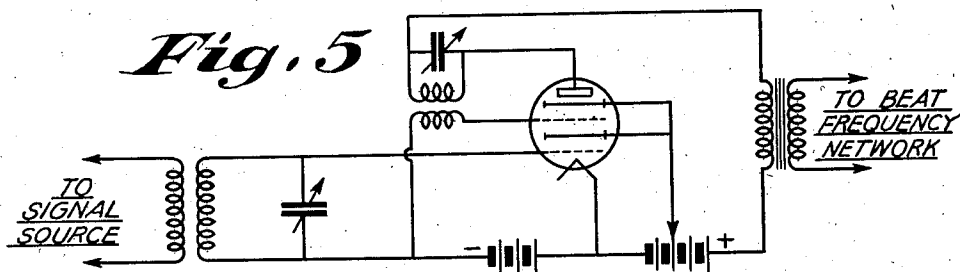
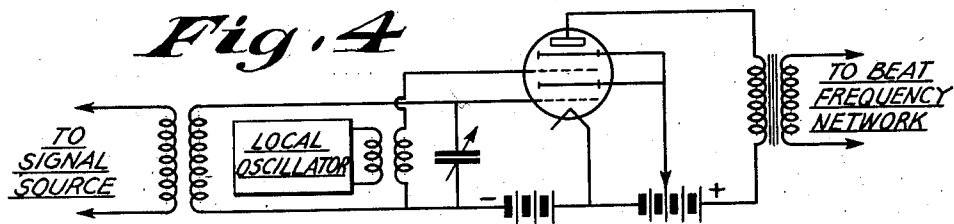
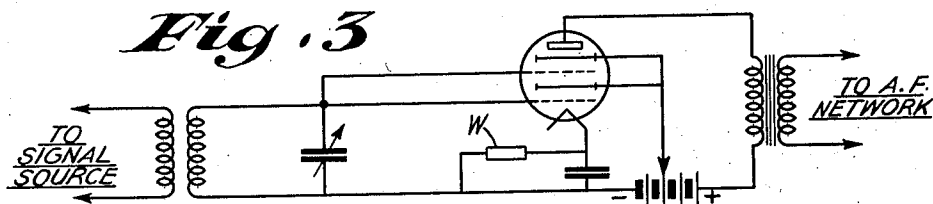
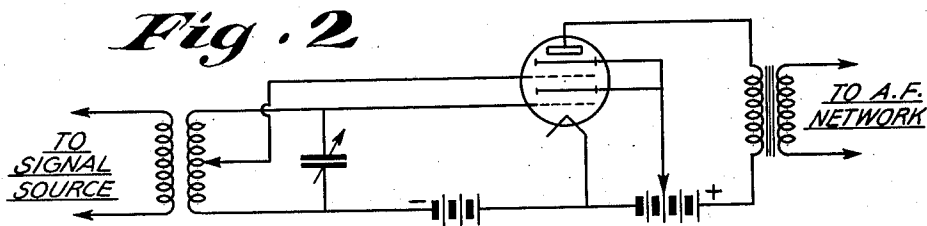
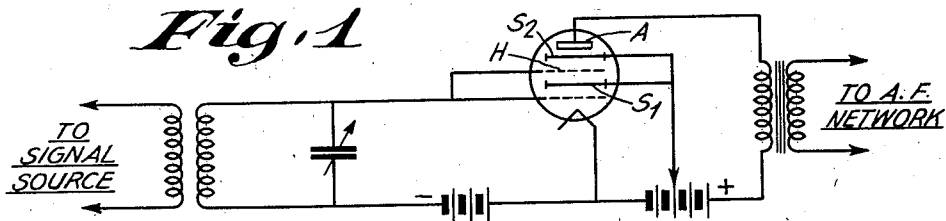


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DEMODULATION CIRCUIT

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The present invention relates to demodulating arrangements for receiving electromagnetic waves.

Demodulation necessitates the formation of the combination frequencies of carrier frequency and side-band frequencies in the case of modulated transmitters, and combination frequencies of the transmission frequency and heterodyne frequency in non-modulated transmitters. Formation of the combination frequency always occurs when a multiplicative effect of the two original voltages of dissimilar frequencies upon each other takes place. This is attainable most simply by that the incoming frequently mixture (spectrum) is brought to act upon a device with non-linear, preferably quadratic current-voltage relation. (Crystal detector, audion, diode, amplifying detector, etc.). All arrangements operating in this manner have certain inherent disadvantages which are obviated in whole or in part by the arrangement hereinafter to be disclosed. In the drawing:

Fig. 1 shows a signal demodulator network embodying the invention,

Fig. 2 shows a modification thereof,

Fig. 3 illustrates a further modification,

Fig. 4 shows an embodiment of the invention applied to a heterodyne system,

Fig. 5 shows a modification of the arrangement shown in Fig. 4.

Multiplicative action of two voltages upon one another is concerned, for instance, in the case of a multi-grid tube of such a nature that the slope of the plate-current characteristic referred to one of the grids

$$\frac{(di_a)}{(deg_1)}$$

(mutual conductance) is adjustable by the voltage of a second grid. Inter alia, this holds good for space-charge grid tubes, though what has to be put up with then is that the space-charge grid maintained at a positive potential will carry current, and thus consume energy. The same thing holds true also of a screen-grid tube which is equipped with an auxiliary grid H between plate A and the screen grid S1. The situation will be still further improved if between the said auxiliary grid and the plate there is disposed a second screen grid S2. (An arrangement of this sort underlies the explanatory key diagrams.) In both the said instances the slope of the plate-current characteristic in reference to the control grid may be varied, to be more precise, in one case by the adjustment of the space-charge grid volt-

age, and in the other case by the adjustment of the auxiliary-grid potential. The multiplicative effect of the two grid potentials arises then as follows:

There is $i_a = S \cdot eg_1$, and on the other hand $S = K \cdot eg_2$, where K is any constant at all, S the slope, i_a the plate-current, and eg_1 , eg_2 the grid voltages. By introduction there results

$$i_a = K \cdot eg_1 \cdot eg_2.$$

Hence, if both grids, for instance, are impressed with the incoming frequency mixture (hereinafter to be called the frequency spectrum) (Fig. 1), there occurs squaring, and thus the formation of combination frequencies, i. e. demodulation, without non-linear relation existing between plate-current and each one of the various grid potentials.

This arrangement offers the advantage over an audion that the amplitude that should be handled without incidentally any distortion being occasioned, may be very large, for there happens no shift in the static grid potentials, which, in an audion, give rise to additional harmful plate rectification. At the same time, there is absent the combination between grid condenser and grid leak which causes both linear as well as non-linear distortions. Compared with the plate rectifier, this scheme offers the merit that the working point of both grids can be readily so positioned that with increasing amplitude the mean slope of the region covered will decrease, in other words, so that a smooth start of the oscillations in regenerative circuit arrangements is assured.

Of course, it is possible, in accordance with the dissimilar modulation range of both grids, to feed the one only with part of the voltage of the other (Fig. 2).

Also automatic volume-control is practicable with this arrangement in that use is made of a variation of the plate direct current as a function of the amplitude of the carrier wave for the purpose of insuring variable biasing voltage either in both controlled grids or only of the grid regulating the slope (mutual conductance). In the case of the tube here chosen for the exemplified key diagram this may be accomplished by the insertion of a resistance W in the cathode lead. (Fig. 3.)

Demodulation by the use of the multiplicative effect of the potentials of two different grids of a tube affords special advantages if both grids are impressed with different potentials. The simplest case resides in the heterodyne reception

of a non-modulated sending station. In this instance, one grid will be fed with the incoming frequency, and the other one with the heterodyne frequency, and in this manner outbalancing or uncoupling of the heterodyne will be secured. (Fig. 4.)

It is also feasible to produce the heterodyne frequency by regeneration of one of the two grids from a tuned circuit in the plate lead, while upon the other grid is impressed the incoming frequency. In such a scheme, there will be no detuning of the input circuit which is required in self-heterodyne arrangement, and which tends to diminish the sensitivity, while in comparison with arrangements involving a local oscillator, one tube is saved. (Fig. 5.)

What seems of especially great value are the arrangements in which, in the reception of modulated oscillations, there is impressed upon one grid the incoming spectrum, and upon the other grid an alternating voltage of the frequency of the carrier wave coming from the transmitter station to be received. In the reception of amplitude-modulated transmitters by means of demodulators whose operation is predicated upon non-linear current-voltage relations, there arise combination frequencies between each and every one of the frequencies comprised in the incoming spectrum and with every other one. The consequence is that several transmitters adjacent as to frequency will be simultaneously demodulated; in other words, in the output end of the demodulator will be present the modulation frequencies of all incoming transmitters. By the use of radio frequency selective means, the amplitudes of the undesired transmitters contained in the incoming spectrum are reduced as far as feasible so that also the amplitudes of the ensuing undesired modulation frequencies will be small compared with the amplitude of the modulation frequencies of the desired transmitter.

The amplitude of a combination frequency is directly proportional to the product of the amplitudes of the two original frequencies. In order that the requisite reductions, especially in the case of an unfavorable relationship of the field intensities (feeble transmitter and powerful disturber station) may be secured, a good deal of radio frequency selection must be provided, and this is an expensive proposition particularly when several circuits must be served simultaneously. Now, if demodulation is effected in this manner that there is impressed upon one grid (of a tube satisfying conditions as outlined above) the incoming frequency spectrum, upon the second grid an alternating voltage of the frequency of the carrier wave of the desired transmitter, formation of a combination frequency will occur only between the carrier frequency, on the one hand, and the other frequencies of the incoming spectrum.

But audible combination frequencies will then be produced only by frequencies of the spectrum being sufficiently close to the carrier frequency, while no such action will be produced between the carrier and the side-band frequencies of the undesired or interfering transmitters with one another, so that, presupposing perfectly linear relations between plate current and voltage of the grid upon which the incoming spectrum is impressed, radio frequency selection will not be necessary. However, even if, owing to not perfectly linear modulation, undesired combination frequencies arise, then, by choosing a region of the characteristic being as straight as possible,

and by sufficiently low amplitudes of the incoming spectrum, the amplitude of the undesired combination frequencies may be minimized in contrast with the amplitudes of the combination frequencies which result from the intentional multiplication of the incoming spectrum with the supplemental carrier voltage of the other grid, but especially also by choosing a large amplitude for the supplemental voltage. The arrangement here described has selective properties, and it allows of doing away with a good deal, if not of all, of the selector means.

What may also be remarked in reference to this arrangement is that upon the reception of amplitude-modulated transmitters with two side-bands, the supplemental carrier voltage should coincide with the alternating carrier wave contained in the incoming spectrum of the desired station not only as regards frequency, but also phase. The ways and means of how to make this supplementary voltage available shall be set forth in more detail further below.

Whereas demodulation of a spectrum originating from frequency-modulated transmitters is not successful with arrangements which are based upon non-linear current and voltage relations for reasons of the change in phase between carrier and side-band frequencies as compared with amplitude modulation, the arrangement here disclosed allows of the demodulation also of frequency spectra of this kind. All that is necessary is that on one of the grids the incoming spectrum, and on the other one again an alternating potential having the frequency of the desired transmitter is impressed, however, in such a way that the supplemental voltage is displaced an angle of 90 degrees in respect to the carrier-wave voltage contained in the incoming spectrum.

If ω is the cyclic frequency of the carrier wave, $\Delta\omega$ the modulation audio frequency, S the side-band amplitude, T the carrier-wave amplitude, then in the case of frequency modulation, the incoming spectrum is of this shape:

$$S \sin(\omega + \Delta\omega)t + T \cos \omega t + S \sin(\omega - \Delta\omega)t$$

Multiplication with a voltage $M \cos \omega t$ which is in phase with the carrier-wave voltage $T \cos \omega t$ included in the spectrum, results in the terms giving the modulation frequency:

$$SM \cos \omega t \sin(\omega + \Delta\omega)t + SM \cos \omega t \sin(\omega - \Delta\omega)t$$

so that the pure $\Delta\omega$ terms will assume this shape:

$$\frac{1}{2} SM \sin(\Delta\omega)t + \frac{1}{2} SM \sin(-\Delta\omega)t = 0$$

Multiplication by a supplemental voltage $M \sin \omega t$ displaced an angle of 90 degrees in reference to the carrier-wave voltage $T \cos \omega t$ contained in the incoming spectrum, on the contrary, furnishes this result:

$$\frac{1}{2} SM \sin \omega t (\omega + \Delta\omega)t + \frac{1}{2} SM \sin \omega t \sin(\omega - \Delta\omega)t$$

whence the pure $\Delta\omega$ terms:

$$\frac{1}{2} SM \cos(-\Delta\omega)t + \frac{1}{2} SM \cos(\Delta\omega)t = SM \cos(\Delta\omega)t$$

In arrangements wherein one of the two grids with multiplicative action is impressed with the incoming spectrum, while upon the other grid is impressed a voltage of the frequency of the carrier transmitted from the desired station, the following may be said respecting the creation or supply of the said supplemental voltage:

As a general rule, there serves for this purpose a generator made available at the receiving point, although there is, of course, also a chance to filter the desired carrier out of the incoming spectrum,

optionally after further amplification, and to feed the same to the second grid. Because of the necessity of preserving frequency equality and the phase relations, it would appear indispensable to act upon the frequency and the phase of the supplemental voltage by the frequency and the phase of the carrier-wave voltage included in the incoming spectrum by ways and means known in the art, for instance, predicated upon what is known as the coherence or entrainment phenomenon. Another mode would be, at least in demodulation of amplitude-modulated transmitters, to use one and the same tube as a demodulator and generator. What must also be noted is that also in the case of the two schemes based upon addition of the carrier-wave voltage, automatic volume-control is accomplishable in the same manner as hereinbefore disclosed (in connection with Fig. 3).

What is claimed is:—

1. In a modulated carrier receiving system, a demodulator network including a tube provided with a cathode, an anode, a screen grid which is maintained at a positive direct current potential with respect to the cathode and at the same alternating current potential as the latter, a signal control grid disposed between the cathode and screen grid, and an auxiliary electrode disposed between the screen grid and anode, an input circuit, tuned to the operating carrier frequency, connected between the cathode and signal grid, means for impressing energy of said carrier frequency upon said auxiliary electrode, said impressing means including a connection between said auxiliary electrode and a point of said tuned input circuit, an output network coupled between the cathode and anode for utilizing the demodulated currents, and means for maintaining both said signal grid and auxiliary electrode at a substantial negative direct current potential with respect to said cathode.

2. In a modulated carrier receiving system, a demodulator network including a tube provided with a cathode, an anode, a positive screen grid, a signal control grid disposed between the cathode and screen grid, and an auxiliary electrode disposed between the screen grid and anode, an input circuit, tuned to the operating carrier frequency, connected between the cathode and signal grid, means for impressing energy of said carrier frequency upon said auxiliary electrode,

said impressing means including a connection between said auxiliary electrode and a point of said tuned input circuit, an output network coupled between the cathode and anode for utilizing the demodulated currents, and means for maintaining both said signal grid and auxiliary electrode at a substantial negative potential with respect to said cathode, said last means including an impedance disposed in the space current path of the tube, and both said signal grid and auxiliary electrode being connected to the anode side of the impedance.

3. In a modulated carrier receiving system, a demodulator network including a tube provided with a cathode, an anode, a positive screen grid, a signal control grid disposed between the cathode and screen grid, and an auxiliary electrode disposed between the screen grid and anode, an input circuit, tuned to the operating carrier frequency, connected between the cathode and signal grid, means for impressing energy of said carrier frequency upon said auxiliary electrode, an output network coupled between the cathode and anode for utilizing the demodulated currents, and means for maintaining both said signal grid and auxiliary electrode at a substantial negative potential with respect to said cathode, said impressing means including an adjustable connection between the auxiliary electrode and the said input circuit, and a second positive screen grid between the anode and auxiliary electrode.

4. In a modulated carrier receiving system, a demodulator network including a tube provided with a cathode, an anode, a positive screen grid, a signal control grid disposed between the cathode and screen grid, and an auxiliary electrode disposed between the screen grid and anode, an input circuit, tuned to the operating carrier frequency, connected between the cathode and signal grid, means for deriving the carrier frequency from the tuned input circuit and impressing the same upon said auxiliary electrode, an output network coupled between the cathode and anode for utilizing the demodulated currents, and means for maintaining both said signal grid and auxiliary electrode at a substantial negative potential with respect to said cathode.

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