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(54) **Remote mains switching means**

(57) Apparatus for performing remote switching of electrical appliances by sending signals along a mains supply, consists of a transmitting station 4 which is plugged into the mains supply and which can control remote receiving stations 2 individually, the receiving stations controlling the switching of electrical power to socket outlets 2, 3 which in use supply power to electrical appliances. The signals transmitted by the transmitting station comprise bursts of an audio modulated carrier, the audio frequency being selectable to address different ones of the receiving stations. The duration of the transmitted bursts is selectable to define an enquire or a command mode. The receiving station is switched on and off successively in response to successive command mode signals. In response to an enquire mode signal, information about the switched state of the addressed receiving station is transmitted back to the transmitting station.

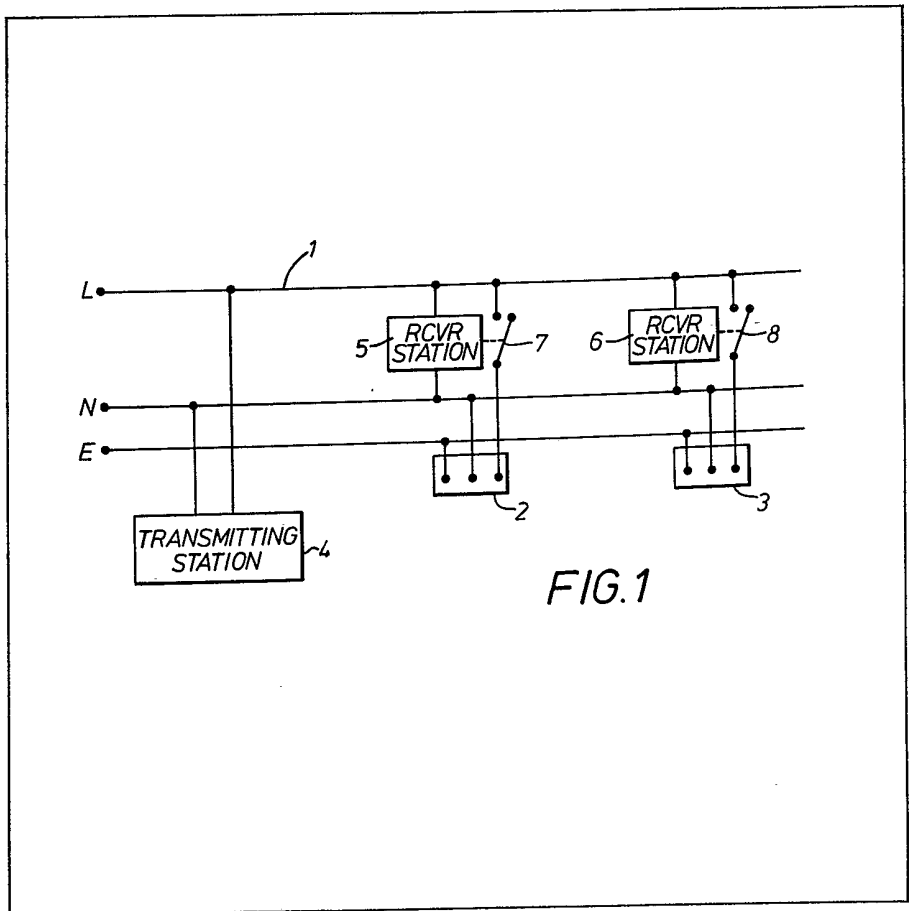


FIG.1

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

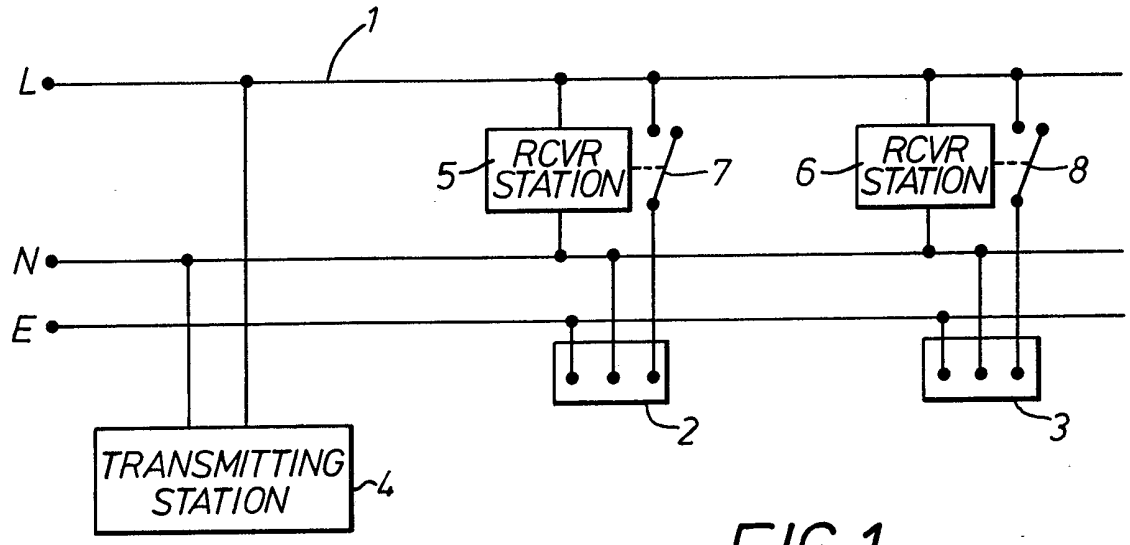

1
L
N
E
5
RCVR STATION
7
6
RCVR STATION
8
2
3
TRANSMITTING STATION
4

FIG. 1

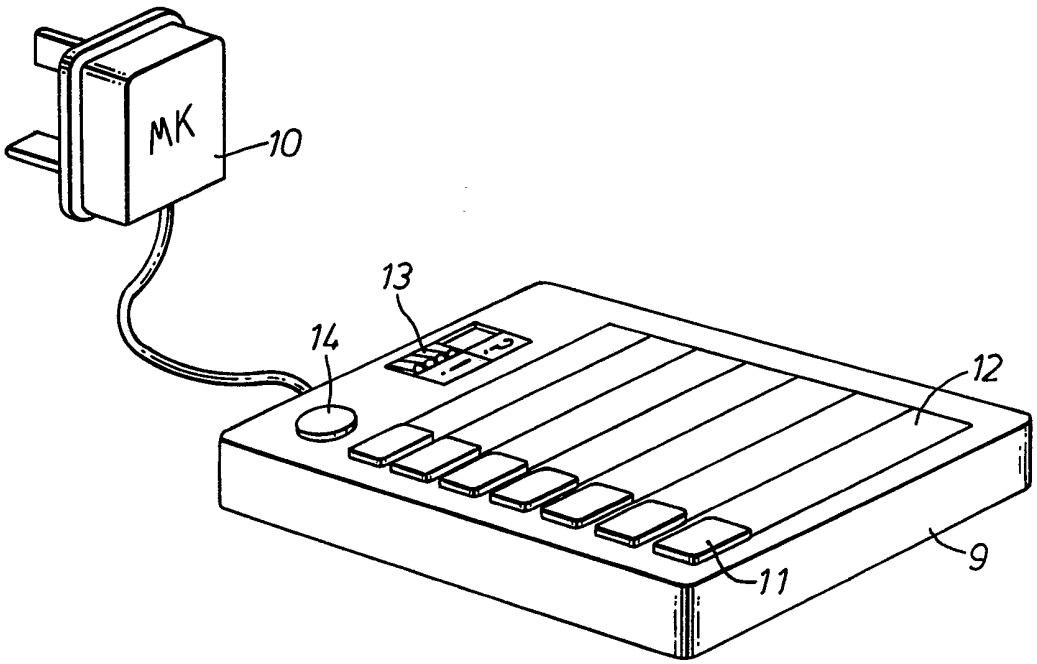

MK
10
13
14
12
11
9

FIG. 2

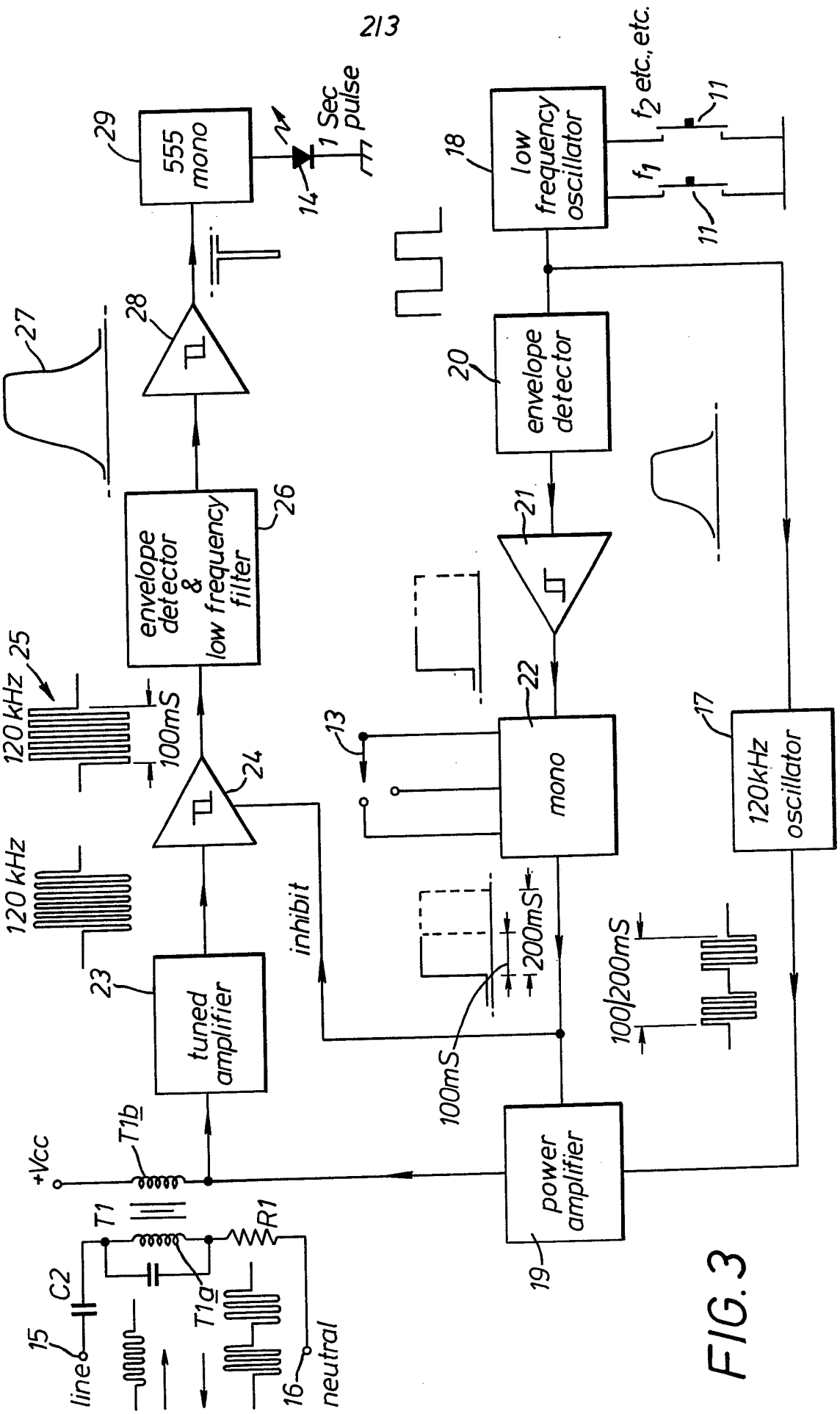

213
line
neutral
C2
T1
T1a
T1b
R1
+Vcc
tuned amplifier
120 kHz
23
120 kHz
24
inhibit
120 kHz
25
100mS
envelope detector & low frequency filter
26
27
28
555 mono
29
1 Sec pulse
14
15
16
power amplifier
19
mono
22
13
100mS
200mS
100/200mS
120kHz oscillator
17
envelope detector
20
21
low frequency oscillator
18
f1
f2 etc., etc.
11
11

FIG. 3

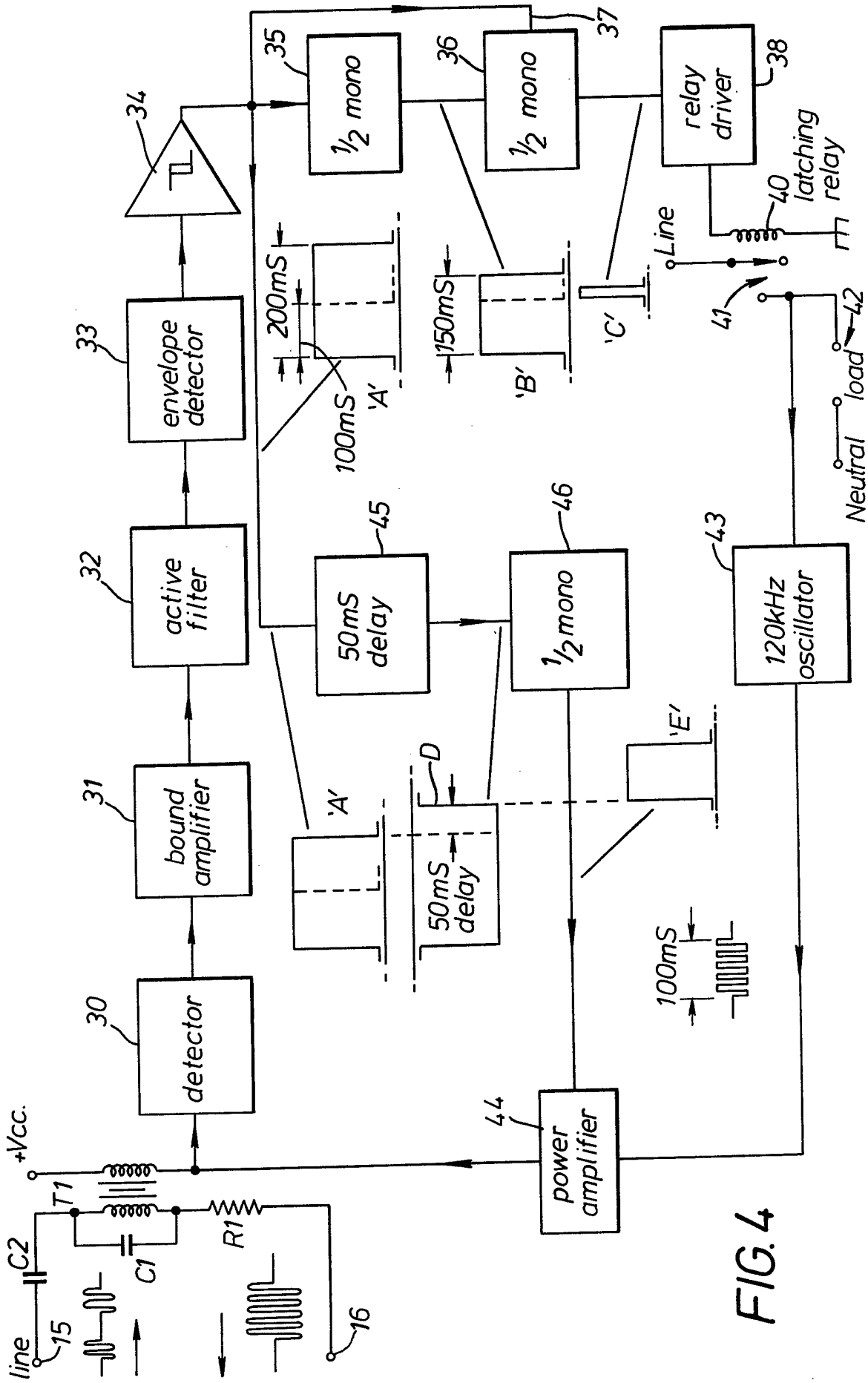

line
15
C2
C1
T1
R1
16
+Vcc.
30
detector
31
bound amplifier
32
active filter
33
envelope detector
34
35
½ mono
36
½ mono
37
relay driver
38
40
latching relay
41
42
load
Neutral
Line
200mS
100mS
'A'
150mS
'B'
'C'
45
50mS delay
46
½ mono
43
120kHz oscillator
'A'
D
50mS delay
'E'
100mS
44
power amplifier

FIG. 4

SPECIFICATION

Remote mains switching means

The invention relates to apparatus for performing remote switching of electrical appliances by transmitting signals along electrical mains supply cables.

Apparatus of this general type has been previously proposed, and one such apparatus is described in "The Intelligent Plug" N. MacArthur et al, Wireless World December 1979, pp 46-51. This apparatus consists of a central transmitter which transmits signals along the mains to decoders disposed at different socket outlets. The transmitter can address the decoders individually to allow remote switching of appliances connected to the socket outlets. The apparatus uses complex digital transmission techniques similar to those used in data processing, to code and transmit the signals along the mains. Consequently the circuits of the transmitter and the decoders are complicated and expensive to produce.

A feature of the present invention is that it provides a much simpler and cheaper apparatus for performing remote switching of electrical appliances by transmitting signals along electrical supply cables.

This and further features and advantages of the invention will appear from the following description of an embodiment thereof, given by way of illustrative example with reference to the accompanying drawings in which:

Figure 1 is a schematic block diagram of a system of the invention connected to a domestic mains supply, to perform remote switching of socket outlets;

Figure 2 is a schematic perspective view of one form of the transmitting station of Figure 1;

Figure 3 is a circuit diagram in block form of the transmitting station; and

Figure 4 is a block circuit diagram of one of the receiving stations.

Referring to Figure 1, a domestic electrical socket outlet system is shown schematically wherein electrical socket outlets receive power from a single phase A.C. supply through live and neutral leads L, N of a supply cable 1. Two socket outlets 2, 3 are shown although in practice there will be many more. Typically the socket outlets are of the conventional 13 amp type connected in a conventional ring main although the outlets can be connected "radially".

The socket outlets 2, 3 can be switched individually from a remote location by sending signals along the leads of the cable 1. To this end, a transmitting station 4 is connected to the cable 1 to send signals along the cable to receiving stations 5, 6 each associated with a respective one of the socket outlets and each arranged to operate a respective switch 7, 8 in the live supply L to the socket outlets.

One form of the transmitting station 4 is shown in Figure 2 and consists of a hand held unit 9 which is connected to the power cable 1 by means of a plug 10 that can be fitted into any of the socket outlets of the system. The unit 9 includes a row of push buttons 11 each of which is for addressing a respective socket outlet. In Figure 2 seven buttons 11 are shown although in practice more may be provided depending upon the number of socket outlets. A space 12 is provided adjacent each button 11 to receive a legend indicating the location or use of the socket outlet addressed by the button.

The unit 9 has two modes of operation which are selected by means of a slide switch 13. One mode is an enquire "?" mode. When the switch 13 selects the "?" mode and one of the push buttons 11 is depressed, a l.e.d. 14 provides an indication of whether the socket outlet addressed by the button 11 is switched on, i.e. switched to conduct power. If the outlet concerned is switched on, the l.e.d. is illuminated for a given time, for example one second.

The other mode of operation is a command "!" mode. When the switch 13 is set to select the command mode, operation of one of the push buttons causes a socket outlet to change its switching state. Thus if the outlet was switched on, it will be switched off and vice versa. The system is also arranged to illuminate the l.e.d. 14 to indicate that the command has been carried out in the event that the command is to switch on the socket outlet.

The transmitting station 4 is adapted to produce a modulated carrier signal which is transmitted along the live and neutral lines of the cable 1, to the various receiving stations 2, 3. Typically the carrier has a frequency of 120 KHz. At this frequency a typical domestic electricity network presents an impedance of about 15Ω. The carrier is modulated by keying it on and off cyclically at an audio frequency to produce which is known as tone modulation. Each push button 11 selects a different frequency of the tone modulation and each of the receiving stations 2, 3 is adapted to respond to a different one of the tone modulation frequencies. Operation of a push button 11 transmits a pulse of the tone modulated carrier. The duration of the transmitted pulse indicates whether the transmitted signal is an enquire or command signal. In this system a short duration transmitted pulse indicates a command and a long duration pulse indicates an enquire signal. The long and short signals typically have durations of 200 and 100 ms respectively. The receiving stations 5, 6 each include logic circuitry to distinguish between the long and short duration signals. Furthermore the receiving stations are adapted to transmit back to the transmitting station 4 an unmodulated burst of the 120 KHz carrier to indicate that the outlet is switched on, in response to an enquire signal, and to indicate that the socket outlet has been switched on in response to a command signal which directs the outlet to become switched on. The l.e.d. 14 (Figure 2) is illuminated in response to the transmitting station detecting the unmodulated burst of carrier.

Referring now in detail to the circuit of the transmitting station as shown in Figure 3, it is connected to the live and neutral leads of the cable 1 at 15 and 16 through a coupling circuit comprising a transformer T1 having a capacitor C1 connected in parallel with the transformer winding T1*a* to define a circuit tuned to the 120 KHz carrier frequency. The coupling circuit further includes a series connected resistor R1 and a capacitor C2 to attentuate noise from the cable 1, such as for example noise pro-

duced by light dimmer circuits.

The transmitting station includes a r.f. oscillator 17 which produces the 120 KHz carrier for the command and enquire signals, and a low frequency oscillator 18 which produces the previously mentioned tone frequencies. The oscillator 18 is actuated by the buttons 11, such that each button upon depression thereof causes the oscillator 18 to operate at a respective different frequency. The resulting burst of tone frequency oscillation produced by the oscillator 18 is fed to modulate the output of the r.f. oscillator 17 so as to produce the tone modulated signal. The tone modulated signal is fed to a power amplifier 19 which is gated on for a predetermined time (in a manner to be described hereinafter) and the amplified tone modulated signal is fed to the transformer winding T1*b* so as to be transmitted along the live and neutral leads of the cable 1.

The signal thus transmitted is coded to be an "enquire" or "command" signal by controlling the period for which the power amplifier 19 is gated on. To this end, an envelope detector 20 provides a d.c. output during the occurrence of an oscillatory output from the oscillator 18, and a Schmitt trigger 21 is arranged to produce an output in response to the leading edge of the d.c. output from the detector 20. Thus, the output from the Schmitt trigger 21 marks the commencement of a transmitted signal. The Schmitt trigger 21 fires a monostable 22 which has two periods, 100 ms and 200 ms, one of which is selected by the switch 13, to define either a command or enquire signal. The power amplifier 19 is gated on for the selected period of the monostable 22 so as to appropriately control the duration of transmission of the tone modulated carrier.

One of the receiving stations 5, 6 (Figure 1) is tuned to respond to the frequency of the tone modulation and if the transmitted signal is a "command" to switch the socket outlet on or, "enquire" when the socket outlet concerned is switched on, the receiver station will, as previously mentioned transmit a burst of unmodulated 120 KHz carrier for a period of 100 ms for example, so as to be received in the coupling circuit of the transmitting station and passed to a circuit which switches on the l.e.d. 14. This circuit consists of an amplifier 23 tuned to the 120 KHz frequency, the output of which is fed to a Schmitt trigger 24 that produces a rectangular waveform at the carrier frequency, as shown at 25. This rectangular waveform is passed to an envelope detector and low frequency filter 26. The filter removes interference received from the cable 1, such as low frequency dimmer circuit transients, and in response to a 100 ms burst of the carrier the circuit 26 will provide an output indicative of the envelope of the modulation burst, as shown at 27. A Schmitt trigger 28 fires on the leading edge of the waveform 27 so as to set a monostable 29 which applies for a predetermined period of one second for example, an appropriate voltage to the l.e.d. 14 to cause it to light.

The l.e.d. 14 is prevented from illuminating in response to operation of the push buttons 11. The Schmitt trigger 24 is gated off by the output of the monostable 22. Otherwise the transmitted carrier of the "enquire" and "command" signals would pass directly from the power amplifier 19 to the tuned amplifier 23 and cause the l.e.d. 14 to be illuminated.

The circuit of one of the receiving stations 5, 6 (Figure 1) will now be described in detail with reference to Figure 4. The receiving station is connected to the live and neutral leads of the cable 1 by means of a coupling circuit which is the same as that of the transmitting station, namely a transformer T1, capacitors C1, C2 and a resistor R1. The tone modulated carrier is thus passed from the cable 1 to a detector circuit 30 typically comprising a diode, which recovers the envelope of the tone oscillation. This envelope is fed to a bound amplifier 31 which over a normal operating range produces a constant amplitude rounded square wave corresponding to the tone modulation envelope, so as to compensate for attenuation of the transmitted signal along the cable 1. The output of the bound amplifier 31 is fed to an active filter 32, typically a bi-quadratic filter which may have a gain of 100 for example. The filter 31 sets the reception frequency of the receiving station and if the tone oscillation frequency is the same as the set frequency of the filter, it passes a sine wave at the frequency of the tone oscillation to an envelope detector 33 for the sine wave. Thus, the output of the envelope detector 33 is a d.c. voltage of a duration of approximately 100 ms or 200 ms depending on whether the received signal is an "enquire" or a "command". The output of the detector 33 is fed to a Schmitt trigger 34 to provide a rectangular pulse of one of these two durations, as shown at waveform "A" in Figure 4. The 200 ms pulse for an "enquire" is shown as a continuous line, and the shorter duration falling edge of a "command" is shown as a dotted line.

The rectangular pulse from the Schmitt trigger 34 is fed to a logic circuit arrangement which distinguishes between the two possible pulse durations to determine if the signal is "enquire" or "command". This logic circuit arrangement includes two so-called half monostables 35, 36 which have the characteristic of behaving like a conventional monostable only if the input signal thereto is of a duration equal to or greater than the period defined by the monostable. Thus a half monostable will provide an output for the defined period of the half monostable if the input signal has a period equal to or greater than the period of the half monostable. However, if the period of the input signal is less than that of the half monostable, the monostable will provide an output only for the period of the input signal.

It will be appreciated that due to the transmission process the period of the rectangular pulse from the Schmitt trigger 34 may not be exactly 100 ms or 200 ms and to overcome this the half monostable logic arrangement is arranged to discriminate between the signal durations by determining whether the Schmitt trigger signal is greater or less than an intermediate duration, for example 150 ms. This 150 ms intermediate duration is defined by the period of the half monostable 35. Thus if the signal from the Schmitt trigger 34 represents a "command" i.e. has duration of approximately 100 ms and less than 150 ms, the half monostable 35 will produce an output pulse of a duration corresponding to the duration of

the output of Schmitt trigger 34. However, if the signal is an "enquire" i.e. of a duration greater than 150 ms, the half monostable 35 will produce an output for 150 ms, and the output of Schmitt trigger 34 will have a duration greater than the output of half monostable 35. The output pulse of the half monostable 35 is shown at waveform B in Figure 4, the dotted line representing the signal for a "command" and the continuous line an "enquire".

The second half monostable 36 is arranged to produce a pulse in response to the trailing edge of the waveform B. The half monostable 36 also has an inhibit input 37 which receives the waveform A from the Schmitt trigger 34.

In the event that the waveform A represents an "enquire" signal its duration will be approximately 200 ms whereas the output of half monostable 35 will be 150 ms as shown at waveform B. Thus, waveform A inhibits half monostable 36 at the occurrence of the trailing edge of the 150 ms pulse from monostable 35, and consequently the half monostable 36 does not produce an output.

In the event that the waveform A represents a "command" signal, the output pulse B will be of approximately the same duration as the pulse of waveform A. Consequently, the inhibiting effect of waveform A on the half monostable 36 is removed at the occurrence of the trailing edge of the pulse of waveform B, and consequently, the half monostable 36 can produce an output. The monostable 36 produces a short duration pulse shown at waveform C in Figure 4, which enables a relay driver 38. The relay driver 38 energizes or de-energizes a coil 39 of a latching relay 40, to operate a switch 41. The switch 41 corresponds to the switch 7 or 8 shown in Figure 1. The switch 41 allows the live and neutral leads of the cable 1 to be connected to and disconnected from a load 42 i.e. an electrical appliance. Successive command signals will cause the relay to connect and disconnect electrical power from the load 42.

In the event that switch 41 connects power to the load 42, power is also applied to operate a 120 KHz oscillator 43 for transmitting the 100 ms unmodulated carrier burst back to the transmitting station 4. The oscillator 43 thus only produces an output when power is connected to the load 42. The 120 KHz carrier is applied to a power amplifier 44 and thence to the coupling circuit comprising transformer T1 capacitors C1, C2 and resistor R1, for transmission along the cable to the transmitting station 4.

The power amplifier 44 is gated on for a period of 100 ms to define the period of the unmodulated carrier burst, this gating being in response to the pulse of waveform A from the Schmitt trigger 34, in the event that the waveform A represents a received "command" or "enquire" signal. the trailing edge of the pulse of waveform A is delayed by 50 ms in a delay circuit 45, and the resulting delayed signal is shown at waveform D in Figure 4. The trailing edge of the delayed pulse fires a half monostable 46 which produces a 100 ms gating pulse "E" for the power amplifier. The purpose of the delay 45 is to delay switching on the power amplifier 44 until after the relay 40, 41 has operated in the event that the received signal is a command signal.

Thus, if the received signal is a "command" which switches power to the load 42, or if the received signal is an "enquire" when power is switched to the load 42, a 100 ms unmodulated carrier burst is transmitted back to the transmitting station 4 to illuminate the l.e.d. 14.

Referring back to the bound amplifier 31, the biquadratic filter 32 and the envelope detector 33, this arrangement provides a simple and convenient way of defining accurately a narrow acceptance band of tone modulation frequency. The bandwidth can be adjusted by selecting a single resistor at the output of the bound amplifier. Each of the receiver circuits such as 5, 6 can be constructed to have identical circuits, and the tone modulation acceptance frequency can then be selected for each unit by an appropriate selection of resistors and capacitors for the filter 32. The resistor and capacitor combination could be formed as a plug in module to be fitted by the retailer when the receiving stations are sold.

Whilst in the system described hereinbefore the receiving stations 5, 6 have been described as installed in socket outlets of a 13 amp ring main, they could also be installed in plugs for insertion into conventional socket outlets. Also, the receiving stations could be installed in lighting circuits, for example in the ceiling roses of a lighting installation. In a domestic wiring installation the 13 amp ring main is connected to the lighting circuits through the usual fuse box or circuit breaker unit, and so signals transmitted by the transmitting station 4 into the ring main 1 will also be transmitted via the fuse box 1 the lighting circuits, and can be used to switch the lights.

Also, we have found that the conventional electricity supply meter produces a substantial attenuation of the aforedescribed carrier signals and so it is unlikely that similar systems installed in adjacent houses will interfere with one another. Moreover, most adjacent houses are usually connected to different phases of the three phase supply so that substantial cable runs with consequent signal attenuation, occur between houses connected to the same phase of supply.

CLAIMS

1. Apparatus for performing remote control of electrical appliances through an electrical mains supply, comprising

a transmitting station for connection to a mains supply and comprising electrical oscillator means for generating a plurality of different modulation frequencies, carrier signal generator means for generating an oscillatory carrier signal for propagation along said mains supply, modulating means for modulating said carrier signal with one of said modulation frequencies to produce a modulated carrier signal, means for selecting the modulation frequency used to modulate the carrier signal, and means for applying a burst of the modulated carrier signal to the mains supply, and

a plurality of receiving stations each arranged to respond to a different one of said modulation frequencies, each receiving station comprising means for receiving the modulated carrier signals

from the mains supply, means for producing a control signal indicative of when the modulation frequency of the received modulated carrier signal corresponds to a predetermined frequency associated with the receiving station, and control means for changing between first and second control conditions the manner in which current is supplied to an appliance from said mains supply in response to successive occurrences of said control signal.

2. Apparatus according to claim 1 including in the transmitting station means for selecting the modulated carrier burst to be of first or second different durations to define respectively enquire and command operating modes of the apparatus, receiver means responsive to a burst of carrier signal of a given frequency, and means arranged to provide a display in response to operation of said receiver means; and including in each said receiving station, means for determining if the modulated carrier burst received from the transmitting means is of a duration which indicates the enquire or the command mode, means for causing the control means to change its control condition in response to a determined command mode, carrier signal transmitting means for transmitting to the mains supply a carrier signal for operating the receiver means in the transmitting station, and means for actuating the carrier signal transmitting means in response to said control means being in a predetermined one of said control conditions and the determined mode is the enquire mode, or in response to said determined mode being a command mode which causes said control means to assume said predetermined one of said control conditions.

3. Apparatus according to claim 2 wherein the transmitting station includes means for disabling operation of said receiver means during the transmission of said modulated carrier burst.

4. Apparatus according to claim 2 or 3 wherein said display means comprises a light emitting diode.

5. Apparatus according to any of claims 2 to 4 wherein each said receiving station includes demodulating means for demodulating said carrier burst so as to recover the modulation frequency, filtering means adapted to produce a filter output only if the recovered modulation frequency corresponds to a predetermined frequency associated with the receiving station, and means for determining if the duration of the filter output is greater or less than a given duration selected to be intermediate the transmitted durations of said modulated carrier burst for said enquire and command modes whereby to determine the mode of the modulated carrier signal received by the receiving station.

6. Apparatus according to any of claims 2 to 5 wherein the receiving station includes a relay arranged to switch electrical power from the mains supply on and off successively in response to successive command mode modulated carrier signals received by the receiving station.

7. Apparatus according to any of claims 2 to 6, wherein each said receiving station includes a local oscillator for generating the carrier signal for transmission to the transmitting station, a power amplifier arranged to amplify the output of the local oscillator, the amplifier having a gating control arranged to enable operation of the amplifier only in response to the mode determining means providing an indication of an enquire mode.

8. Apparatus according to claim 7 wherein said local oscillator is activated for operation only in response to said control means assuming said predetermined one of said control conditions.

9. Apparatus according to any preceding claim wherein said transmitting station and said receiving stations each include a respective transformer for coupling the carrier signals to and from the mains supply.

10. Apparatus according to any preceding claim wherein said transmitting station and said receiving station are connected to the mains supply.

11. Apparatus for performing remote control of electrical appliances through an electrical mains supply, substantially as hereinbefore described with reference to the accompanying drawings.

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