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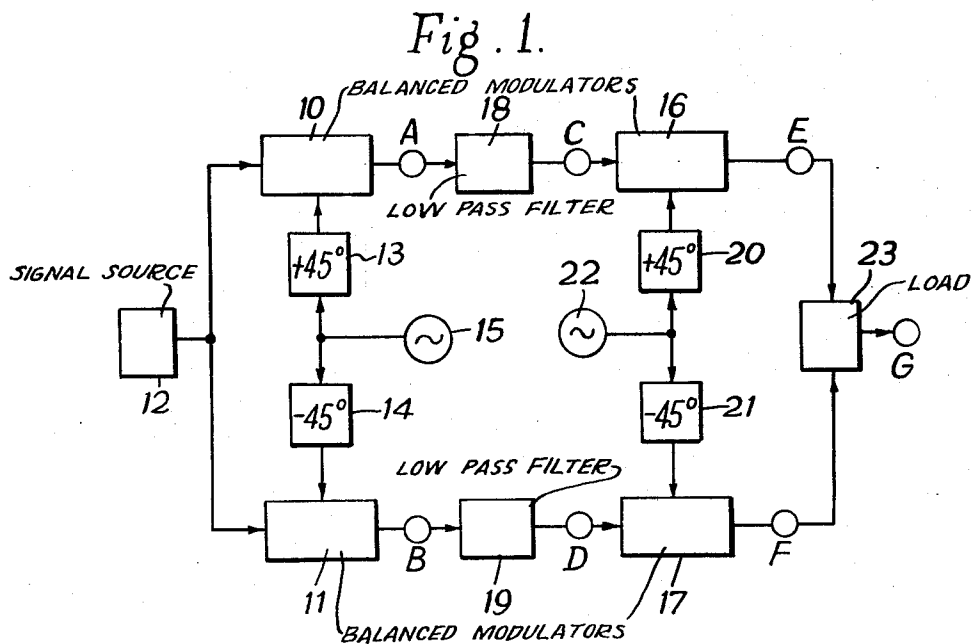
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MULTI-CHANNEL ELECTRIC WAVE SIGNALLING APPARATUS

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2 Sheets-Sheet 1



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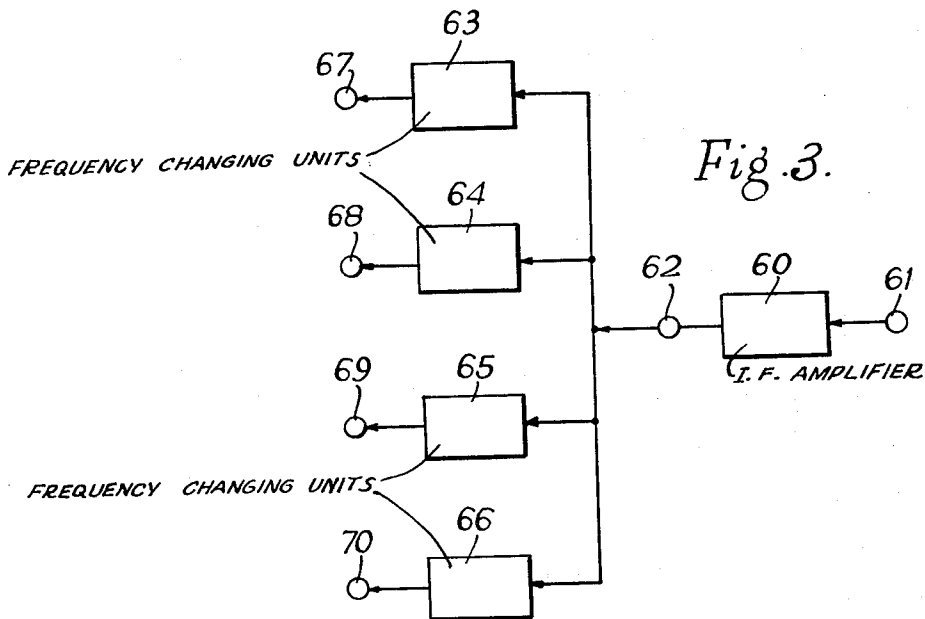
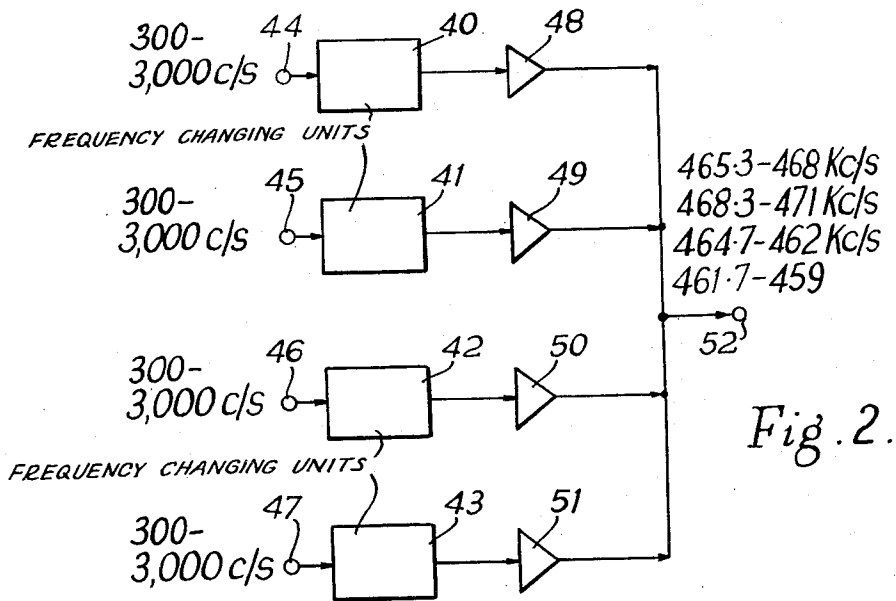
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3,259,692 MULTI-CHANNEL ELECTRIC WAVE SIGNALLING APPARATUS

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5 Claims. (Cl. 179—15)

This invention is concerned with electric wave signalling systems in which several channels of intelligence are transmitted simultaneously.

Radio and wire communication systems are known, in which a number of electric signals, each occupying a similar band of frequencies, are transmitted simultaneously. It is normal practice first to produce a single multi-channel signal by transposing the original signals in frequency, so that the various signals then occupy adjacent portions of a continuous frequency band wide enough to accommodate all the signals. The frequency of the resultant multi-channel signal is then transposed to a radio frequency or carrier frequency suitable for transmission.

In such systems, complex electric wave filters are required for the formation of the multi-channel signal.

At the receiving end of these systems, the multi-channel signal is transposed to a lower frequency and the frequency bands occupied by the separate signals are individually transposed to their original positions in the frequency scale thereby restoring the original signals. Again, complex wave filters are required to separate the bands of frequencies corresponding to each signal channel.

In modulated wave radio communication systems, it is usual to use one sideband only for the transmission of a multi-channel signal or to use the two sidebands independently, each transmitting a different multi-channel signal. In such systems, the frequency transposition processes referred to above are used to produce the multi-channel signal and to restore the separate signals transmitted by the individual channels.

It is an object of the present invention to provide carrier or radio frequency signalling apparatus whereby multi-channel electric signals are produced from a number of separate signals without the use of complex, and hence expensive, electric wave filters.

It is a further object of the invention to provide a multi-channel carrier or radio frequency signalling apparatus whereby the individual signals are separated into their separate channels from a multi-channel signal without the use of complex and expensive electric wave filters.

Accordingly, one form of the invention provides multi-channel electric wave signalling apparatus having separate signal channels for a plurality of signals each occupying a band of frequencies, comprising separate frequency changing means for each signal, each frequency changing means employing at least two simultaneous modulation processes for transposing in frequency the signal concerned, the frequency changing means together transposing the frequency of the plurality of signals to a plurality of adjacent or closely-spaced frequency bands and the output signals from the separate frequency changing means being combined into a single multi-channel signal, so that each signal is transposed in frequency by separately modulating the signal twice using different carriers in each modulation.

Another form of the invention provides multi-channel electric wave signalling apparatus having separate signal channels for a plurality of signals each occupying a band of frequencies, comprising separate frequency changing means for each signal, each frequency changing means

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employing at least two simultaneous modulation processes for transposing in frequency the signal concerned, the input signals to the frequency changing means being a single multi-channel signal and the frequency changing means together transposing the plurality of signals in frequency from a plurality of adjacent or closely-spaced frequency bands, to provide separate signals each occupying a band of frequencies, so that each signal is transposed in frequency by separately modulating the signal twice using different carriers in each modulation.

The frequency bands of the separate signal channels within the single multi-channel signal, representing the output signal or the input signal of the apparatus as the case may be, may either be adjacent channels, in that the upper frequency limit of one channel is also the lower frequency limit of the next channel of higher frequency or the channels may be closely spaced channels, in that consecutive channels extend over two frequency bands which are separated by a narrower frequency band in which no signals are transmitted.

In order that the invention may be more readily understood two embodiments will now be described by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a block schematic diagram of one form of known apparatus used in the embodiments for changing the position in the frequency scale of an electric signal occupying a band of frequencies.

FIG. 2 is a block schematic diagram of an arrangement for the generation of the multi-channel electric signals of an independent sideband radio communication system; and

FIG. 3 is a block schematic diagram of an arrangement for the reception of multi-channel electric signals in an independent sideband communication system.

The multi-channel electric wave signalling arrangements to be described have separate frequency changing units associated with each signal channel. In each of these units the position in the frequency scale of the band of frequencies comprising each signal channel is changed by a method involving the use of two or more simultaneous modulation processes and the subsequent combination of the modulation products.

The units are adjusted so that the frequency band corresponding to each channel occupies a desired frequency range and is adjacent to or spaced from but close to the frequency band occupied by another channel. Thus, the multi-channel signal formed when the separate signals from a group of frequency changing units are combined, occupies a total bandwidth approximately n times that of each individual signal channel, n being the number of such channels.

This multi-channel signal may occupy a frequency band which is suitable for transmission over wire circuits or it may occupy a frequency band to provide, after amplification, a single sideband or independent sidebands in a carrier or radio frequency signalling system. The same frequency changing units, adjusted in the manner referred to above, may be used in the reverse process, in a receiving arrangement, to restore each band of frequencies corresponding to a signal channel to its original frequency band.

Referring to FIG. 1, a first pair of balanced modulators 10 and 11 have their inputs connected in parallel and receive an electric signal from a source 12. The modulators 10 and 11 are supplied, via phase shifting networks 13 and 14, respectively, with an electric oscillation of fixed frequency from a first oscillator 15. The network 13 advances the phase of the oscillation fed to the modulator 10 by 45° and the network 14 retards the phase of the oscillation fed to the modulator 11 by 45° . The frequency of the oscillator 15 is set to a value corresponding

to the mid-frequency of the band occupied by the input signal. The resultant difference frequencies therefore, lie in a band between zero and a frequency corresponding to half the bandwidth of the input signal. The balanced modulators ensure that no appreciable output voltage is present at the frequency of the oscillator 15.

Second balanced modulators 16 and 17 receive, via low pass filters 18 and 19, having a cut-off frequency approximately equal to that of the frequency of the oscillator 15, only the difference frequency outputs of the first modulators 10 and 11 respectively. The modulators 16 and 17 are supplied, via phase shifting networks 20 and 21, with an electric oscillation of fixed frequency from a second oscillator 22. The network 20, associated with the modulator 16, advances the phase of the oscillation by 45° and the network 21, associated with the modulator 17, retards the phase of the oscillation by 45°, the phases of the oscillations fed to the modulators 16 and 17 are therefore in quadrature. The frequency of the oscillator 22 is set to a value to provide, in an output load 23 common to the modulators 16 and 17, a band of frequencies in the desired frequency range. The modulators 16 and 17 are balanced to ensure that no appreciable output is present at the frequency of the oscillator 22.

The generation of a single sideband signal, using the apparatus shown in FIG. 1, will now be given briefly in mathematical form. A full description is given in a paper published in the December 1956 issue of the Proceedings of the I.R.E. (U.S.A.).

Let the signal from the input source be:

$$e_s = 2 \sin \omega_s t \quad (1)$$

where $\omega_s = 2\pi f_s$ and f_s is a frequency in a band of frequencies occupied by the signal derived from the source 12. Then the outputs of the modulators 10 and 11 at terminals A, B, respectively, are:

$$e_A = e_s \sin \omega_0 t \quad (2)$$

$$e_B = e_s \cos \omega_0 t \quad (3)$$

where $\omega_0 = 2\pi f_0$ and f_0 is the frequency of the oscillator 15.

Substituting (1) in (2) and (3):

$$e_A = 2 \sin \omega_s t \sin \omega_0 t = \cos (\omega_s - \omega_0) t - \cos (\omega_s + \omega_0) t \quad (4)$$

and

$$e_B = 2 \sin \omega_s t \cos \omega_0 t = \sin (\omega_s + \omega_0) t + \sin (\omega_s - \omega_0) t \quad (5)$$

Frequencies above that of the oscillator 15 are removed by the filters 18 and 19. The inputs to the modulators 16 and 17 at terminals C and D respectively are:

$$e_C = \cos (\omega_s - \omega_0) t \quad (6)$$

and

$$e_D = \sin (\omega_s + \omega_0) t \quad (7)$$

The outputs of the modulators 16 and 17 at terminals E and F are:

$$e_E = e_C \sin \omega_1 t = \cos (\omega_s - \omega_0) t \sin \omega_1 t = \frac{1}{2} \sin (\omega_s - \omega_0 + \omega_1) t - \frac{1}{2} \sin (\omega_s - \omega_0 - \omega_1) t \quad (8)$$

$$e_F = e_D \cos \omega_1 t = \sin (\omega_s + \omega_0) t \cos \omega_1 t = \frac{1}{2} \sin (\omega_s + \omega_0 + \omega_1) t + \frac{1}{2} \sin (\omega_s + \omega_0 - \omega_1) t \quad (9)$$

where $\omega_1 = 2\pi f_1$, and f_1 is the frequency of the oscillator 22.

The outputs of the modulators 16 and 17 are combined in the circuit 23, the output at terminal G is therefore:

$$e_G = e_E + e_F = \sin (\omega_s - \omega_0 + \omega_1) t \quad \text{i.e. (8) and (9)}$$

Thus, the frequency band occupied by the input signal is raised to a position in the frequency scale corresponding to the upper sideband of a carrier frequency represented by $\omega_1 - \omega_0$ in the equation for e_G above.

The frequency $f_1 - f_0$ is not generated in the circuit and does not appear in the output.

Referring to FIG. 2, four frequency changing units, 40, 41, 42 and 43 have applied to their input terminals 44, 45, 46 and 47 respectively, four signals in the frequency band 300-3,000 c.p.s. comprising the separate

input signals of a multi-channel system. The units 40 to 43, of the type described with reference to FIG. 1, have their first oscillators set to generate oscillations at a frequency of 1,650 c.p.s. The frequencies of the second oscillators in the units 40, 41, 42 and 43 are set to provide oscillations at frequencies of 466.65 kc./s., 469.65 kc./s., 463.35 kc./s. and 460.35 kc./s., respectively.

The outputs of the units 40, 41, 42 and 43 are connected respectively to amplifiers 48, 49, 50 and 51, whose outputs are connected in parallel to feed a load, which is not shown, connected to terminal 52. Terminal 52 thus represents the input of the linear amplifying system of an independent sideband system. The generation of unwanted intermodulation products in the signals at terminal 52 is avoided by using amplifiers 48 to 51 of a type having an output impedance which remains substantially constant with varying signal amplitude.

In the unit 40, the signal applied to the input terminal 44 is transposed in frequency, to the frequency band 465.3 to 468 kc./s., that is $f_1 - f_0 + 300$ c.p.s. and $f_1 - f_0 + 3,000$ c.p.s.

Similarly the signal applied to the input terminal 45 of the unit 41 is transposed in frequency to the band 468.3 to 471 kc./s. The phases of the oscillations fed to the second modulators of the units 40 and 41 are in quadrature, as represented in Equations 8 and 9 by terms $\sin \omega_1 t$ and $\cos \omega_1 t$.

The converted signals produced by the units 40 and 41 thus occupy closely-spaced and virtually adjacent channels forming the upper sideband associated with a carrier frequency having a nominal frequency of 465 kc./s.

In the unit 42, the signal applied to the input terminal 46 is transposed in frequency to the band from 464.7 down to 462 kc./s. In the unit 43, the signal applied to the input terminal 47 is transposed in frequency to the band from 461.7 down to 459 kc./s.

The phases of the oscillations fed to the second modulators of the units 42 and 43 are in quadrature, but the input to one of the second modulators in each of the units is in phase opposition to that of the corresponding modulators of the units 40 and 41, thus making the terms in Equations 8 and 9— $\sin \omega_1 t$ and $\cos \omega_1 t$ and the output

$$e_G = \sin (\omega_s - \omega_0 + \omega_1) t$$

The converted signals produced by the units 42 and 43 thus occupy very closely-spaced and virtually adjacent channels forming the lower sideband associated with a carrier having a nominal frequency of 465 kc./s.

The converted signals produced by the units 40, 41, 42 and 43 therefore occupy consecutive channels spaced 3 kc./s. apart in independent sidebands associated with a fully suppressed carrier having a nominal frequency of 465 kc./s.

Referring to FIG. 3, a four channel independent sideband signal derived from an I.F. amplifier 60 connected at terminal 61 to an independent sideband receiver of conventional design, which is not shown, is supplied to four units of the type described in relation to FIG. 1. The signals in the four channels occupy the bands 459 to 461.7 kc./s., 462 to 464.7 kc./s., 465.3 to 468 kc./s., and 468.3 to 471 kc./s., as in the arrangement already described in relation to FIG. 2.

The multi-channel signal is fed at terminal 62 to frequency changing units 63, 64, 65 and 66 in the reverse direction to that of the arrangement previously described, that is to say, with the combining circuits of the second modulators connected in parallel.

The first oscillators of the units 63, 64, 65, 66 are each set to generate a frequency of 1,650 c.p.s. and the second oscillators to generate frequencies of 460.33, 463.35, 466.65, and 469.65 kc./s. respectively.

In the frequency changing units, the signals corresponding to each channel are modified in a manner which is the reverse of that employed for transmission. A sig-

nal occupying the frequency band 0 to 1,350 c.p.s. is produced by the second modulators of each unit as a result of the combination of the signals in the bands 459 to 461.7 kc./s., 462 to 464.7 kc./s., 465.3 to 468 kc./s. and 468.3 to 471 kc./s. with the inputs at 460.35 kc./s., 463.35 kc./s., 466.65 kc./s. and 469.65 kc./s. from the second oscillators of the units 63, 64, 65 and 66 respectively.

The first modulators of each unit produce a signal occupying the frequency band $1,650 \pm 1,350$ c.p.s. as a result of the combination of the signal derived from the second modulators in the band 0 to 1,350 c.p.s. and the input from the first oscillator at a frequency of 1,650 c.p.s. Thus, the outputs at terminals 67, 68, 69 and 70 are signals in four separate channels each occupying the frequency band 300–3,000 c.p.s.

In the arrangements described in relation to FIGS. 2 and 3, the phase changing networks of the first modulators of all four units may conveniently be fed with an oscillation at a frequency of 1,650 c.p.s. generated by a common oscillator.

What I claim is:

1. Multi-channel electric wave signalling apparatus having separate signal channels for a plurality of signals each occupying a band of frequencies comprising separate frequency changing means for each signal, the frequency changing means together transposing the frequency of the plurality of signals to a plurality of adjacent or closely spaced frequency bands; each frequency changing means comprising a first pair of balanced modulators having first inputs connected in parallel and supplied with the signal concerned and having second inputs supplied from a first oscillator through first and second phase-shifting networks respectively advancing and retarding the phase of the first oscillator signal, a second pair of balanced modulators having first inputs separately fed from the outputs of the first pair of balanced modulators and having second inputs supplied from a second oscillator through third and fourth phase-shifting networks respectively advancing and retarding the phase of the second oscillator signal, and an output load common to the outputs of both of the second pair of balanced modulators, so that each signal is transposed in frequency by separately modulating the signal twice using different carriers in each modulation; output means being provided in said apparatus to combine the output signals from the separate frequency changing means into a single multi-channel signal.

2. Multi-channel electric wave signalling apparatus as claimed in claim 1, wherein the apparatus has a plurality of input terminals each supplied with one signal occupying a band of frequencies and each connected to the input of the frequency changing means, the output of each frequency changing means being connected by way of an amplifier to a common output terminal.

3. Multi-channel electric wave signalling apparatus as claimed in claim 2, wherein the amplifiers are of a type having an output impedance which is substantially constant with varying signal amplitude.

4. Multi-channel electric wave signalling apparatus having separate signal channels for a plurality of signals each occupying a band of frequencies, comprising separate frequency changing means for each signal, the input signals to the frequency changing means being a single multi-channel signal and the frequency changing means together transposing the plurality of signals in frequency from a plurality of adjacent or closely spaced frequency bands to provide separate signals each occupying a band of frequencies; each frequency changing means comprising a first pair of balanced modulators having first inputs connected in parallel and supplied with the signal concerned and having second inputs supplied from a first oscillator through first and second phase-shifting networks respectively advancing and retarding the phase of the first oscillator signal, a second pair of balanced modulators having first inputs separately fed from the outputs of the first pair of balanced modulators and having second inputs supplied from a second oscillator through third and fourth phase-shifting networks respectively advancing and retarding the phase of the second oscillator signal, and an output load common to the outputs of both of the second pair of balanced modulators, so that each signal is transposed in frequency by modulating the signal twice using different carriers in each modulation; separate output means being provided in said apparatus for each signal.

5. Multi-channel electric wave signalling apparatus as claimed in claim 4, wherein the apparatus has a single input terminal supplied with a single multi-channel signal and supplying the inputs of a plurality of frequency changing means, each frequency changing means being connected to a separate output terminal for one signal occupying a band of frequencies.

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