

May 18, 1937.

R. S. CARUTHERS

2,080,459

MODULATING SYSTEM

Filed March 28, 1935

FIG. 1

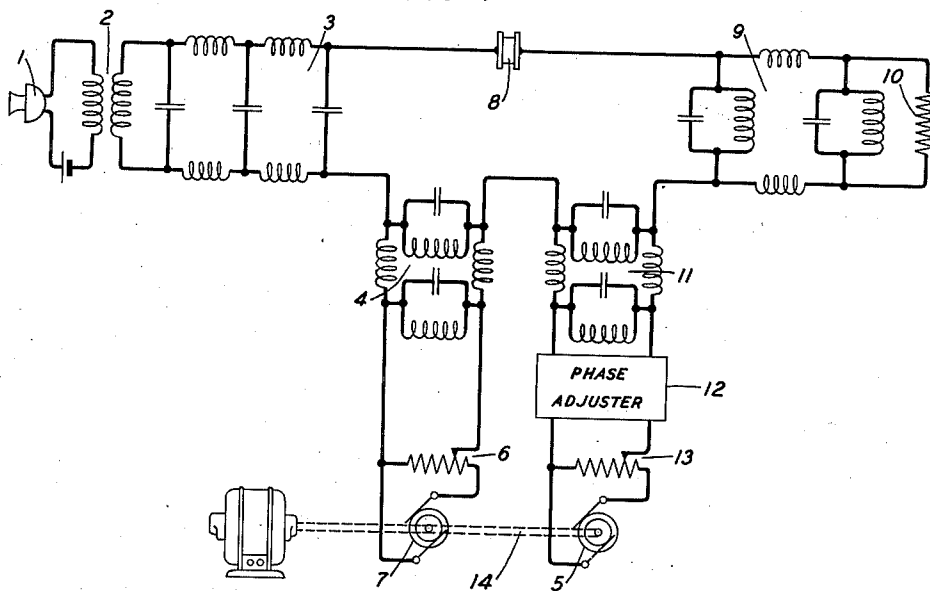


FIG. 2

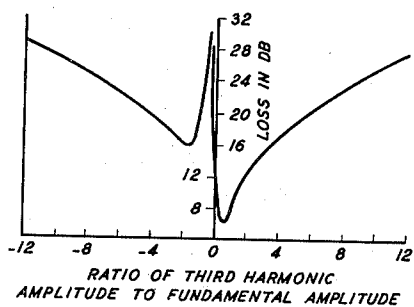


FIG. 3

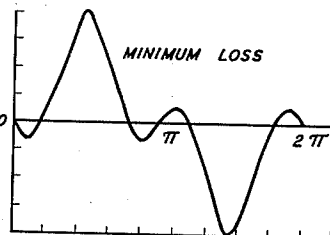
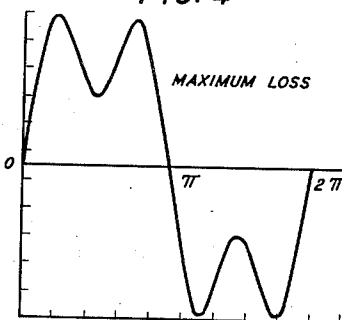


FIG. 4



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2,080,459

MODULATING SYSTEM

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Application March 28, 1935, Serial No. 13,412

10 Claims. (Cl. 179—171)

This invention relates to arrangements for the modulation or detection of electric waves and more particularly to means for controlling the application of the carrier wave to the modulating element.

An object of the invention is to promote a more complete conversion of the energy from the form of a signal wave into that of a modulated carrier wave.

Another object is to regulate the transmission loss in a modulating system.

It is known that the process of modulation involves essentially a periodic variation of the impedance of a circuit connecting a signal source to a load. Proper timing of the impedance variation is important for efficient modulation. It is also recognized that in general, given proper timing, the more abruptly the impedance is varied the more marked is the modulation. It is evident that the abruptness of the impedance change may be due either to the mode of variation of impedance in the variable element or to the wave shape of the control voltage by which the impedance variation is effected. The time element is particularly adapted to be governed by the wave shape of the control voltage.

In accordance with the invention the wave shape of the carrier wave is controlled by adding one or more harmonics of the carrier frequency from separate sources, each source being subject to adjustment both as to amplitude and phase. In this way any desired wave shape is obtainable. In many cases the optimum carrier wave form is known and is readily simulated. In other cases the best shape may be found by experiment.

One embodiment of the invention is shown in the drawing in which:

Fig. 1 shows a modulator connected to a signal source and a carrier source, the wave form of the latter being altered by the addition of one harmonic of the fundamental.

Fig. 2 shows the transmission efficiency obtained by adding the third harmonic of the fundamental at various amplitudes and phases.

Fig. 3 shows the wave form of the carrier for maximum transmission efficiency when the third harmonic only is added, and

Fig. 4 shows the wave form of the carrier for minimum transmission efficiency when the third harmonic only is added.

Referring now particularly to Fig. 1, a circuit arrangement is shown interconnecting in serial relation a signal source 1, a generator 7 of a carrier wave, a generator 5 of one of the harmonics of the wave produced by generator 7, a modulator 8 and a load 10. Each of these circuit elements except modulator 8 is connected to the circuit through a filter which has a low terminal impedance for waves having frequencies outside

the band for which it is designed but which transmits to or from the common circuit waves having frequencies within its band. Thus the signal source 1 is associated with a low pass filter 3 which has a low terminal impedance to carrier waves generated by generator 7, generator 5, and the side-band waves from modulator 8 but transmits waves having frequencies in the voice range such as may originate in voice frequency device 1. Similarly filter 4 presents a low terminal impedance to waves of the frequencies generated by source 1, generator 5 and the side-band waves from modulator 8 but transmits carrier waves from generator 7 to the circuit; and filter 11 presents low terminal impedance to waves of the frequencies generated by source 1, generator 7 and modulator 8 but transmits the harmonic wave generated in generator 5. Filter 9 transmits the modulated waves which are desired in the load 10 but offers low terminal impedance to waves of the other frequencies present in the circuit. The generator 7 is provided with a potentiometer 6 and the generator 5 with a potentiometer 13 and a phase adjuster 12.

In the operation of the system of Fig. 1 as a modulating system, the wave form of the carrier frequency wave can be altered or shaped by the addition of the third harmonic of the fundamental in varying amplitude and phase. The carrier fundamental is generated in generator 7, and is combined in modulator 8 in known manner to produce third order modulation, which appears as side-band waves having frequencies in the neighborhood of the second harmonic of the carrier fundamental. In definite phase relation with the fundamental is generator 5 which generates a wave of three times the frequency, commonly known as the third harmonic, of the fundamental. This phase relation may be controlled by connecting generators 7 and 5 together mechanically as indicated diagrammatically at 14. The amplitude of the fundamental may be varied at will by means of the potentiometer 6. The amplitude of the third harmonic carrier may be controlled by potentiometer 13 and the phase angle between the fundamental and the third harmonic can be adjusted at will by means of phase adjuster 12 without altering the mechanical phase relation between the generators, in case the generators are mechanically coupled. Any means of altering the phase angle may be used as phase adjuster 12. One arrangement which has been found to be advantageous because the phase angle is controlled without affecting the amplitude is shown in Patent No. 1,926,877, granted September 12, 1933 to Warren A. Marrison.

Modulator 8 may be any device used for modulating a carrier wave with a signal wave. Such devices are essentially non-linear in character

having an equation approaching the form $y = Kx^n$ in which x and y are respectively, the amplitudes of the input and output quantities. Several terms having different powers of x may be present in varying amounts at the same time. It is contemplated that any device in which any power of x other than unity exists may be used without exceeding the scope of the invention. A third order modulator in which the third power of x predominates is shown in the co-pending patent application of L. R. Cox, Serial No. 629,487, filed August 19, 1932, Patent No. 1,998,119, April 16, 1935. Another modulator in which the third power term predominates is shown in Patent No. 1,678,163 granted to Eugene Peterson, July 24, 1928.

For the sake of simplicity the drawing shows facilities for the addition of only one harmonic of the fundamental with controlled amplitude and phase but it is clear that other harmonics of the fundamental could be added in a similar manner if desired. It is also clear that filters of other types than those shown but having the same purpose might be used.

Fig. 2 shows a typical curve representing the loss in signal energy due to modulation in a representative third order modulating system as disclosed in the Cox application, in which the third harmonic of the carrier wave was added to the carrier fundamental in varying amplitude and phase in accordance with the invention. The loss plotted as ordinate is a measure of the loss in decibels occasioned by inserting the modulation system in question, together with a certain conventional demodulator, between the input transformer 2 and a signal indicator comprised in the load 10. The loss may be conveniently measured, except for a constant correction term, by comparing the amount of side-band power delivered to the load 10 with the amount of signal power supplied by transformer 2, taking as zero loss the standard condition where the two amounts of power are equal. In that portion of the curve which lies to the right of the vertical axis the phase relation between the carrier and the third harmonic is such that the maximum positive value of the fundamental coincides with a maximum positive value of the harmonic wave. In the portion of the curve which lies to the left of the axis the phase relation between the carrier and the third harmonic is such that a maximum negative value of the third harmonic occurs at the same instant as the maximum positive value of the fundamental. An analysis of the curve shows that the least loss is suffered when the third harmonic is about one-half the amplitude of the fundamental and in a phase relation such that the maximum positive values of fundamental and third harmonic occur at the same instant. The resultant wave shape for this condition is shown in Fig. 3 and agrees with the fact analytically and experimentally determined that the wave shape for least loss approximates a square topped wave of width equal to

$$\frac{\Pi}{2}$$

The curve in Fig. 2 also shows that the loss is greatly increased when the amplitude of the third harmonic is about half the amplitude of the fundamental and the phase relation is such that the maximum negative value of the third harmonic occurs at the same instant as the maximum positive value of the fundamental. The resultant

wave shape for this condition is shown in Fig. 4 and agrees with the fact experimentally determined that a maximum of loss occurs when the carrier approximates a square topped wave of width equal to Π .

In addition to indicating the harmonic relations corresponding to maximum and minimum loss, the curve of Fig. 2 makes it evident that the potentiometer 13 is useful as a volume control for varying the loss continuously over a wide range of values. Likewise it appears that the phase adjuster 12 may be used to vary the loss in a somewhat similar manner.

In case two or more carrier harmonics are introduced, a set of curves of the general nature of that shown in Fig. 2 may be found experimentally by varying one harmonic at a time, and the desired operating condition determined from the curves, or the system may be adjusted by trial.

What is claimed is:

1. A modulating system comprising a source of modulating waves, a source of carrier waves, a source of harmonic waves of a frequency bearing an integral multiple relation to the frequency of the carrier waves, a third order or cubic modulator for combining waves from all three of said sources to produce modulated carrier waves of a plurality of frequencies, and a load circuit for selecting third order modulation products from the modulated waves so produced.

2. A modulating system in accordance with claim 1 with the addition of means for varying the relative amplitudes of the impressed carrier and harmonic waves, whereby the output of the selected modulated waves may be adjusted.

3. A modulating system in accordance with claim 1 with the addition of means for varying the relative phases of the impressed carrier and harmonic waves whereby the output of the selected modulated waves may be adjusted.

4. A modulating system comprising a source of modulating waves, a source supplying a fundamental carrier wave and a harmonic carrier wave in fixed phase relationship to each other, a third order or cubic modulator for combining waves from said sources to produce modulated carrier waves of a plurality of frequencies, and a load circuit for selecting from the modulated waves those comprising third order modulation products.

5. A modulating system comprising a source of modulating waves, a source supplying a fundamental carrier wave and a harmonic carrier wave having a frequency three times the fundamental carrier frequency and so phased with respect to the fundamental carrier wave that a maximum voltage of the harmonic wave occurs simultaneously with each maximum voltage of the fundamental carrier wave, a third order or cubic modulator for combining waves from said sources to produce modulated carrier waves of a plurality of frequencies, and a load circuit for selecting from the modulated waves those comprising third order modulation products.

6. In a modulating system including a source of modulating waves, a third order or cubic modulator, a source of fundamental carrier waves, and a source of harmonic waves of three times the fundamental frequency, the method which comprises combining in a single operation waves from all three of said sources to produce modulated waves of a plurality of harmonically related frequencies, selecting from said modulated waves one having twice the fundamental carrier

frequency, and utilizing said selected wave for transmission purposes.

5 7. The method of producing modulated carrier waves at high efficiency in a third order or cubic modulator which comprises producing a modulating current, generating a carrier wave of fundamental frequency, generating a harmonic wave having a frequency which is an integral multiple
10 of the fundamental carrier frequency, combining in said modulator in a single operation said modulating current, said fundamental carrier wave and said harmonic carrier wave to produce modulated waves having respectively the frequency of the fundamental carrier and of a plurality of harmonic carriers, and selecting from
15 said modulated waves one comprising a third order modulation product.

8. A modulating system comprising a modulating device having a cubic relationship between
20 the voltage impressed thereon and the current passed thereby, a source of oscillations of signal frequency, a source of oscillations of fundamental carrier frequency, a source of harmonic oscillations having a frequency which is an integral
25 multiple of the fundamental carrier frequency, means for impressing oscillations from all three of said sources upon said modulating device simultaneously to produce fundamental carrier oscillations modulated by signals and a plurality of
30 harmonic carrier oscillations modulated by the same signals, a load circuit, and means for se-

lectively transmitting to said load circuit from the output of said modulating device modulated harmonic carrier oscillations of the third order.

9. In a modulating system including a source of modulating waves, a third order or cubic
5 modulator, a source of fundamental carrier waves and a source of third harmonic carrier waves, the method which comprises proportioning the third harmonic to approximately one half the amplitude of the fundamental carrier, adjusting the
10 phase relation of the third harmonic and the fundamental to accentuate the carrier wave peaks, and combining in the modulator the waves from all three of said sources to produce third
15 order modulated waves in the frequency region of the second harmonic of the carrier.

10. A modulating system comprising a third order or cubic modulator, a source of modulating waves, a source of fundamental carrier waves,
20 a source of third harmonic carrier waves of approximately one half the amplitude of the fundamental carrier waves, the relative phase relation of the fundamental and harmonic waves being such as to increase the peakedness of the resultant carrier wave, and means to impress
25 the modulating waves together with the peaked carrier wave upon the modulator to produce a modulated wave in a frequency range in the neighborhood of twice the fundamental carrier
30 frequency.

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