

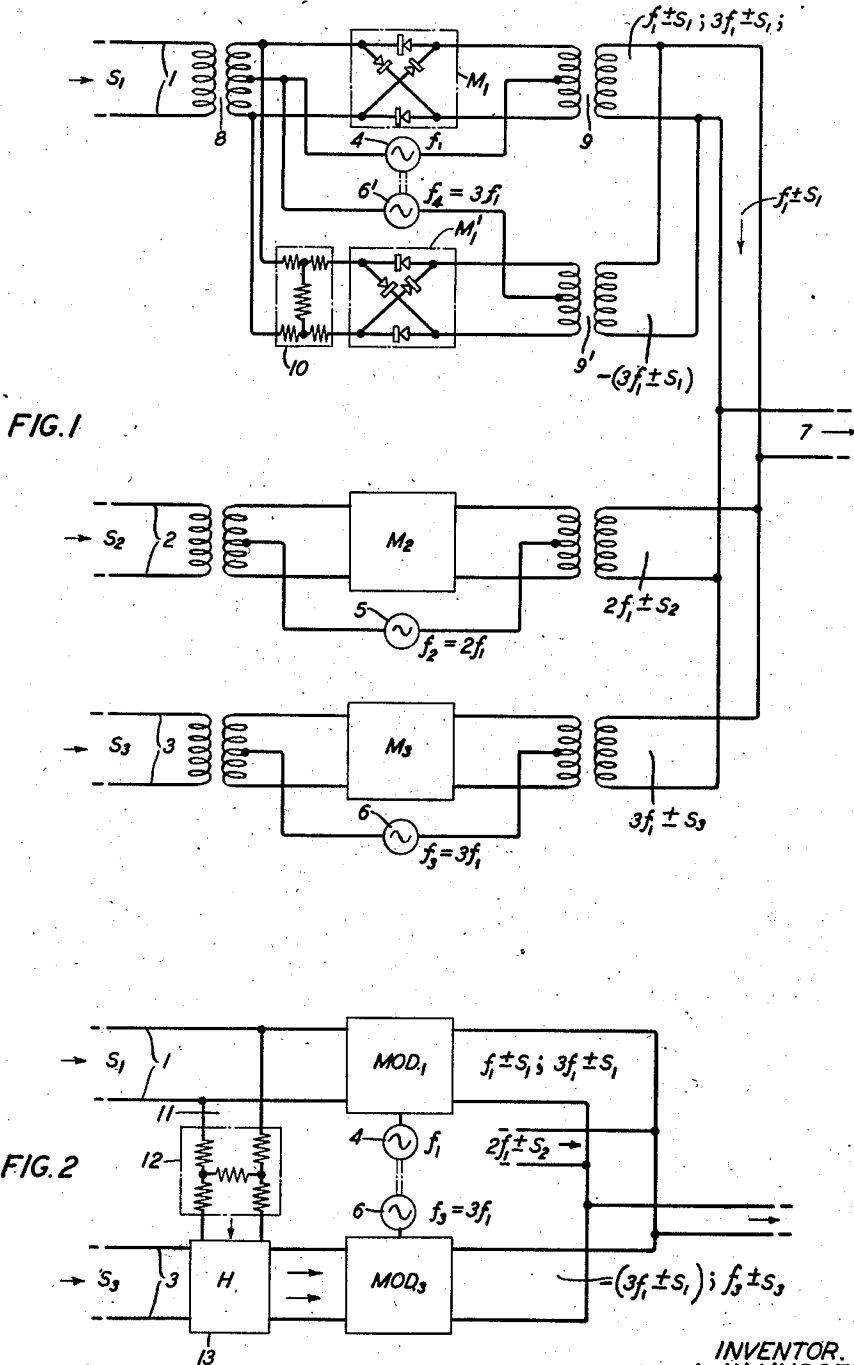
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MODULATION

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## MODULATION

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This invention relates to carrier wave signaling systems and more particularly to modulating arrangements for such systems.

An object of the invention is to improve the economy and simplicity of modulating arrangements known heretofore and to neutralize or reduce the deleterious effects of distortion products that tend to appear.

It is well known that if an electric wave of a given frequency  $f$  and another wave of frequency  $s$  are applied to an element having a non-linear current-voltage characteristic there are generated waves of other frequencies, which generally comprise  $f \pm s$ ,  $2f$ ,  $2s$ ,  $2f \pm s$ ,  $f \pm 2s$ ,  $3f$ ,  $3s$ ,  $3f \pm s$ , etc., the relative amplitudes of the waves generated being dependent on the particular non-linear characteristic of the modulating element. In a carrier signaling system, where  $f$  would represent the carrier wave and  $s$  the signal, it is desired to segregate one of the modulation products, as they are called, of the form  $nf \pm s$ , where  $n$  is an integer, usually unity, so that that product can be transmitted to the receiving station and the other modulation products suppressed. Suppression of these other products is especially necessary in a multiplex carrier signaling system for they may fall in the frequency range occupied by other carrier signals, thus giving rise to interchannel interference or cross-talk.

In accordance with the present invention, unwanted modulation products in the output of a modulator are reduced by generating like modulation products in a separate modulator and combining them in opposing relation with the unwanted products of the first modulator in such manner that the desired signal sidebands are not affected. The separate modulator may be used solely for the generation of the neutralizing products or, in accordance with a modification, it may be used simultaneously to provide another carrier signaling channel.

The nature of the present invention and its various features, objects and advantages will be more fully apparent from a consideration of the following description of the preferred embodiments illustrated in the accompanying drawing:

Fig. 1 shows a modulation arrangement for a multiplex carrier signaling system utilizing a separate modulator in accordance with the invention for neutralizing certain disturbing modulation products; and

Fig. 2 shows schematically a modification in which one modulator serves both to provide a sig-

nal channel and to neutralize interchannel modulation.

Although any modulator tends to generate the various modulation products noted hereinbefore, there are some modulators which operate inherently to suppress certain of these modulation products. Those products not suppressed inherently may be and usually are eliminated by passing the wave output of the modulator through a filter that passes the desired signal sidebands but which attenuates the undesired products to a negligible value. A modulator of this type has been chosen for the embodiments of the present invention illustrated in the drawing inasmuch as it not only will serve for purposes of exposition of the basic principles of the invention but it also makes possible by application of the invention a multichannel modulating arrangement requiring no filters.

Referring now to Fig. 1, there is represented a modulating arrangement for a three-channel carrier system in which signals  $s_1$ ,  $s_2$  and  $s_3$  are taken from respective signal frequency circuits 1, 2, 3, which may be telephone subscriber lines for example, applied to individual modulators and therein impressed on individual carrier waves supplied by respective sources 4, 5, and 6, the modulated carrier waves being then applied to a transmission circuit 7. Each of the modulators is of the so-called double-balanced or ring type well known in the art and comprises an input transformer 8, an output transformer 9 and four asymmetrically conducting resistance elements, copper-oxide rectifiers for example, connected therebetween in the form of a bridge  $M_1$ ,  $M_2$ ,  $M_3$ . Internally of each bridge the asymmetric elements are connected in a closed loop and are like poled with respect to their loop connection. Each input transformer is connected across a pair of diametrically opposite terminals of its associated bridge and the other pair of terminals of the bridge is connected to the associated output transformer. The carrier wave source 4, 5, 6 is connected between the mid-points of the secondary and primary windings of the transformers 8 and 9, respectively.

It has been shown that in a modulator of the kind described, when the amplitude of the carrier wave is made much greater than that of the signal wave, all odd order modulation products are inherently suppressed by virtue of the balanced arrangement of the circuit, that the principal modulation product in the output circuit is the second order double side-bands with frequencies

$f \pm s$ , where as before  $f$  represents the frequency of the carrier wave and  $s$  the signal, and that other even order modulation products are also present in the output circuit. Of the latter products only the one comprising the frequencies  $3f \pm s$  is usually of sufficient relative intensity to require attention. The problem is an aggravated one in the present instance for it will be supposed that the three carrier frequencies  $f_1, f_2, f_3$  are in the harmonic relation  $f, 2f, 3f$ . These harmonically related carrier frequencies may be for specific example 8, 16 and 24 kilocycles per second. In the case assumed the distortion component  $3f_1 \pm s_1$  falls squarely in the frequency range occupied by the desired signal side-bands  $f_3 \pm s_3$ . It may readily be shown also that all other principal modulation products of the form  $(2n+1)f \pm s$  fall outside of the frequency range occupied by the three carrier channels. The application of the present invention to the typical modulating arrangement disclosed will accordingly be directed and confined to the reduction or neutralization of the distortion product  $3f_1 \pm s_1$ .

In accordance with the invention as illustrated in Fig. 1, the modulator to which signal  $s_1$  is applied is paralleled by another or "auxiliary" modulator comprising a modulator bridge  $M_1'$  and an output transformer  $9'$  that have substantially the same electrical characteristics as the corresponding circuit elements  $M_1$  and  $9$ . Duplication of the input transformer  $8$  is unnecessary and the latter may serve for both modulators. Carrier waves of frequency  $f_4 = 3f_1$  are applied to the second modulator from a source  $6'$  connected between the secondary mid-point of transformer  $8$  and the primary mid-point of transformer  $9'$ . The two carrier wave sources  $4$  and  $6'$  are electrically or mechanically geared together in exact harmonic relation and so phased that carrier wave  $f_4$  passes through zero value whenever the instantaneous value of carrier wave  $f_1$  is zero. In practice all four carrier waves could well be derived from a harmonic generator comprising a diode or other reactance-free non-linear resistance device so that the desired phase relation between carrier waves  $f_1$  and  $f_4$  would inherently obtain. If the phase characteristics of the paralleled modulators are not exactly alike, it is permissible and desirable to compensate for the difference by departing from the phase relation indicated.

The principal modulation product of the auxiliary modulator is the second order double side-band  $f_4 \pm s_1$  which is of exactly the same form as the distortion product to be neutralized, viz.  $3f_1 \pm s_1$ . By proper poling of the connections between the respective secondary windings of transformers  $9$  and  $9'$ , therefore, the product  $f_4 \pm s_1$  can be combined with the distortion product  $3f_1 \pm s_1$  in opposition to each other in relation to their common output circuit. To adjust the relative amplitudes of the opposing products an attenuator pad  $10$  is connected between the input terminals of modulator bridge  $M_1'$  and input transformer  $8$ , and on adjusting the attenuation of the pad to an optimum value equalizing the amplitudes of the opposing products their neutralization is effected. Although the equalizer function could be accomplished by various alternative means, that illustrated is preferred inasmuch as by reducing the amplitude of the waves applied to the auxiliary modulator the various unwanted modulation products it tends to produce are reduced in greater proportion than the wanted product  $f_4 \pm s_1$ .

The modulating arrangement described with reference to Fig. 1 may be modified in the manner indicated in Fig. 2 so that one of the three channel modulators performs the additional function of generating the modulation products desired for effecting neutralization of interchannel cross-talk. The modification in part consists in the elimination of the auxiliary modulator of Fig. 1 and the provision of a circuit  $11$  including an attenuator pad  $12$  connecting signal circuits  $1$  and  $3$  so that an attenuated fraction of signal  $s_1$  is applied together with signal  $s_3$  to the modulator  $MOD_3$  associated with the latter. A hybrid coil  $13$  is interposed in the connection described so that circuits  $3$  and  $11$  are in conjugate relation with each other but in energy transfer relation with the modulator  $MOD_3$ . The carrier wave sources  $4$  and  $6$  are coupled together in any suitable manner to maintain the same phase relation as was prescribed for sources  $4$  and  $6'$  in Fig. 1. It will be readily perceived that the output of modulator  $MOD_3$  includes not only the principal desired signal side-band  $f_3 \pm s_3$  but also a second order modulation product  $f_3 \pm s_1$  falling in the same frequency range. In accordance with the procedure outlined hereinbefore, viz., that of proper poling of the output terminals of  $MOD_3$  and adjustment of the attenuator pad  $12$  as described with reference to Fig. 1, the last-mentioned product  $f_3 \pm s_1$  will be combined in neutralizing relation with the distortion product  $3f_1 \pm s_1$  originating in the modulator  $MOD_1$  associated with signal circuit  $1$ .

Although the present invention has been described with reference to its application to the neutralization of a particular distortion product in a second order modulator of specific type, it will be understood that the invention and the principles underlying the invention have widely diversified application within the spirit and scope of the appended claims.

What is claimed is:

1. In combination, two modulators that are substantially alike in their modulating characteristics; a common source of signals and a common output circuit for said modulators, means for supplying respective carrier waves of different frequencies and fixed relative phase to said modulators, said carrier frequencies being so related that an unwanted modulation product of a given order produced by one of said modulators is in phase opposition with a principal modulation product of a different order produced by the other of said modulators, and means for equalizing the amplitudes of said modulation products, whereby they tend to neutralize each other.

2. In combination, two modulators, a common source of signals and a common output circuit for said modulators, means for supplying respective carrier waves to said modulators, means for maintaining said carrier waves in fixed harmonic phase relation with each other, one of said modulators producing a wanted double side-band and unwanted distortion products of order differing from that of said double side-band, said carrier waves being so related in frequency that a principal modulation product produced by the other of said modulators coincides in frequency and composition with one of said distortion products, means for equalizing the amplitudes of said modulation and distortion products, and means for combining them in phase opposition in said common output circuit without substantially interfering with said wanted double side-band.

3. A multiplex carrier wave signaling system

comprising a first modulator and a second modulator, means for applying to said first modulator for intermodulation therein a signal  $s_1$  and a carrier wave of frequency  $f_1$ , the said first modulator generating a principal modulation product of the form  $pf_1 \pm s_1$  and a distortion product of the form  $qf_1 \pm s_1$ , means for applying to said second modulator for intermodulation therein a carrier wave and the said signal  $s_1$ , the principal modulation product of said second modulator being of substantially the same composition as said distortion product  $qf_1 \pm s_1$ , means for maintaining said carrier waves in fixed relative phase, means for intermodulating a second signal  $s_2$  and a carrier wave of frequency  $f_2$  such that the principal resulting modulation product  $rf_2 \pm s_2$  coincides at least in part with the frequency range  $qf_1 \pm s_1$ ,  $p$ ,  $q$  and  $r$  being integers, means for combining said distortion product and the said principal modulation product of said second modulator in mutually opposing relation whereby they tend to neutralize each other, and a common load circuit for said principal modulation products  $pf_1 \pm s_1$  and  $rf_2 \pm s_2$ .

4. A system in accordance with claim 3 comprising means substantially attenuating the said signals as applied to said second modulator relatively to said signals as applied to said first modulator.

5. A system in accordance with claim 3 comprising a third modulator for the said modulation of said second signal.

6. A system in accordance with claim 3 in which the said modulation of said second signal is effected in said second modulator.

7. In combination, a pair of double-balanced modulators having substantially the same electrical characteristics, a common source of signals and a common output circuit for said modulators, means for supplying respective carrier waves to said modulators, the frequency of one of said carrier waves being three times that of

the other and maintained in fixed harmonic phase relation therewith, whereby the second order signal side-bands from one of said modulators coincides in frequency with the fourth order signal side-bands from the other, means for equalizing the amplitudes of said second and fourth order side-bands, and means for combining them in mutually opposing relation in said common output circuit.

8. A combination in accordance with claim 7 in which said equalizing means comprises means for adjusting the amplitude of the signal applied to one of said modulators.

9. In a multichannel carrier signaling system, two modulators each of a type such that modulation products of the form  $2n \pm s$  are suppressed but in which modulation products of the form  $3n \pm s$  tend to appear, means for supplying said modulators with respective carrier waves, the frequency of the carrier waves supplied to one of said modulators being three times the frequency of the carrier waves supplied to the other, means for supplying the same signal to both of said modulators, a common output circuit for said modulators, means for adjusting the amplitude of the  $3n \pm s$  products of said one modulator to equality with the amplitude of the  $n \pm s$  products of said other modulator, means for combining said two last-mentioned products in phase opposition in said output circuit, means for translating a different signal to the frequency range of said last-mentioned products, and means for applying said different signal so translated to said output circuit.

10. A combination in accordance with claim 9 in which said other modulator effects the frequency translation of said different signal.

11. A combination in accordance with claim 9 including a separate modulator for effecting the frequency translation of said different signal.

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