June 19, 1945. W. VAN B. ROBERTS 2,378,581

CONVERSION OF AMPLITUDE MODULATION TO FREQUENCY MODULATION

Filed June 25, 1942

Fig. 1.

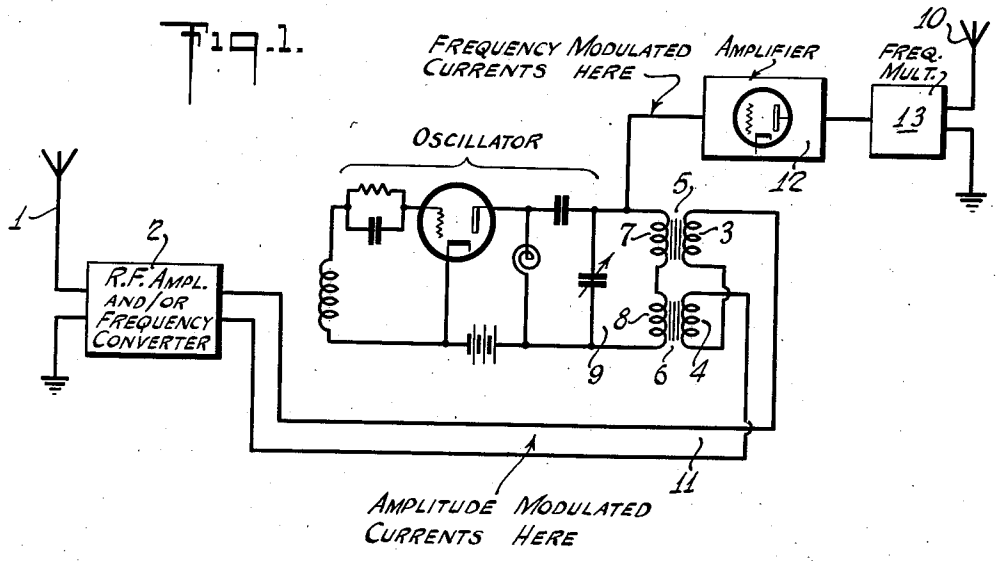
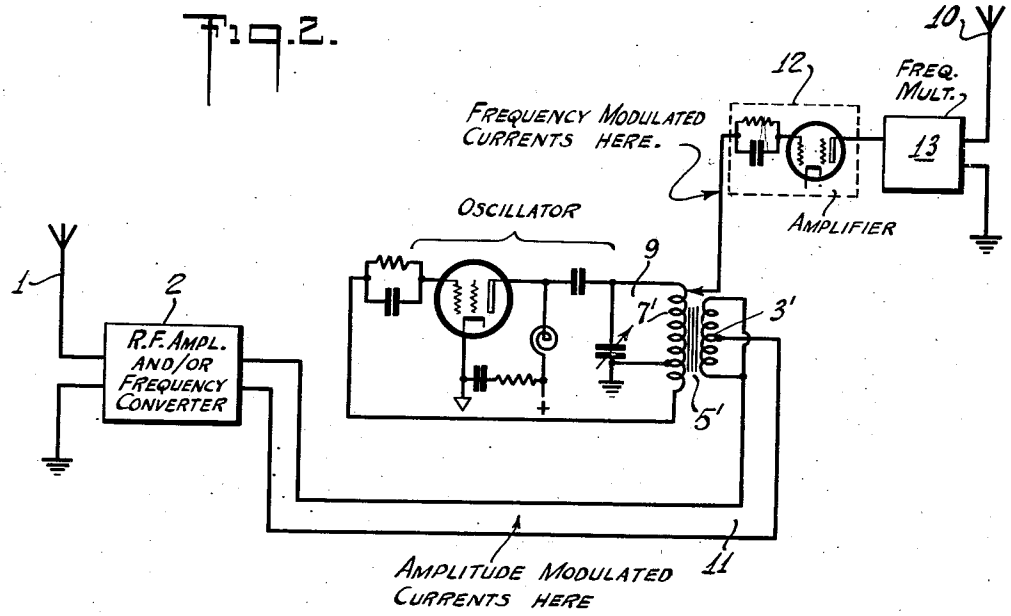


Fig. 2.



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CONVERSION OF AMPLITUDE MODULATION TO FREQUENCY MODULATION

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9 Claims. (Cl. 250—15)

This invention relates to a method of and apparatus for directly converting an amplitude modulated radio frequency wave into a frequency modulated radio frequency wave without the need for an intervening detection step. In the past, it has been customary in converting an amplitude modulated radio frequency wave to a frequency modulated frequency wave to employ suitable detecting apparatus to convert the amplitude modulated wave to audio frequency and then to employ this audio frequency to modulate the frequency of a frequency modulation transmitter. This process introduces a certain amount of distortion, commonly called detector distortion, in the detecting means.

It is an object of the present invention to avoid such detector distortion by providing means for converting amplitude modulated waves to frequency modulated waves without going through the process of detection.

In brief, this object is achieved by employing as a frequency determining element in an oscillator generating the oscillations to be frequency modulated, an inductance whose magnitude varies in accordance with the amplitude of the amplitude modulated waves. This action is based upon the following experimentally determined phenomenon. If an inductance coil is wound upon a suitable iron core, and if the magnetization of this core is caused to vary at a high frequency, then the effective inductance of the coil measured at a relatively low frequency is found to increase as the amplitude of the aforesaid variation of magnetization increases. Specifically, it has been found that if the variation of magnetization of the core is produced by an auxiliary winding carrying the high frequency current, the effective low frequency inductance is found to be substantially proportional to the square of the amplitude of the high frequency magnetizing current over a wide range of amplitude. For a more detailed description of this phenomenon, reference is herein made to copending Gerard Hepp application, Serial No. 334,530, filed May 11, 1940, now United States Patent 2,291,715, granted August 4, 1942.

A more detailed description of the invention follows in conjunction with a drawing, wherein Figs. 1 and 2 show, by way of example only, two different radio relaying systems embodying the principles of the present invention, for converting an amplitude modulated radio frequency wave into a frequency modulated radio frequency wave. Throughout the two figures, the same parts are labeled by the same reference characters.

Although the two figures of the drawing illustrate the principles of the invention applied to a radio relaying system, and particularly to a repeater station, it should be understood that the invention has wider application.

Referring to the radio repeater station of Fig. 1, it is assumed that amplitude modulated radio frequency waves are received by an antenna 1. These received waves are amplified and/or changed in frequency in apparatus 2, and then passed over leads 11 to magnetizing coils 3 and 4 which are wound on iron cores 5 and 6. Coils 7 and 8 are also wound on cores 5 and 6, respectively, and these last coils form the inductance or at least a portion thereof of the tank circuit 9 of an oscillator system indicated by the legend "oscillator." The exact type of oscillator circuit used is immaterial but the frequency of oscillation is chosen low compared to the frequency of the amplitude modulated current traversing the magnetizing windings 3 and 4. The oscillator frequency may, conversely, be as high as desired, if a suitable increase of the frequency of the amplitude modulated waves to satisfy the aforesaid requirement is provided. The oscillator frequency is preferably of radio frequency, but could even be an audio frequency oscillator although in such case a considerable number of stages of frequency multiplication would be required to raise the frequency of the frequency modulated waves to the high frequencies commonly used for their transmission over the ether.

The operation of the arrangement is as follows: The coils 3 and 4 are preferably connected in series so as to assure equal currents in each of them, and the relative polarity of connections is so chosen (as indicated in the drawing) that there is no net high frequency voltage induced in tank circuit 9 by the high frequency current in coils 3 and 4. It is not essential that separate cores 5 and 6 and separate coils be employed, as the same results may be obtained to a somewhat lesser degree (as shown in Fig. 2) by the use of a single coil 7' on a single core 5' in tank circuit 9 (to replace the coils 7 and 8) and a mid-tapped magnetizing coil 3' (to replace coils 3 and 4) having the amplitude modulated radio frequency currents flowing both ways through this coil from the mid-tap. In fact, it is not necessary to avoid the induction of high frequency currents in the oscillator tank, but it is preferable simply to avoid the waste of high frequency power. In any case, the effective inductance in the tank circuit, meas-

ured at the natural frequency of the tank circuit, is substantially proportional to the square of the amplitude of the magnetizing high frequency current so that the natural period of the tank circuit 9 which is proportional to the square root of the effective inductance will be directly proportional to the amplitude of the high frequency magnetizing current. If the natural period of the oscillator is proportional to the amplitude of the high frequency current, then for small percentage changes in this natural period the variation of frequency of the oscillator will be substantially linearly related to the variation of amplitude to the high frequency exciting currents, and thus the amplitude modulation of the exciting current is converted substantially without distortion into frequency modulation of the oscillations generated in tank circuit 9. These frequency modulated oscillations may then be amplified and/or multiplied in frequency in electron discharge device apparatus 12 and further multiplied in frequency, amplified, limited, and converted in frequency in apparatus 13, in accordance with well known practice, to obtain any desired output frequency to be radiated from antenna 10 together with any desired amount of maximum frequency deviation corresponding to 100% modulation of the amplitude modulation current.

Although the invention has been described in connection with receiving amplitude modulated waves and rebroadcasting them in the form of frequency modulated waves, it will be appreciated that the system may be employed as a unitary means for generating frequency modulated waves from audio signals if a small amplitude modulation transmitter is used to generate the magnetizing current referred to.

What is claimed is:

1. The method of varying the frequency of a low frequency oscillator including as a frequency determining element thereof an inductor wound upon an iron core, which comprises magnetizing said core in accordance with the amplitude of a relatively high frequency amplitude modulated radio frequency wave.

2. The method of varying the frequency of a low frequency oscillator including as a frequency determining element thereof an inductor wound upon an iron core, which comprises magnetizing said core in accordance with the amplitude of a relatively high frequency amplitude modulated radio frequency wave, and multiplying the frequency of oscillations produced by said oscillator.

3. In combination, an oscillation generator, a frequency determining element for said generator comprising an inductance coil wound upon a magnetizable core, and another coil wound on said core, and means for supplying said last coil with amplitude modulated alternating currents of a frequency higher than the frequency of oscillation of said generator, whereby the magnetization of said core is varied in accordance with the amplitude of said alternating currents, said means being so connected to said last coil that no voltage is induced in said inductance coil by said amplitude modulated alternating currents.

4. An amplitude modulation to frequency modulation converter comprising an oscillation generator, an inductor element whose value determines in part at least the frequency of oscillation of said generator, said element being wound upon a magnetizable core, a coil for magnetizing said core wound upon said core, and a source of amplitude modulated alternating currents of a frequency higher than the frequency of oscillation of said generator coupled to said coil in such manner that the magnetization of said core is varied in accordance with the amplitude of said alternating current but no voltage is induced in said inductor element by said amplitude modulated currents, and means coupled to said converter for utilizing the frequency modulated waves produced in said converter.

5. An amplitude modulation to frequency modulation converter comprising a radio frequency oscillation generator, a frequency determining circuit for said generator including as part thereof an inductor element wound upon a magnetizable core, a coil for magnetizing said core, and a source of amplitude modulated radio frequency currents of a frequency higher than the frequency of oscillation of said generator coupled to said coil, whereby the magnetization of said core is varied in accordance with the amplitude of said amplitude modulated currents.

6. An amplitude modulation to frequency modulation converter comprising an oscillation generator, an inductor element whose value determines in part at least the frequency of oscillation of said generator, said element being wound upon a magnetizable core, a coil for magnetizing said core wound upon said core, and a source of amplitude modulated alternating currents of a frequency higher than the frequency of oscillation of said generator coupled to said coil.

7. An amplitude to frequency modulation converter comprising an oscillation generator having a parallel tuned circuit of a condenser and an inductance coil controlling the frequency of the oscillations produced by said generator, said inductance coil being wound upon a magnetizable core, another coil wound upon said core for magnetizing said core, a connection between both terminals of said last coil, a source of amplitude modulated alternating current of a frequency higher than the frequency of oscillation of said generator, and a pair of connections extending from one terminal and from the mid point of said last coil to said source, whereby the magnetization of said core is varied in accordance with the amplitude of said alternating current but no voltage is induced in said inductance coil by said amplitude modulated current, and means coupled to said generator for utilizing the frequency modulated waves produced in said converter.

8. A radio relaying station comprising a receiving antenna for collecting amplitude modulated waves radiated from a distant station, an oscillation generator, an inductor element whose value determines in part at least the frequency of oscillation of said generator, said element being wound upon a magnetizable core, a coil for magnetizing said core wound upon said core, means for supplying said coil with amplitude modulated currents representative of the modulation on the waves collected by said antenna but of a frequency higher than the frequency of oscillation of said generator, said coil being coupled to said means in such manner that the magnetization of said core is varied in accordance with the amplitude of said currents supplied to said coil, and a transmitting antenna coupled to said oscillation generator.

9. An amplitude to frequency modulation converter comprising an oscillation generator having a parallel tuned circuit controlling the frequency of the oscillations produced by said generator,

said tuned circuit including a pair of coils in series relation, each wound upon a magnetizable core, other coils wound upon said cores, one for each core, means connecting said last coils in series relation and to a source of amplitude modulated alternating currents of a frequency higher than the frequency of oscillation of said generator, the polarity of the connections between said last coils being so chosen that no high frequency voltage is induced in said first pair of coils by the currents of said source, and means coupled to said generator for utilizing the frequency modulated waves produced in said converter.

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