May 19, 1942. W. VAN B. ROBERTS 2,283,575

HIGH FREQUENCY TRANSMISSION SYSTEM

Filed April 19, 1938

Fig. 1

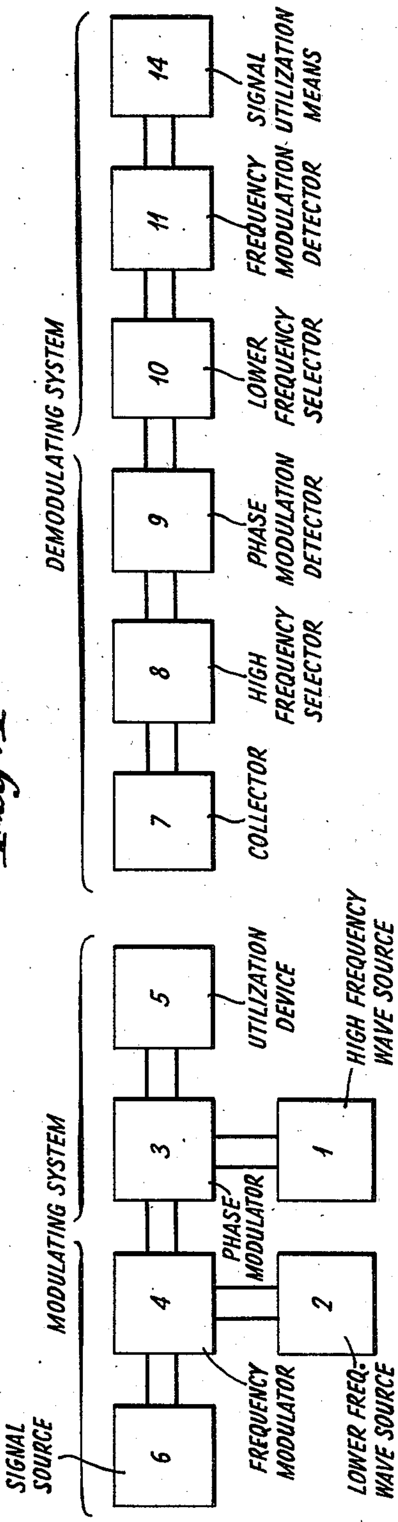
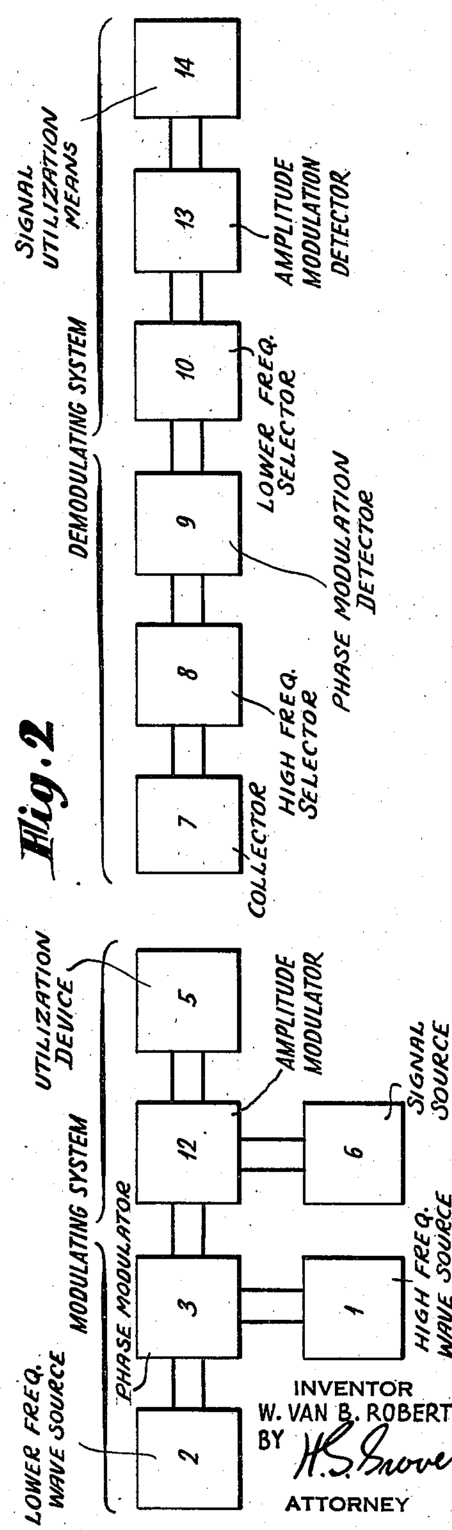


Fig. 2



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HIGH FREQUENCY TRANSMISSION SYSTEM

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6 Claims. (Cl. 250—6)

My present invention relates to double modulation systems of transmission and in particular to a system wherein each successive modulation affects the phase or frequency rather than the amplitude of the wave being modulated.

The object of the invention is to provide a carrier wave communication system wherein the carrier wave component is inherently absent or greatly reduced. A subsidiary object is to provide a method for detecting waves modulated in accordance with the method of the invention.

Modulation methods are known in the art wherein the carrier wave is suppressed or balanced out in the modulator, or eliminated from the radiated spectrum by filtering methods. However, signals transmitted in accordance with these known methods require that energy of carrier frequency be re-supplied at the receiver in order that the detector output should be a faithful reproduction of the original modulating signal.

In accordance with the present invention, carrier wave energy is eliminated or greatly reduced by phase modulating a high frequency wave by a constant amplitude wave of lower frequency, the amplitude of the phase swing of the high frequency wave being chosen such that the radiated spectrum contains little or no energy at the frequency of the high frequency wave. As will appear upon further examination, this is quite a different thing from eliminating the carrier wave from a spectrum to which it normally belongs and to which it must be returned before demodulation is possible.

In order fully to understand the operation of the invention it will be desirable to summarize briefly the results of phase modulating a high frequency wave in accordance with a constant amplitude lower frequency wave of simple harmonic form. It is well known in such a case that the radiated spectrum includes in general components proportional to the various terms of the series

$$J_0 \cos wt + J_1[\cos(w+p)t - \cos(w-p)t] + J_2[\cos(w+2p)t + \cos(w-2p)t] \text{------} \quad (1)$$

In this expression w represents the angular frequency of the high frequency wave, p the angular frequency of the low frequency wave and the coefficients J are Bessel's functions of orders indicated by their subscripts. The value of each of these Bessel's functions depends upon the angle through which the phase of the high frequency wave is swung by the modulating wave.

It will thus be seen that the result of such modulation is to produce an infinite series of side frequencies on each side of the frequency of the original high frequency wave, these side frequencies all being uniformly spaced at intervals equal to the modulation frequency. In practice, however, the amplitudes of the side frequencies fall off rather rapidly as one departs more than a certain distance on either side of the original or carrier frequency so that for all practical purposes the signalling energy resides within a finite band whose width is determined by the amount of phase swing or depth of phase modulation employed. This band width is greater the deeper the phase modulation. It should be noted that in the case of constant modulation such as so far considered, there is no possible distinction between phase and frequency modulation. If we were to look upon the modulation here described as the result of swinging the instantaneous frequency of the high frequency wave in accordance with the lower frequency wave, we would obtain the same spectrum as already described and would also have a simple physical picture of the radiation as consisting of a high frequency wave swinging in frequency back and forth between limits determined by the depth of frequency modulation. However, for the purpose of describing the present invention the concept of phase modulation is preferred.

It has been mentioned that the values of the coefficients J of expression (1) depend upon the angular deviation or phase swing employed. As the phase swing increases the J functions oscillate about the value zero so that each of the J functions vanishes for a certain characteristic series of values of phase swing. In particular, J_0, the Bessel's function of zero order, vanishes for a phase swing of approximately 2.4 radians and again at a value lying between 5 and 6 radians, and so on for a series of values which may readily be determined by reference to a table of Bessel's functions. In accordance with my invention I choose the amount of phase modulation of the high frequency wave as 2.4 radians or any one of the larger possible values that cause J_0 to vanish, and thus obtain a radiated spectrum substantially lacking in energy at the carrier frequency. The value 2.4 is chosen if the radiation is to be kept within as narrow a band as possible while one of the higher values is chosen if a wide band transmission is desired.

Since the avoidance of any appreciable amount of transmitted carrier depends upon maintaining the amplitude of the lower frequency wave constant, signalling voltage, applied to the lower frequency wave prior to its employment to modulate the higher frequency wave, must modulate the lower frequency wave not in amplitude but only in phase or frequency. Means for phase and frequency modulating the lower frequency wave are well known and need not be described in detail. Since the modulation of the lower frequency wave does not vary its amplitude it will not affect the phase depth of modulation of the higher frequency wave and its only result is to spread apart or shrink together all the component frequencies of the radiated spectrum in accordance with the varying frequency of the lower frequency wave. The main point to be stressed is that regardless of the signal modulation the radiated energy is substantially free of any considerable concentration of energy at the carrier frequency.

Since my method of modulation and detecting arrangements for receiving signals modulated in accordance with my method may be carried out by connecting together in suitable relation units of equipment whose construction and operation are in themselves well known, I prefer to avoid unnecessarily lengthening the description of the various embodiments of my invention by indicating such component parts merely by rectangles. Hence in the appended drawing,

Figure 1 shows schematically the connections for producing waves modulated in accordance with my invention and for demodulating such waves;

Figure 2 shows a modified form of the system.

Referring to Figure 1 a source of high frequency wave energy 1 is connected to a phase modulating unit 3 whose output is connected to a utilization device 5 which may, for example, consist of a transmitting antenna or a wire line. The high frequency wave energy impressed upon modulator 3 is modulated in accordance with the output wave of phase or frequency modulator 4 to which is supplied lower frequency energy from a source 2. This lower frequency energy is frequency modulated in device 4 in accordance with signals impressed upon modulator 4 from a source of signals shown at 6. In the absence of signals the lower frequency wave passes unaltered from source 2 through modulator 4 and modulates high frequency energy impressed upon modulator 3 to a phase depth of 2.4 radians or any other fixed value for which the zero order Bessel's function vanishes. The so modulated high frequency wave is then impressed upon the utilization device 5. In the presence of signal voltages the frequency but not the amplitude of the modulating wave impressed upon modulator 3 is varied so that the frequency spectrum delivered to device 5 is altered not in relative amplitudes but only in spacing between its components.

The remainder of Figure 1 shows an arrangement for receiving the double modulated wave delivered to device 5. A collector 7 which may be a receiving antenna in the case of radiated energy or the terminals of a wire line in case of wire transmission, collects the doubly modulated wave and impresses it upon a tuning or selective system 8 which is tuned to accept a sufficiently wide band of frequencies in the vicinity of the carrier frequency. The selected band of frequencies is passed from selector 8 and impressed upon a phase modulation detector 9. The output of detector 9 consists of the lower frequency voltage frequency modulated in accordance with signals, that is, just such a voltage as impressed upon modulator 3 from modulator 4 of the drawing. This lower frequency output is impressed upon a lower frequency selector system 10 whose output is in turn impressed upon a phase or frequency modulation detector 11. The type of detector here corresponds to the type of modulator in 4 whose output reproduces the original signals as provided by source 6 and which is connected to a utilization device 14 which may be for example, a loudspeaker. It will be understood throughout the foregoing that amplification may be added at any point throughout the modulating and demodulating circuits that may be necessary for providing a sufficiently high output level in device 14.

The behavior of the detecting system may be summarized by saying that it is inverse to the modulation system, that is, the signals as first collected are converted to the lower frequency which carries in the form of frequency modulation the original signals. This frequency modulated lower frequency current is then detected to yield the original modulating signals.

Figure 2 is similar to Figure 1 in the high frequency waves from source 1 are modulated in the modulator 3 in accordance with lower frequency waves provided by source 2 and the modulation is to one of the critical values described above. However, instead of modulating the frequency of the lower frequency wave, signal voltage from signal source 6 is used to modulate the amplitude of the output of modulator 3 by impressing both the output of modulator 3 and the output of source 6 upon an amplitude modulator 12 whose output is connected to a desired utilization device 5. In this case the output spectrum at 5 has components whose frequency separation is constant and whose relative amplitudes are constant but all of whose amplitudes are varied in accordance with the signalling voltage from source 6.

The receiving arrangement for the modulation system of Figure 2 is correspondingly altered from that of Figure 1. The collection, selection, phase modulation detection, and lower frequency selection arrangements indicated by devices 7, 8, 9, 10 are similar to the corresponding arrangements of Figure 1 but the final detection of the lower frequency wave is made by an ordinary amplitude modulation detector 13 whose output is impressed upon a utilization circuit 14. It will be seen that in both Figure 2 and Figure 1 the characteristic lack of any substantial amount of carrier frequency energy is maintained despite modulation in accordance with desired signals.

It will be understood that in case frequency multipliers are utilized in obtaining the phase modulated high frequency wave, the depth of phase modulation must always be such that the final frequency obtained by multiplication has its phase modulated by one of the critical angles described so that in accordance with the invention there is relatively little energy in the radiated spectrum at the carrier frequency.

While I have shown specific steps which may be taken in accordance with the invention for providing a transmission system relatively free of carrier frequency energy, it will be understood that a low order component other than the carrier may be reduced or caused to vanish. As stated hereinbefore, each of the various J functions of expression (1) vanishes for a certain characteristic series of values of phase swing and components other than the carrier or zero order component may be caused to vanish. In my method and means I propose to reduce or cause to vanish the carrier or other low order component such as, for example, the first or second order component, and the expression "low order" is hereby defined.

The invention may be practiced in many modified forms and I therefore do not wish to limit its scope except in accordance with the following claims.

I claim:

1. The method of signalling within a channel of given width which includes the steps of, varying the instantaneous frequency of a substantially constant amplitude auxiliary wave as a function of signal voltage and utilizing said modulated auxiliary wave to continuously vary the phase of a higher frequency wave between fixed limits of phase swing, the amplitude of said auxiliary wave being such as to reduce to a negligible value at least one low order component of the resulting spectrum within said channel.

2. The method of signal transmission which includes the steps of phase modulating a high frequency wave in accordance with a constant amplitude lower frequency wave to such a phase deviation as to eliminate energy at the carrier frequency from the radiated spectrum, varying a characteristic of the thus modulated high frequency wave in accordance with signals, transmitting the resulting spectrum, demodulating the phase modulated high frequency wave in accordance with its phase modulation to reproduce the signal varied lower frequency wave, demodulating the lower frequency wave, and utilizing the resulting signals.

3. In a high frequency signalling system, the method of modulating a high frequency carrier wave which includes generating an auxiliary wave, phase modulating said carrier wave by said auxiliary wave to a phase deviation whose zero order Bessel function is substantially zero, and varying a characteristic of the resulting energy spectrum in accordance with signals to be transmitted.

4. In a high frequency signalling system the method of modulating a high frequency carrier wave in accordance with signals which includes the steps of, generating an auxiliary wave, of substantially constant amplitude continuously varying the phase of said carrier wave by said auxiliary wave between fixed limits of phase deviation such that the carrier component of the resulting modulation is reduced to a negligible value, and varying the frequency of the auxiliary wave in accordance with the said signals.

5. In a signaling system, means for frequency modulating a sub-carrier wave of substantially constant amplitude with a signal, means for continuously varying the phase of a high frequency carrier between fixed limits in accordance with the frequency modulated sub-carrier of substantially constant amplitude, the amplitude of said sub-carrier being such as to reduce to a negligible value at least one low order component of the resulting spectrum within said channel and at the receiver means for deriving from the phase modulated high frequency carrier a frequency modulated sub-carrier wave, and means for deriving a signal from the frequency modulated sub-carrier wave.

6. The method of signalling by means of a high frequency carrier, an auxiliary wave of substantially constant amplitude and signal potentials which includes the steps of, modulating the wave length of said high frequency carrier by said auxiliary wave to produce a spectrum of frequencies corresponding to different orders of Bessel's functions, adjusting the amount of said modulation to a value at which one of said frequencies corresponding to a low order one of said Bessel's functions vanishes to thereby suppress from the said spectrum of frequencies one of its low order component frequencies and modulating the wave length of said auxiliary wave in accordance with said signal potentials.

WALTER VAN B. ROBERTS.