# United States Patent [19]

**Wilkinson**

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[54] **RADIO COMMUNICATIONS RECEIVERS**

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[73] Assignee: **The Marconi Company Limited**, England

[21] Appl. No.: **389,905**

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[30] **Foreign Application Priority Data**

Jun. 22, 1981 [GB] United Kingdom ................ 8119215

[51] **Int. Cl.**$^3$ ............................................. **H04B 1/10**

[52] **U.S. Cl.** ....................................... **375/1**; 375/104; 455/304; 455/312

[58] **Field of Search** ..................... 360/38.1, 41; 375/1, 375/102, 104; 371/31, 65, 69; 455/303, 304, 312; 358/314

[56] **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 2,996,576 | 8/1961 | Dolby | 360/38.1 |
| 3,347,984 | 10/1967 | Holmberg | 360/38.1 |
| 3,688,039 | 8/1972 | Ishiguro | 371/31 |
| 3,700,812 | 10/1972 | Springett | 455/312 |
| 3,824,620 | 7/1974 | Langer | 360/38.1 |
| 3,947,636 | 3/1976 | Edgar | 328/163 |
| 4,291,405 | 9/1981 | Jayant et al. | 371/31 |
| 4,376,289 | 3/1983 | Reitmeier et al. | 360/38.1 |
| 4,398,296 | 9/1983 | Gott et al. | 375/1 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| 2916127 | 11/1979 | Fed. Rep. of Germany . |
| 2297524 | 8/1976 | France . |

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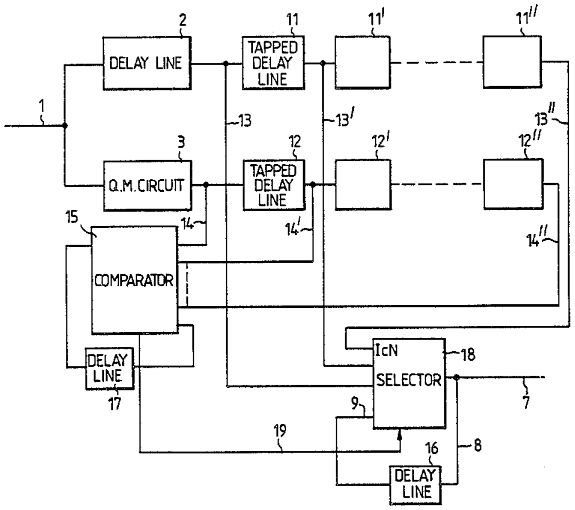
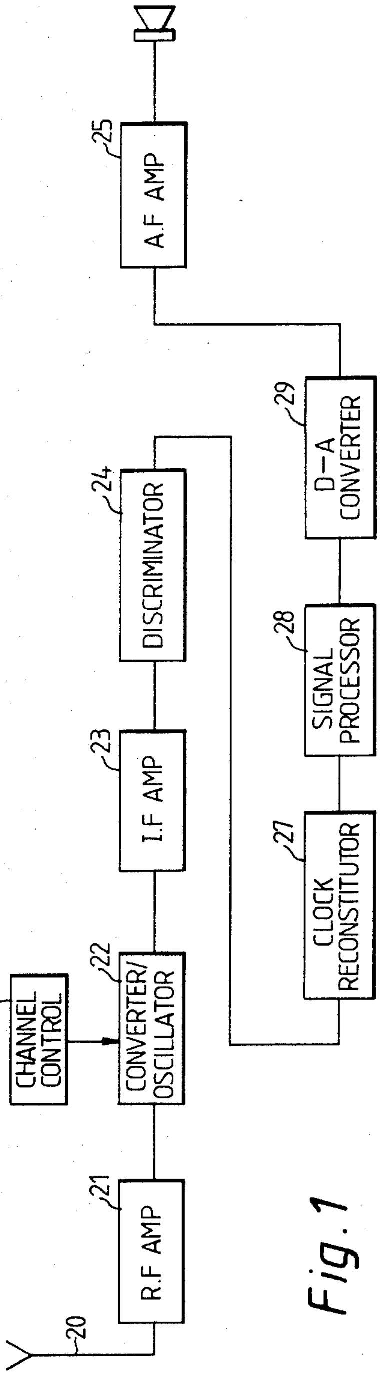
[57] **ABSTRACT**

In radio communications receivers for use on frequency hopping radio communications networks, the received signal in each hop period is analyzed and assigned a quality value. If more than one signal is present during the hop period it is determined that more than one network has changed to the same frequency. Similarly if the received signal is out of synchronism it is determined that more than one network has changed to the same frequency. When more than one network has changed to the same frequency, the received signal is not output by the receiver but is replaced by an earlier (or later) received signal.

**8 Claims, 4 Drawing Figures**

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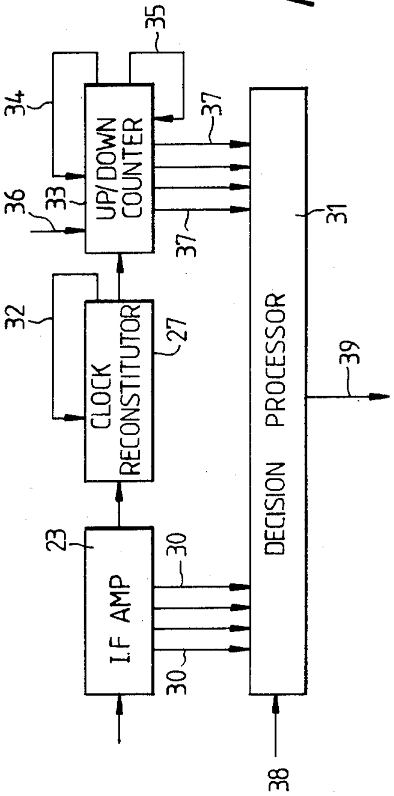
R.F AMP
21
CHANNEL CONTROL
26
CONVERTER/ OSCILLATOR
22
I.F AMP
23
DISCRIMINATOR
24
A.F AMP
25
CLOCK RECONSTITUTOR
27
SIGNAL PROCESSOR
28
D–A CONVERTER
29

Fig. 1


I.F AMP
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30
30
CLOCK RECONSTITUTOR
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UP/DOWN COUNTER
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34
35
36
37
37
DECISION PROCESSOR
31
38
39

Fig. 4

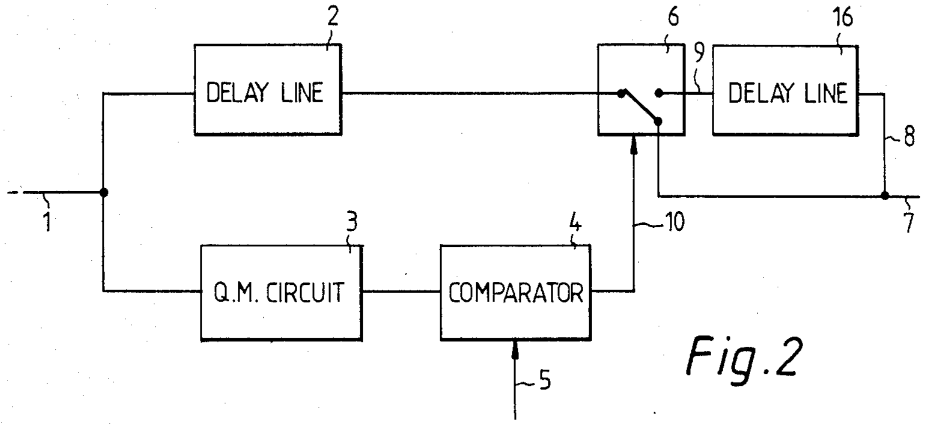
2
6
16
9
DELAY LINE
DELAY LINE
8
1
7
3
4
10
Q.M. CIRCUIT
COMPARATOR
5

Fig.2

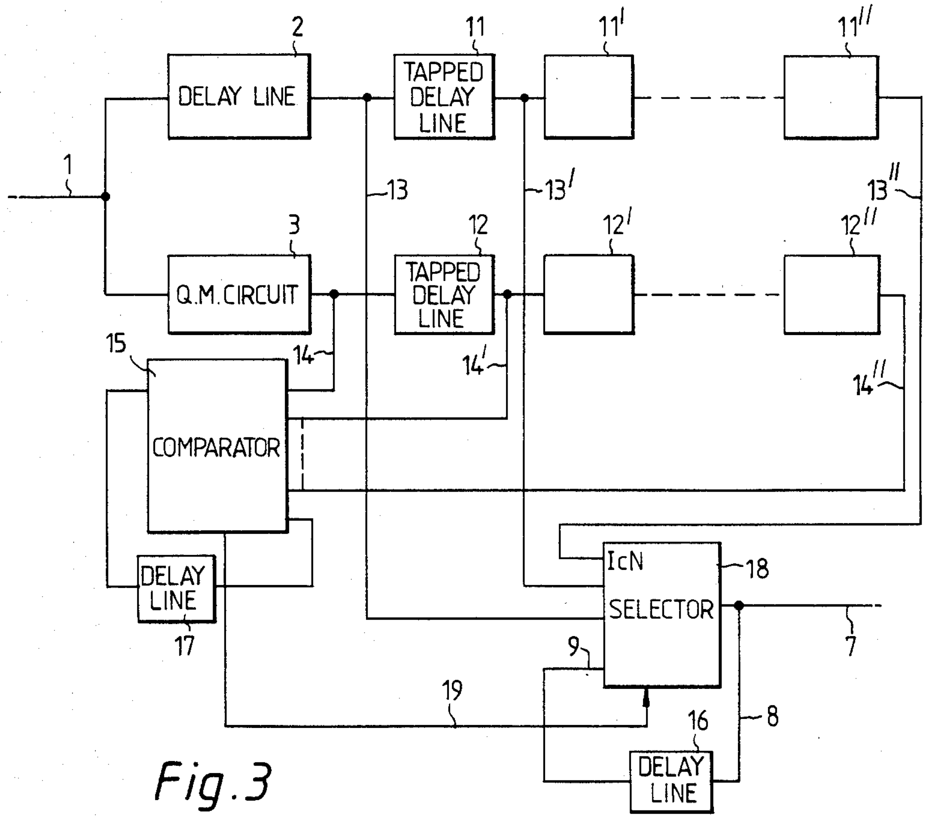
2
11
11'
11''
DELAY LINE
TAPPED DELAY LINE
1
13
13'
13''
3
12
12'
12''
Q.M.CIRCUIT
TAPPED DELAY LINE
15
14
14'
14''
COMPARATOR
IcN
18
SELECTOR
7
DELAY LINE
17
9
19
16
8
DELAY LINE

Fig.3

## RADIO COMMUNICATIONS RECEIVERS

The present invention relates to radio communications receivers and in particular to such receivers for use in frequency hopping radio communications networks.

One technique of overcoming deliberately introduced radio interference signals (jamming) in a radio communications network is to change the frequency on which the transmitters and receivers operate at periodic intervals. When such frequency changes occur at periodic intervals of the order of milliseconds with each frequency change occurring by the transmitter and receiver in synchronism with each other the technique provides some confidentiality to the transmissions as well as some immunity to jamming. This method of operation is referred to herein as "frequency hopping".

When frequency hopping communications networks are in use with several groups of radio sets using a similar set of frequency channels interference between groups of sets hopping in pseudo random fashion may occur due to two of the groups hopping to the same channel simultaneously. Such frequency coincidences will usually generate an interference burst of one "hop" period. When the network is being used for voice communication with a hop period of, say, a few milliseconds the interference bursts are characterised by a noise background of apparent clicks superimposed on a voice message. As the number of groups of radio sets using the frequency channels available increases the probability of two or more groups selecting the same channel increases and consequently the intelligibility of voice communications in the networks decreases.

In practical tests it has been determined that if 25% or greater obliteration of the voice signal waveform occurs the voice communication is no longer intelligible. Without special processing of the voice signal the intelligibility limit is reached when approximately N/3 groups of radio sets are independantly hopping between the same N frequency channels.

It is an object of the present invention to provide radio communications apparatus in which the tolerable level of signal obliteration is increased.

According to the present invention a radio communication receiver for use in a frequency hopping radio communication network comprises store means to store a representation of a received signal for a period of T2; selection means which is responsive to a control signal selectively to output either a currently received signal, or the stored representation from said store means of a received signal received T2 earlier; and signal quality measurement means which determines from at least one characteristic of the received signal in each of a succession of said periods T1 within those periods, whether the received signal comprises more than one transmitted signal and, if so, forwards said control signal to said selection means such that, for any of the periods T1 in which the received signal has a low signal quality value, an alternative signal is output by the receiver.

Preferably the period of T2 is in the range of eight to ten milliseconds and the means to store is a delay line.

The received signal may be delayed by a period of T1 before being selected for output and for storage by the delay line.

In a preferred embodiment the received signal is stored in a delay line having a plurality of tappings at intervals of T2 and the tapping having the highest of said signal quality values is selected as the output signal if the received signal quality value is less than a predetermined value.

The received signal may be delayed by an additional period of multiples of T2 so that a later received signal may be selected as the output signal if the quality values so require.

Radio communications apparatus in accordance with the invention will now be described with reference to the accompanying drawings of which:

FIG. **1** is a block schematic diagram of a frequency hopping radio receiver;

FIG. **2** is a block diagram of a signal processing circuit for use in the apparatus;

FIG. **3** is a block diagram of an alternative form of signal processing circuit for use in the apparatus; and

FIG. **4** is a block schematic diagram of a quality assessment circuit used in the processing circuits of FIGS. **2** and **3**.

It will be appreciated that speech waveforms comprise a basic frequency on which a number of harmonics are superimposed. The average pitch period of the basic frequency of an adult male speaker has been determined to be in the range from eight to ten milliseconds.

It is convenient to note that frequency hopping radio communications apparatus may change frequency (hop) at intervals of less than the average pitch period previously referred to.

For the avoidance of doubt it is noted that the period between each change of frequency is referred to hereinafter as a "hop period".

For the purpose of description the signal arriving at a radio receiver in a hop period in which two or more radio communications sets are transmitting on the same frequency is referred to hereinafter as a "corrupt hop". Similarly the signal arriving at a radio receiver in a hop period in which only an associated group of radio communications sets have switched to the channel is referred to as a "valid hop".

Referring to FIG. **1** radio signals received at an aerial **20** of the typical frequency hopping receiver are amplified by a radio frequency amplifier **21** and the selected radio signal is converted to an intermediate frequency by mixing in a converter/oscillator **22**. The intermediate frequency signal is amplified by an intermediate frequency amplifier **23** before being applied to a discriminator **24** and an audio amplifier **25**.

As the frequency of the wanted signal from the aerial **20** changes (hops) at periodic intervals a channel control circuit **26** causes the frequency of the oscillator **22** to change in a pseudo-random manner in synchronism with channel changes of the transmitted signal. A channel control circuit suitable for use as the channel control circuit is described in co-pending patent applicaton Ser. No. 386,296 filed June 8, 1982.

Since in the present system the received signals represent digitally encoded speech signals a clock reconstitutor circuit **27** is used to extract the digital data which is then stored in a signal processing circuit **28**. Digital data selected by the circuit **28** as hereinafter described is converted to analogue form by a digital to analogue converter **29** before amplification by the amplifier **25**.

Referring now to FIG. **2** a digital signal received by the radio communications set is demodulated and fed to an input **1** of the signal processing circuit **28** (of FIG. **1**). The signal is delayed in a delay line **2** for a period of T1 which is one hop period. A quality measurement circuit **3** determines from the strength and synchronisation of the received signal on the lead **1** a value representing the average quality of the signal received in the immediately preceding period T1.

The quality measurement value determined by the quality measurement circuit **3** is compared by a comparator **4** with a threshold signal supplied on a connection **5**. If the quality value exceeds the threshold signal value the signal from the delay line **2** is switched through an electronic changeover circuit **6** to an output line **7** which is connected to the digital to analogue converter **29** (of FIG. **1**).

If the quality value does not exceed the threshold signal value the comparator **4** provides a signal on lead **10** to cause the changeover circuit **6** to switch to pass a previously received signal to be fed from a lead **9** from a second delay line **16** to the output line **7** until the average quality of the signal determined by the quality measurement circuit **3** again exceeds the threshold.

The delay line **16** is fed from the output line **7** by a line **8** and introduces a delay "T2" of from eight to ten milliseconds, the average male pitch period between its input on the lead **8** to its output on the lead **9**.

Thus the signal processing circuit of FIG. **1** is arranged to replace any corrupt hop, as detected by the quality measurement circuit **3**, with a previously received valid hop. The valid hop replacing a corrupt hop is one received a period of "T2" earlier, the delay being introduced by the delay line **16**.

It has been determined that if T2 is close to the "hop" period causing each corrupt hop to be replaced by an immediately preceding valid hop signal obliteration of up to 40% may be achieved before the received signal becomes unitelligible. However, if T2 is close to the hop period the voice output of the apparatus taken on an unnatural sounding monotonic pitch since the voice pitch tends to be replaced by the pitch of the hop frequency.

By arranging T2 to be close to the natural pitch the correct fill-in waveform is provided approximately 90% of the time due to the nature of speech waveforms. Although pitch tracking may improve the voice output it has been found that arranging "T2" to be of the order of eight to ten milliseconds provides a natural sounding output from the radio receiver.

The signal processing circuit of FIG. **3** to which reference is now made is arranged to extend the technique of replacing corrupt hops with a previously received valid hop to either a previously received or later received valid hop.

The signal from the delay line **2** is fed to a tapped delay line shown as a number of individual delays **11**, **11'** to **11''** and the accompanying quality value from the quality measurement circuit **3** is fed to a respective tapped delay line **12**, **12'** to **12''**. Each delay period of the tapped delay lines **11**, **11'** to **11''** and **12**, **12'** to **12''** is of length "T2" which is preferably eight to ten milliseconds.

The quality value from each output of the delay line **12**, **12'** to **12''** is fed to a quality comparison device **15** which determines by "weighting" the quality value of each of the previously received signal segments stored in the delay line **11**, **11'** to **11''** and each subsequently received signal segment against the value of the signal segment which is due to be output (the current signal segment). If the quality value of the current signal segment is acceptable the comparison device **15** causes a one out of n selector **18** to output the current signal segment to the line **7**.

If the current signal segment is corrupt the comparison device causes the signal segment previously received or the signal segment next received to be output by the one-out-of-n selector **18** on the lead **7** in dependence upon their respective quality values as determined by the quality measurement circuit **3**. If both the previously received and next received signal segments are also corrupt, the next nearest signal segment is selected for output if its quality is acceptable.

Two further delay lines **16** and **17** are provided each having a delay of "T2". The delay line **16** is arranged to store the signal segment last output to the lead **7** whilst the delay line **17** stores its respective quality value. Thus if none of the signal segments stored in the delay line **11**, **11'** to **11''** has an acceptable quality value the signal segment output to the line **7** a period of "T2" milliseconds previously is repeated.

The value of the delay "T2" introduced by the delay lines **11**, **11'**, to **11''**, **12**, **12'** to **12''**, **16** and **17** is preferably in the range of eight to ten milliseconds if the apparatus is for use by male persons.

The quality comparison device **15** may be made up of analogue or digital voltage comparators or may be implemented by use of a micro-processor.

In an analogue measuring technique used by the quality measurement circuit **15**, since it is known that the variation in loss on the propagation path between differing frequencies remains within a predictcable range, say, plus or minus six decibels about an average, any increase of the received signal strength above six decibels (dB) indicates that another unwanted signal is present. Thus any hop in which such an increase occurs is determined as a corrupt hop and the output signal is derived from a valid hop as hereinbefore described.

Another method of utilising signal strength to determine whether the received hop is a corrupt hop or a valid hop is to utilize the signal strength distribution of a wanted signal. In such a method the quality measurement circuit **15** is arranged either to accummulate the signal strength distribution or to assume a signal strength distribution. By comparing the accumulated or assumed signal strength distribution for a hop with the average value of the signal strength of a received hop a probability value of the received hop may be deduced.

The probability value of the received hop is then compared with a probability threshold and if the probability value does not exceed the threshold, the hop is determined to be a corrupt hop and is replaced by a valid hop as hereinbefore described.

Whilst the above methods are adequate when two or more transmitters in different networks are transmitting at the same time it is possible that two or more networks may have changed to the same frequency together and at that time only one transmitter or one of the networks is in use.

The network in which that transmitter is working is, of course, unaffected but the other networks may receive a perceivable click as the signal would be identified as a valid hop.

Thus the signal strength quality measurement is augmented by a digital comparison.

It will be appreciated that a digital transmission has a certain regularity in the transitions from one binary value to the other. Thus from a received transmission a clock reconstitutor may generate a clock signal which is in synchronism with the data transitions. This clock signal is more usually used to determine the optimum

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