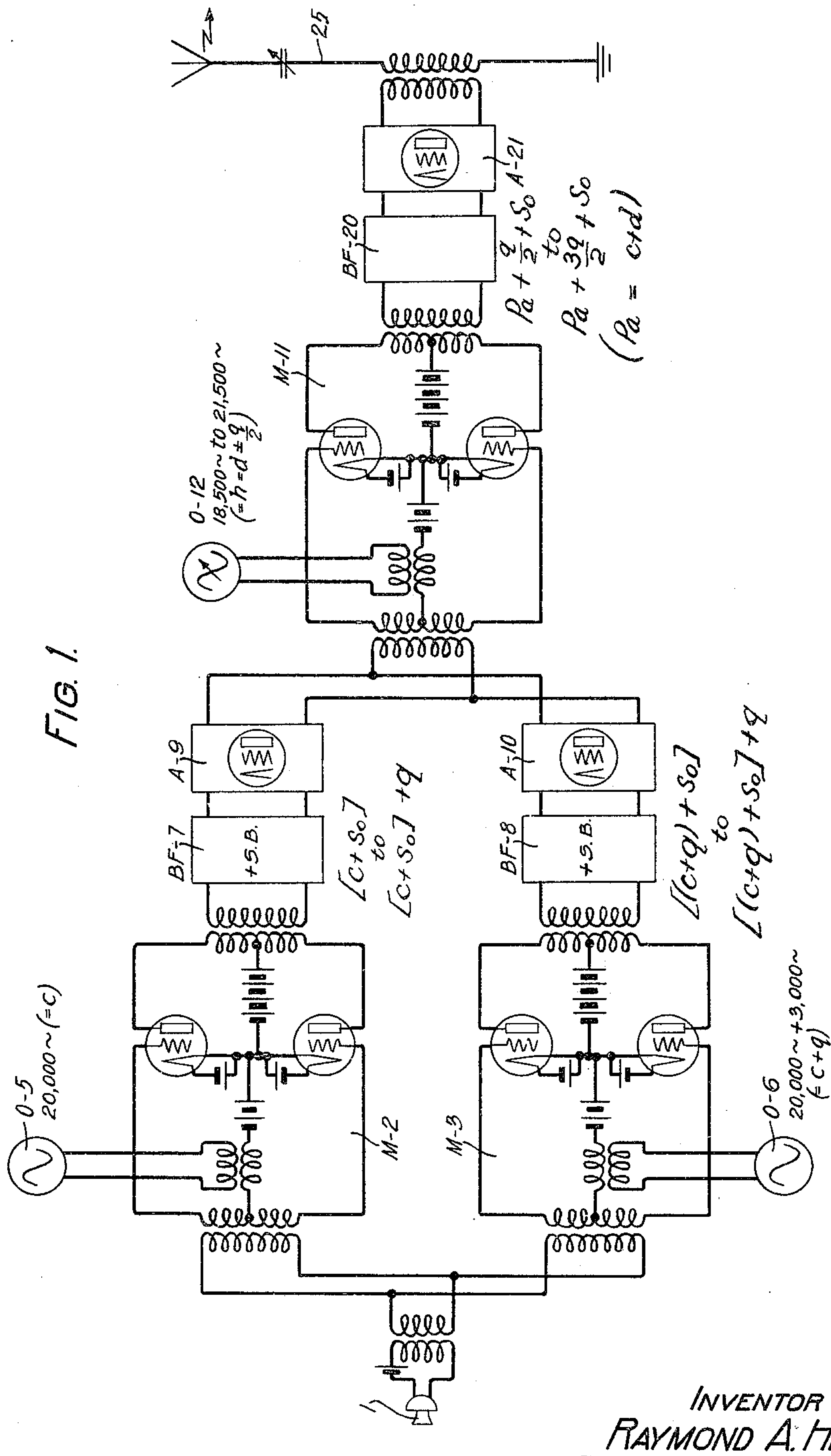
July 23, 1929. R. A. HEISING 1,722,047

SYSTEM FOR SIGNALING

Filed Nov. 4, 1927 2 Sheets-Sheet 1

FIG. 1.



INVENTOR
RAYMOND A. HEISING
BY H.A. Burgess
ATTORNEY

FIG. 2.

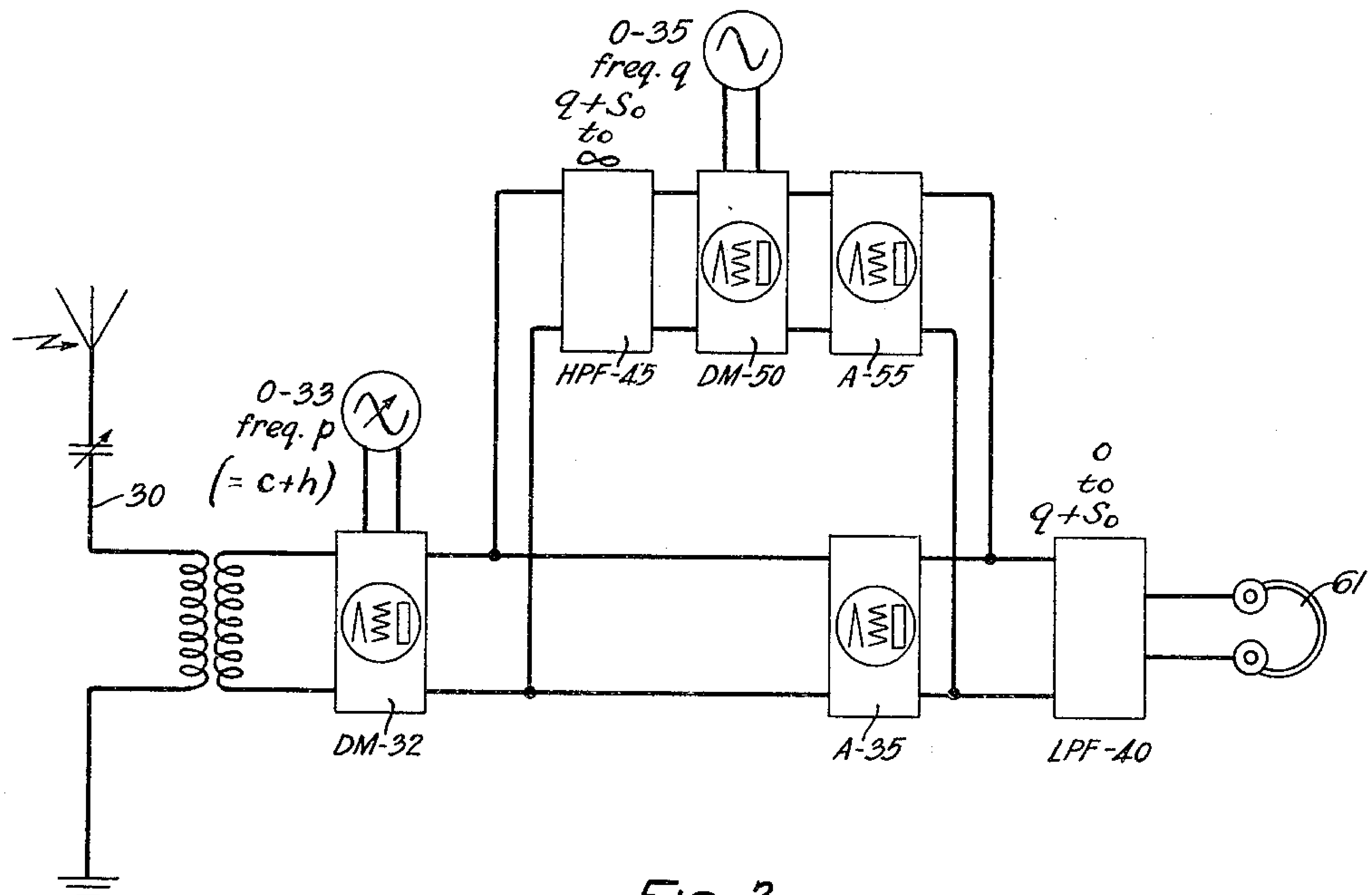
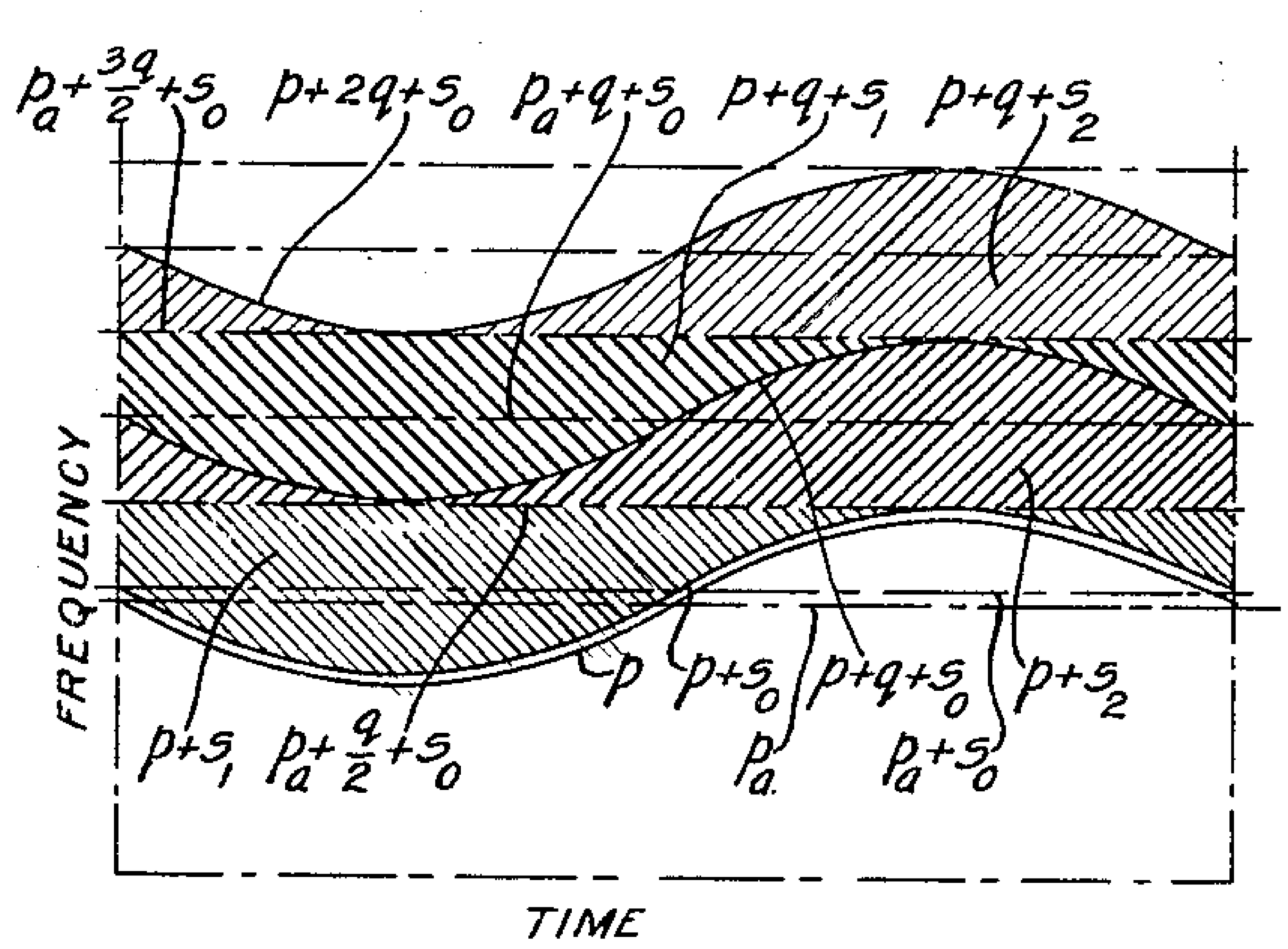


FIG. 3.



INVENTOR
RAYMOND A. HEISING
BY H. A. Burgess
ATTORNEY

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UNITED STATES PATENT OFFICE.

RAYMOND A. HEISING, OF MILLBURN, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SYSTEM FOR SIGNALING.

Application filed November 4, 1927. Serial No. 230,947.

This invention relates to wave transmission, especially signaling by electric waves.

An object is to prevent unauthorized obtaining of information carried by transmitted waves.

Another object is to obtain such secrecy and at the same time obtain high quality of received signals; and a further object is to obtain such secrecy and quality without unduly broadening the requisite width of the frequency band comprising the frequencies which the components of a wave transmitting information have in the transmission medium.

In one specific aspect the invention is a radio telephone system which is an improvement over the system of application Serial No. 230,222, filed November 1, 1927, by Englund and Llewellyn. In that system a speech wave separately modulates two carrier waves of such frequencies that the resulting upper side bands, for example, are contiguous and when selected and added form a band of frequencies double the width of the speech band, the carrier waves being suppressed in the modulators. This band of double the speech band width is caused to modulate a variable frequency carrier wave, which is suppressed in the modulator. The resulting upper side band, for example, is a "wobbling" band, its width in the frequency scale being twice the width of the speech band at each instant, and its position in the frequency scale varying, in synchronism with the variation of the frequency of the carrier wave, through a frequency range of variation equal to that of the carrier wave.

This "wobbling" band is impressed on a filter which passes only a frequency band of the speech band width having its center somewhere between the frequency limits of the wobbling band, as for example midway between the frequency limits of the wobbling band. The passed band is radiated from a transmitting antenna and received by a distant receiving antenna. The pass band of the filter is of constant width, and at each instant the radiated band contains components representing all of the components of the speech wave, with their identity preserved. However, the components representing speech components are permuted in a cyclic order in this radiated band. The band consists of two contiguous sub-bands each of varying width, the upper one containing components representing the components of a variable portion of the speech band extending upward from the lower limit of the speech band, and the lower of the two sub-bands containing components representing the remaining components of the speech band. The information carried by the radiated band cannot be obtained from the band without knowledge of various factors, including the frequency of the variable frequency carrier wave.

The band incident on the receiving antenna is demodulated separately by two waves of variable frequencies, the frequency of one of these waves being the algebraic sum of the variable carrier frequency and the lower of the two fixed carrier frequencies employed at the transmitter, and the frequency of the other variable frequency carrier wave employed at the receiver being the algebraic sum of the variable carrier frequency and the higher of the two fixed carrier frequencies employed at the sending station. This demodulation yields the two above mentioned variable portions of the speech band, which together comprise at each instant all of the components of the speech wave. The demodulations also yield distortion components, but certain of these are filtered out, and the others do not render the received speech unintelligible.

In the system of this invention in the form specifically described and shown herein, the appearance of certain of these other distortion components with the speech wave produced at the receiver is avoided. The transmitter may be the same as described above. The band incident on the receiving antenna has its components of various frequencies varied to translate its two above mentioned sub-bands into two frequency bands of components which lie in mutually exclusive frequency ranges, respectively. The latter bands are then separated, so that they can be operated upon differently, to produce the above mentioned two portions of the speech band.

By thus obtaining the two bands to be modulated or otherwise operated upon differently, the operations necessary to produce from those bands the two constituent portions of the speech band can be effected without introducing distortion other than such as is customarily introduced by such operations.

As is apparent from the foregoing statements, one object of the present invention is to receive signals transmitted by a wave such as that sent from the transmitting station described above, and at the same time to obtain high quality of received signals; and in one specific aspect the invention is a receiving system for receiving signals in the manner indicated above.

Other objects and aspects of the invention will be apparent from the following description and claims.

Fig. 1 of the drawing is a circuit diagram of the sending station referred to above; Fig. 2 is a similar diagram of the receiving station referred to above as embodying a form of the invention; and Fig. 3 is a set of graphs for facilitating explanation of the invention.

In the following description, frequencies are given in terms of radians per second, except when otherwise indicated, and in symbolical expressions for current or voltage waves, coefficients indicating amplitudes are omitted, only quantities that indicate frequency being given. Specific values of quantities such as frequencies, speeds, etc., are mentioned merely by way of example, and the invention is not limited thereto.

In Fig. 1 a signal wave, for example a speech wave from telephone transmitter 1, is introduced into the speech or signal frequency input circuit of each of two modulators M—2 and M—3. Each of the modulators may be, for example, the usual type of balanced vacuum tube modulator arranged for carrier wave suppression.

The carrier wave for modulator M—2 may be obtained from an oscillator O—5 of a frequency c which may be, for example, $2\pi\times 20{,}000$.

The carrier wave for modulator M—3 may be obtained from an oscillator O—6 of a frequency $c+q$, where q is the difference between the highest and the lowest frequencies of the speech wave that is to be transmitted. Thus if q is $2\pi\times 3{,}000$, then the frequency of oscillator O—6 may be $2\pi\ (20{,}000+3{,}000)$. The lowest frequency of the speech band that is to be transmitted may be designated s_0.

The upper side bands, for example, from the modulators M—2 and M—3 are selected by filters BF—7 and BF—8 respectively, and amplified by amplifiers A—9 and A—10 respectively, and applied as a modulating wave to a modulator M—11, which may be, for example, of the usual type of balanced vacuum tube modulator arranged for suppression of the carrier wave. The filter BF—7 may be, for example, a band filter passing only frequencies between $c+s_0$ and $c+s_0+q$. The filter BF—8 may be, for example, a band filter passing only frequencies between $c+s_0+q$ and $c+s_0+2q$. The modulating wave supplied to modulator M—11 from amplifiers A—9 and A—10 is then two identical speech sidebands one immediately above the other, the two occupying the frequency range from $c+s_0$ to $c+s_0+2q$.

In modulator M—11 this wave modulates a variable frequency carrier wave supplied from source O—12. The frequency of this carrier wave may vary in any suitable manner, as for example sinusoidally, ten times per second, between a lower limiting frequency $d-\frac{q}{2}$ and an upper limiting frequency $d+\frac{q}{2}$. Then, designating the value of this variable carrier frequency h, the frequency h will vary about an average value d through a range q. The source O—12 may be, for example, a variable frequency oscillator of any suitable type. A suitable type is disclosed in Kendall Patent 1,571,010 January 26, 1926 or 1,592,940, July 20, 1926. The frequency d may be, for example, $2\pi\times 20{,}000$.

The speech wave that is to be transmitted is assumed, as indicated above, to have a frequency spectrum extending from a frequency s_0 up to frequency $q+s_0$, and to facilitate explanation of the invention is also assumed to consist of two contiguous sub-bands or portions which may vary in width in a complementary manner so that their combined width is always the width of the speech frequency band to be transmitted. The width of one of these sub-bands will be taken to be a fraction $\frac{1}{x}$ of the width of the speech band to be transmitted (where x may be variable and is never less than unity) and the remaining sub-band will then be the remaining (complementary) portion of the speech band to be transmitted. The value of x at any instant will depend upon the variable frequency h and the portion of the circuit beyond (following) the point at which the frequency h is introduced. A quantity s_1 will be taken as representative of those frequencies in the band between s_0 and $\frac{1}{x}\ (q+s_0)$ and s_2 will be taken as representative of the band of remaining frequencies, which are those between $\frac{1}{x}\ (q+s_0)$ and $q+s_0$. The speech may then be symbolically written $\cos s_1 t+\cos s_2 t$, where for generality, s_1 and s_2 may exist either simultaneously or one at a time.

The output wave from modulators M—11 is applied to band pass filter BF—20. Letting $h+c=p$, the upper sideband in this output wave consists of

$\cos (p+s_1)t$

and $\cos p+s_2)t$, both due to the modulating wave from amplifier A—9,

and $\cos (p+q+s_1)t$

and $\cos (p+q+s_2)t$, both due to the modulating wave from amplifier A—10.

As indicated in Fig. 3, this sideband represents two variable frequency or "wobbling" sidebands exactly alike except relatively displaced in the frequency scale so that the lowest frequency of the sideband due to the modulating wave from amplifier A—10 is equal to the highest frequency of the sideband due to the modulating wave from amplifier A—9.

The average value of frequency p will be designated p_a. The band pass filter BF—20 passes only the frequencies between $p_a+\frac{q}{2}+s_0$ and $p_a+\frac{3q}{2}+s_0$. That is, it passes only the frequencies lying $\frac{q}{2}$ radians per second on either side of its center frequency, p_a+q+s_0. The frequency p may take on any values between $p_a-\frac{q}{2}$ and $p_a+\frac{q}{2}$, and still all frequencies of the speech spectrum be transmitted, although, to be sure, in cyclically varying order. In Fig. 3, p is indicated as varying over a frequency range of width equal to that of the range s_0 to $p+s_0$.

The output wave from band pass filter BF—20 consists of components which may be symbolically written

$$\cos (p+s_2)t \text{ and } \cos (p+q+s_1)t$$

This output wave is amplified in amplifier A—21 of any desired number of stages and radiated from the sending antenna 25 and received by the receiving antenna 30 at the distant receiving station, shown in Fig. 2. Although the wave contains components representing all of the speech components, with the identity of each preserved, the information which it carries cannot be obtained from it without knowledge of various factors, including the variable frequency p, which is not transmitted.

From the antenna 30 the received wave is transmitted to the input circuit of a demodulator DM—32, which may be, for example, like modulator M—2.

The carrier or demodulating wave for demodulator DM—32 has the variable frequency p. In the system of the drawing, this demodulating wave is obtained from a variable frequency oscillator O—33 like the oscillator O—12 at the sending station. That is, if desired the oscillator O—33 can be carefully constructed to have the same frequency variations as oscillator O—12, although in a different frequency range.

The low frequency output wave from demodulator DM—32 contains components which may be symbolically written as $\cos s_2t$ and $\cos (q+s_1)t$, both resulting from the demodulating action of the frequency p. It also contains the usual distortion component $\cos (q+s_1-s_2)t$ which results from the beating together of the components of the wave received from the antenna. As usual, since the amplitude of the locally generated wave (of frequency p) is much larger than that of the incoming wave, the distortion component just mentioned contains a relatively small amount of energy. Therefore, the courses of only the components $\cos s_2t$ and $\cos (q+s_1)t$ will be traced. The component $\cos s_2t$ is part of the original speech and may be received directly. Actually it may be found convenient to pass it through an amplifier A—35 and a low pass filter LPF—40 having a cut-off frequency just below $q+s_0$ before it goes to the telephone receiver 61. The course of the component $\cos (q+s_1)t$ is somewhat more complicated. A high pass filter HPF—45 having a cut-off frequency $q+s_0$, which does not pass the component $\cos s_2t$, transmits the component $\cos (q+s_1)t$ to a demodulator DM—50, which is supplied with a demodulating frequency q by an oscillator O—35. In DM—50 the wave of frequency q modulates the wave $\cos (q+s_1)t$ to produce a wave $\cos s_1t$. This is amplified by an amplifier A—55 to bring its energy level up to a value properly related to that of the energy level of the wave from amplifier A—35 and is then transmitted to filter LPF—40. The amplifier A—35 prevents the wave from amplifier A—55 from getting back to the input of amplifier A—55 and causing singing. The filter LPF—40 prevents the component $\cos (q+s_1)t$ from amplifier A—35 from getting into the telephone receiver 61, and passes only the wave $\cos s_1t+\cos s_2t$ which is the original speech wave.

It will be apparent that the invention is not limited to radio transmission but is applicable, for example, to wire carrier systems and to systems in which the frequencies employed for transmitting speech or other signals between two stations are within the frequency limits of the original frequencies of the signal components, the radio transmission channel between the stations being representative of any suitable type of transmission channel such as a voice frequency or wire carrier frequency channel.

Although in the system shown in the drawing the waves of the frequencies c and $c+q$ are generated at the transmitting station by separate oscillators, it will be apparent that, if desired, suitable means, as disclosed in Fig. 3 of H. W. Nichols Patent 1,545,270, July 7, 1925, may be employed for deriving the second wave from the first by modulating the first with a wave of frequency equal to the difference between the desired frequency of the second wave and the frequency of the first wave, and selecting the upper side frequency from the modulation products.

It will be apparent that the frequencies of the carrier waves at the transmitting station and the demodulating waves at the receiving station may be kept in proper relation by suitable electrical means as for example in the manner indicated in the above mentioned Kendall patents, or in the manner in which television transmitting apparatus and receiving apparatus has been synchronized. Means which has been employed for synchronizing such television apparatus is disclosed for example in a copending application of H. M. Stoller and E. R. Morton, Serial No. 200,799, June 23, 1927.

Although the specific value of frequency d mentioned above by way of example is equal to the value mentioned for frequency c, such equality is not necessary. Frequency d may have any suitable value. However, its value is preferably such that the pass band of filter BF—20 does not in any way overlap the frequency range covered by the output waves from amplifiers A—9 and A—10 (that is, the frequency range extending from $c+s_0$ to $c+s_0+2q$), so that the components of the output waves of amplifiers A—9 and A—10 do not pass through the filter BF—20.

As indicated above, it is not necessary that the frequencies of oscillators O—12 and O—33 vary throughout frequency ranges equal in width to the range from s_0 to $q+s_0$. With any smaller variation, if still of considerable magnitude, the system will still afford a large element of secrecy, because all components of the signal undergo variation in frequency, in the wave transmitted between the sending station and the receiving station. If the frequencies of oscillators O—12 and O—33 vary less than q radians, then the pass band of filter BF—20 does not have to be located exactly midway in the extreme sideband variation range but may be in any position in that range such that the speech side bands do not materially slide off the characteristic selective range of the filter. The rate of variation of the frequencies of oscillators O—12 and O—33 preferably should be sufficiently high to prevent syllable reception with use of a constant beating frequency. Preferably the frequency of variation is between about 5 cycles per second and about 15 cycles per second. As indicated above, 10 cycles a second is a very satisfactory frequency of variation. It will be apparent that the variation need not be sinusoidal, and that if desired it may be intermittent rather than continuous and moreover, that the mode of the variation of frequency may be changed, in any suitable manner agreed upon between the operators at the two stations, to still further increase the secrecy of transmission. For simplicity the drawing shows the variation as sinusoidal; but for greater secrecy it is preferable to have the variation irregular within each cycle of variation.

It will be apparent to those skilled in the art that various modifications may be made in the system shown in the drawing, without departing from the invention. Thus, for example, the filter BF—20 may be omitted if the antenna 25 is tuned sufficiently sharply to suppress the frequencies outside of the band which it is desired to radiate.

What is claimed is:

1. A method of operating on signal components which form two frequency bands meeting at a frequency value variable with time, which method comprises so varying the frequencies of the components as to produce two frequency bands meeting at a frequency value which is constant, separating the two latter bands, and modulating the components of one of them alone.

2. A method of operating on signal components which form two frequency bands meeting at a frequency value variable with time, which method comprises so varying the frequencies of the components as to produce two frequency bands meeting at a frequency value which is constant, separating the two latter bands, and operating upon them in different ways, respectively, to produce from them two frequency bands forming the signal.

3. A method of operating on mutually exclusive portions of a band of signal components of various frequencies, which portions are variable in width in the frequency scale in such manner that the respective frequency ranges over which said portions extend at least partly overlap, said method comprising translating said portions into bands of signal components which are of variable width in the frequency scale and which are contained in mutually exclusive frequency ranges, respectively, and modulating one of the latter bands of components alone.

4. The method which comprises relatively displacing, in the frequency scale, groups of wave components that form portions of a band of frequencies and varying the width of one of the relatively displaced portions, transmitting the relatively displaced portions to a distant point, at that point varying the frequencies of the components transmitted, to form a resulting wave, and so operating on the resulting wave as to restore the portions to their initial relation.

5. The method of transmitting signal components of different frequencies comprised in a frequency band, which comprises transposing groups of the components that form por-

tions of the band in the frequency scale and varying the width of certain of the frequency bands formed by the transposed groups, for transmission of the signal components, and, for reception of the signal components, varying the frequency of the components of the last mentioned bands, to form a resulting wave, and so operating on the resulting wave as to restore the transposed groups to their initial relative positions in the frequency scale.

6. The method of operating on a plurality of frequency bands of components, each band varying in width but all of the bands forming a band of constant width, which comprises varying the frequency of each of the components of the first mentioned bands, to form a resulting wave, and transposing frequency bands of the resulting wave in the frequency scale.

7. A secrecy signaling system comprising a transmitting station having means for producing from the signal to be transmitted a wave in which complementary portions of the signal frequency band each of which has cyclical variations in width are transposed in the frequency scale, and a receiving station having means for producing similar cyclical variations in the frequency of the components of said wave, to form a resulting wave, and means at said receiving station for so operating on the resulting wave as to restore said portions to their original positions in the frequency scale.

8. Apparatus for receiving signal wave components forming a plurality of frequency bands each varying cyclically in width, said apparatus comprising means for cyclically varying the frequency of each of the components at the frequency of said cyclical variation of band width, to form a resulting wave, and means for relatively displacing frequency bands of the resulting wave, in the frequency scale.

9. Apparatus for receiving signal wave components forming a plurality of frequency bands each varying cyclically in width, said apparatus comprising means for cyclically varying the frequency of each of the components at the frequency of said cyclical variation of band width, to form a resulting wave, and means for transposing frequency bands of the resulting wave, in the frequency scale.

10. Apparatus for receiving signal wave components forming a plurality of frequency bands each varying cyclically in width, said apparatus comprising means for cyclically varying the frequency of each of the components at the frequency of said cyclical variation of band width, to form a resulting wave, means for selecting a frequency band of the resulting wave, and means for so modulating the selected band as to transpose it in the frequency scale with respect to the frequency band formed by the remaining frequencies of that wave while the last mentioned band remains fixed in its position in the frequency scale.

11. In combination, modulating means, a filter and unidirectionally transmitting means having an input circuit and an output circuit, means connecting said filter and the input circuit of said unidirectionally transmitting means to said modulator, a second modulating means connected to said filter, a second filter, and means connecting said output circuit and said filter to said second modulator in parallel.

In witness whereof I hereunto subscribe my name this 11th day of October, A. D. 1927.

RAYMOND A. HEISING.