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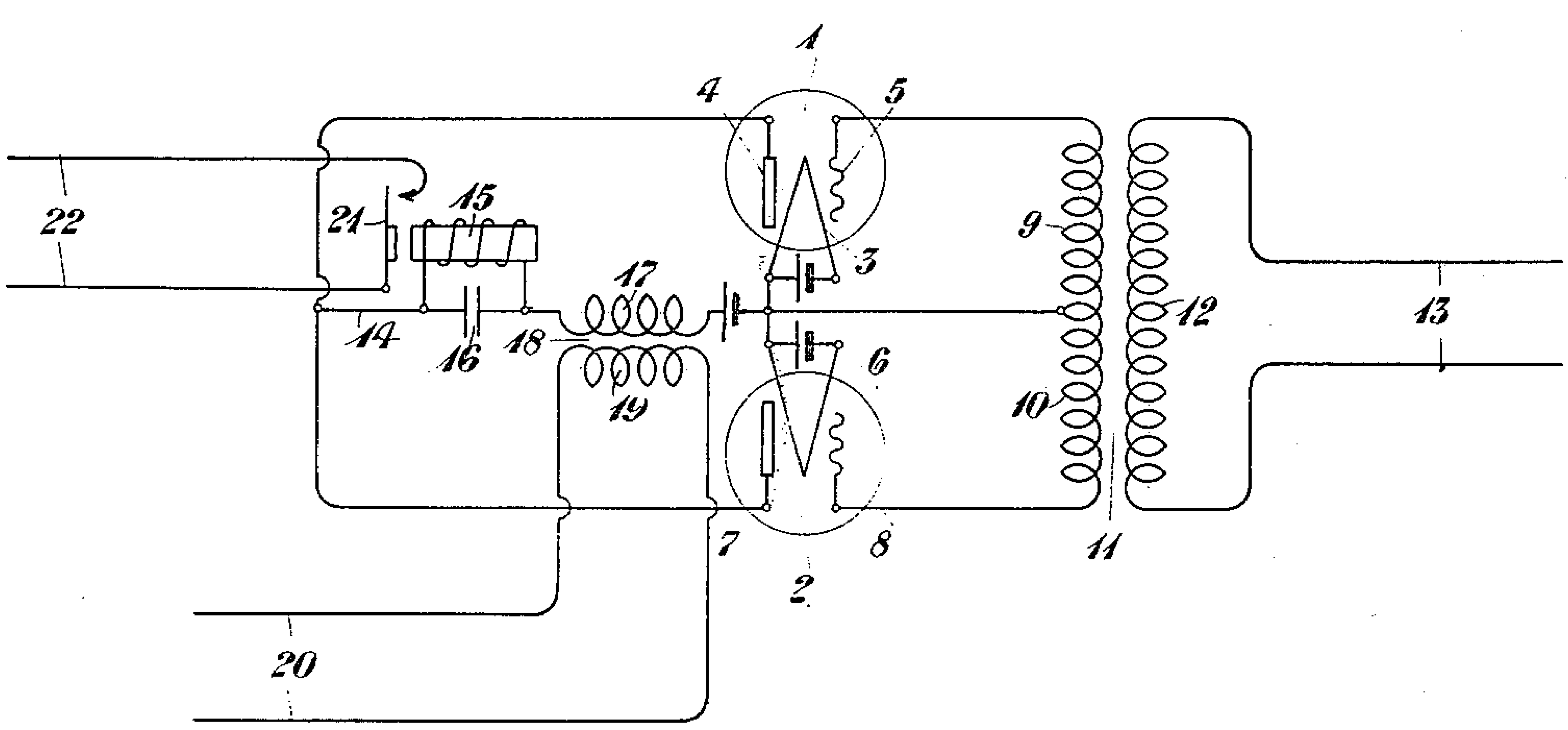
H. A. AFFEL

DEMODULATING APPARATUS

Filed Dec. 31, 1920



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UNITED STATES PATENT OFFICE.

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DEMODULATING APPARATUS.

Application filed December 31, 1920. Serial No. 434,226.

To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Demodulating Apparatus, of which the following is a specification.

This invention relates to signaling by means of carrier currents, and more particularly to demodulating apparatus for use in connection with carrier signaling systems.

It has heretofore been proposed to transmit the ringing signals over a carrier system by transmitting the unmodulated carrier frequency component along with the modulated side band and cause the ringing signal at the distant station to be controlled by interruptions of the unmodulated carrier frequency component.

It is one of the objects of this invention to provide a demodulating apparatus which will combine the functions of detecting the voice signals from the modulated side band and which will also receive the ringing signals produced by interrupting the carrier frequency.

Another object of the invention is to produce a demodulating apparatus in which both the unmodulated carrier frequency component and the side band frequencies will be suppressed, so that they do not appear in the output circuit of the demodulator.

Other and further objects of the invention will be clear from the following description when read in connection with the accompanying drawing, the figure of which is a simplified circuit diagram of one embodiment of the invention.

Referring to the figure two vacuum tube detecting devices 1 and 2 are disclosed. The tube 1 comprises a heated filament 3, a plate 4, and a grid 5, and similarly the tube 2 comprises a heated filament 6, a plate 7, and a grid 8. The grids 5 and 8 are connected to the secondary windings 9 and 10 of the transformer 11, whose primary winding 12 is connected to an incoming circuit 13, over which the unmodulated carrier frequency and the modulated side band frequencies may be impressed upon the demodulator. The plates 4 and 7 are connected together in parallel as shown and a common branch 14 of the parallel plate circuits leads to the filaments 3 and 6. The common branch 14 includes a direct current relay 15, whose winding is shunted by a condenser 16 for by-passing the alternating current components appearing in the plate circuits of the tubes, and the common branch 14 also includes the primary winding 17 of a transformer 18, whose secondary winding 19 is connected in the outgoing circuit 20, over which the detected voice currents may be transmitted. The armature 21 of the relay 15 controls a circuit 22 leading to any suitable ringing apparatus.

Assuming that a modulated voice band, together with an unmodulated carrier frequency component, is incoming from the circuit 13 and is transmitted through the primary winding 12 of the transformer 11 to the secondary windings 9 and 10, it will be observed that since the grids of the two tubes are connected in series with respect to the input oscillations, the oscillations of corresponding frequency appearing in the plate circuits will also flow in series from plate to plate without flowing in the common circuit 14 and consequently the fundamental carrier frequency and the frequencies included in the side band will not in themselves be transmitted to the outgoing circuit 20. The tubes will function. however, to detect the low frequency signaling currents in accordance with which the side band was modulated, so that the low frequency currents will appear in the branch 14 and be transmitted to the circuit 20. An increase in the steady plate current flowing through the winding of the relay 15 will also be produced, due to the detected direct current component, as long as the fundamental carrier frequency is applied to the detector. As soon as the unmodulated carrier frequency component is interrupted, however, the steady plate current again drops to normal and the armatures of the relay 15 falls off and opens the ringing circuit 22.

The general theory underlying a balanced circuit of this character is fully set forth in British Patent No. 102,503 accepted November 30th, 1917. While the theory as outlined in said British patent was applied particularly to the case of a balanced form of modulator, it is equally applicable to a balanced form of demodulator, since the two devices operate upon the same principle. As set forth in said British patent, if a variable voltage represented by v be impressed on the input side of a simple demodulator, such as an ordinary vacuum tube demodulator, the resultant voltage variation V appearing on the output side of the modulator may be expressed as follows:

$$V=av+bv^2+cv^3+dv^4 \quad (1)$$

If now a second demodulating tube be connected as proposed by the present invention, the input currents will be applied in opposite phase relation, and, representing the output voltage variation by V′ and the input variation by $-v$, the output voltage variation of the opposing tube may be represented as follows:

$$V'=a(-v)+b(-v)^2+c(-v)^3+d(-v)^4=-av+bv^2-cv^3+dv^4 \quad (2)$$

In equations 1 and 2 the quantities a, b, etc. are constants depending upon the character of the demodulating tubes. Let it now be assumed that V″ represents the voltage variation in a common or combined output circuit of the two tubes, whose output circuits are operating in opposite phase, then V″ will equal V+V′. Hence, combining equations 1 and 2, and omitting the fourth power term which is negligible, we have:

$$V''=2bv^2 \quad (3)$$

It will now be assumed that the unmodulated carrier wave incoming from the circuit 13 is of frequency $\frac{Q}{2\pi}$. This wave may then be mathematically expressed as equal to A sin Qt, wherein A represents the amplitude of the carrier wave and t represents the time. The modulated side band is made up of a number of frequencies corresponding to the frequencies in the original modulating signal wave, but it will be sufficient to consider the case of a single side wave whose frequency may be assumed to be $\frac{P}{2\pi}$. This side wave which would be produced by modulating the carrier wave by a singing note may be mathematically expressed as equal to B sin (P$t-\phi$), wherein B is the amplitude of the signal wave t in accordance with the time, and a ϕ equals any arbitrary phase angle which may be assumed. From these two expressions it will be at once apparent that the input voltage impressed upon the modulator may be represented as follows:

$$v=A\sin Qt+B\sin(Pt-\phi) \quad (4)$$

Substituting this value of v in equation (3), we have:

$$V''=2b\Big[(A\sin Qt)^2+AB\cos\Big((Q-P)t+\phi\Big)-AB\cos\Big((Q+P)t-\phi\Big)+(B\sin(Pt-\phi)^2\Big] \quad (5)$$

The first expression on the left hand side of equation (5), it will be observed, represents the square of the unmodulated carrier frequency component. The second expression is a function of the difference between the carrier frequency and the side frequency which, in the case assumed, would be the signal frequency or the frequency of the singing note in accordance with which the carrier was originally modulated. This difference frequency is the detected signal frequency which it is desired to transmit to the circuit 20. The third expression corresponds to the sum of the carrier frequency and the side frequency. This frequency is so high as to be above audibility, and if desired may be eliminated by tuning, and hence may be considered as taking no part in the detecting operation. The fourth expression is negligible because B is usually very small as compared with A. The first expression on the left hand side of the equation, representing the square of the unmodulated carrier wave, may be written in expanded form, so that equation 5 becomes:

$$V''=bA^2(1-\cos 2Qt)+2bAB\cos\Big((Q-P)t+\phi\Big)-2bAB\cos\Big((Q+P)t-\phi\Big) \quad (6)$$

Considering the first expression on the left hand side of the equation, it will be seen that it comprises a constant term vA², which represents the direct current component resulting from the modulating action of the balanced detector upon the unmodulated carrier frequency. This direct current component, it will be observed, appears as one of the factors of the squared term and the unmodulated carrier frequency itself and the side frequency do not appear in the output circuit. The remaining portion of the first term, which is cos Qt, is a term corresponding to twice the carrier frequency, and will also be above the audible limit, and may be eliminated by filters. The constant term

vA^2 representing the direct current component in flowing through the winding of the relay 15 causes it to attract its armature so long as the carrier frequency is applied to the demodulator, but when the carrier frequency is interrupted this component is no longer present and the armature of the relay is permitted to fall off and operate the ringing signal. The component representing a function of Q—P, as already stated, corresponds to the detected signals and will be transmitted through the transformer 18 to the circuit 20.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. A demodulating apparatus comprising a pair of balanced detecting elements, the circuits of said detecting elements having a common branch, and means in said common branch responsive to the detected low frequency signaling current and to the unmodulated carrier wave.

2. A demodulating apparatus comprising a pair of balanced detecting elements, the circuits of said elements having a common branch, means in said common branch responsive to detected low frequency signaling currents, and means in said common branch responsive to the unmodulated carrier frequency.

3. A demodulating apparatus comprising a pair of detecting elements, the circuits of said detecting elements having a common branch and said elements being connected in such phase relations with respect to each other as to suppress frequencies corresponding directly to the unmodulated carrier and the frequencies of the modulated side band, means in said common branch responsive to the low frequency current detected from the modulated side wave, and means in said common branch responsive to the direct current component detected from the unmodulated carrier component.

4. In a demodulating apparatus a pair of detecting elements having input and output circuits so connected that said input and output circuits have branches common to both elements and means in said common branch of the output circuits responsive to detected low frequency signaling currents and responsive to the unmodulated carrier frequency component.

5. A demodulating apparatus comprising a pair of detecting elements each having input and output circuits, the said input and output circuits being so connected as to have branches common to both elements, means in the common output branch responsive to detected low frequency signaling currents, and means in said common branch responsive to the unmodulated signal component.

6. A demodulating apparatus comprising a pair of detecting elements each having input and output circuits, said input and output circuits being so connected as to have branches common to both elements whereby frequencies corresponding directly to the unmodulated carrier and the modulated side band will be suppressed from the output circuits, means in the common branch of said output circuits responsive to the low frequency signaling currents detected from the side band, and means in said common branch responsive to the direct current component detected from said unmodulated carrier.

7. A demodulating apparatus comprising a pair of vacuum tubes each having grid and plate electrodes, a serial connection between said grid electrodes and means whereby incoming unmodulated carrier components and modulated side band frequencies are serially impressed upon said grids, a series connection between said plates and a common branch so associated with said plates that they will be in parallel with respect thereto whereby frequencies directly corresponding to the unmodulated carrier frequency and the modulated side band frequencies will be suppressed from said common branch, and means in said common branch responsive to detected low frequency signaling currents and responsive to said unmodulated carrier component.

8. A demodulating apparatus comprising a pair of vacuum tubes each having grid and plate electrodes, a serial connection between said grid electrodes and means whereby incoming unmodulated carrier components and modulated side band frequencies are serially impressed upon said grids, a series connection between said plates and a common branch so associated with said plates that they will be in parallel with respect thereto whereby frequencies directly corresponding to the unmodulated carrier frequency and the modulated side band frequencies will be suppressed from said common branch, means in said common branch responsive to detected low frequency signaling currents and means in said branch responsive to the unmodulated carrier component.

9. A demodulating apparatus comprising a pair of vacuum tubes each having grid and plate electrodes, a serial connection between said grid electrodes and means whereby incoming unmodulated carrier components and modulated side band frequencies are serially impressed upon said grids, a series connection between said plates and a common branch so associated with said plates that they will be in parallel

with respect thereto whereby frequencies directly corresponding to the unmodulated carrier frequency and the modulated side band frequencies will be suppressed from said common branch, means in said common branch responsive to the low frequency signaling currents detected from said side band, and means in said common branch responsive to the direct current component detected from said unmodulated carrier component.

In testimony whereof, I have signed my name to this specification this 30th day of December, 1920.

HERMAN A. AFFEL.