(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 084 967**
**A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **83300320.5**

(22) Date of filing: **21.01.83**

(51) Int. Cl.³: **H 04 K 1/00**, H 04 B 7/26

(30) Priority: **27.01.82 GB 8202357**

(43) Date of publication of application: **03.08.83**
**Bulletin 83/31**

(84) Designated Contracting States: **AT BE CH DE FR IT LI NL SE**

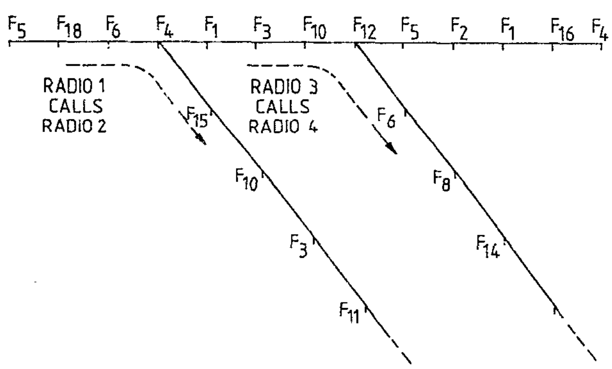
(71) Applicant: **THE MARCONI COMPANY LIMITED, The Grove Warren Lane, Stanmore Middlesex HA7 4LY (GB)**

(72) Inventor: **Dent, Paul Wilkinson, 1 Blackbrook Park Avenue, Fareham Hampshire (GB)**

(74) Representative: **Keppler, William Patrick, The General Electric Company, p.l.c. Central Patent Department (Wembley Office) Hirst Research Centre East Lane, Wembley, Middlesex HA9 7PP (GB)**

(54) **Radio communication system.**

(57) A frequency-hopping radio communication system in which a network of stations operate on the same sequence of frequencies, in synchronism, controlled by pseudo-random generators which are initially synchronised. Each station has means for modifying its p.r. sequence dependent only upon the instant in the main line sequence at which the modification is switched. In order to communicate, one station transmits, on the current main-line frequency sequence, the address of the desired other station and then signals the seqence switch. At this instant both transmitting and receiving stations switch to a modified frequency sequence and are thus isolated from the remaining stations. At the end of the message a signal from the transmitting to the receiving station causes both stations to revert to the main line sequence.




EP 0 084 967 A2

This invention relates to radio communication apparatus and particularly to such apparatus in which the carrier frequency is changed periodically in an attempt to maintain security and overcome jamming of the radio transmission. Such periodic frequency changing is called hopping.

In a typical example of such a system operating in the VHF band 30 - 88 MHz there are a possible 2320 channels at a spacing of 25 kHz. Of this number a limited fraction are made available to the radio sets in the network. The greater the number of available channels the more secure the system but the greater is the storage capacity required for the identification of the valid channels. The set of channels over which frequency hopping takes place, i.e. the available channels, is called a 'hop-set'.

Each radio set in the network may be adapted to operate on a common hop-set according to its own pseudo-random sequence thus giving what is called a random hopping system. In this system, statistically predictable interference occurs as a result of random frequency coincidences when two communications are being conducted simultaneously. UK Patent Application Serial No. 2103052 describes a random frequency hopping system in which such random interference is avoided without serious damage to the transmission.

The alternative, so-called orthogonal, system is one in which both the hop-set and the pseudo-random sequence is common to each radio set in the network. Some means then has to be employed to prevent continuous interference between the channels used in simultaneous communications. Such a system is described in UK Patent Application Serial No. 2101847.

An object of the present invention is to provide a random frequency hopping system which permits simultaneous non-interfering conversations in a radio network.

According to the present invention, a frequency-hopping radio communication system comprises a plurality of radio transmitter/receiver sets having means for changing their operating frequencies periodically, in synchronism, and according to a common main-line pseudo-random channel sequence, each radio set having means for modifying its operating channel sequence to a side track sequence dependent upon the point in said main line sequence at which the modification is initiated and means for transmitting a signal to a selected other radio set to initiate said side track sequence in the receiving radio set at the same instant as in the transmitting radio set, both radio sets being arranged to revert to the main-line channel sequence on termination of the transmission.

The modification may be effected by a change in a feedback path of a pseudo-random number generator in each radio set which generator determines the operating channel sequence of the radio set.

A frequency-hopping radio communication system in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, of which:-

Figure 1 is a block diagram of one radio set of the network indicating the generation of main-line and modified channel sequences;

Figure 2 is a timing diagram of the channel changes in different operating conditions of the system;

and Figure 3 is a diagram of a frequency hopping radio communication system employing two radio sets as a relay station.

Referring to the drawings, a number of different radio sets in a network, which are required to be able to communicate with each other, each include apparatus as shown in Figure 1. A real time clock 1 steps a random number generator 2 through a pseudo random number sequence, the output number at any instant being determined by the original number, i.e. the key variable, with which the random number generator was loaded, and the time elapsed since that occurrence. All radio sets in the network are loaded with the same key variable and their clocks are initially synchronised, so that all radio sets will produce the same pseudo-random number sequence in synchronism. There may be a very slight phase drift between the number sequences of the different radio sets if they should run on for a substantial time without communication but this is accommodated as will be seen.

Each radio set has a stored table 3 of permitted frequencies, i.e. a large random selection of the total possible channels in the band. This hop-set is again common to all radios of the network.

The table 3 is addressed by each multi-digit random number as it arises and the resulting channel frequency identity is applied to a transmitter/receiver radio 14 which is frequency agile and electronically tunable. The operating frequency thus changes periodically and synchronously for all radios of the network in accordance with the number sequence provided by a number generator. This common basic sequence will be referred to as the main-line sequence.

The key variable initially loaded into each random number generator 2, can be changed periodically for different networks on a geographical or other basis.

The random number generator 2 consists of a shift register with predetermined feedback in known manner. In addition to the basic construction there is a controllable feedback path 4 which, when effective, changes the pattern generated in a predetermined manner. This feedback path is controlled by a switch 6, the modified number sequence produced by the generator then depending upon the content of the generator when the modification is initiated.

A bistable 8 determines the condition of the switch 6, the switch being closed when the bistable is 'set'.

In the passive condition of the network, i.e. with no transmissions in progress, all radio sets operate on the same main-line sequence of channels and are therefore all receptive to any transmission from another set. In order to make selective transmissions while operating on this main-line sequence therefore, a selected receiving set is identified by a calling signal, this address being transmitted to all sets. Prior to the called radio address however, a synchronising sequence is transmitted to correct any timing drift that may have occurred since the previous transmission. Each transmitter is thus assumed to have correct timing but each radio set as a whole will have its timing corrected whenever it operates as a receiver. There will therefore be a tendency to bring all the radio sets of a network into synchronism.

Following the synchronising sequence and the address of the called radio, an absolute time marker is transmitted, a so-called 'bingo' signal. It is the transmission and reception of this signal which initiates the modification of the random number generator 2 in the transmitting and receiving radios.

Referring to Figure 1 again, this modification is initiated as follows. The bistable 8 has a set input derived by way of an OR-gate 10 from a 'bingo' detector 12 which monitors the signal received by the basic radio 14. Immediately therefore, on reception of the 'bingo' signal the bistable 8 is set, the switch 6 is closed, and a modified random number sequence is generated dependent upon the content of the generator at the instant of switch closure. At the transmitting radio the bistable 8 is set at the same instant by a signal following the synchronising and addressing preamble. This post-transmission synchronising signal is applied by way of the OR-gate 10.

Both transmitting and receiving radios are thus modified at the same instant and with the same content in their random number generators. The resulting modified sequences, which bear no relation to the main-line sequence, are therefore identical and communication can proceed between these two radios. If, of course, transmission to two or more other radios is required this is easily accommodated, by transmission of the respective addresses on the main line sequence.

Figure 2 shows the effect of closure of the switch 6 on the operating frequency sequences. The upper horizontal line indicates the main-line frequency sequence $F_5$ $F_{18}$ $F_6$ etc (a typical part of the sequence), the frequency changes occurring at regular intervals determined by the clock. If, for example radio 1 calls radio 2, and the 'bingo' signal arises at the instant of the main-line change to $F_4$, then a sidetrack sequence will occur in radios 1 & 2 having typical frequencies $F_{15}$ $F_{10}$ $F_3$ etc as shown. These latter changes will occur in synchronism with the main-line changes $F_1$ $F_3$ $F_{10}$ etc. Radios 1 & 2 will then operate on the modified or sidetrack sequence while the remainder of the radios in the network carry on passively on the main-line sequence.

If at a later instant radio 3 should call radio 4 and emit a 'bingo' signal at $F_{12}$ in the main-line sequence then the content of the random number generators of radios 3 & 4 will at that instant be different from the content of the generators of radios 1 & 2 and consequently a new sidetrack sequence will arise for the operation of radios 3 & 4. No interference between the two communications will arise other than the predictable statistical coincidence of frequencies. As mentioned previously, the system described in Patent Application No. 8119215 will alleviate any troubles arising from this cause.

At the end of a transmission an 'end-of-message' code is transmitted, which is detected by a detector 16. An output from the detector 16 resets the bistable 8 by way of an OR-gate 18, the switch 6 opens, and the generator 2 reverts to the production of the main-line sequence in the same phase as if it had not been interrupted.

A transmit key input 20 also serves to reset the bistable 8 by way of OR-gate 18 to ensure that on transmission the radio is operating on the main-line sequence i.e. on which all other (passive) radios are listening for their address code.

The system described has the significant feature, in contrast with fixed frequency radio systems, that an ongoing selective communication does not prevent the rest of the net communicating, or setting up selective calls of their own, since the sequence of frequencies used to set up calls, the main line sequence, is unrelated to the sequence of frequencies used for the message, the side-track sequence. Furthermore, there are as many different sidetrack sequences as there are points of departure from the main line sequence, the only limiting factor to their use being the acceptability of interference caused by the statistical probability that two or more sequences will alight on the same frequency at the same time.

Some incidental advantages of the above 'divergent-key-operation' system arise as follows.

If a frequency hopping radio using the basic main line sequence for all purposes is captured by an enemy with its key variable and hopset programming intact, it would ordinarily be possible for the enemy to employ the radio to jam the rest of the net of which it was part, merely by switching it permanently to 'transmit'.

However, the system, as described above, makes this virtually impossible. If the captured radio is switched permanently to 'transmit' in an attempt to jam, it will, after the short initial preamble, switch to the sidetrack sequence of frequencies which will then not interfere with any other transmission. Even if a receiver is addressed, and follows the spurious transmission, the operator can, upon determining that the message is of not value, switch the receiver back to the main line by pressing the transmit switch 20 momentarily.

The main-line sequence could be rendered unavailable to a large extent by constantly switching a captured radio between transmit and receive. Software or hardware traps may be built into the radio to prevent a captured radio being switched in this way. Such a trap may for instance cause erasure of the key variable upon detection of such behaviour.

A captured radio may, of course, be modified by the enemy to bypass these traps; but that would involve laboratory work, and by the time the radio was returned to the field, the key variable would no longer be current. It may also be made extremely difficult to extract the key variable from one radio in order to transfer it to a modified radio.

In order to extend the coverage range of ground wave radio systems, retransmission is often employed, whereby the signal is received from the initiating transmitter on one frequency, and relayed on another frequency. Two conventional radio sets may be connected back-to-back to provide such an automatic relay station, as illustrated diagrammatically in Figure 3. In military systems, single frequency simplex is used on each leg of the path, and the relaying transmitter is keyed only when the receiver detects the presence of a valid signal. Since the two legs of the relay path must be on different frequencies to provide adequate isolation between the co-sited transmitter and receiver, the frequency on which a receiving station should best listen depends on its geographical position, i.e., whether it is nearer to the initiating station or the appropriate relay site. In a conventional system therefore, a mobile station may have to change frequency according to position. Thus, the relay station may comprise two radio sets B & C each as aforesaid but modified in that set B is made receptive to all transmissions irrespective of address, any valid transmission so received on the main line sequence causing conversion to a sidetrack sequence at the BINGO code reception. The first radio link in the relay process, i.e. between the originating station A and the relay station B/C is then operated on a first side track sequence. On such valid reception the transmitting set C of the relay station is caused to initiate re-transmission on the main line sequence, of the synchronising and address preamble, the address being that of the out-station D, relayed from the originating station A. On transmission of the BINGO code by the set C both set C and out-station set D switch to a side-track sequence which is different from that in operation between the AB link since it arises at a later time. There is again, therefore, no interference between the AB transmission and the CD transmission.

In the return direction the functions of sets A & D are interchanged and the operation proceeds exactly as before.

The mobile radio set D will lock onto the first synchronisation preamble which it receives successfully whether from the initiating station A or the relay station B/C. As it moves out of range of one relay site and into the coverage zone of another, no action is thus required by the operator to pick up the new relay link.

1. A frequency-hopping radio communication system comprising a plurality of radio transmitter/receiver sets (Fig. 1) characterised in that the radio sets have means (2, 3) for changing their operating frequencies periodically, in synchronism, and according to a common main-line pseudo-random channel sequence, each radio set having means (4, 6) for modifying its operating channel sequence to a side-track sequence dependent upon the point in said main line sequence at which the modification is initiated and means for transmitting a signal to a selected other radio set to initiate said side-track sequence in the receiving radio set at the same instant as in the transmitting radio set, both radio sets being arranged (6, 8, 16, 18) to revert to the main-line channel sequence on termination of the transmission.

2. A system according to Claim 1, characterised in that each radio set (Fig. 1) incorporates a pseudo random number generator (2) and a channel frequency identifying store (3), each number generated by the pseudo random number generator (2) determining a respective operating channel frequency for the radio set, and wherein the pseudo random number generator (8) incorporates a controllable two-state feedback path (4) which, in one state causes the pseudo random number generator to produce a said side-track sequence.

3. A system according to Claim 2, characterised by transmit-key means (2) whereby, before transmission, operation of said transmit key means causes said feedback path (4) to adopt the other of the two states.

4. A system according to any preceding claim characterised by a relay station which comprises two radio sets (B,C) each as aforesaid, one (B) of said two radio sets being adapted to accept transmissions irrespective of addressee and the other (C) of said two

radio sets being coupled to said one radio set (B) to re-transmit all signals received thereby, the difference in time between reception by said one set (B) and re-transmission by said other (C) causing the two links to operate on different side-track sequences and thus provide frequency isolation.

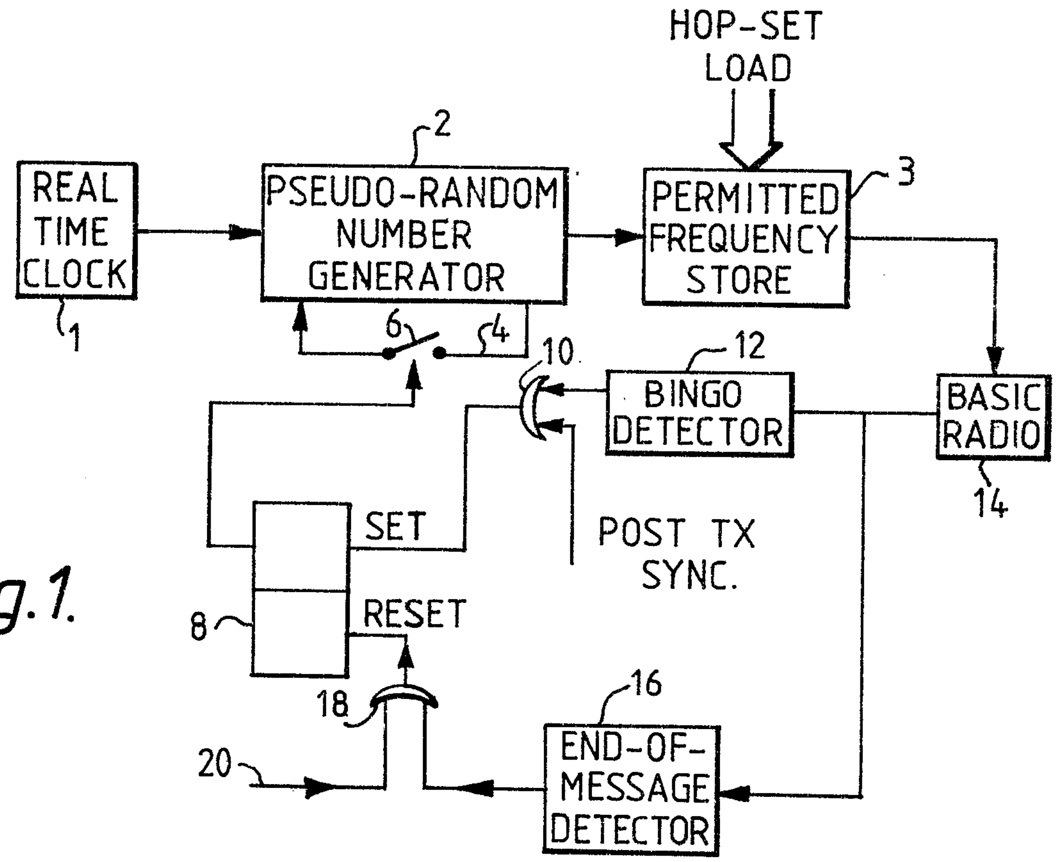

HOP-SET
LOAD
REAL
TIME
CLOCK
PSEUDO-RANDOM
NUMBER
GENERATOR
PERMITTED
FREQUENCY
STORE
BINGO
DETECTOR
BASIC
RADIO
SET
RESET
POST TX
SYNC.
END-OF-
MESSAGE
DETECTOR
1
2
3
4
6
8
10
12
14
16
18
20

Fig.1.

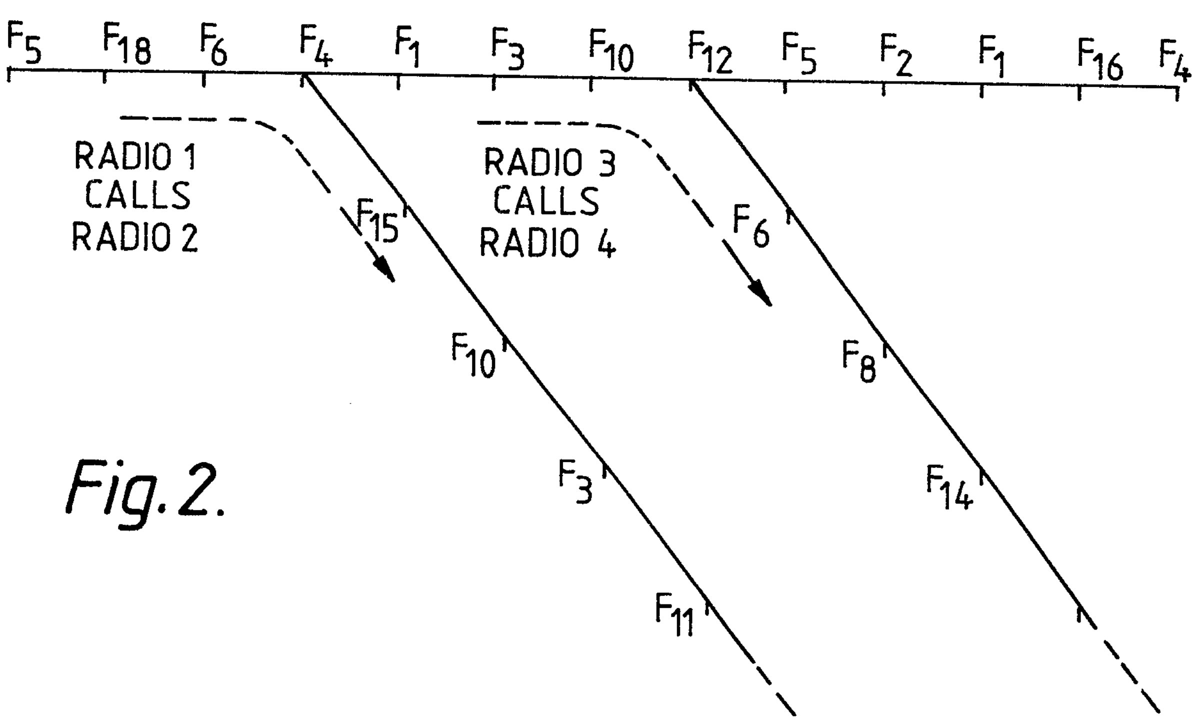

F5 F18 F6 F4 F1 F3 F10 F12 F5 F2 F1 F16 F4
RADIO 1
CALLS
RADIO 2
RADIO 3
CALLS
RADIO 4
F15
F10
F3
F11
F6
F8
F14

Fig.2.

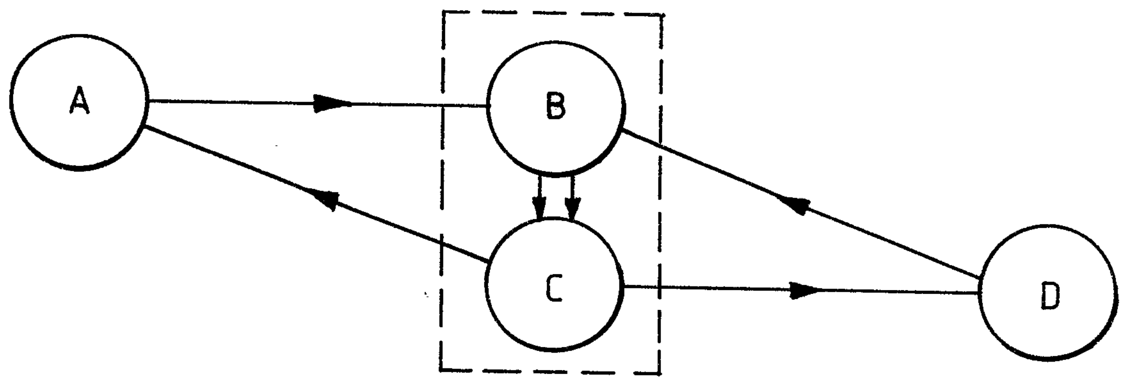



Fig. 3.