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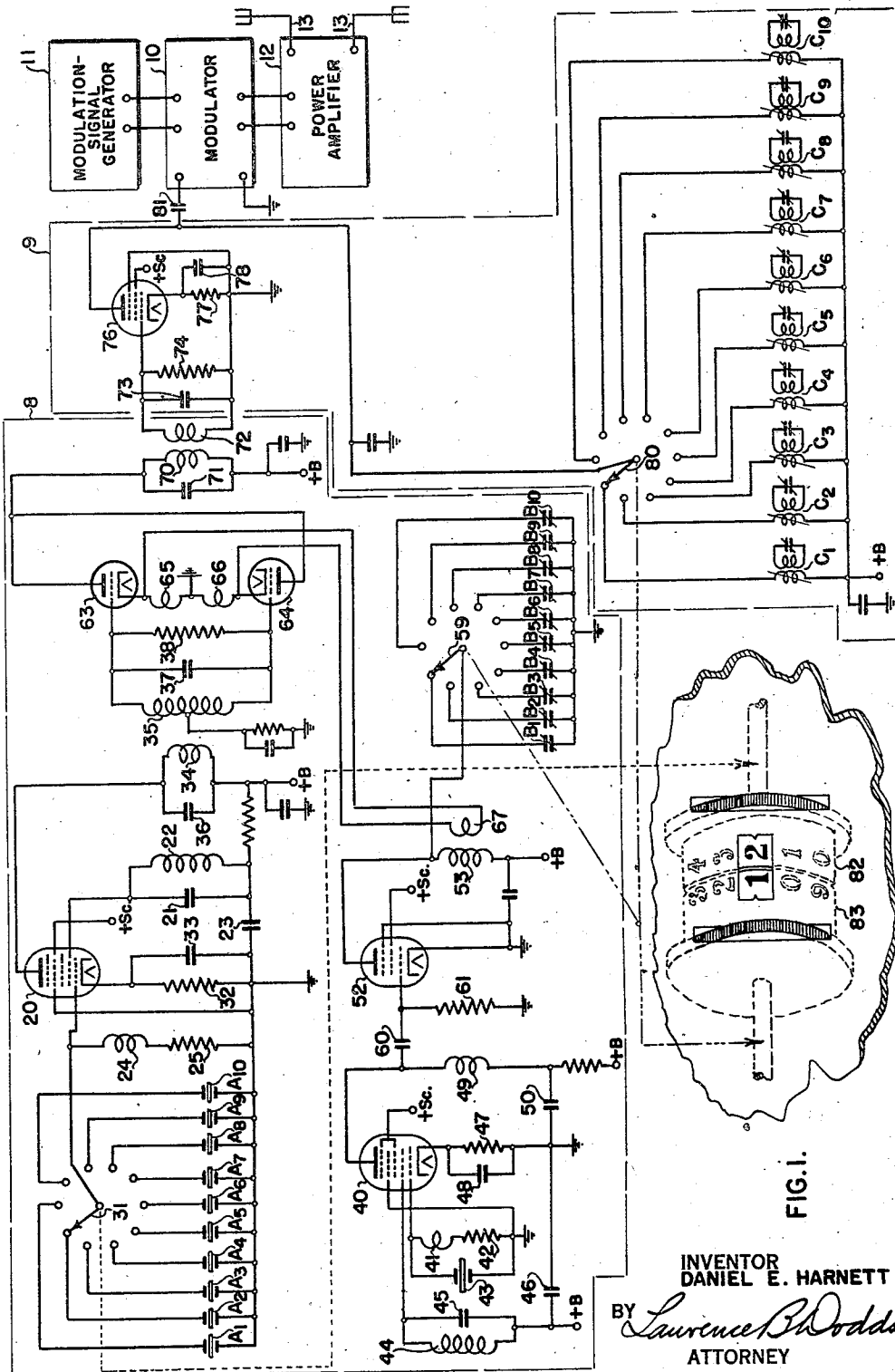
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2,401,481

HIGH-FREQUENCY SIGNAL GENERATOR

Filed Sept. 30, 1940

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FIG. 2.

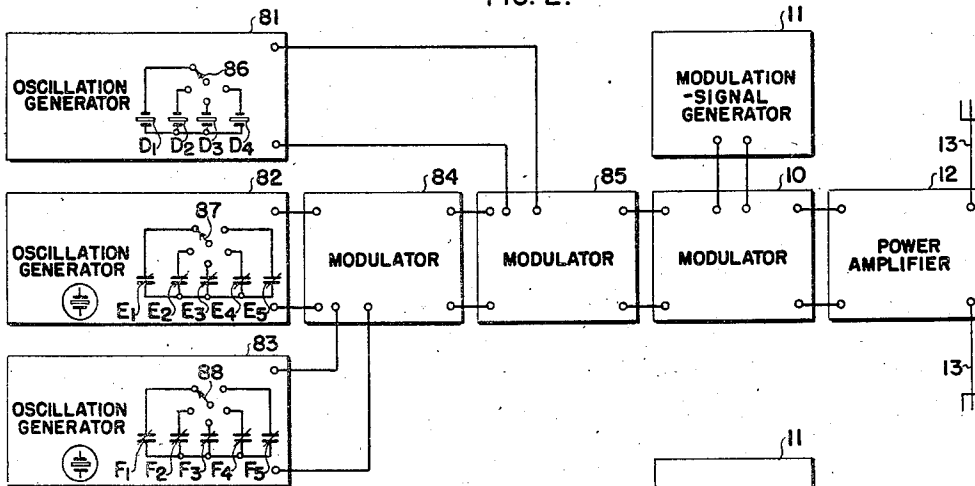
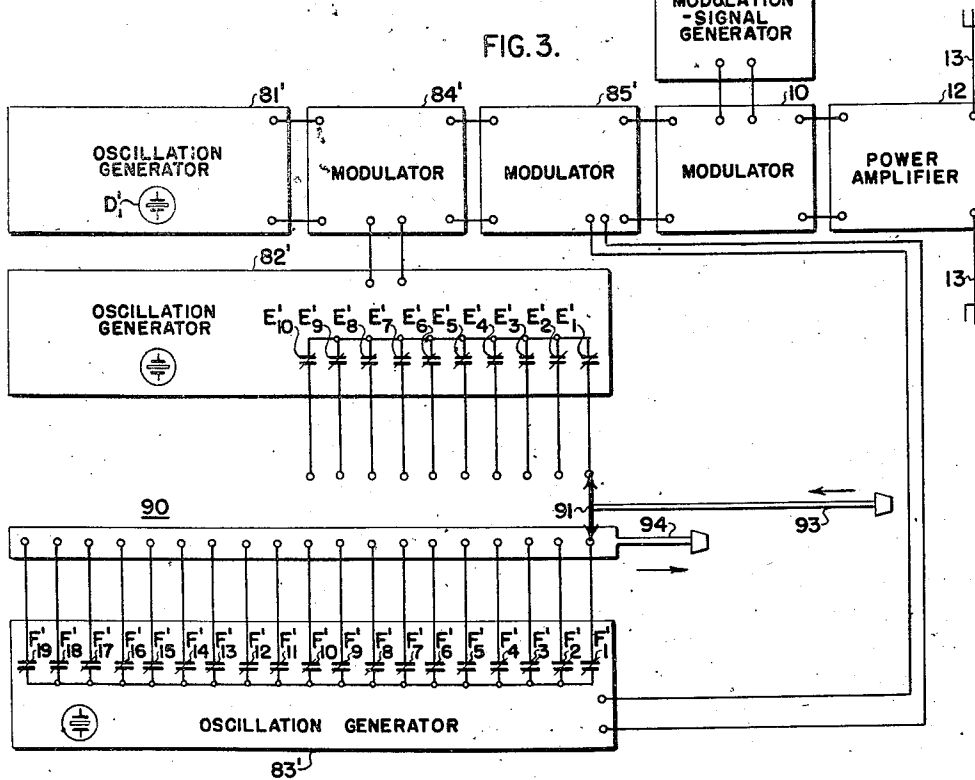


FIG. 3.



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HIGH-FREQUENCY SIGNAL GENERATOR

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4 Claims. (Cl. 250—36)

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This invention relates to high-frequency signal generators for generating stabilized oscillations at any one of a plurality of predetermined high frequencies and, while the invention is of general application, it is particularly suitable for use as a carrier-frequency generator in a carrier-signal transmitter adapted to transmit carrier signals having any one of a plurality of different carrier frequencies.

It is frequently desirable to provide a high-frequency signal generator or oscillator for generating stabilized high-frequency oscillations at any one of a plurality of predetermined high frequencies. For instance, such an oscillator is useful in a carrier-signal transmitter adapted to transmit carrier signals of any one of a plurality of different carrier frequencies. If a tunable high-frequency oscillator is used in such a transmitter, it is generally found that the frequency of the generated carrier signal tends to drift; for instance, such a drift or change in frequency may be caused by variations in humidity or temperature which affect the oscillator. Crystal-controlled oscillators have been used in order to eliminate such difficulties, but if the transmitter is to be used on a large number of different channels, the circuit for such an oscillator becomes very complicated and very costly due to the large number of crystals and switching elements required. Other expedients have, therefore, been suggested to overcome these difficulties. Thus, it has been proposed to provide a tunable low-frequency oscillator, the stability of a low-frequency oscillator being relatively much better than that of a high-frequency oscillator, and to heterodyne the output of the low-frequency oscillator with the output of a high-frequency crystal-controlled oscillator to provide a source of relatively stable high-frequency oscillations adjustable over a range of frequencies. Such a system, however, also usually has the disadvantages that the frequency drift thereof is greater than is tolerable under certain conditions of operation and that a frequency error is introduced in determining the correct adjustment of the tunable low-frequency oscillator for each high-frequency signal to be generated. It is very desirable, therefore, to provide a high-frequency signal generator which is not subject to one or more of the disadvantages enumerated above.

It is, therefore, an object of the present invention to provide an improved high-frequency signal generator for generating signals of any one of a plurality of predetermined high frequencies which is not subject to one or more of the disad-

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vantages of the prior art arrangements mentioned above.

It is another object of the invention to provide a simplified crystal-controlled high-frequency signal generator for generating signals of any desired one of a plurality of predetermined high frequencies.

In accordance with the invention, a high-frequency signal generator for generating any desired one of a plurality of predetermined signals comprises a first crystal-controlled oscillator for generating oscillations of a predetermined frequency, and a second crystal-controlled oscillator for generating oscillations of a predetermined frequency and comprising a fundamental component and a plurality of harmonic components. Means are provided for selecting any one of predetermined ones of the above-mentioned generated components, together with means for heterodyning the selected component with the first-named oscillations, to develop a desired output signal.

In accordance with a preferred embodiment of the invention, the signals generated are equally and closely spaced relative to the mean frequency of the band of frequencies including the desired output signal and the said first crystal-controlled oscillator generates oscillations of a relatively high frequency, while the said second crystal-controlled oscillator generates oscillations of a relatively low frequency.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Fig. 1 of the drawings is a circuit diagram, partly schematic, of a complete carrier-signal transmitter for operating on any one of a plurality of different channels which includes a high-frequency signal generator in accordance with the invention; while Figs. 2 and 3 are schematic diagrams of different embodiments of the invention.

Referring now more particularly to Fig. 1 of the drawings, the circuit thereof represents a conventional carrier-signal transmitter comprising, in cascade, a carrier-signal generator 8 and carrier-signal amplifier 9, the details of which are described hereinafter, a modulator 10 to which is also coupled a modulation-signal generator 11, a power amplifier 12 and an antenna circuit 13. The operation of the transmitter, neglecting the details of operation of units 8 and 9 compris-

ing the present invention, will be readily understood by those skilled in the art, rendering a detailed description thereof unnecessary. In brief, however, modulation signals are generated in unit 11 and are applied to the modulator 10 where they are caused to modulate carrier-frequency oscillations of a selected frequency supplied by units 8 and 9, the modulated-carrier signal so produced being thereafter amplified in the amplifier 12 and supplied to the antenna circuit 13, 13 for transmission.

Coming now to the portion of the system of Fig. 1 comprising the present invention, the high-frequency signal generator 8 includes a first crystal-controlled oscillator including tube 20 for generating oscillations of any one of a plurality of predetermined relatively high frequencies. The oscillator is of the tuned grid-tuned plate type and includes a parallel-resonant circuit including a condenser 21 and an inductance 22 coupled between the oscillator-anode element of the tube and ground through a condenser 23 and also an inductance 24 connected between the first signal-input electrode of tube 20 and ground through a resistor 25, the series-connected inductance 24 and resistor 25 being adapted to have included in parallel therewith by means of a switch 31 any one of a plurality of frequency-controlling crystals A₁-A₁₀, inclusive. A suitable bias is provided for the tube 20 by means of a cathode resistor 32 by-passed by a condenser 33. The output circuit of the oscillator tube 20 includes a band-pass selector circuit comprising a transformer 34, 35 tuned by condensers 36, 37, respectively, a damping resistor 38 being coupled across the secondary winding 35 to broaden and flatten its response characteristic so that it is effective to pass any of the predetermined oscillations generated by the oscillator tube 20 with approximately uniform response.

A second crystal-controlled oscillator including a vacuum tube 40 is provided for generating oscillations of a predetermined relatively low frequency and of a wave form rich in harmonic components, for example, a square wave form, this oscillator also being of the tuned grid-tuned plate type. This oscillator comprises a series-connected inductance 41 and resistor 42, which is shunted by a frequency-controlling crystal 43, connected between the first signal-input electrode of tube 40 and ground and a parallel-resonant circuit, comprising an inductance 44 and a condenser 45 coupled between the oscillator-anode element and ground, through a by-pass condenser 46. A cathode-biasing resistor 47 by-passed by a condenser 48 is provided for vacuum tube 40, while the output circuit thereof includes in series an inductance 49 and a by-pass condenser 50.

As stated above, the circuit of the oscillator 40 is so proportioned that oscillations are generated comprising a fundamental component and a plurality of harmonic components of substantial amplitude. This is accomplished by operating the anode of tube 40 at a relatively low voltage so as to obtain anode-circuit limiting of the tube current, in which case the generated oscillations are of substantially square wave form. Although such an output signal is rich in harmonics, the intensity of the harmonics may be a discontinuous function of the order of the harmonics and the inductance 49 is provided for differentiating the oscillations.

The generator 8 also includes means for selecting any one of a predetermined number of the

above-mentioned fundamental and harmonic components generated in oscillator tube 40 specifically for selecting consecutive ones of the components. This means comprises a tube 52 having an output circuit including an inductance 53 adapted to be tuned by any one of condensers B₁-B₁₀, inclusive, selected by means of a switch 59. The output signal from oscillator 40 is supplied to the signal-input electrode of tube 52 through a coupling condenser 60 and a grid-leak resistor 61. The oscillator 40, together with the selector 52, may, therefore, be considered as a crystal-controlled oscillation generator for generating oscillations of any of a plurality of predetermined frequencies.

In order to heterodyne the selected component derived from oscillator 40 by means of tube 52 and its associated selector circuits and the oscillations developed by oscillator 20, there is provided a modulator including tubes 63, 64 having a balanced input circuit including inductances 65 and 66 respectively in series with the cathodes of tubes 63 and 64. The signal components of oscillator 40, which are selected through the circuits associated with vacuum tube 52, are applied to the modulator by means of an inductance 67 inductively coupled to inductance 53 and coupled across series-connected inductances 65, 66. In order to supply the oscillations of a selected frequency generated by the crystal-controlled oscillator 20 to the modulator tubes 63, 64, the terminals of the secondary winding 35 of transformer 34, 35 are coupled respectively to the signal-input electrodes of tubes 63, 64 in push-pull relation. The output circuit of the modulator 63, 64 is of the unbalanced type and includes a tuned circuit comprising a parallel-connected inductance 70 and condenser 71, inductance 70 being inductively coupled to an inductance 72 connected to the input terminals of unit 9, the inductance 72 being tuned by a condenser 73 and damped by a resistor 74. The input circuit of modulator 63, 64 is thus untuned with respect to the signals provided from the low-frequency oscillator 40 and is relatively broadly fixed-tuned with respect to the range of signal frequencies provided by oscillator 20. Such a circuit avoids the necessity for switching in the input and output circuits of the modulator comprising tubes 63 and 64.

In order further to select the modulation signal developed in modulator 63, 64, there is provided a selector system including an amplifier tube 76 having input electrodes connected across the secondary winding of transformer 70, 72 through a cathode-biasing resistor 77 shunted by a condenser 78, any one of a plurality of selector circuits C₁-C₁₀, inclusive, being adapted to be coupled into the output circuit of tube 76 by means of a switch 80. Each of the tuned circuits C₁-C₁₀, inclusive, is individually adapted to pass a band of frequencies comprising the signals generated by modulator 63, 64 when a corresponding one of the condensers B₁-B₁₀, inclusive, is connected into circuit to tune inductance 53 and the crystals A₁-A₁₀, inclusive, are successively switched into circuit to tune inductance 24. The anode of tube 76 is coupled to the input circuit of modulator 10 by a coupling condenser 81. Suitable operating potentials for the tubes 20, 40, 52, 63, 64, and 76 are supplied from the sources +Sc and +B in a conventional manner, as indicated.

The system preferably includes a dial arrangement 82 adapted to be uncontrolled with switch 31 and having thereon digits from zero to nine,

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inclusive, to indicate the particular one of the crystals A_1 - A_{10} , inclusive, which is coupled into the circuit of tube 20 by switch 31. Also, there is provided a similar dial 83 uncontrolled with switches 59 and 80, thereby to indicate which of condensers B_1 - B_{10} , inclusive, and selector circuits C_1 - C_{10} , inclusive, are included in the circuit. The dials 82 and 83 are disposed adjacent to one another and, since there are ten selectable frequencies generated by each of the oscillators 20 and 40, forming a decade system, the two associated digits thereon indicate numerically the particular channel to which the transmitter is tuned.

In considering the operation of the high-frequency generator 8, 9 of Fig. 1, it will be assumed that crystals A_1 - A_{10} , inclusive, are adapted to tune the crystal-controlled oscillator 20 in equal frequency steps each equal to the desired frequency separation of the resultant carrier signals. Furthermore, it will be assumed that oscillator 40 is adapted to generate oscillations such that, with the cooperation of selective circuits formed by inductance 53 and condensers B_1 - B_{10} , inclusive, fundamental and harmonic components of such oscillations which are selected vary in steps which are multiples of the over-all range of oscillator 20, in this case the steps being ten times those of oscillator 20, that is, ten times the desired frequency separation of the resultant carrier signals. Furthermore, it is assumed that the selector circuit 70, 71, 72, 73 in the output circuit of modulator 53, 54 is effective to pass components corresponding to only the sum frequencies of the first and second crystal-controlled oscillations.

It is thus seen that tube 20 operates in a conventional manner to develop sustained sinusoidal oscillations at a frequency determined by the particular one of the crystals A_1 - A_{10} , inclusive, which is coupled into its circuit. Similarly, tube 40 generates oscillations, the frequency of which is determined by the crystal 43, the feed-back coupling being sufficiently great and the anode voltage being sufficiently low that the oscillations are of substantially square wave form. The signal input to tube 52 comprises the square-wave oscillations generated by tube 40 differentiated by inductance 49 into oscillations of double-impulse wave form which are applied to the signal-input electrode of tube 52 through the coupling condenser 60 and grid-leak resistor 61 so that the positive peaks of the differentiated signal pulses are stabilized at the zero grid-voltage level, while the negative pulses of the wave are in the cutoff region of the grid voltage-plate current characteristic of tube 52. The output of tube 52 under these conditions consists of narrow current pulses which include harmonics which progressively decrease in amplitude with the order of the harmonic. The selector circuits in the output circuit of tube 52 have a common inductance 53 so that, when the various condensers B_1 - B_{10} , inclusive, are successively switched thereacross, the L/C ratios of the resulting selector circuits progressively increase with frequency, thus compensating for the progressive decrease in amplitude of the harmonic components with increase in their order. While the oscillator 20 has been described as a multicrystal sinusoidal oscillator and the oscillator 40 as a single-crystal multiharmonic oscillator, it will be understood by those skilled in the art that either of the oscillators 20 and 40 may be of either of these types, depending on the frequency requirements. However, usually the frequency relations are such that one of the oscillators is a

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relatively high-frequency oscillator for which the multicrystal oscillator is most suitable. Furthermore, it will be understood that the number of harmonic components which can be usefully separated in the output circuit of an oscillator of the type of oscillator 40 is limited by the limitations of conventional selector circuits.

Under the conditions assumed above, it will be seen that, with the switches in the positions illustrated, the frequency of the oscillations of oscillator 20 is determined by crystal A_2 and the frequency component of the output of oscillator 40 which is selected is determined by the condenser B_2 . Therefore, the carrier signal developed by the modulator 53, 54 has a frequency which is the heterodyne sum of these frequencies, that is, the twelfth channel signal, as indicated by the dials 82, 83 uncontrolled with the selector switches 59 and 81, respectively. At the same time, the switch 80 is operated to connect the selector circuit C_2 in the output circuit of amplifier 76, this circuit being effective to pass all carrier signals generated by selection of condenser B_2 by switch 59, with which switch 80 is uncontrolled, and by the selection of any of the crystals A_1 - A_{10} , inclusive, associated with oscillator 20. It is, therefore, seen that the transmitter illustrated is adapted to operate on any of 100 adjacent channels while only eleven crystals are required in the circuit; that is, the high-frequency generator of the invention is effective to generate any one of a plurality of signals which are equally and closely spaced relative to the mean frequency of the band including the desired output signals.

It is thus apparent that by utilizing the principles of the invention, any desired frequency range can be covered in steps of any desired frequency separation by providing a first crystal-controlled oscillator, such as oscillator 20, for generating oscillations of predetermined frequencies having frequency spacings equal to those of the signals to be generated and by providing a second frequency-controlled oscillation generator, such as oscillator 40, for generating oscillations comprising a fundamental component and harmonic components, the fundamental frequency thereof being equal to the product of the desired frequency spacing of adjacent channels and the number of oscillation frequencies developed by the first oscillator.

The principle of the embodiment of the invention illustrated and described in Fig. 1 may be generally defined in terms of certain elementary or basic factors which are usually the known characteristics of any system to be designed and which will aid in such design. If it is assumed that the system is required to cover n adjacent channels having a frequency separation f_s and a lowest carrier frequency f_c , the following relations apply:

Let

m =number of frequencies developed by the first oscillator, for example, oscillator 20;

H =lowest order harmonic of oscillator 40 utilized when oscillator 20 is tuned by a single crystal.

Then the lowest order harmonic which can be satisfactorily utilized for any given set of conditions is H/m . This factor H/m is determined by the selectivity of the selector 70, 71, 72, 73 in the output of modulator 53, 54, that is, the lowest frequency spacing of the sum and difference frequency components in the output of modulator 53, 54 that can be satisfactorily separated. If n

is the lowest percentage difference between such sum and difference frequencies which can be readily separated in terms of the lowest carrier frequency f_c , then

$$H = \frac{pf_c}{200f_s}$$

Under these conditions, the fundamental frequency f_1 of the second or low-frequency oscillator, for example, oscillator 40, is $m f_s$ and the particular frequencies of the first oscillator are:

$$f_s - H f_s = f_s - \frac{H}{m} f_1 \text{ where } f_1 = m f_s$$

$$f_s - H f_s + f_s$$

$$f_s - H f_s + 2 f_s \dots \text{ to}$$

$$f_s - H f_s + (m-1) f_s$$

The orders of the particular harmonic components selected from the output of the second oscillator are the successive harmonics from

$$H/m \text{ to } H/m + \left(\frac{n}{m} - 1\right)$$

The number of harmonic filters required for tube 52 = n/m . The relative tolerance limits for the selector circuits including condensers B₁-B₁₀, inclusive, equals mA , where A is a constant depending on the power factor of the selector circuits. The value of H/m is approximate and actually the next higher integer will generally be selected as the lowest order harmonic. Furthermore, in some cases, it may be desirable, arbitrarily, to select the lowest order harmonic at some higher value.

While applicant does not intend to be limited to any particular circuit values, the arrangement of Fig. 1 has been found to be of particular utility in providing an oscillation source for a transmitter adapted to operate over the frequency spectrum of 20-28 megacycles and including one hundred channels each having a separation f_c of 80 kilocycles, the lowest carrier frequency f_c being 20.04 megacycles. In such an embodiment, ten crystals were provided for the first oscillator ($m=10$) to develop output oscillations therefrom of 7.64, 17.72, 17.80, 17.88, 17.96, 18.04, 18.12, 18.20, 18.28, and 18.36 megacycles. Correspondingly, the second oscillator corresponding to oscillator 40 was provided with a crystal resonant at a fundamental frequency $m f_s$ of 800 kilocycles, while the selector included in the output circuit of tube 52 was provided with ten condensers effective to select the 2.4, 3.2, 4.0, 4.8, 5.6, 6.4, 7.2, 8.0, 8.8, and 9.6 megacycle components of the second oscillator, comprising the third (H/m) to twelfth ($H/m + n/m - 1$) harmonics of the frequency-determining crystal. In this embodiment of the invention, it was found expedient to utilize crystals in the first or high-frequency oscillator 20 of the low-temperature coefficient "A cut" type oscillating in shear in the third-harmonic mechanical mode. Such crystals are readily obtainable with a temperature coefficient of 2 cycles per megacycle per degree C. in the temperature range of 20 to 55 degrees C. This corresponds to a stability of about 0.01 per cent. Also, a crystal of the "A cut" type, but oscillating in the fundamental mechanical mode, is preferred for use in the second or low-frequency oscillator 40. The following tube types were utilized in the transmitter referred to:

Tube 20	Type 6K8
Tubes 63, 64	Type 6J5G
Tube 40	Type 6K8
Tube 52	Type 6SK7GT

In Fig. 2 there is illustrated in schematic form a complete carrier-signal transmitter which includes an embodiment of the signal generator of the invention generally similar to that of Fig. 1

and similar circuit elements have identical reference numerals. In order to generate a carrier-frequency signal to be supplied to the modulator 10 of the transmitter of Fig. 2, there are provided three crystal-controlled oscillation generators 81, 82, and 83 and modulators 84 and 85. Only the portions of the oscillation generators necessary to an understanding of the invention are shown in the drawings. Oscillation generator 81, the circuit of which may be of any conventional type, for instance, of the same type as oscillator 20 of Fig. 1, is provided with frequency-controlling crystals D₁, D₂, D₃, D₄, individually adapted to be connected into the circuit of the oscillator by means of switch 86 in the manner described above with reference to oscillator 20. Oscillation generators 82 and 83 may be of the same type as the oscillation generator including tubes 40 and 52 of Fig. 1, the oscillation generators being adapted to have their output frequency determined by condensers E₁-E₅ and F₁-F₅, respectively, adapted to be connected into the circuit of their respective oscillators by means of switches 87 and 88, respectively. The output circuit of modulator 84 is tuned to select the sum heterodyne signal derived from oscillators 82 and 83 and apply it to the input terminals of modulator 85. The oscillations generated by oscillation generator 81 are also applied to input terminals of modulator 85 and the sum heterodyne components are selected in the output circuit thereof as an input signal for modulator 10. The remaining portion of the system is the same as that of Fig. 1.

In considering the operation of the circuit of Fig. 2, it will be seen that the elements 81-85, inclusive, perform the same function as elements 8 and 9 of Fig. 1; that is, they cooperate to produce a carrier-signal input to modulator 10. Also, it will be seen that the carrier signals so developed are such that the transmitter may be operated in one of 100 adjacent channels. In order to effect this type of operation, the crystals D₁-D₄, inclusive, are so chosen that individually they condition oscillation generator 81 to provide output signals of relatively high frequency which are spaced by the desired frequency spacing of the carrier signals to be developed by the transmitter. Condensers E₁-E₅, inclusive, are so chosen that they condition oscillation generator 82 to generate output signals of a relatively intermediate frequency and having a frequency spacing of one-fifth of the over-all frequency spectrum to be covered by the transmitter, while condensers F₁-F₅, inclusive, are so chosen that the output signals of oscillation generator 83 are of a relatively low frequency and have a frequency spacing of one-fifth of the frequency spacing of the signals developed by oscillation generator 82. As used herein the terms "relatively high," "relatively intermediate," and "relatively low" are intended to distinguish between the mean frequency of the oscillators to which the terms refer even in case the bands of frequencies covered by the oscillators may be, in part, coextensive or overlapping. If the circuit is proportioned as stated above and if the switches 86, 87, and 88 are in the positions shown, a carrier-frequency signal corresponding to the lowest channel in the frequency range to be covered by the transmitter will be generated and

carrier-frequency signals corresponding to the succeeding four channels will be obtained by operating switch 86 through each of its successive positions. Thereafter, if switch 88 is operated to its second position, the operation of switch 86 through each of its four positions is effective to condition the transmitter to generate the next succeeding four carrier signals required, etc.

It will be understood that any of oscillators 81, 82, and 83 may be of either of the types shown and that each of the oscillators may be adapted to provide any required number of output signals in accordance with the requirements of any particular installation.

A preferred modified arrangement of the embodiment of Fig. 2 is adapted to cover the frequency range of 20-28 megacycles in 100 channels of 80 kilocycles band width. In this arrangement, a single crystal is provided for oscillation generator 81 which is effective to provide output oscillations of 17.4 megacycles. Also, in this arrangement, each of oscillation generators 82 and 83 is adapted to provide ten different output signals, the oscillation generator 82 comprising an 800-kilocycle crystal-controlled oscillator and the condensers being adapted to be switched by switch 87 to select the third to the twelfth harmonic thereof, while the oscillation generator 83 comprises an 80-kilocycle crystal-controlled oscillator and the condensers thereof are to be switched by switch 88 to select the third to the twelfth harmonic thereof.

In this arrangement, therefore, and with the switches in the position shown, the output signal of oscillation generator 81 is 17.4 megacycles, that of oscillation generator 82 is 2.4 megacycles, and that of oscillation generator 83 is .24 megacycles. The signal output of oscillation generators 82 and 83 is, therefore, heterodyned in modulator 84 to provide an output signal of 2.64 megacycles, which signal is heterodyned in modulator 85 with the output signal of 17.4 megacycles from oscillation generator 83 to provide an output signal of 20.04 megacycles which is the frequency required for the first channel. The remaining higher frequency signals may be developed by operating the switches 87 and 88 in the sequence described above. If desired, these switches may be uncontrolled with a decade dial mechanism, such as that included in the system of Fig. 1.

In Fig. 3 there is illustrated still another embodiment of the invention which is generally similar to that of Fig. 2 and similar circuit elements have similar reference numerals with the addition of a prime. The circuit of Fig. 3 differs from that of Fig. 2, however, in the number of harmonic frequencies generated by each of the oscillation generators which are utilized and in the manner of combining the different signal outputs thereof to provide the desired output signals. The oscillation generator 81' has only a single-frequency-determining crystal D1', while oscillation generator 82' includes ten condensers E1'-E10', inclusive, for selecting ten consecutive harmonics thereof and oscillation generator 83' has nineteen condensers F1'-F19', inclusive, for selecting nineteen consecutive harmonics thereof. In this arrangement, however, the output circuit of modulator 84' is adapted to select the difference heterodyne signal from oscillators 81' and 82', while the output circuit of modulator 85' is proportioned to select the sum heterodyne signal from the modulator 84' and oscillator 83'.

Assuming, as before, that it is desired to provide

the output signals required for 100 channels in the frequency range of 20-28 megacycles, the oscillation generator 81' is adapted to produce output signals of 19.88 megacycles, while the oscillation generator 82' comprises an 800-kilocycle crystal-controlled oscillator, condensers E1'-E10', inclusive, being effective to select ten consecutive harmonics thereof, specifically, the harmonic components from 2-11, inclusive. Oscillation generator 83' comprises an 880-kilocycle crystal-controlled oscillator and condensers F1'-F19', inclusive, are so proportioned that the second to twentieth harmonics thereof are selected as an output signal for oscillation generator 83'. In order to select desired harmonics of the oscillators 82' and 83', there is provided a switch 90 having a series of ten stationary contacts connected to condensers E1'-E10', inclusive, a series of nineteen movable contacts coupled to condensers F1'-F19', inclusive, and a contact member 91 being operable to connect pairs of corresponding elements of the oscillation generators 82' and 83' into their respective oscillator circuits. The switch 90 also includes an operating handle or knob 93 to operate the contact member 91 and a handle or knob 94 for operating the movable contacts connected to the condensers F1'-F19', inclusive. With the switches in the position shown, the transmitter of Fig. 1 is conditioned to operate on the lowest channel of the range and may be conditioned for operating on the succeeding nine channels by operating lever 93 to the left successively to connect corresponding pairs of condensers into the circuits of oscillators 82' and 83', thereby selecting the successive harmonics of both oscillators, progressively increasing the frequency of the output of modulator 85' in steps of 80 kilocycles. In order to condition the transmitter for operation on the succeeding channel, the switch contact member 91 is returned to the position shown and handle 94 is moved one position to the right, thereby effectively adding to the frequency of the oscillator 81' the difference between the third harmonic of oscillator 83' and the second harmonic of oscillator 82'. The transmitter may then be conditioned for operation on the succeeding nine channels by moving handle 93 to the left and may similarly be conditioned to operate on the remaining channels by similar operations of the switch 90. It will be understood also that the oscillation generators 82' and 83' may be of the type of oscillator 20 of Fig. 1 rather than of the type of oscillator 40 of Fig. 1. It will also be understood that switch 90 may be of the drum type, elements 91 and 94 being rotatable, in which case these elements may be uncontrolled with a decade dial indicator as in the system of Fig. 1.

It is seen that each of oscillation generators 82, 83 and 82', 83' of Figs. 2 and 3 comprises a crystal-controlled oscillator for generating oscillations of a predetermined frequency including a fundamental component and a plurality of harmonic components. Furthermore, it is seen that any of the oscillation generators of Figs. 2 and 3, except oscillation generator 81', is a crystal-controlled oscillation generator for generating oscillations of a plurality of frequencies.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed

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in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A high-frequency signal generator for generating any one of a plurality of signals which are closely spaced relative to the mean frequency of the band of frequencies including the desired output signals comprising, a first oscillator for generating oscillations of any of a plurality of predetermined relatively high frequencies and including a plurality of frequency-determining crystals each resonant at one of its oscillation frequencies, a second crystal-controlled oscillator for generating oscillations of a predetermined relatively low frequency and comprising a fundamental component and a plurality of harmonic components having a frequency spacing greater than the frequency spacing of said predetermined relatively high frequencies, means for selecting any predetermined one of said high-frequency oscillations and any one of predetermined ones of said components, and means for heterodyning said selected component with said selected oscillations to develop a desired output signal, each of said predetermined harmonic components being so related in frequency to said selected oscillations that the sum and difference heterodyne components can be readily separated.

2. A high-frequency signal generator for generating any desired one of a plurality of predetermined equally-spaced signals comprising, a first oscillator for generating any of a plurality of oscillations of predetermined relatively high frequency, a second crystal-controlled oscillator for generating oscillations of a predetermined relatively low frequency comprising a fundamental component and a plurality of harmonic components having a frequency spacing greater than the frequency spacing of said predetermined relatively high frequencies, means for selecting any predetermined one of said high-frequency oscillations and any one of predetermined consecutive ones of said components, and means for heterodyning said selected component with said selected oscillations to develop a desired output signal, each of said predetermined harmonic components being so related in frequency to said selected oscillations that the sum and difference heterodyne components can be readily separated.

3. A high-frequency signal generator for generating any one of a plurality of predetermined equally-spaced signals comprising, a first relatively high-frequency crystal-controlled oscillation generator for generating any of a plurality

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of oscillations of predetermined frequencies having a frequency spacing equal to that of the signals to be generated, a second crystal-controlled oscillation generator for generating oscillations of a relatively intermediate predetermined frequency and comprising a generator for generating oscillations having a fundamental component and a plurality of harmonic components having frequency spacings equal to the product of the frequency spacing of said first-mentioned generator and the number of said first plurality of oscillations, a third crystal-controlled oscillation generator for generating oscillations of a relatively low predetermined frequency and comprising a fundamental component and a plurality of harmonic components having frequency spacings equal to the product of said second frequency spacing and the number of said plurality of harmonic components to be selected, means for adjusting said first oscillation generator to generate a predetermined one of said oscillations, means for selecting from each of said second and third oscillation generators predetermined harmonic components, means for heterodyning the harmonic components selected from said second and third oscillation generators to provide modulation components, and means for heterodyning said modulation components and the oscillations produced by said first oscillation generator to provide a desired output signal.

4. A high-frequency signal generator for generating any one of a plurality of predetermined equally-spaced signals comprising, a first relatively high-frequency crystal-controlled oscillation generator for generating any one of a plurality of oscillations of predetermined frequencies having frequency spacings equal to that of the signals to be generated, a second crystal-controlled oscillation generator for generating oscillations of a relatively low predetermined frequency, and comprising a fundamental component and a plurality of harmonic components having frequency spacings equal to the product of the frequency spacing of said first-mentioned generator and the number of said first plurality of oscillations, means for adjusting said first oscillation generator to generate a predetermined one of said oscillations, means for selecting from said second oscillation generator a predetermined one of said harmonic components, and means for heterodyning the harmonic component selected from said second oscillation generator and the oscillations produced by said first oscillation generator to develop a desired output signal.

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