Jan. 22, 1946. W. VAN B. ROBERTS 2,393,414

MODULATION SYSTEM FOR ULTRA HIGH FREQUENCY WAVES

Filed Sept. 25, 1942

Fig. 1

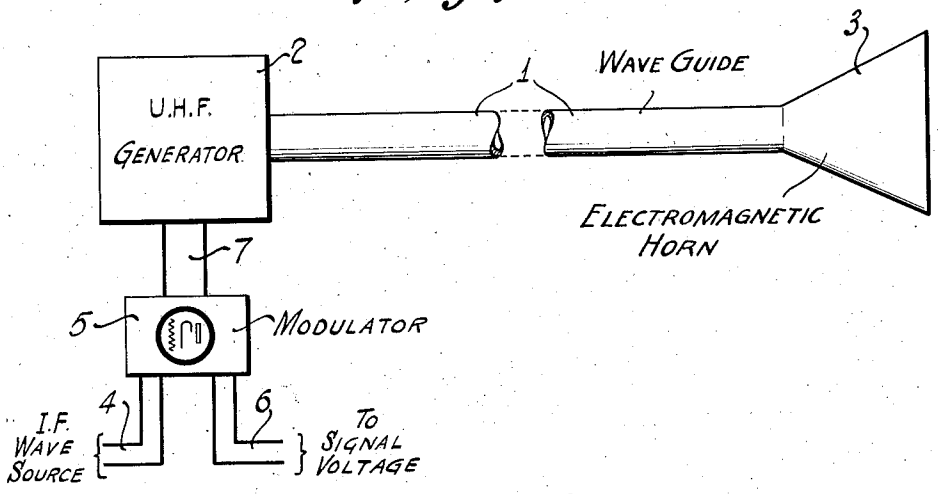
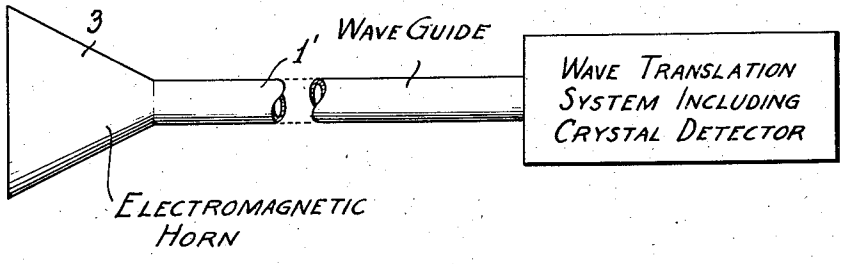


Fig. 2



INVENTOR
WALTER VAN B. ROBERTS.
BY H. S. Grover
ATTORNEY

Patented Jan. 22, 1946 2,393,414

UNITED STATES PATENT OFFICE

2,393,414

MODULATION SYSTEM FOR ULTRA HIGH FREQUENCY WAVES

Walter van B. Roberts, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 25, 1942, Serial No. 459,654

9 Claims. (Cl. 250—6)

This invention relates to a method of and apparatus for producing amplitude modulated ultra high frequency waves.

In the past, difficulty has been experienced in amplitude modulating sources of ultra high frequency energy. In many cases, it has been found that on attempting to produce amplitude modulation by varying the operating potential of the ultra high frequency source, there inherently occurs a relatively large amount of undesirable frequency modulation instead of any great amount of desired amplitude modulation. In accordance with one embodiment of the present invention, such inadvertent frequency modulation is utilized to cause a further amplitude modulation of the transmitted waves.

As an illustration, let us assume that in the case of a particular generator of ultra high frequency waves the application of a voltage increase of one of the operating voltages of the generator causes an increase in amplitude and also an increase in frequency. In accordance with the invention, the output of this generator is connected to a wave radiating device, preferably of the electromagnetic horn type, through a wave guide consisting of a hollow metal pipe. By choosing the diameter of this pipe sufficiently small in comparison with the wavelength of the generator, the attenuation in the pipe will decrease rapidly with increasing wave frequency over a particular range of frequencies, and this principle is employed in the practice of the invention. There are, of course, minimum or critical frequencies for different types of waves below which they cannot exist in and cannot be transmitted through the hollow pipe. Thus, in the case assumed, as the modulating voltage increases, the amplitude of the waves fed into the pipe will increase and simultaneously therewith there will occur an increase in frequency. The increase in frequency of the waves impressed upon the wave guide decreases the attenuation within the pipe so that the waves upon emerging from the wave guide for radiation by the horn have their amplitude increased both by the fact that the input amplitude was increased and also by the fact that the attenuation in the pipe was decreased. The resulting radiation from the horn located at the remote end of the pipe is thus amplitude modulated to a greatly increased extent. It is, of course, also frequency modulated but this fact is of no importance when the radiated signals are to be received in a simple crystal detector circuit of a multi-detection receiver. The first detection circuit of such a receiver for the ultra high frequency waves is desirable in order to convert the extremely high frequencies of the received waves to a more readily handled lower frequency which has been impressed upon the ultra high frequency generator at the transmitter. That is, the modulating voltage for the ultra high frequency generator is not the desired signal voltage but an intermediate frequency voltage which, in turn, is modulated either as to amplitude or frequency by the signaling voltage.

In the foregoing illustration it was assumed that undesired frequency modulation of the ultra high frequency source was inherently produced by attempts to amplitude modulate the source. It should be appreciated, however, that in the practice of the invention an ultra high frequency source may be employed at the transmitter which has its frequency modulated deliberately with no thought of obtaining any amplitude modulation. This can be achieved by employing a reactance tube associated with said source in a manner well known in the art of frequency modulation of oscillations. Such an arrangement is preferred in the practice of the present invention.

Fig. 1 of the drawing diagrammatically illustrates, by way of example only, a transmitter embodiment of the present invention, while Fig. 2 illustrates a receiver embodiment of the invention.

Referring to Fig. 1 of the drawing, there is shown a wave guide 1 in the form of a metallic pipe having at one end an ultra high frequency generator 2 for impressing upon the pipe a frequency modulated ultra high frequency wave. The pipe 1 at the remote end is terminated by a suitable wave radiating structure 3, here shown by way of example as an electromagnetic horn.

The pipe 1 is employed for transmitting certain types of high frequency electromagnetic waves, sometimes called dielectric guided waves, provided the frequency of the waves exceeds a certain critical or cut-off frequency that is dependent on the type of wave, the transverse dimensions of the pipe and the dielectric coefficient of the medium filling the interior of the pipe. The various types of guided waves are distinguished by their respective characteristic spacial distribution of the component electric and magnetic fields and they may be represented as E and H waves, as indicated in the articles by G. C. Southworth and J. R. Carson et al., appearing in the April, 1936, issue of the Bell System Technical Journal. Both of these articles disclose the critical relation that exists at cut-off between frequency, dielectric coefficient and diameter of guide for each of the four principal types of waves

transmitted through a hollow pipe of circular cross section.

In order to modulate the frequency of the ultra high frequency generator 2 in accordance with a signal voltage, there is preferably provided a source of relatively low radio frequency waves labeled "I. F. wave source" which is impressed upon the leads 4 and modulated in the modulator 5 by signal voltage impressed upon the leads 6. The modulated I. F. waves appearing in the output leads 7 of the modulator 5 are then utilized to modulate the frequency, or frequency and amplitude, of the ultra high frequency generator 2. It is preferred that the ultra high frequency generator produce a frequency only slightly above the cut-off frequency of the pipe 1 for the type of wave employed for transmission through the pipe. This is because the greatest change in attenuation for a given small change in frequency occurs in the frequency region which is slightly higher than the cut-off frequency for all types of waves.

As an example of one practical construction which might be employed in the practice of the present invention, the pipe 1 might comprise a vertically arranged affair extending for a distance of several hundred feet in the air, with the bottom end coupled to the ultra high frequency generator whose frequency is to be modulated in accordance with signal potentials, and with the upper end of the pipe terminated by an electromagnetic horn radiating structure adapted to transmit signals in a desired direction and to a distance which increases with the height of the horn. The upper end of the pipe 1 in the example just given will most likely be curved so that the direction of emission of waves from the wave radiating horn will be horizontal. The wave guiding pipe, in the example just given, may act as a self-supporting structure or be additionally supported by guy wires. Where the pipe is placed in a congested area where there are tall buildings, this pipe can be supported by the building structure. The pipe 1 may be as long as feasible and of a diameter of fifteen inches, by way of example, at which diameter the frequency of operation for a particular type of wave, assuming in this case an H1 type of wave, would be in the vicinity of five hundred megacycles. Of course, for a different pipe diameter, the operating frequency will be different in inverse proportion.

Any suitable type of receiver can be used in connection with the transmitting system of the drawing. As an example, such a receiver might comprise a crystal detector connected to an intermediate frequency amplifying and detecting system adapted to select, amplify and detect the intermediate frequency wave impressed upon the ultra high frequency generator 2. Fig. 2 shows, by way of example, a receiving circuit for use in the invention, wherein the frequency modulated waves are received on an electromagnetic horn 3' connected at one end to a suitable wave guide 1' which in turn is terminated at its other end in a detecting system utilizing a crystal detector.

It will be evident that the action of the wave guide in converting a frequency modulated input wave into an amplitude modulated output wave may also be employed for the reception of frequency modulated ultra high frequency waves. In such a case, frequency modulated ultra high frequency waves would be collected, passed through the guide (emerging therefrom with amplitude modulation), and then detected by a simple crystal detector. Such operation is, however, essentially the same as described in connection with the drawing, the sole difference being that the waves pass through the frequency modulation to amplitude modulation converting pipe prior to being radiated in one case and after being radiated and picked up in the other case.

What is claimed is:

1. A system for modulating the amplitude of ultra high frequency waves comprising a generator of said ultra high frequency waves, a wave guide in the form of a hollow conducting member, said generator being coupled to said wave guide at one end for impressing a wave thereon to be transmitted therethrough, a wave radiator in the form of an electromagnetic horn connected to said guide at its other end, the diameter of said wave guide being so chosen with relation to the frequency of operation of said generator that the attenuation of the wave through said guide varies rapidly with respect to the frequency of said generator, and means for varying the frequency of said generator in accordance with modulating potentials.

2. A system for modulating the amplitude of ultra high frequency waves comprising a generator of said ultra high frequency waves, a wave guide in the form of a hollow conducting member, said generator being coupled to said wave guide at one end for impressing a wave thereon to be transmitted therethrough, a wave radiator connected to said guide at its other end, the diameter of said wave guide being so chosen with relation to the frequency of operation of said generator that the attenuation of the wave through said guide varies rapidly with respect to the frequency of said generator, the frequency of said generator being slightly above the cut-off frequency of said wave guide, and means for varying the frequency of said generator in accordance with modulating potentials.

3. A system for modulating the amplitude of ultra high frequency waves comprising a generator of said ultra high frequency waves, a wave guide in the form of a hollow conducting member, said generator being coupled to said wave guide at one end for impressing a wave thereon to be transmitted therethrough, a wave radiator connected to said guide at its other end, the diameter of said wave guide being so chosen with relation to the frequency of operation of said generator that the attenuation of the wave through said guide varies rapidly with respect to the frequency of said generator, the frequency of said generator being slightly above the cut-off frequency of said wave guide, and means for varying the frequency of said generator in accordance with modulating potentials, said modulating potentials being constituted by a radio frequency wave which is modulated by the signal to be transmitted.

4. A system in accordance with claim 1, characterized in this that said wave guide is a vertically arranged pipe of at least several hundred feet in length and said horn is arranged to radiate waves from the top of said guide in a substantially horizontal direction.

5. A system for converting frequency modulated waves to amplitude modulated waves, comprising a source of waves whose frequency is modulated, a wave guide, means coupling said source to said wave guide at one end for impressing the frequency modulated waves on said guide for transmission therethrough, an electrical transducer coupled to the other end of said guide, the diameter of said guide being so chosen with relation to the frequency of said

source that the attenuation of the waves through said guide varies rapidly with respect to said frequency.

6. A system in accordance with claim 5, characterized in this that said wave translation system is a receiver including a crystal detector.

7. A system for converting frequency modulated waves to amplitude modulated waves, comprising a source of waves whose frequency is modulated, a wave guide in the form of a hollow conducting member, means coupling said source to said wave guide at one end for impressing the frequency modulated waves on said guide for transmission therethrough, an electrical transducer coupled to the other end of said guide, the diameter of said guide being so chosen with relation to the frequency of said source that the attenuation of the waves through said guide varies rapidly with respect to said frequency, the frequency of said source being slightly above the cut-off frequency of said wave guide.

8. A system for converting frequency modulated waves to amplitude modulated waves, comprising a source of ultra short waves whose frequency is modulated, a wave guide in the form of a hollow conducting member, means coupling said source to said wave guide at one end for impressing the frequency modulated waves on said guide for transmission therethrough, an electrical transducer in the form of an antenna coupled to the other end of said guide, the diameter of said guide being so chosen with relation to the frequency of said source that the attenuation of the waves through said guide varies rapidly with respect to said frequency, and a multi-detection receiver having a crystal detector circuit for receiving the signals radiated by said antenna.

9. A system for converting frequency modulated waves to amplitude modulated waves, comprising a source of ultra high frequency waves, a reactance tube modulator for varying the frequency of said ultra high frequency waves in accordance with modulation potentials, a wave guide, means coupling said source to said guide near one end for impressing the frequency modulated waves on said guide for transmission therethrough, an electrical transducer coupled to the other end of said guide, the diameter of said guide being so chosen with relation to the frequency of said source that the attenuation of the waves through said guide varies rapidly with respect to said frequency, the frequency of said source being slightly above the cut-off frequency of said wave guide.

WALTER VAN B. ROBERTS.