

Aug. 15, 1939.

E. H. ARMSTRONG

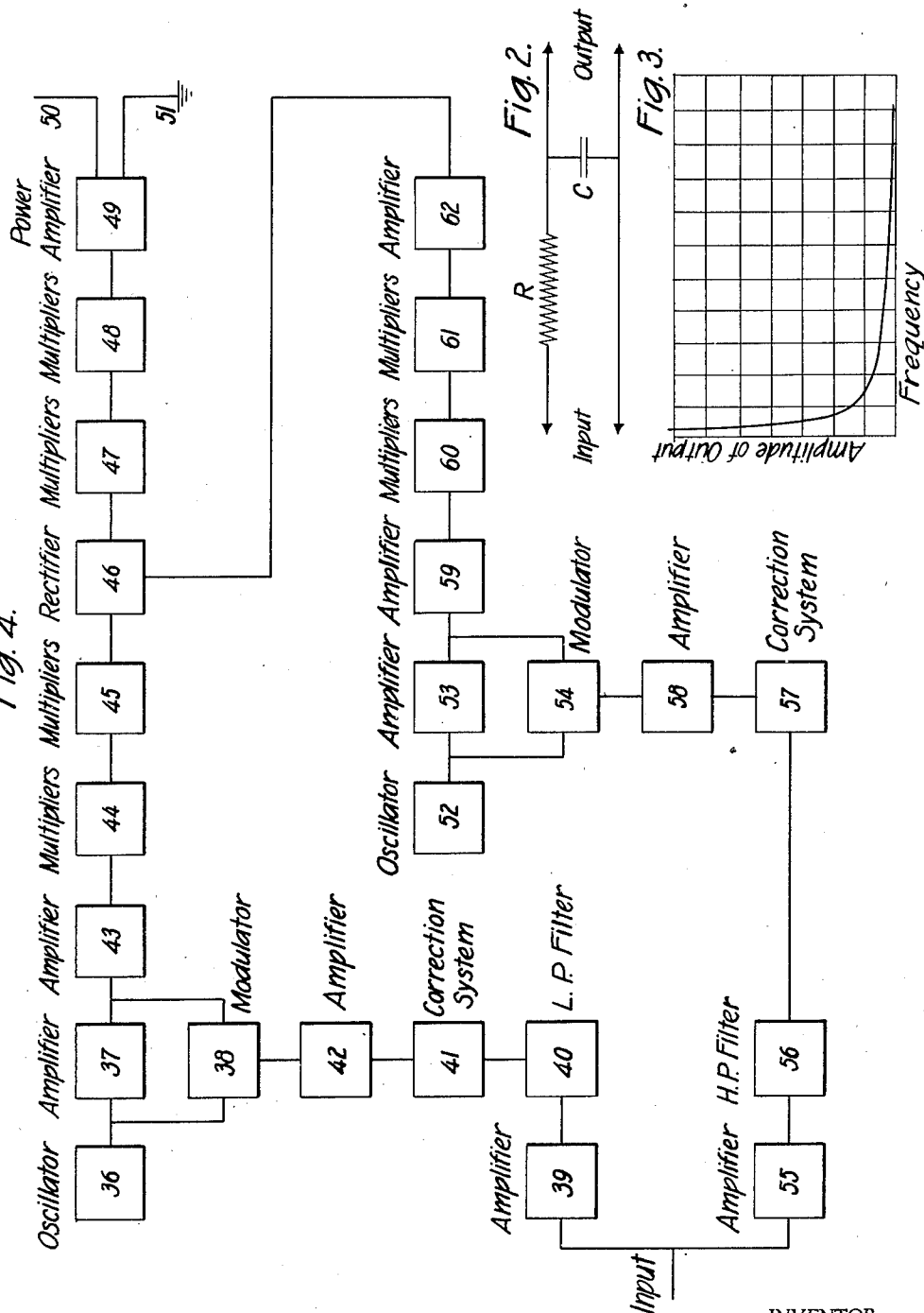
2,169,212

RADIO TRANSMITTING SYSTEM

Original Filed Jan. 16, 1937

3 Sheets-Sheet 2

Fig. 4.



BY

INVENTOR.

Edwin H. Armstrong.

Moses & Nolte

ATTORNEYS

Aug. 15, 1939.

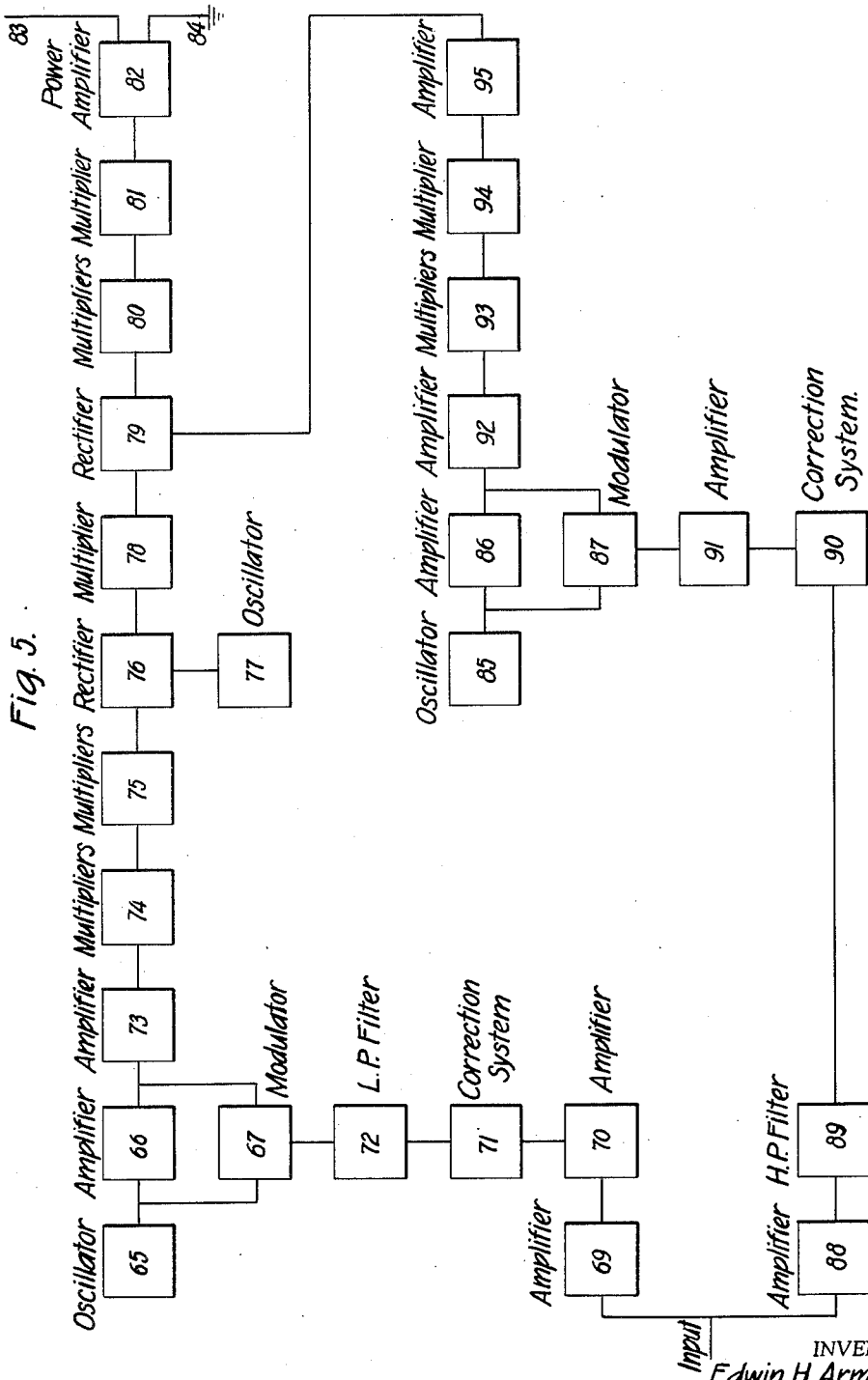
E. H. ARMSTRONG

2,169,212

RADIO TRANSMITTING SYSTEM

Original Filed Jan. 16, 1937

3 Sheets-Sheet 3



BY

INVENTOR.
Edwin H. Armstrong.
Moses & Nolte
ATTORNEYS

UNITED STATES PATENT OFFICE

2,169,212

RADIO TRANSMITTING SYSTEM

Edwin H. Armstrong, New York, N. Y.

Application January 16, 1937, Serial No. 120,943

Renewed April 22, 1938

10 Claims. (Cl. 250—9)

This invention relates to improvements in radio transmitting systems in which signaling is accomplished by modulation of the frequency of the transmitted wave, in the manner described in my United States Patent Nos. 1,941,068 and 1,941,069. It is particularly applicable when the frequency of modulation covers a relatively wide range such as in multiplex signaling, television and like kinds of transmission. It has for its object, the reduction of distortion and the elimination of background disturbances which occur in this type of transmitter under certain conditions.

Fig. 1 illustrates an arrangement of circuits showing the application of the invention to a multiplex signaling system. Figs. 2 and 3 illustrate certain details which will be referred to hereinafter. Figs. 4 and 5 illustrate arrangements which are applicable to the transmission of television signals.

The particular difficulties which this invention overcomes will be understood from the following analysis. In my United States Patent No. 1,941,068 there is described a method of producing a frequency modulated current from a source of fixed frequency such as a crystal controlled oscillator in which a current derived from this source is varied in phase by an amount which is directly proportional to the amplitude of the modulating current and inversely proportional to its frequency. By keeping this phase angle below 30° for the lowest modulating frequency substantial proportionality of phase shift may be obtained. By subsequently multiplying this phase shift a sufficient number of times any desired frequency change may be produced. In the practical application of this system many thousand fold frequency multiplication may be necessary.

In order to produce a phase shift inversely proportional to the frequency of the modulating current, it is necessary to use a correction network as is described in the patent above referred to. This usually consists of a resistance and capacity combination RC as illustrated in Fig. 2. The characteristic of the arrangement for constant voltage applied at varying frequency across the input is shown in Fig. 3. Now it will be observed from this characteristic that where a considerable frequency range must be covered as in multi-channel operation which requires a range of from 30 cycles to a value perhaps several times the audible range the voltage output of the correction system will vary in a ratio of over a thousand to one.

Two difficulties arise. The first is that it is

not easy to maintain an exact proportionality of the input to the output of the correction system over this range due to various kinds of leakage, and very careful design and shielding become necessary. The second is that the output voltage of the correction system for the higher frequencies of modulation become very low and reach levels where the residual noise occurring in the tubes and tube circuits succeeding the correction network become commensurate therewith and produce frequency changes in the transmitted wave which manifest themselves as a hiss in the receiver. Attempts to correct this condition by operating at higher levels in the tube circuits preceding the correction network usually result in distortion at the lower modulating frequencies due to the rapidly increasing level of the output of the correction system at these frequencies.

In accordance with the present invention all these difficulties are overcome by the use of a system of circuits which enables a plurality of correction networks to be employed, each one of which operates over a limited frequency range and so combining their outputs that a strict proportionality can be obtained, while the level of the signaling currents are kept at all times at a high ratio with respect to the various tube and circuit disturbances. The fundamental principle may be understood by an examination of Fig. 1 in which the invention is shown applied to a multiplex system.

Referring now to this figure, 1 represents the source of fixed frequency; 2 an amplifier of the carrier frequency; and 3 a modulating system as described in my United States Patent No. 1,941,068 or preferably as described in my United States application for patent Serial No. 97,736, filed August 25, 1936, now pending. 4 represents the input of the main channel; 5 the usual correction system; 6 an amplifier and 7 a low pass filter; 8 represents an amplifier for amplifying the phase modulated currents resulting from the combination of the outputs of 2 and 3, and 9 and 10 are the usual series of frequency multipliers. 11 represents a rectifier and 12 an oscillator for beating down the frequency of the output of the multiplier 10 to some submultiple of the frequency to be transmitted; 13 and 14 represent multipliers for raising the frequency to the desired value and 15 represents the power amplifier supplying the antenna systems 16 and 17.

Referring now to the second channel 18 represents the source of fixed frequency; 19 an amplifier for that frequency and 20 the modulating

system all similar in character to the apparatus previously referred to as 1, 2 and 3. 21 represents the input for modulating this second channel, 22 the correcting system, 23 an amplifier and 24 an L. P. filter. 25 represents an amplifier for amplifying the phase modulated current produced by the combination of the currents of 19 and 20, and 26, 27 the usual series of multipliers. 28 represents a rectifier and 29 an oscillator for beating down the output frequency of the multiplier 27 to some superaudible but relatively low value in the manner described in my United States application for patent, Serial No. 40,548, filed September 14, 1935. 30 represents an amplifier for this current, 31 a second correction system, 32 a second amplifier, and 33 a band pass filter. The output of the band pass filter is applied to the actuation of the modulator 3 of the main system.

The operation of the multiplex system is along the same lines as that described in my application for United States patent Serial No. 40,548, filed September 14, 1935, with, however, this difference. The modulation of the main channel which, in high fidelity broadcasting, may cover a range from 30 to 15,000 cycles is accomplished thru the correction system 5 that is followed by a low pass filter 6 which passes only frequencies below 15,000 N. This effectively limits the band to 15,000 cycles so that no disturbing currents (such as those due to tube and circuit disturbances) having a frequency above 15,000 will reach the modulating system of the main channel. Channel #2 is similarly modulated in the same way and the modulator of this channel is similarly protected against frequencies above the audible frequency band by the L. P. filter 24. As previously described, the modulated output of 19, 20 is multiplied up to some high frequency, depending on the extent of the frequency deviation it is desired to obtain for this channel, and then reduced in frequency by the heterodyning system 28, 29 to some relatively low value which may conveniently be of the order of 30,000 cycles. This current which may vary in frequency between the limits of 15,000 and 45,000 cycles likewise requires correction and consequently is passed thru the correction system 31. A band pass filter 33 passes the desired frequency range from 15,000 cycles to 45,000 cycles and this band of frequencies is applied to the actuation of the main modulating system 3 where the modulation is accomplished as explained in my United States application for patent Serial No. 40,548, filed September 14, 1935. It will be obvious that by the use of this arrangement of the modulating systems that at no point is a correction system required to operate over a greater ratio of frequency change than the ratio of the highest to the lowest frequency of the audible range, namely 15,000 cycles to 30 cycles which is a ratio of five hundred to one. As a consequence of this multiplex modulation can be produced with the same freedom from disturbances that originate within the tubes and circuits of the transmitter as is possible with simplex modulation. The arrangement just described is quite practical for multiplex operation of aural broadcasting systems where the range of modulation frequency may run from 30 to the order of 50,000 or more cycles.

In television signaling where the frequencies of modulation may run from 30 cycles to 2,000,000 cycles or more, all the difficulties which have been described are encountered in a more aggravated form and some additional ones appear. The principal new difficulty arises from the fact that it

is essential, where a modulation frequency of 2 megacycles is employed that the initial frequency to be modulated must be very high. Something of the order of 10 megacycles is required and it then becomes extremely difficult to secure the necessary amount of frequency multiplication for the lower frequencies of modulation in order to produce a full frequency swing or 100% modulation. In accordance with the present invention all these problems are solved by dividing the modulating frequencies into two or more bands, in which the ratio of the highest to the lowest frequency in any given band is kept below a certain limit, carrying out the processes of phase shifting at frequencies which are most suitable, and after sufficient separate multiplications combining the two sets of frequency modulated currents to produce a modulated signal in which the frequency modulations correspond to the full initial modulating current.

Referring now to Fig. 4 the general arrangement for carrying out this process is shown. The input circuit for the modulating current is divided into two paths, one of which may carry all the frequencies up to a certain point and the other which will carry all the frequencies above this point. 40 and 56 represent the low pass and high pass filters which constitute the means of dividing the modulating currents into two bands, lower and upper respectively. The characteristics required in these filters will be referred to later.

36 represents an oscillator of a relatively low frequency; 37 is an amplifier which, with 38 the modulator, comprise the phase shifting system for the lower band of frequencies. 41 represents the correction system, which may be similar to design to that used in simplex aural broadcasting, and 42 an amplifier, 43 represents an amplifier for the phase modulated currents produced by 37 and 38, and 44, 45 a series of multipliers whose output is supplied to a rectifier 46, whose purpose will be described hereinafter.

Referring now to the modulating arrangement for the upper band of frequencies 56 represents the high pass filter for selecting out the upper part of the frequency range of the modulating current. 52 represents an oscillator of relatively high frequency which should be at least several times the frequency of the highest modulating frequency of the upper band. 53 is an amplifier which, with the modulator 54 forms the usual phase shifting arrangement similar in principle to those already described in this specification but operating at a very much higher frequency. 57 represents a correction system and 58 an amplifier of the output of the correction system. 59 is an amplifier of the phase modulated current produced by the combination of the output currents of 53 and 54 and 60 and 61 are a series of frequency multipliers for raising the frequency to the proper point for combination with the frequency modulated currents produced by the lower frequency part of the band. 62 is an amplifier for applying the output of the multiplier 61 to the rectifier 46 to effect the combination heretofore referred to.

The initial frequencies of the oscillators 36 and 52 and the point of division between the two bands of the modulating frequency should be so chosen that the phase shift of the output current of the multiplier 45 due to the highest frequency of the lower modulating band, is equal to the phase shift of the output current of the multiplier 61 due to the lowest frequency of the upper modulating band. The output frequencies

of the multipliers 45 and 61 may be arranged to differ by a sub-multiple of the frequency which it is desired to radiate. The two frequencies then beat together to form a complementary current containing all the modulations corresponding to the initial modulating current. This current is then raised by the multipliers 47, 48 to the desired frequency amplified by the power amplifier 49 and supplied to the antenna system 50, 51.

In view of the practical impossibility of obtaining filters with ideal characteristics, the cut off will necessarily occur gradually and care should be taken to make the characteristics complementary and to use filters of a type having a minimum phase shift. It is necessary to arrange the polarity of the modulation of one system with respect to that of the other to insure an additive combination of the frequency swing in the overlap range of the two filters.

Where the full range of 30 to 2,000,000 cycles or more is to be transmitted it will be necessary to employ additional frequency multiplication for the lower band of modulation over and above that which may be effectively obtained by the precise method of Fig. 4. Fig. 5 illustrates an arrangement for obtaining this additional multiplication. This arrangement is exactly the same as that of Fig. 4 except that an additional multiplication is obtained in the lower band part of the system prior to the combination of the two frequency modulated currents in the rectifier 79. This is obtained by heterodyning down the output of the multiplier 75 by means of the rectifier 76 and oscillator 77, and securing additional multiplication by the multiplier 78 before making the combination in the rectifier 79. In all other respects the operation of the systems of Fig. 4 and Fig. 5 are identical.

It will be understood, of course, that the multipliers referred to contain circuits which are in effect band pass filters and that they are suitably designed for the band width of the frequencies which they are intended to handle. It will likewise be understood that they are operated in an over-excited condition so that they simultaneously act as limiters and remove undesirable amplitude modulation.

It is, of course, clear that while in the example illustrated, the modulating current was divided into two sections only that any desired number of sections may be used.

It will also be understood that with respect to the design of those filters in which an overlap of the attenuation characteristics is required as in the arrangements of Figs. 4 and 5, due regard must be paid to their phase shift as well as to their amplitude changes in order that the separated bands of frequencies may complement each other when recombined.

I have described what I believe to be the best embodiments of my invention. I do not wish, however, to be confined to the embodiments shown, but what I desire to cover by Letters Patent is set forth in the appended claims.

I claim:

1. The method of simultaneously transmitting a plurality of signaling channels by frequency-modulated waves, which consists in causing one channel to frequency-modulate a source of oscillating current of relatively low frequency, causing another channel to frequency modulate a source of oscillating current of relatively higher frequency, multiplying the frequency of the first frequency modulated current, heterodyning the two frequency modulated currents with each

other to produce a third frequency modulated current and transmitting the third frequency modulated current.

2. The method of simultaneously transmitting a plurality of signaling channels by frequency-modulated waves, which consists in causing one channel to frequency-modulate a source of oscillating current of relatively low frequency, causing another channel to frequency-modulate a source of oscillating current of relatively higher frequency, multiplying the frequency of at least one of said frequency-modulated currents, heterodyning the two currents with each other to produce a third frequency modulated current and frequency multiplying such third frequency modulated current to the desired frequency of transmission and transmitting such current.

3. The method of simultaneously transmitting a plurality of signaling channels by frequency-modulated waves, which consists in causing one channel to frequency-modulate a source of oscillating current of relatively low frequency, causing another channel to frequency-modulate a source of oscillating current of relatively higher frequency, heterodyning the two frequency-modulated currents with each other to produce a third frequency modulated current and transmitting such current.

4. The method of transmitting by frequency-modulated waves a frequency band of relatively great width, which consists in splitting the said band into a plurality of channels, causing one of the channels to frequency-modulate a source of oscillations of relatively low frequency, causing another of said channels to frequency-modulate a source of oscillations of relatively higher frequency, multiplying the frequency of the first frequency-modulated current, heterodyning the two frequency-modulated currents with each other to produce a third frequency modulated current and transmitting such third current.

5. Apparatus for simultaneously transmitting a plurality of signaling channels by frequency modulated waves, comprising means for causing one channel to frequency-modulate a source of oscillating current of relatively low frequency, means for causing another channel to frequency-modulate a source of oscillating current of relatively higher frequency, means for multiplying the frequency of the first frequency modulated current, means for heterodyning the two frequency modulated currents with each other to produce a third frequency modulated current and means for transmitting the third frequency modulated current.

6. Apparatus for simultaneously transmitting a plurality of signalling channels by frequency-modulated waves, comprising means for causing one channel to frequency-modulate a source of oscillating current of relatively low frequency, means for causing another channel to frequency-modulate a source of oscillating current of relatively higher frequency, means for multiplying the frequency of at least one of said frequency-modulated currents, means for heterodyning the two currents with each other to produce a third frequency modulated current and frequency multiplying such third frequency modulated current to the desired frequency of transmission and means for transmitting such current.

7. Apparatus for simultaneously transmitting a plurality of signaling channels by frequency-modulated waves, comprising means for causing one channel to frequency-modulate a source of oscillating current of relatively low frequency,

means for causing another channel to frequency-modulate a source of oscillating current of relatively higher frequency, means for heterodyning the two frequency modulated currents with each other to produce a third frequency modulated current and means for transmitting such current.

5 8. Apparatus for simultaneously transmitting by frequency-modulated waves a frequency band of relatively great width, which consists in splitting the said band into a plurality of channels, 10 means for causing one of the channels to frequency-modulate a source of oscillations of relatively low frequency, means for causing another of said channels to frequency-modulate a source 15 of oscillations of relatively higher frequency, means for multiplying the frequency of the first frequency-modulated current, means for heterodyning the two frequency-modulated currents with each other to produce a third frequency 20 modulated current and means for transmitting such third current.

9. The method of transmitting by frequency modulated waves a frequency band of relatively great width which consists in splitting the said

band into a plurality of portions, modulating a relatively low frequency by one of said portions, modulating a relatively high frequency by the other of said portions, combining the two portions to form a single frequency-modulated wave 5 having the total width of the frequency band to be transmitted and transmitting such combined wave as a single channel.

10. Apparatus for transmitting by frequency modulated waves a frequency band of relatively 10 great width, comprising means for splitting the said band into a plurality of portions, a source of relatively low frequency and a source of relatively high frequency, means for modulating 15 said low frequency source by one of said portions and said high frequency source by the other of said portions, means for combining the two modulations to form a single frequency modulated wave having the total width of the frequency band to be transmitted, and means for 20 transmitting such combined wave as a single channel.

EDWIN H. ARMSTRONG.