking for a match with the code sequence of the RF signal. More specifically, the receiver code sequence is time shifted by 1/2 clock period increments, under the control of the microprocessor 8, and the received power observed. Synchronisation is indicated by maximum power as shown by the output of a correlation score registered in the microprocessor in accordance with the received RF signal power. In general, such a process is also known as "acquisition from a cold start".

With regard to maintaining synchronisation once established, the code sequence applied at either the transmitting unit 1 or the receiving unit 2 is periodically advanced and retarded (dithered). It is then possible to monitor received power and detect when the two sequences are moving out of synchronisation since when they are synchronised, two power peaks will be observed evenly spaced during
each dither period. As synchronisation begins to slip, the two power peaks will become unevenly spaced until eventually only one power peak is observed.

In addition to the above acquisition and synchronisation monitoring facilities, it is of course possible to provide standard error detection and correction procedures, including automatic packet retransmission on request, under the control of the microprocessor 8 and as extensions of the described manner of operation.

During the establishment, course and termination of a call, the communications equipment uses the supervisory channel in a series of different ways. This embodies a controlling protocol for call initiation, duration and termination. The use of the supervisory channel is as follows.

Protocol - (Supervisory) Mode Operation

a) Sleep Mode

This mode is reserved for the period when no calls have been or are about to be initiated and involves monitoring of the electromagnetic environment by each receiver, with analysis of traffic and/or interference on each channel. This results in a prioritization of favourable channels in readiness for call initialization.

If required, synchronization pulses can be sent and received at periodic intervals on the supervisory channel and status of the link and operational hardware verified in anticipation of call requests.

b) Initialization Mode
This mode is used to establish call initiation by use of the supervisory channel. The first objective is to prepare both units 1, 2 for an orderly data transfer. This includes the decision on a mutually agreeable code, verification of hardware operation and synchronization, advance information regarding imminent data transfer and the decision as to which unit 1, 2 will go first into transmit mode. Diagnostics relating to the quality of the link can be gathered e.g. fades and multipath and corrective action taken as required.

c) Data Transfer Mode

Although the major task being performed in this mode is associated with the act of communication, there are certain supervisory activities which also have to be sustained. In particular, the system must maintain vigilance in order to prevent contention problems from arising (it being possible for units to establish contact under benign conditions and then to drift into each other's zones as a result of user motion). Contingency measures such as back-off and reassignment have to be implemented and coordinated in order to avoid crosstalk. Automatic retransmission on request can be employed to retransmit corrupted data if appropriate. On call termination, the supervisory operations return to sleep mode. Overall however, in data transfer mode the supervisory channel is left substantially free for use by other, independent users.

Referring to Figures 2, 3 and 8, as described above, the operation of the communications
equipment is under the overall control of the microprocessor 8. This control is implemented as follows.

Signals to be output from the transmitter 5 require application of a code sequence whether relevant to a supervisory channel or to a data transfer channel. The microprocessor 8 determines the code sequence to be applied and controls an electrically programmable logic device (EPLD) 41 to supply the selected code sequence to the oscillator pair 12. The digitised signal is formatted and stored in a transmitter (TX) buffer 42, from which it is read out at 16 times the acquisition rate under a clock control input 43 from the microprocessor 8. The 8 bit (256 level) "analogue" conversion is then performed on the high speed read out from the buffer 42 and the signal is supplied to the "Audio Modulation Data In" terminal 44 of the transmitter 5.

The microprocessor 8 also controls the output power of the transmitter 5, via the power amplifier 17 between the transmitter 5 and the T/R switch 7. It does so by means of a charge pump 90, that is, a gated integrator, as known for instance for use in remote control of television loudness or brightness.

In the receive mode, the microprocessor 8 receives the output of the IF discriminator 32, again via a digitiser 46. It also receives power information from the RF signal at correlation and dither inputs 47, 48 for use in establishing and monitoring synchronisation.

The code sequence to be applied for despread the signal is again determined by the microprocessor 8 and applied to the oscillator pair.
12, and thus to the local oscillation for the receiver 6, by means of the EPLD 41.

The received signal packets are then transferred to a receiver (RX) buffer 49 and read out at low speed (divided by 16) to provide a re-expanded output signal for analogue conversion, filtering, and playback at the audio output 11.

The microprocessor 8 controls the receiver gain at the IF amplifier 34, again by use of a charge pump 91, and determines whether the associated unit 1, 2 is in transmit or receive mode by two further dedicated control outputs 92, 93.

Overall, embodiments of the present invention provide a secure, adaptive form of communication which can be used in a wide range of environments. A range between mobile units 1, 2 of from 2.5 km to 10 km in free space can be achieved, with the ability to offer more than 1000 independent channels. The mutually orthogonal Gold codes selected lend themselves to unscannable communication far superior for security purposes to narrow frequency band communication.

Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention as hereinbefore described with reference to the accompanying drawings.

Standard techniques such as dialling processes, and details of actual signal processing steps such as digitising, delta modulation, data compression and silence detection, are not described since these are all known techniques and steps. Further, it will be clear that specific part numbers or values indicated on the drawings should not be treated as essential features of the invention.
Mobile units 1, 2 for use in equipment according to embodiments of the invention can be designed to fit the stringent requirements of size, weight, power consumption and cost constraints that may be applied to a portable, hand-held communications unit while at the same time offering good quality, secure communication in a wide range of environments. The adaptive power and gain control minimises the overall electromagnetic disturbance created by the units while the signalling regime described provides enhanced resistance to fading and interference and multipath rejection.

By implementing short duty cycles, it is possible to conserve battery life.

Figures 10, 11 and 12 illustrate an alternative embodiment of the invention. The same reference numerals have been used to denote parts which correspond to those of the previous embodiments.

Figure 10 generally corresponds to the system illustrated in Figure 3. The principal difference however is that the pair of frequency modulated sources 12 of Figure 3 is replaced by a carrier oscillator 200 which has a frequency of 921.5 MHz the output of which is coupled to an FM modulator 202. The modulator 202 receives input from the digital to analog converter 45 which corresponds to the same element in Figure 8. Output from the modulator 202 passes to a bi-phase modulator 204 which also receives input from a pseudo-random noise code generator 206 which in turn receives input from an oscillator 208 which has a frequency of 26 MHz. The bi-phase modulator 204 corresponds generally to the switch 13 of Figure 3 except that instead of switching between the frequencies of the oscillators 12, the modulator 204 reverses the phase of the signal from the FM modulator 202. The resultant signal passes through the
amplifier 17 and switch 7 to the antenna 15. The signal is analogous to a DSB suppressed carrier signal.

The receiver 6 is again similar to the receiver arrangement illustrated in Figure 3 except that the receiver has its own oscillator 210 having a frequency equal to the sum of the carrier and intermediate frequencies i.e. 956.5 MHz. Its output is coupled to a bi-phase modulator 212 connected to the despreading mixer 31. The modulator 212 and intermediate frequency amplifier 34 are controlled by a code tracking loop 214 which is functionally equivalent to the up-converter 18 of Figure 3. The code tracking loop 214 includes a clock generation and control circuit 216 the output of which is coupled to a PN code generator 218 the output of which is, in turn, connected to a dither generator 220. The circuit 216 includes a dither clock output 219 which is also connected to the generator 220. Output from the generator 220 is inputted to the bi-phase modulator 212 as shown in Figure 10. The loop 214 also includes a carrier detection and AGC circuit 224 which corresponds generally to the component 6A of Figure 3.

Figure 11 illustrates in more detail the code tracking loop 214. This circuit could be implemented in a variety of ways and the circuit illustrated is by way of example only.

Figure 12 shows one circuit realisation for the circuit 224. The circuit includes an integration control logic circuit 230 the truth table of which is set out below.
TRUTH TABLE FOR INTEGRATE CONTROL LOGIC 230

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The operation of the arrangement of Figure 10 is similar to that of Figure 3 and therefore need not be described in detail. Briefly its operation is as follows.

During transmission, the information signal (voice or data) from D/A converter 45 frequency modulates a carrier at 921.5 MHz from oscillator 200. The resulting signal is bi-phase modulated in modulator 204 by a PN code sequence generated by the PN code generator 206 at a rate of 6.5 MHz. The resulting spread spectrum signal is amplified by amplifier 17 and transmitted via the antenna 15 to the receiving unit. Transmission power is controlled by means of manual adjustment of the transmitter power amplifier gain.

At the receiver, the received spread spectrum signal received by the antenna 15 is filtered and amplified before being despread by the receiver's local reference code sequence in mixer 31, which is synchronized to the transmitted modulating code. The resulting despread signal...
is FM demodulated by discriminator 32 to recover the
original information signal at output 19.

During signal reception, carrier detection circuitry
provides signal diagnostics to the microprocessor 8, which
uses the information to take adaptive measures, thereby
maintaining overall system performance.

The microprocessor 8 issues control signals to the
clock generation and control circuitry 216, to control the
phase and frequency of the receiver's code generator for
code synchronization.

The code tracking loop 214 performs three basic
functions:
  1. Initial Synchronization
  2. Tracking
  3. Automatic Gain Control

During initial synchronization, the receiver 6 is
receiving a maximal length code modulated carrier, sent by
the transmitter. To acquire synchronization, the receiver
performs a phase search of its local reference code sequence
until the point of maximum correlation is found. The phase
searching process is controlled by the microprocessor 8,
with code phase shifts initiated by means of "retard" and
"advance" control signals.

The phase search process consists of acquiring the
level of correlation for each 0.5 bit phase shift of the
local reference code sequence over the entire length of the
code sequence. The carrier level provides an indication of
the level of correlation and is made available to the
microprocessor 8, using a square law detection circuit 232
and low pass filter 234, as an analog signal to be sampled
and digitized. The carrier detection circuitry comprising
the square law detector circuit 232 and low pass filter 234 is also shown in circuit realisation of Figure 12.

For a cordless telephone extension the remote unit is generally the same as that described previously and the base unit 1 would be adapted to directly connect to the public switched telephone network.

Although the embodiment described above operates in relation to audio signals, any relatively slow data input could be transmitted on an RF link according to the above arrangement.
CLAiMS

1. Mobile communications equipment comprising a first, mobile unit (2) incorporating transceiving means (5,6), and a second unit (1) incorporating transceiving means (5,6) and coupling means (3) for connecting the second unit (1) to a telephone switching system or network, the transceiving means of the first and second units being adapted for establishing a communication link (4) between them, wherein either the first, mobile unit or the second unit further incorporates a sensing means (6,8), for sensing characteristics of the communication link (4), and the equipment further comprises feedback and control means (5,8) for controlling aspects of said link (4) in response to the sensed characteristics, such that the link is adaptive in accordance with its communications environment.

2. Mobile communications equipment according to claim 1 wherein said sensing means senses characteristics of the link after the link has been established, such that the link is dynamically adaptive in accordance with its communications environment.

3. Mobile communications equipment according to either preceding claim wherein said characteristics comprise a level of interference or noise associated with the link.

4. Mobile communications equipment according to any preceding claim wherein said characteristics comprise signal power being received over the link.

5. Mobile communications equipment according to any preceding claim wherein said coupling means comprises means for connecting the second unit to a low data rate port of a telecommunications network.

6. Mobile communications equipment according to claim 5
wherein said port comprises an audio input/output port.

7. Mobile communications equipment according to any preceding claim wherein said coupling means comprises means for connecting the second unit to a public switched telephone network.

8. Mobile communications equipment according to any preceding claim wherein said coupling means comprises means for connecting the second unit to an audio input/output port of a cellular telephone system.

9. Mobile communications equipment according to any preceding claim wherein said second unit is mobile.

10. Mobile communications equipment according to any preceding claim wherein said first unit is a portable, handheld unit.

11. Mobile communications equipment according to claim 10 wherein said first unit incorporates said sensing means.

12. Mobile communications equipment according to any preceding claim wherein either the first unit or the second unit comprises said feedback and control means.

13. Mobile communications equipment according to any one of claims 1 to 11 wherein said first unit and said second unit together comprises said feedback and control means.

14. Mobile communications equipment according to any preceding claim wherein said first unit and said second unit each incorporate a sensor for sensing characteristics of the radio communication link once established, and said feedback and control means controls aspects of said link in response to the output of both sensors.
15. Mobile communications equipment according to claim 14 wherein said feedback and control means comprises a microprocessor which receives and analyses the output of the sensors.

16. Mobile communications equipment according to any preceding claim wherein said aspects of the link comprise power and gain levels of the respective transceiving means of the first and second units.

17. Mobile communications equipment according to any preceding claim wherein said first and second units comprise means for selecting a communication channel on which a radio communication link is to be established and said feedback and control means comprise means for changing the selected communication channel on which a link has been established.
18. Mobile communications equipment according to any preceding claim wherein said link is established by means of a spread spectrum signalling technique.

19. Mobile communications equipment according to claim 18 wherein the transceiving means of each unit comprises a plurality of oscillators having different output frequencies and spread spectrum signal transmission is achieved by switching sequentially between the outputs of the oscillators according to a preselected pseudo random code.

20. Mobile communications equipment according to claim 18 wherein the transceiving means of each unit can act either in transmit mode or in receive mode, and comprises a plurality of oscillators whose output is controlled to provide the spread spectrum signalling in transmit mode, the transceiving means operating as a heterodyne receiver when in receive mode, the output of the plurality of oscillators then being applied to the transceiving means via a frequency conversion device so as to provide local oscillation and an intermediate frequency for the heterodyne receiver.

21. A mobile unit for use in mobile communications equipment comprising transceiving means for establishing a communication link with another such unit, wherein the mobile unit incorporates a sensor for sensing characteristics of the link, and feedback and control means for controlling aspects of said link in response to the sensed characteristics, such that the link is adaptive in accordance with its communications.
environment.

22. A mobile unit according to claim 21 wherein said sensor senses characteristics of the link after it has been established, such that the link is dynamically adaptive in accordance with its communications environment.

23. A mobile unit according to either of claims 21 or 22 wherein said link is established by means of a spread spectrum signalling technique.

24. A mobile unit according to any of claims 21, 22 or 23 further comprising a switch, the transceiving means operating in transmit mode or in receive mode under the control of said switch, the transceiving means operating as a heterodyne receiver when in receive mode, the unit also comprising oscillation means whose frequency output is used directly when the transceiving means operates in transmit mode and is used via a frequency up-converter when the transceiving means operates in receive mode, the frequency up-converter providing a fixed increase in said frequency output which can be used as an intermediate frequency for said heterodyne receiver.
FIGURE 2

T/R SWITCH

TRANSMITTER

RECEIVER

MICROPROCESSOR AND INPUT/OUTPUT CONTROL ELEMENTS

DIGITISER

D/A CONVERTER

AUDIO IN

AUDIO OUT

FIGURE 2
FIGURE 4

DIGITISING

PACKET FORMATTING, STORAGE AND ENCODING

PLAY BACK (HIGH SPEED)

ANALOGUE CONVERSION

TO OSCILLATORS

MICROPROCESSOR AND INPUT/OUTPUT CONTROL ELEMENTS

8

80

81

82

83

10

12
FIGURE 7

SUBSTITUTE SHEET
FIGURE 10
INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00020

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl. 5 HO4Q 7/04, HO4M 1/72, HO4B 7/26

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System | Classification Symbols
---|---
IPC | HO4B 7/00, 7/005, 7/26; HO4M 1/72; HO4Q 1/32, 1/39, 7/04
US Cl. | 379/60, 61, 63, 56, 59

Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

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<th>Citation of Document, with indication, where appropriate, of the relevant passages 12</th>
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<td>EP,A, 244872 (NEC CORPORATION) 11 November 1987 (11.11.87)</td>
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* Special categories of cited documents: 10 "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report
---|---
1 May 1990 (01.05.90) | 9 May 1990

International Searching Authority

Australian Patent Office

Signature of Authorized Officer | R. CHIA

Form PCT/ISA/210 (second sheet) (January 1985)
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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