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MOLECULAR RESONANCE MODULATORS AND DEMODULATORS

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FIG. 1

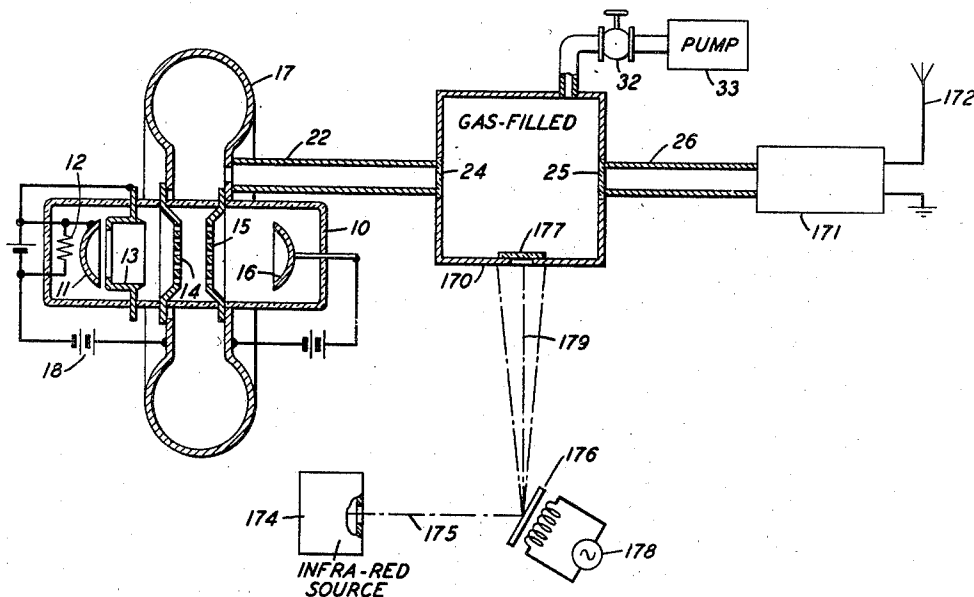
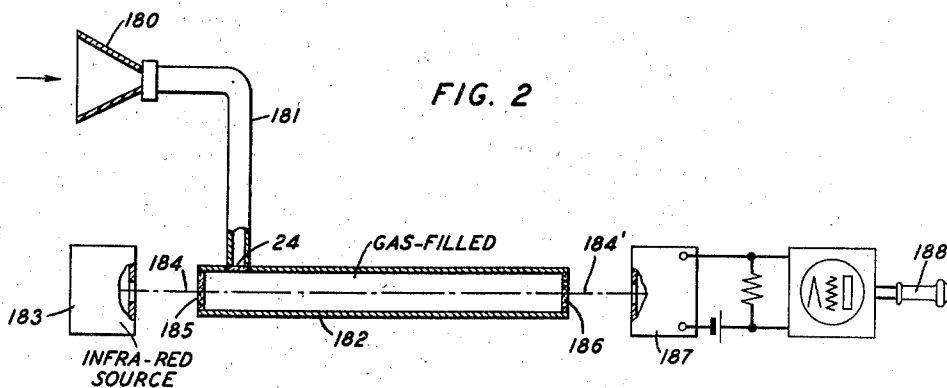


FIG. 2



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## MOLECULAR RESONANCE MODULATORS AND DEMODULATORS

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Original application April 26, 1947, Serial No. 744,236, now Patent No. 2,707,235, dated April 26, 1956. Divided and this application April 1, 1955, Serial No. 498,643

## 5 Claims. (Cl. 332—57)

This application is a division of my copending application Serial No. 744,236, filed April 26, 1947, which issued as U. S. Patent No. 2,707,235, April 26, 1955.

This invention relates to systems and methods for modulating electromagnetic wave energy, particularly energy in the microwave range.

An object of the invention is to provide a simple and efficient system for modulating microwave energy by audio or other signaling waves to produce amplitude modulations thereof representative of such signals.

Another object of the invention is to provide a simple and efficient system for demodulating microwave energy to recover the signal with which it has been amplitude-modulated.

In accordance with the present invention these and other objects are attained by the utilization of the natural resonance absorption characteristics of gases. These resonant absorption characteristics become manifest when the gas is subjected to electromagnetic fields, particularly to fields produced by waves of frequencies in the microwave and infrared regions. The nature of such action, the types of gas in which it is most evident, the effect of pressure conditions of the gas, the effect of electrostatic and magnetostatic fields, and related features are fully discussed in the patent application previously identified.

In accordance with the present invention a particular characteristic of the gas resonant absorption effect is utilized to produce modulation and demodulation of microwaves. This phenomenon is the dependency of the absorption coefficient to electromagnetic waves of one frequency upon the energy level of electromagnetic waves of a different frequency to which the gas is simultaneously subjected. This effect is due to the fact that the sharp, selective absorption of electromagnetic wave energy of one frequency by such a gas is dependent upon the numbers of the gas molecules that are at the various possible energy levels. The molecular population at these energy levels can be varied by subjecting the gas to electromagnetic wave energy of a frequency different from that of the energy being absorbed. This energy varies the number of molecules in the various energy states, consequently varying the absorption due to molecular resonance of the electromagnetic energy of the first frequency being transmitted through the gas.

In accordance with one feature of this invention microwaves which are desired to be modulated are transmitted through a confined body of gas exhibiting molecular resonant absorption at the frequency of the microwaves. Simultaneously the gas is irradiated by other electromagnetic wave energy such as infrared rays. By varying, in accordance with a signal to be transmitted, the level of the energy of these other electromagnetic waves which are permitted to irradiate the gas, it is possible to vary the absorption coefficient of the gas to the microwaves and consequently to amplitude-modulate the microwaves taken out of the gas in accordance with such a signal.

In accordance with another feature of the invention

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microwaves that are modulated in amplitude in accordance with a signal are caused to impinge on a gas which exhibits molecular resonant absorption with respect to other electromagnetic waves that are transmitted there-through. As a result the signal modulations are transferred to these other electromagnetic waves from which they can be separated by conventional detectors.

Referring to the figures of the drawing:

Fig. 1 shows an amplitude modulator of microwaves utilizing the molecular resonance absorption of a gas irradiated by an auxiliary infrared source; and

Fig. 2 shows a corresponding demodulator.

The absorption coefficient of many molecularly resonant gases for microwaves or the like is dependent on the presence or absence of an auxiliary electromagnetic field of a different frequency. This permits the energy absorbed from incident electromagnetic waves to be varied at will by subjecting the gas at low pressure to the irradiation by electromagnetic energy of a different frequency.

In accordance with the present invention, amplitude modulation may be imparted to a microwave frequency or frequencies by passing the microwaves through a molecularly resonant gas and irradiating the gas by a source of different frequency, such as other microwaves, light, or infrared radiations, and varying the irradiation of the gas thereby under the control of a desired modulating signal.

The absorption by a molecularly resonant gas of microwave energy may be modified in amount by irradiating the gas with electromagnetic waves of a different frequency. Thus, for example, the microwave absorption at low pressures by ordinary ammonia gas of the molecular resonance line at 23,870 megacycles is about 0.2 decibel per foot of length of the gas chamber, for a single energy pass. When, however, the gas is irradiated by infrared radiation, the absorption of the ammonia resonance line is considerably reduced. In the case of other gases or electromagnetic waves of other frequencies the effect may be an increase of absorption. Whether it be a reduction or an increase depends in a complicated fashion on the various characteristics of the particular molecule in question and the frequency of the disturbing radiation. In general, however, there can be a marked alteration in the absorption of microwaves of a first frequency by molecular resonance when the gas molecules are irradiated by a different frequency radiation.

This phenomenon is turned to account here to provide amplitude modulation of microwave energy. Various methods and apparatuses may be employed to produce such modulation and demodulation of microwaves. Apparatus of one such form is depicted in Fig. 1, wherein a microwave oscillation source 10, which may be similar to that described in connection with my aforementioned application or of any desired variety, delivers energy from its resonant cavity 17 to a gas-containing molecular absorption cell 170 by way of a wave guide 22. The input frequency to the cell 170 should be substantially equal to the frequency at which the gas is resonant; e. g., if the gas is ordinary ammonia, the frequency should be 24,000 megacycles (more precisely, 23,870 megacycles) and the oscillation source 10 should be tuned to this frequency and stabilized thereat.

The resonant gas cell 170 may be provided with a mica window 24 at the point at which the input wave guide 22 is coupled to it and with a window 25 at the point to which an output wave guide 26, leading to an amplifier 171 and a load circuit, e. g., an antenna 172, is coupled to it. The gas may be introduced by way of a valve 32 and its pressure adjusted by means of a pump 33. The cell 170 may be a wave guide, preferably of the resonant

type hereinabove discussed. Its dimensions should be selected so that its resonant frequency, regarded as a tuned cavity, coincides with the resonant frequency of the gas, and its tuning should preferably be substantially broader than the resonant absorption band of the gas.

An infrared radiation source 174, for example, an electrically heated platinum ribbon or a caesium vapor lamp, is provided, whose rays 175 may be reflected on a suitable mirror 176, for example a polished copper surface, to enter the resonant gas chamber 170 by way of a window 177 which is transparent to infrared radiation of the frequency in question, for example a window of silver chloride. The mirror may be caused to vibrate in accordance with a signal, being mounted, for example, in the familiar manner of a galvanometer element, the oscillating signal being derived from an audio frequency source 173. Thus the reflected infrared beam 179 will be caused to swing on and off the silver chloride window 177 in relation to the signal, and infrared radiation will enter the gas chamber 170 by way of the silver chloride window in greater or lesser amount in dependence on the amplitude of the audio frequency signal.

The population of molecules in their various energy states is altered by the incident infrared, and this view is useful in visualizing the phenomenon involved.

When the infrared beam is deflected past the silver chloride window 177 so that none of it enters the gas chamber 170, the resonant absorption of the ammonia gas to the microwave energy of 24,000 megacycles has its full value of 0.2 decibel per foot of passage through the gas. When the reflected infrared beam 179 is centered on the window 177, this absorption is reduced. Thus the microwave energy passing through the chamber 170 and into the output wave guide 26 is alternately increased and reduced in accordance with the signal of the source 173; i. e., amplitude modulation of the microwaves of the source 10 through the medium of a molecularly resonant gas is provided.

Fig. 2 shows a system for demodulating microwave energy which may be received, for example, after radio transmission, and which bears a desired signal in the form of amplitude modulation. The incoming amplitude-modulated microwaves may be picked up by an antenna 180 and supplied by way of a wave guide 181 and a mica window 24 into a resonant gas chamber 182 as before. An infrared radiation source 183 is provided in a position such that its rays 184 shine directly into the gas chamber 182 by way of a suitable window 185, for example of silver chloride. At the far end of the chamber 182 another silver chloride window 186 is provided through which emerges the infrared radiation 184' which has not been absorbed by the gas in the chamber 182. The amount of absorption of infrared radiation is dependent on the excitation of the gas by the incoming microwave energy; and since the strength of the latter varies in accordance with the signal which is amplitude-modulated thereon, so the transmitted infrared radiation varies similarly. The transmitted infrared radiation 184', now modulated in accordance with the signal, may be applied to a suitable detector 187, for example a bolometer thermistor of the type described in an application of J. A. Becker, Serial No. 602,261, filed September 26, 1946, Patent 2,414,792, January 28, 1947. The output of this detector 187 may be amplified as desired and reproduced in a

suitable manner, for example, by a telephone receiver 188. Thus demodulation or detection of amplitude-modulated microwave radiation is effected through the medium of the resonant absorption band of a gas.

What is claimed is:

1. Apparatus for modulating the amplitude of oscillations derived from a microwave source, which comprises a gas at low pressure characterized by sharp resonance lines of selective absorption of incident microwave energy of the frequency of said source in an amount dependent on the numbers of the molecules of said gas in the various possible energy levels, means for guiding waves of said source through said gas, whereby energy of said source is absorbed by said gas, an auxiliary source of electromagnetic waves of a higher frequency, means for subjecting said gas to the field of said auxiliary source to alter the said numbers and so the amount of said absorption, and means for varying the strength of said auxiliary source field under control of a modulating signal.

2. In a signaling system, a body of gas characterized by the sharp molecular resonance absorption of incident electromagnetic wave energy of one frequency in an amount dependent upon the numbers of the molecules of said gas in the various possible energy levels as determined by the energy level of electromagnetic waves of a second higher frequency also incident upon said gas, means for impressing electromagnetic wave energy of said one frequency on said gas, means for impressing electromagnetic wave energy of said second frequency on said gas at energy levels varying in accordance with a signal, and means responsive to the electromagnetic wave energy of said one frequency after transmission through said gas for communicating said signal.

3. A signalling system comprising a generator of microwaves, a hollow wave guide connected thereto, a resonant cavity interposed in said wave guide having therein a gas at pressures sufficiently low in the millimeter pressure range to provide sharp molecular resonance absorption, a source of energy for irradiating said gas to vary the absorption coefficient of said gas whereby the amplitude of the microwaves transmitted through said gas is varied, and means utilizing the microwaves transmitted through said gas.

4. The system of claim 3, wherein said irradiating source has a frequency higher than said microwaves and means for varying the irradiating energy in accordance with a signal.

5. A signalling system comprising a wave guide, a gas at low pressure confined in said wave guide to provide sharp molecular resonance lines, a source of microwaves of frequency corresponding to one of said resonant lines, means for transmitting waves from said source through said wave guide, another source of electromagnetic waves of frequency higher than said microwaves, means for irradiating said gas by waves from the second source, means for varying in accordance with a signal the energy of waves irradiating said gas to vary the absorption coefficient of said gas whereby amplitude modulation of the microwaves is produced.

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