

Oct. 28, 1941.

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2,260,844

ULTRA HIGH FREQUENCY CONVERTER

Filed March 12, 1940

Fig. 1.

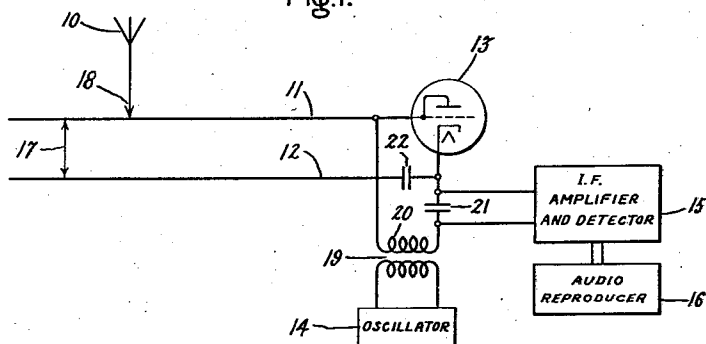


Fig. 2.

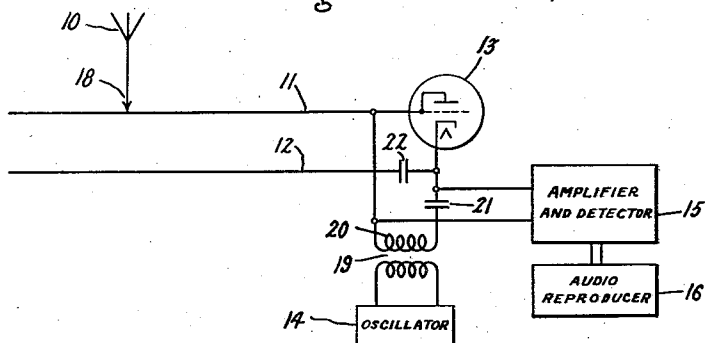
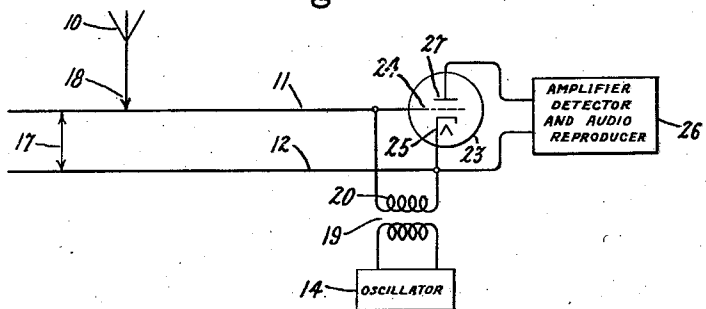


Fig. 3.



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UNITED STATES PATENT OFFICE

2,260,844

ULTRA HIGH FREQUENCY CONVERTER

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Application March 12, 1940, Serial No. 323,577

9 Claims. (Cl. 250-20)

This invention relates to ultra-high frequency circuits for heterodyne conversion of ultra-high frequency waves into lower frequency waves for easier amplification and has for an object to provide a simple and easily adjusted converter of such nature.

It is also an object of my invention to provide a converter circuit which includes a transmission line resonant to an ultra-high frequency wave to be converted in frequency, and which also includes conversion means arranged in a simplified manner so that the heterodyne wave which produces the conversion is not short circuited by the resonant transmission line.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates a circuit embodying my invention; Fig. 2 illustrates a different form of circuit embodying my invention; and Fig. 3 illustrates a third modification of a circuit embodying my invention.

Referring to Fig. 1, an antenna 10 receives an ultra-high frequency wave in the order of 30 to 50 centimeters in wave length and impresses it on a resonant or standing wave line 11, 12, which is terminated by a diode 13. A heterodyne oscillator 14 generates a wave which is also transmitted to the diode 13, where heterodyne action between the two waves produces a third wave as a modulation product, whose frequency is low enough to be readily amplified. This new wave is transmitted by suitable means, to be described later, to an intermediate frequency amplifier and detector 15, which amplifies and demodulates the wave, and then to an audio reproducer 16, which translates the audio wave produced by demodulation, into a sound wave.

In a particular case, where the diode 13 was a 955 tube with, the anode and grid connected together, the diode was found to be self-resonant at a wave length of about 37 centimeters. Such self-resonance is due to internal capacitance between electrodes and to the inductance of the leads within the device and which comprise structural parts of the device itself. The end of the line 11, 12 remote from the diode 13 is bridged by an adjustable connection 17 by which the line may be tuned. The antenna 10 is connected to the wire 11 of the line through an adjustable tap

18. With such connections the line 11, 12 is adjusted to a length equal to one-half of a wave length of the wave received from the antenna 10, or to an integral multiple thereof, thereby to respond to the wave received, which wave should be near in frequency to the resonant frequency of the diode itself. Excellent results have been obtained with the line 11, 12 adjusted to one-half of a wave length, and such adjustment is therefore preferred at present. Current maximum points exist in the connection 17 and in the terminals of the diode 13. The self-resonance of the diode causes a voltage maximum between its anode and cathode when a current maximum exists in its terminals.

The oscillator 14 transmits a wave to the diode 13 through a transformer 19, whose secondary winding 20 impresses the output of the oscillator through a condenser 21 upon the diode. The condenser 21 is made of sufficient capacitance to transmit waves of the frequency generated by the oscillator 14 with low impedance. The frequency of the wave produced by the oscillator 14 is chosen so that the line 11, 12 has high impedance thereto. To satisfy this condition the line must be an odd integral multiple of a quarter wave length of the wave from the oscillator. The oscillator wave is rectified by the diode 13 and a harmonic thereof is produced across the electrodes of the diode. This harmonic heterodynes with the wave from the antenna 10 to produce the desired wave of intermediate frequency. When the length of line 11, 12 is equal to a half wave length of the wave received from the antenna, it is convenient to make the oscillator frequency different from but in the neighborhood of half the antenna frequency so that the second harmonic of the oscillator wave heterodynes to produce the intermediate frequency wave.

The line 11, 12 does not affect the wave of fundamental frequency from the oscillator 14, if it is very nearly a quarter wave, or an odd integral multiple thereof, in length with respect thereto, so that a current maximum exists at the connection 17 and a voltage maximum at the diode 13. Similarly, the transformer 19 and the oscillator 14 present a higher impedance to the wave from the antenna 10 than the diode 13, which is self-resonant at the frequency of the received waves, so that currents from the antenna 10 flow principally through the diode.

A condenser 22 is connected between the line 11, 12, and the diode 13, and is of sufficient capacity to transmit a wave from antenna 10 with low impedance from the line 11, 12 to the diode

13. The wave of intermediate frequency produced in the diode is made substantially lower in frequency than either of the waves from the oscillator 14 or from the antenna 10, so that the condensers 21 and 22 can be and are given a sufficiently high impedance to prevent the intermediate frequency wave from being short circuited by the oscillator 14 or the line 11, 12 respectively. The intermediate frequency voltage therefore appears across both condensers 21 and 22, and the amplifier 15 is connected across one of these condensers, which may be, as is shown, condenser 21. Such connection has been found to give excellent results when the line 11, 12 has been tuned to waves between 35 and 40 centimeters long received by the antenna 10.

Referring to Fig. 2, there is shown a slightly different connection of the amplifier 15 to be excited by the intermediate frequency wave from the diode 13. In this figure each part corresponds to a similar part shown in Fig. 1 and is given a like reference character. The amplifier 15, however, is connected in shunt to the diode 13. This amplifier is provided with a higher impedance than the diode 13 at the frequency of either of the waves from the oscillator 14 or from the line 11, 12, so that it does not absorb an appreciable amount of either of these waves.

It is to be noted that there is no short circuiting connection for the line 11, 12 corresponding to the connection 17 illustrated in Fig. 1. The frequency relations are somewhat different with this apparatus than with that of Fig. 1, since line 11, 12 operates as an open ended standing wave line which is resonant only to waves which produce a voltage loop or point of maximum voltage upon the open end. For the wave received by the antenna 10, since a current maximum must exist at the terminals of the diode 13 in order that a voltage maximum for this wave shall exist between the anode and cathode thereof, the line 11, 12 as in Fig. 1, must be resonant somewhere near the self-resonant frequency of the diode 13. The line 11 and 12 therefore may have an electrical length of one-quarter of a wave length of the wave received from the antenna 10, or an odd integral multiple thereof.

In the apparatus illustrated in both Figs. 1 and 2 the physical length of the line 11 and 12 will usually not appear to be the same as the electrical length of the wave from the antenna 10 or of any multiple of one-quarter of that length. This is due to the fact that the apparatus can be operated in a considerable band near the self-resonant frequency of the diode 13. If it be operated below that frequency, the diode 13 appears to have capacitive reactance and the mechanical length of the line 11, 12 must be shorter than the apparent electrical length necessary. Correspondingly, if the line 11, 12 be tuned to receive a wave from the antenna 10 of higher frequency than the self-resonant frequency of the diode 13, the diode appears to be inductive, and the mechanical length of the line 11, 12 appears somewhat longer than a multiple of one-quarter of the length of the wave from the antenna 10. I mean, therefore, when speaking of making the line 11, 12 of a certain length in terms of wave length, to indicate that the adjustment of the length of the line 11, 12 shall be such that the apparatus as a whole is resonant to the wave referred to.

It is apparent that the oscillator 14 of Fig. 2 can be operated, as with Fig. 1, so that any har-

monic of its wave which is produced in the diode 13 may heterodyne with the wave from the antenna 10 to produce the desired converted frequency. Two conditions are necessary in order that the converter operate properly in any case. The first condition is that the line 11, 12 be adjusted in length to be resonant near the self-resonant frequency of the diode 13 and that the desired wave from the antenna 10 be of the frequency to which the line 11, 12 is resonant. So long as the frequency at which the oscillator 14 is operated is substantially different from the frequency of the wave received by the antenna 10, the diode 13 can be self-resonant thereto and a substantial part of the voltage from the oscillator 14 appears between the anode and cathode thereof. A second essential condition is that a frequency of operation of the oscillator 14 must be chosen so that a harmonic heterodynes with the antenna wave to produce the desired intermediate frequency wave and so that the line 11, 12 offers a high impedance to the oscillator wave itself. For example, if the line 11, 12 be made $\frac{3}{4}$ of a wave length in length with respect to the antenna wave, so that maximum current flows between the terminals of the diode 13 and maximum voltage exists between the open ends of the line 11, 12, and if the oscillator be operated at $\frac{2}{3}$ of the frequency of the wave from the antenna, so that the line 11, 12 is a half wave length with respect thereto, conversion can take place, an intermediate frequency being produced by heterodyne action between the third harmonic of the oscillator wave and the wave from the antenna so that a relatively low intermediate frequency appears.

Fig. 3 illustrates a different modification of my invention in which certain parts are similar to those shown in Fig. 1 and are given like reference characters. Instead of the diode 13, a triode 23 terminates the line 11, 12, so that a control electrode 24 thereof is connected to wire 11 and cathode 25 thereof to wire 12. The secondary 20 of the transformer 19 is connected directly between electrode 24 and the cathode 25. Condensers are unnecessary in this modification, since intermediate frequency voltage is not derived from the circuits to the antenna 10 and the oscillator 14, but this voltage is instead derived from the electron stream produced by the cathode 25 and modulated by the electrode 24. An intermediate frequency amplifier, detector, and audio reproducer 26 is connected between the cathode 25 and an anode 27 of the discharge device 23 to amplify the intermediate frequency wave, detect it, and to reproduce the received signals.

The action of the circuits in this figure is similar to that of the apparatus shown by Fig. 1. The impedance of the secondary 20 of the transformer 19 is made high compared to that of the path from the electrode 24 to the cathode 25 so that the wave from the antenna 10 is not absorbed by the transformer 19. Similarly the line 11, 12 has a length about one-half of a wave in length of the wave from the oscillator 14, or some multiple thereof, so that a current maximum exists at the connection 17 and a voltage maximum exists between the electrode 24 and the cathode 25.

It is obvious that my invention is not limited in scope to the exact circuits which are shown, since various modifications may be made such as using instead of the device 13 as shown, a diode having no control electrode therein connected as

an anode, or using a device having more than one control electrode, particularly in the type of circuit shown in Fig. 3, in which the use of screen and suppressor electrodes may be desired. It is within the scope of my invention to use any sort of standing wave line 11, 12, either open ended or short-circuited as shown, and of any length which resonates with a wave near the self-resonant frequency of a converter discharge device, and also to use other harmonics than the second of the wave from the oscillator 14 to be impressed across the converter device, so long as the oscillator wave is substantially different in frequency from the wave to be converted and is of such frequency as to produce a voltage maximum at the terminals of the converter device by resonance with the line 11, 12.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto, since different modifications may be made both in the circuit arrangement and instrumentalities employed, and I aim by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave line terminated by two of said electrodes and energized by said wave from said source, said line being resonant to said wave, means operative at a lower frequency than said wave for utilizing said wave after conversion in frequency, means for impressing across said two electrodes a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, and means for transmitting said modulation products to said first means.

2. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave transmission line having a short circuiting device at one end and two of said electrodes connected across its other end, said line being energized by the wave from said source and being adjusted so that said line terminated by said electrodes is resonant to said wave, an amplifier operative at a lower frequency than said wave, means for impressing across said two electrodes a second wave of which an even harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, and means for transmitting said modulation products to said amplifier.

3. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave transmission line having one end open circuited and two of said electrodes connected across its other end, said line being energized by the wave from said source and being adjusted in length so that, when terminated by said electrodes, said line is resonant to said wave, an amplifier operative at a lower frequency than said wave, means for impressing across said two electrodes a second wave of which a harmonic

produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, and means for transmitting said modulation products to said amplifier.

4. In a heterodyne frequency conversion circuit, an electron discharge device having two electrodes, and terminals and leads respectively connected thereto, said electrodes and leads being self-resonant at a certain frequency, a source of an electric wave whose frequency is near said certain frequency, a standing wave transmission line connected across said two terminals at one end and energized by the wave from said source, said line being resonant to said wave, an amplifier operative at a lower frequency than said wave, means for impressing across said two terminals a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, and means for transmitting said modulation products to said amplifier.

5. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave line terminated by two of said electrodes and energized by said wave from said source, said line being resonant to said wave, means operative at a lower frequency than said wave for utilizing said wave after conversion in frequency, means for impressing across said two electrodes a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, means for preventing said line and said last means from short-circuiting said modulation products, and means to transmit said modulation products from said short-circuit preventing means to said amplifier.

6. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave line terminated by two of said electrodes and energized by said wave from said source, said line being resonant to said wave, means operative at a lower frequency than said wave for utilizing said wave after conversion in frequency, means for impressing across said two electrodes a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, a low frequency blocking condenser connected between said electrodes and said last means for preventing said line and said last means from short circuiting said modulation products, and means for transmitting said modulation products from said low frequency blocking condenser to said amplifier.

7. In a heterodyne frequency conversion circuit, an electron discharge device having a plurality of electrodes, a source of an electric wave, a standing wave line terminated by two of said electrodes and energized by said wave from said source, said line being resonant to said wave, means operative at a lower frequency than said

wave for utilizing said wave after conversion in frequency, means for impressing across said two electrodes a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave, means for preventing said line and said last means from short-circuiting said modulation products, and means for transmitting said modulation products from said discharge device to said amplifier.

8. In a heterodyne frequency conversion circuit, an electron discharge device having a cathode, an anode, and a control electrode, a source of an electric wave, a standing wave line terminated by said cathode and control electrode and energized by said wave from said source, said line being resonant to said wave, means operative at a lower frequency than said wave for utilizing said wave after conversion in frequency, means for impressing across said cathode and control electrode a second wave of which a harmonic produces modulation products of said lower frequency when heterodyned with said first wave in said device, said harmonic being related in frequency to said first wave so that said line presents a high impedance to said second wave,

and means connected between said anode and cathode including a source of potential for transmitting said modulation products to said first means.

9. In a heterodyne frequency conversion circuit, an electron discharge device having two electrodes and terminals and leads respectively connected thereto, said electrodes and leads being self-resonant at a certain frequency, a source of an electric wave whose frequency is near said certain frequency, a standing wave transmission line having a short circuiting device at one end and being connected across said two terminals at its other end, said line being energized by the wave from said source and being a half wave in length with respect thereto, an amplifier operative at a lower frequency than said wave, means for impressing across said two terminals a second wave whose second harmonic produces modulation products of said lower frequency when heterodyned with said first wave, whereby said line presents a high impedance to said second wave, means for preventing said line and said last means from short circuiting said modulation products, and means to transmit said modulation products from said short circuit preventing means to said amplifier.

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