

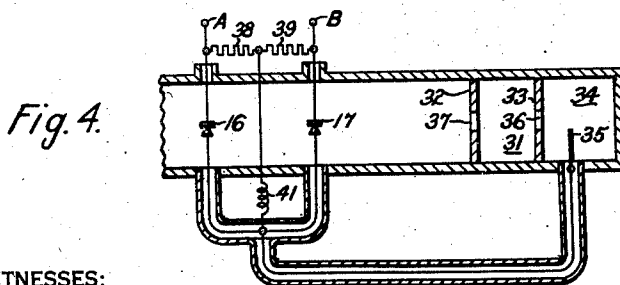
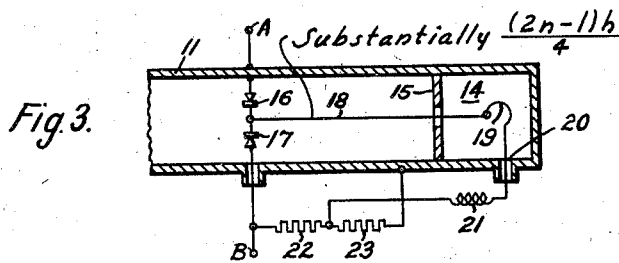
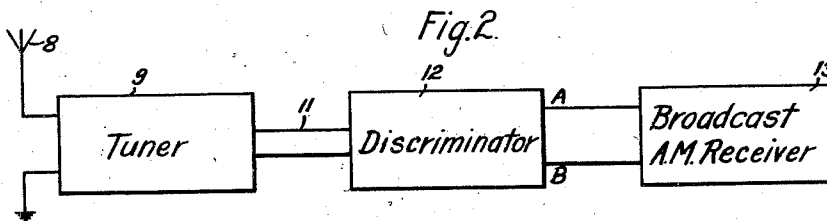
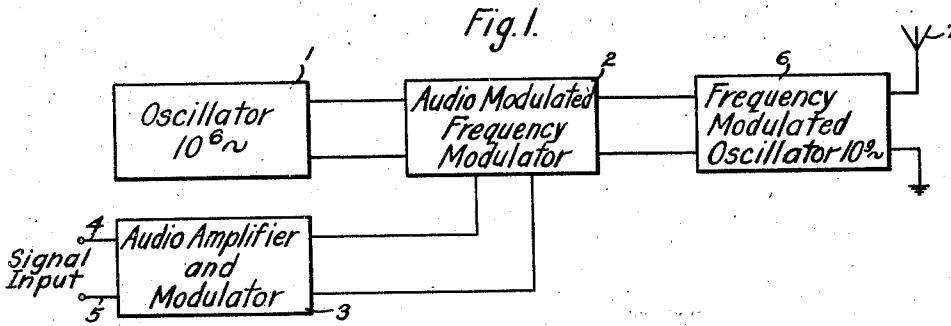
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FREQUENCY MODULATION DETECTOR

Filed July 7, 1944



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FREQUENCY MODULATION DETECTOR

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My invention relates to systems of communication using carrier waves of ultra high-frequencies, and in particular relates to such systems using frequency modulation.

In the ultra high-frequency region of the radio spectrum there exists room, lacking at lower frequencies, for many channels of frequency modulated communication. Furthermore, the particular types of tubes which have been developed for use at these ultra high-frequencies are particularly well suited for the application of frequency modulation. However, certain problems arise in adapting to the very high-frequency channels which I now contemplate systems of frequency modulation now in use in frequency ranges rather lower than those just mentioned. For example, in the frequency ranges that I have in mind effects of distributed capacitance and inductance make the ordinary capacitors and inductors commonly employed for resonant circuits completely unsuitable, and it is necessary to employ circuit elements of quite different structure in the system which I am about to describe. However, it so happens that it is possible to substitute for these poorly adapted circuit elements now used at lower frequency, certain devices, such as wave guides and resonant cavities, which are of very simple structure and of low first cost. As a result of the particular adaptability of the oscillation generator, amplifier, and other ultra high-frequency tube structures and circuit elements mentioned in the preceding sentence, highly desirable communication systems are possible employing the extremely high frequencies which I am about to describe.

One object of my invention is accordingly to provide a system of communication employing frequencies much higher than those now prevalent in the communication art.

Another object of my invention is to provide a system of communication which makes use of frequency modulation applied to carrier currents of frequency much higher than those now prevalent.

Still another object of my invention is to provide a communication system in which a signal-modulated wave of very high frequency of the general order of one million cycles per second acts to frequency modulate a wave of much higher frequency, say of the order of one billion cycles per second.

Still another object of my invention is to provide a receiver system for a communication system employing waves of the character described in the preceding paragraph.

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A still further object of my invention is to provide a receiver system of the type described in the preceding paragraph which shall employ an ordinary amplitude modulated broadcast receiver preceded by a converter which is both simple and inexpensive in construction.

Still another object of my invention is to provide a novel arrangement for converting frequency modulated waves of ultra high-frequency into amplitude modulated waves.

A yet further object of my invention is to provide a discriminator for frequency modulated waves of frequency ranges suitable for transmission through wave guides.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawings, in which:

Figure 1 is a block diagram of the component elements for a transmitter useful in a frequency-modulated communication system embodying the principles of my invention.

Fig. 2 is a block diagram of a receiver useful in association with the transmitter shown in Fig. 1.

Fig. 3 is a schematic diagram of a discriminator useful in the receiver shown in Fig. 2, and

Fig. 4 is an alternative type of discriminator to that of Fig. 3.

Referring in detail to Fig. 1, an oscillation generator 1 which may have a frequency of the order of one million cycles per second delivers its energy to a modulator 2 in which this energy is affected by the output of an audio amplifier and modulator 3 in accordance with a signal input at the terminals 4, 5. The output of the audio amplifier 3 is arranged to amplitude-modulate, in ways too well known in the art to require detailed description here, the output from the oscillation generator 1. The output from the modulator 2 is, accordingly, an amplitude modulated wave of the base-frequency of a million cycles per second, and this output is impressed as the frequency controlling input of a frequency-modulated oscillation generator 6 having a mid-frequency which may be of the order of one billion cycles per second. Arrangements for frequency modulating the output of oscillation generators like generator 6 are too well known in the art to require detailed description here. The output of the generator 6, which it will be observed is a carrier wave of the mid-frequency of the order of one billion cycles a second frequency-modulated in accordance with a complex wave comprising a sine wave having a frequency of the order of one million modulated in turn at a signal frequency, is impressed on a transmission chan-

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nel of any suitable type; for example, through the agency of the antenna 7.

Turning now to Fig. 2, a suitable receiver system for cooperating with the transmitter just described comprises a receiver antenna 8 connected to a tuner 9 which is resonant to frequencies of the order of the output of oscillator generator 6 in Fig. 1. Arrangements suitable to resonate with the input to tuner 9 from antenna 8 and thereby attain greater selectivity are well-known in the art, and any suitable one of these may be employed to constitute the tuner 9. Methods are well-known by which the amplified output from the resonators embodied in tuner 9 may be transmitted through a hollow wave guide 11 to a discriminator 12 which may be of any suitable type such as those shown in Figs. 3 and 4 of the drawing. The output of the discriminator 12, which will be described at greater length below, is an amplitude modulated wave having a frequency of the order of oscillator 1 in Fig. 1; that is to say, a frequency of one million cycles. This output is, accordingly, of the same general type as the radio waves used in ordinary amplitude-modulated broadcasting services and may be demodulated and the original signal reproduced on an ordinary broadcast receiver for amplitude-modulated waves of this frequency. Such receivers are, of course, too well-known to require detailed description.

Turning now in detail to the discriminator shown in Fig. 3, the wave guide 11 is provided at its closed end with a chamber 14 which is adapted to act as a resonant cavity at the frequency of the wave being received. Communication between the chamber 14 and the body of the wave guide 11 is through an aperture in a partition 15.

As is well-known in the art, the wave guide 11 has to be dimensioned to correspond approximately with the frequency of the waves being transmitted through it, and it is preferably of rectangular section and dimensioned to have a mode of vibration in which the electric field of the waves is parallel to one pair of sides. Situated some distance in front of the partition 15 is a pair of rectifiers of any suitable type, such as a pair of crystal detectors 16, 17, so located that the direction of the electric field of the waves traversing guide 11 is parallel to their rectifying junctions. The crystal 16 is connected to one wall of the wave guide 11 and immediately adjacent the latter is positioned one output terminal A for connecting the discriminator to any load circuit, such as the receiver 13 in Fig. 2. The corresponding terminal of the rectifier 17 is connected to a conductor which passes through an opening in the opposite wall of the wave guide 11 and connects to the other terminal B of the discriminator intended for connection to the other terminal of the above-mentioned load. The hole in the wall of wave guide 11 through which the conductor of rectifier 17 passes out to terminal B is preferably provided with a collar or other means to constitute a proper bypass at the frequencies of the waves traversing the wave guide.

The common terminal of rectifier 16, 17 is connected through a conductor 18 running substantially along the axis of wave guide 11 through the opening in partition 15 to one end of a loop 19 situated within chamber 14. The other end of the loop 19 passes through an opening 20 in the wall of chamber 14, and thence through a radio frequency choke coil 21 to the midpoint of a pair of resistors 22, 23 which are connected between the terminal B and the wall of wave guide 11.

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The opening 20 is provided with means to properly bypass the lead through wall guide 11 at the frequency of the transmitted waves.

The loop 19 is so positioned in the chamber 14 as to be inductively related to the alternating magnetic field therein, and as a result tends to impress vibrations along the conductor 18. By properly proportioning the length of this conductor 18 in ways obvious to those skilled in the art, the phase of the voltage impressed by this conductor on the above-mentioned common junction can be controlled at will.

It will be noted that the transverse conductors embodying the rectifiers 16, 17 are oppositely poled relative to the electric gradient of the waves within the chamber 11, and when looked at from the common junction of the rectifiers 16 and 17, are impressed with voltages which are 180° out of phase with each other by that electric gradient. By properly dimensioning the length of the conductor through which the loop 19 impresses voltage at the above-mentioned common junction, the voltage thus impressed may be given a phase midway between the two oppositely phased voltages just mentioned. This proportioning is indicated on the drawing by the legend

$$\frac{(2n-1)h}{4}$$

h being a wave length and n being any integer. The potential difference between the loop 19 and the terminal A will thus be seen to be produced by two voltages which are 90° out-of-phase with each other in one sense, while the voltage between the loop 19 and the terminal B will be produced by a pair of voltages, equal in magnitude to those just mentioned but 90° out-of-phase with each other in the opposite sense. As is well-known to those skilled in the art, such a set of voltage pairs constitutes a discriminator in which the voltage between the points A and B will be zero when the frequency of the transmitted waves corresponds to resonance of the circuit tuning elements (in this case the resonant frequency of the chamber 14), and in which the polarity of the voltage between the points A and B will be of one sign when the impressed frequency is less than the above-mentioned resonant frequency and will be of opposite sign when the impressed frequency is greater than the resonant frequency. The arrangement of Fig. 3 is thus suitable to constitute the discriminator 12 in the Fig. 2 receiver.

Fig. 4 shows the alternative arrangement acting as a discriminator for electric waves traversing a wave guide. The wave guide 11 has a chamber 31 between partitions 32 and 33 so spaced that the chamber 31 will resonate at the frequency at which it is desired to have zero potential difference between the output terminals. At one side of the chamber 31 is a second chamber 34 having an opening in one wall through which a probe electrode 35 extends into the chamber 34. At the other side of the chamber 31 is positioned in the wave guide a pair of rectifiers 16 and 17 which are, like the rectifiers 16 and 17 of Fig. 3, placed so that the electric gradient of the waves in the wave guide 11 is normal to their rectifying junction. In the case of Fig. 4, however, the rectifiers 16 and 17 are poled in the same direction, and they are spaced apart an odd number of half wave lengths at the resonant frequency of chamber 31. The chamber 31 communicates with the chamber 34 by an aperture 36 and with the remainder of the wave guide by an aperture 37.

The rectifier 16 is connected to the wall of the

wave guide 11 while the corresponding lead from the rectifier 17 passes through an opening in the wall of the wave guide 11 and is connected to the output terminal B. The output terminal A is connected to the wall of the wave guide 11 and is connected to the output terminal B through two equal resistors 38—39.

The remaining terminals of the rectifiers 16 and 17 are connected to conductors which pass through openings in the adjacent wall of the wave guide 11, and thence through conducting tubes to meet in a common junction. This common junction is connected through a radio frequency choke coil 41 to the common junction of the resistors 38—39. It is also connected through a conductor encased in a conducting tube to the probe electrode 35.

The enclosing tube for the conductor connected to probe-electrode 35 constitutes a concentric transmission line and the length of this transmission line is made such that at the resonant frequency of the cavity 31, the voltage impressed on the common junction of the rectifiers 16 and 17 is 90° out-of-phase with the voltages of the leads containing the rectifiers 16 and 17; that is to say, it leads one of the last-mentioned voltages by 90° and lags the other by 90°.

The opening through which the lead from rectifier 17 passes through the wall of the wave guide 11 is provided with a collar or other sufficiently extended surface to capacitatively connect the lead to the wave guide wall at the resonant frequency.

When the frequencies of the waves passing through the guide 11 are in exact resonance with the natural period of the chamber 31, the potential difference between the terminals A and B will be zero. The potential difference between the terminals A and B will be zero at no other frequency and will be of one sign for frequencies below the resonant value and of the other sign for frequencies above it. The arrangement of Fig. 4 is, accordingly, adapted to act as a discriminator for the frequency at which chamber 31 resonates, and like Fig. 3, to fulfill any of the known functions of discriminators in alternating-current circuits.

In compliance with the patent statutes, I have described particular embodiments of the principles of my invention, but these principles will be of broader application in ways which will be evident to those skilled in the art.

I claim as my invention:

1. In combination, a wave guide having a chamber adapted to resonate at a frequency which said wave guide is dimensioned to transmit located in a portion of said wave guide, a pair of rectifiers positioned to be impressed with voltages of opposite polarities by the electric gradient of waves traversing said wave guide and having a common junction, means for impressing a voltage generated in said chamber on the common junction of said rectifiers, a pair of resistors connected across the remote terminals of said rectifiers and a conductive channel interconnecting the common junction of said resistors with the common junction of said rectifiers.

2. In combination, a wave guide having a chamber adapted to resonate at a frequency which said wave guide is dimensioned to transmit located in a portion of said wave guide, a pair of rectifiers positioned to be impressed with voltages of opposite polarities by the electric gradient of waves traversing said wave guide and having a common junction, means for impressing on the common junction of said rectifiers a voltage generated in said chamber, which is 90° dephased from that impressed across one of said rectifiers, a pair of resistors connected across the remote terminals of said rectifiers and a conductive channel interconnecting the common junction of said resistors with the common junction of said rectifiers.

3. In combination with a wave guide, a pair of partitions therein adapted to form a chamber resonating at a frequency which said wave guide is dimensioned to efficiently transmit, a pair of rectifiers positioned transverse to said wave guide outside said chamber with terminals of the same polarity connected together to constitute a common junction, the other terminal of one said rectifier being connected to said wave guide and the other terminal of the other said rectifier being connected to a conductor passing through an opening in the wall of said wave guide, a pair of resistors connecting a point on the last-mentioned conductor which is outside said wave guide to the wall of said wave guide, a conducting loop positioned in said chamber and having a lead passing through a second opening in the wall of said wave guide to the common junction of said resistors and having its other terminal connected to a lead passing through an opening in one of said partitions to the common junction of said rectifiers, the length of said lead being such that the voltage impressed on the common junction of said rectifiers is 90° dephased from the voltage impressed by the electric gradient in said wave guide on one of said rectifiers.

4. In combination with a wave guide, a pair of partitions therein forming a chamber resonating at a frequency which said wave guide is dimensioned to efficiently transmit, apertures in each of said partitions, a probe electrode in said wave guide outside one of said apertures, a pair of rectifiers positioned transverse to said wave guides outside the other said aperture, a terminal of one said rectifier being connected to said wave guide, a conductor connecting the corresponding terminal of the other said rectifier through an opening in the wall of said wave guide to a terminal outside said wave guide, a pair of resistors connecting the wall of said wave guide to the last-mentioned terminal, a pair of conductors passing from the remaining terminals of said rectifiers through two openings in the wall of said wave guide to a common junction, a concentric transmission line connecting said common junction to said probe electrode and a connection embodying a choke coil connecting said common junction to the common junction of said resistors.

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