

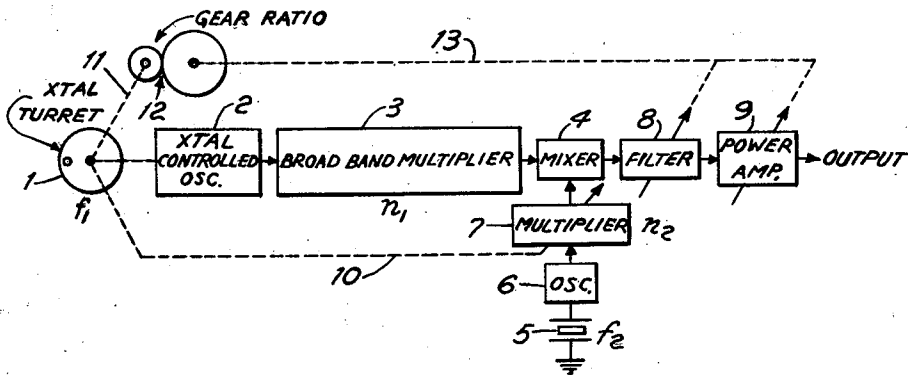
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MULTI-CHANNEL RADIO EQUIPMENT

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*Fig. 1*



*Fig. 2*

| NUMBER CHANNELS | NUMBER CRYSTALS | MULTIPLIER BAND WIDTH | F <sub>2</sub> MC | N <sub>2</sub> | GEAR RATIO |
|-----------------|-----------------|-----------------------|-------------------|----------------|------------|
| 126             | 43              | 42                    | 42                | 1              | 3          |
| 125             | 26              | 25                    | 25                | 1-2            | 5          |
| 126             | 19              | 18                    | 18                | 1-3            | 7          |
| 126             | 15              | 14                    | 14                | 1-4            | 9          |
| 132             | 13              | 12                    | 12                | 1-5            | 11         |
| 130             | 11              | 10                    | 10                | 1-6            | 13         |
| 135             | 10              | 9                     | 9                 | 1-7            | 15         |
| 136             | 9               | 8                     | 8                 | 1-8            | 17         |
| 136             | 8               | 7                     | 7                 | 1-9            | 19         |

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## MULTI-CHANNEL RADIO EQUIPMENT

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This invention relates to multi-channel radio equipment and more particularly to means for generating a plurality of crystal-controlled radio-frequency channels.

In many radio communication systems, such as aerial navigation or mobile services, the need often arises for the generation of a hundred or more crystal-controlled frequencies. Obviously, the use of a separate crystal for the generation of each frequency channel (while providing extreme stability) is in practice uneconomical. Many so-called crystal saving circuits that have been devised for use in multi-channel radio equipment have depended upon the mixing of two or more frequencies, one or more of which was generated in response to a crystal. This mixing normally produces spurious frequency responses. The spurious responses may be classified as being filterable or unfilterable frequencies. For example, where we mix a first and second frequency to obtain a third frequency, we would have filterable spurious responses at the first and second frequencies and these could be removed by a sufficient degree of selectivity provided they were far enough removed in the frequency spectrum from the third frequency. However, if the first frequency is a sub-harmonic of the third frequency then no amount of filtering can eliminate the harmonic signal due to the first frequency which was generated by the necessarily non-linear mixing circuit.

It has been shown that for low values of unfilterable spurious frequencies, the ratio of the first and second frequencies should be as high as possible while for the easiest filtering the reverse is true and thus all crystal saving circuits heretofore designed have necessarily involved a compromise. Other disadvantages of the prior art systems have included the necessity for requiring a large number of tuned circuits at the final frequency for reasons other than spurious frequency suppression. For example, where a large number of vacuum tubes must be used in cascade in order to get the required gain and/or power output, each stage required its own tuned circuit. In such systems it becomes economical to use a good crystal saving circuit in which the unfilterable spurious responses are kept low by using high ratios of mixing frequencies and thus cutting down on the number of tuned circuits required.

One of the objects of this invention, therefore, is to provide a system for generating a plurality of crystal-controlled frequencies in which the number of crystals utilized is less than in circuits heretofore known.

Another object of this invention is to reduce the bandwidth of multiplier circuits utilized in multi-channel radio equipment in accordance with the principles of this invention.

Still another object of this invention is to substantially eliminate spurious frequency responses in the output of this equipment due to frequency generation.

One of the features of my invention is the use of a plurality of crystals which can be selectively coupled to a crystal-controlled oscillator. The output of the oscillator is multiplied in a broadband multiplier circuit and

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coupled as one input to a mixer circuit. A crystal-controlled local oscillator has its output selectively multiplied, by one of a plurality of integers, in a multiplier circuit whose output is coupled as a second input to the mixer circuit. The output of the mixer circuit is filtered and amplified to provide the radio frequency for each channel.

As the crystal is selected from the plurality of crystals to be coupled to the first crystal-controlled oscillator, there is also selected responsive to this crystal selection the integer by which the output of the local oscillator is multiplied and also responsive to the original crystal selection is the tuning of the circuits associated with the filters and amplifiers coupled to the output of the mixer circuit.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic drawing in block form of a multi-channel radio equipment frequency generator in accordance with the principles of my invention; and

Fig. 2 is a chart helpful in explaining my invention.

Referring now to the specific embodiment of the present invention illustrated in Fig. 1, it is seen that a crystal turret 1 containing a plurality of crystals is provided to mechanically couple one of the plurality of crystals in the turret to a crystal-controlled oscillator. In accordance with well known principles, the output of the crystal-controlled oscillator will be at a frequency dependent upon the resonant frequency of the crystal coupled to the crystal turret 1. The output of the crystal-controlled oscillator is passed through a broadband multiplier 3 whose bandwidth must be sufficiently broad to encompass the resonant frequencies of all the crystals contained in turret 1. The output of the broadband multiplier 3 is coupled as one input to a mixer circuit 4.

Another crystal 5, distinct from the plurality of crystals contained in crystal turret 1, is coupled to a local oscillator 6. The output of the crystal-controlled local oscillator 6 is coupled through a multiplier 7 which multiplies the frequency of the output of oscillator 6 by one of a plurality of integers. The output of the multiplier 7 is coupled as the second input to the mixer circuit 4. The outputs of the multipliers 3 and 7 forming the inputs to mixer 4 are mixed together to produce the usual beat frequencies. The output of mixer 4 is coupled through filter 8 which selects one of the beat frequencies and couples this frequency to power amplifier 9 whose output forms the frequency of one of the channels of the multi-channel radio equipment.

As indicated by mechanical coupling linkage 10, the selection of the integer by which multiplier 7 multiplies the output of local oscillator 6 is responsive to the rotation of the crystal turret 1. Movement of the crystal turret 1 is coupled via mechanical linkage 11 and gear train 12 and mechanical linkage 13 to control the selection of the beat frequency from the output of mixer 4 by the tuned circuits in the filter 8 and power amplifier 9.

The operation of the foregoing circuit will become clearer from the following description. Assuming for a given example that it is desired to produce a minimum of 126 channels each 1 mc. wide in the 1025–1150 mc. band, then it can be shown that by utilizing 42 crystals in the crystal turret 1 ranging from 39.5 to 41 mc. and having the broadband multiplier comprising three tripler circuits to multiply the crystal frequencies by 27 to produce as one input to the mixer signals within the 1067–1108 mc. band and by having the frequency of crystal 5 at 42 mc. and having multiplier 7 multiplying the output of the local oscillator 6 by unity it is obvious that the

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filter 8 can select 126 channels within the 1025-1150 mc. band from the output of mixer 4. For example, let it be assumed that the 40 mc. crystal is coupled to an oscillator whose output is multiplied by 27 in circuit 3 to produce as one input to mixer 4 a signal at 1080 mc. If the output of the local oscillator 6 at 42 mc. is coupled to mixer 4, it is obvious that the output of mixer 4 will contain the 1080 mc. signal and the  $1080 \text{ mc.} \pm 42 \text{ mc.}$  produced at the output of the equipment shown in Fig. 1, dependent upon the setting of filter 8 and the tuned circuit of power amplifier 9, three crystal-controlled channel frequencies. Each of the other crystals in the crystal turret will also produce three crystal-controlled frequencies for use in the multi-channel equipment and thus 126 channels can be generated from the 42 crystals in the crystal turret 1 and the single crystal utilized with local oscillator 6. Since each crystal coupled to crystal oscillator 2 can produce three channel frequencies, it is obvious that the filter 8 and the tuned circuit of power amplifier 9 must be set in one of three positions for each crystal coupled to the oscillator 2. This is accomplished by having gear ratio 12 provided so that for each crystal coupled to the oscillator 2 there are three positions of the frequency sensitive portion contained in filter 8, power amplifier 9. The above system for generating 126 channels is charted on line 1 of Fig. 2 where it is seen that 126 channels require a total of 43 crystals and a multiplier bandwidth of approximately 42 mc. while using a 42 mc. local oscillator and a gear ratio of 3.

By using more than a single multiple of the local oscillator frequencies but having a plurality of integers by which the output of local oscillator 6 can be multiplied, an additional reduction in the number of crystals in the total system is achieved and, equally important, the bandwidth of the multiplier 3 is decreased. Assuming the same requirements as set forth above for the desired output, by utilizing a crystal turret 1 containing only 25 crystals and a local oscillator frequency of 25 mc. instead of 42 mc. but by having a multiplier 7 selectively produce an output either equal to or twice the frequency of local oscillator 6, an equivalent number of channels can be achieved. For example, again assuming that the 40 mc. crystal is coupled to oscillator 2 and multiplied by 27 in circuitry 3 to form one input of the mixer 4 and further assuming that the frequency output of local oscillator 6 is 25 mc. which can be coupled to mixer 4 or doubled before it is coupled to mixer 4, it is obvious that the output of mixer 4 will contain the following frequencies:

$$f_{1n_1} = 1080 \text{ mc.}$$

$$f_{1n_1} - f_{2n_2} = 1055 \text{ mc. when } n_1 \text{ equals 1; and } 1030 \text{ mc. when } n_2 \text{ equals 2}$$

$$f_{1n_1} + f_{2n_2} = 1105 \text{ mc. when } n_2 \text{ equals 1; and } 1130 \text{ mc. when } n_2 \text{ equals 2}$$

Thus it is apparent by using more than a single multiple of  $f_2$ , which is achieved through the use of a multiplier circuit 7, the output of the mixer 4 can be made to contain five frequencies instead of the three frequencies obtained utilizing only a single frequency for mixing with the output of multiplier 3. However, it is obvious that in order to achieve each of these frequencies in the output of the system, the crystal turret 1 must rotate a complete revolution while the multiplier 7 multiplies the output of local oscillator 6 by a single integer and on the next revolution of the crystal turret 1 the multiplier 7 should multiply the output of the local oscillator 6 by another integer. It is also obvious that since there are five frequencies in the output of mixer 4, the tuned circuits of mixer 8 and power amplifier 9 must be positioned in one of five positions for each position of the crystal turret 1 and this again is achieved by the use of gear ratio 12.

Referring to Fig. 2, it is seen that further reduction in the number of crystals utilized in this system and a

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further reduction in the multiplier bandwidth can be achieved through the use of a greater number of local oscillator frequencies which can be mixed with the broad-band multiplier 3 output.

It will be appreciated that the filterable spurious signal at the output of the mixer 4 differs from the desired frequencies by a factor equal to  $f_2 n_2$  and, therefore, can be as low as  $f_2$  on some channels. It is thus seen that a limit is consequently reached when sufficient selectivity of filter 8 cannot be economically provided.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A device for generating a plurality of radio frequencies comprising a plurality of first piezo-electric devices each adapted to resonate at a given frequency, means to generate a first frequency responsive to the given frequency of one of said devices, means to couple a selected one of said plurality of piezo-electric devices to said first frequency generating means, a second piezo-electric device, means to generate a second frequency responsive to said second piezo-electric device, means to selectively multiply by one of a plurality of integers the frequency of the output of said second frequency generating means, means to mix the output of said multiplying means with said first frequency to produce at the output of said mixing means a plurality of distinct frequencies and filter means to select one of said plurality of mixer means output frequencies.

2. A device for generating a plurality of radio frequencies comprising a plurality of first piezo-electric devices each adapted to resonate at a given frequency, means to generate a first frequency responsive to the given frequency of one of said devices, means to couple a selected one of said plurality of piezo-electric devices to said first frequency generating means, a second piezo-electric device, means to generate a second frequency responsive to said second piezo-electric device, frequency multiplying means to produce in its output the product of said second frequency and a selected one of a plurality of consecutive integers, means to mix the output of said multiplying means with said first frequency to produce at the output of said mixing means a plurality of distinct frequencies and filter means to select one of said plurality of mixer means output frequencies.

3. Multi-crystal control channel radio equipment comprising a plurality of crystals, less than the number of channels and each having a different frequency at which it is resonant, means to generate a first frequency responsive to one of said plurality of crystals, means to selectively couple one of said plurality of crystals to said first frequency generating means, a second crystal distinct from said plurality of crystals, means to generate a second frequency responsive to said second crystal, means to selectively multiply by one of a plurality of integers the output of said second frequency generating means, said one of the plurality of integers being selected responsive to said selective coupling means, means to mix the output of said first frequency generating means and the output of said multiplying means to produce at the output of said mixing means a plurality of frequencies and means to select one of said plurality of output frequencies from the output of said mixing means.

4. Multi-channel radio equipment in accordance with claim 3, wherein said means to select one of said plurality of frequencies from the output of said mixing means includes variable filter means responsive to said selective coupling means.

5. Multi-crystal control channel radio equipment comprising a plurality of crystals less than the number of channels and each having a different frequency at which

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it is resonant, means to generate a first frequency responsive to one of said plurality of crystals, means to selectively couple one of said plurality of crystals to said first frequency generating means to produce said first frequency, multiplying means to raise said first frequency to a higher frequency, a second crystal distinct from said plurality of crystals, means to generate a second frequency responsive to said second crystal, means to selectively multiply by one of a plurality of integers the output of said second frequency generating means, said one of the plurality of integers selected responsive to said selective coupling means, means to mix the multiplied output of said first frequency generating means and the output of

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said multiplying means to produce at the output of said mixing means a plurality of frequencies and means responsive to said selective coupling means to select one of said plurality of output frequencies from the output of said mixing means.

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