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CARRIER WAVE MODULATION

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FIG. 1

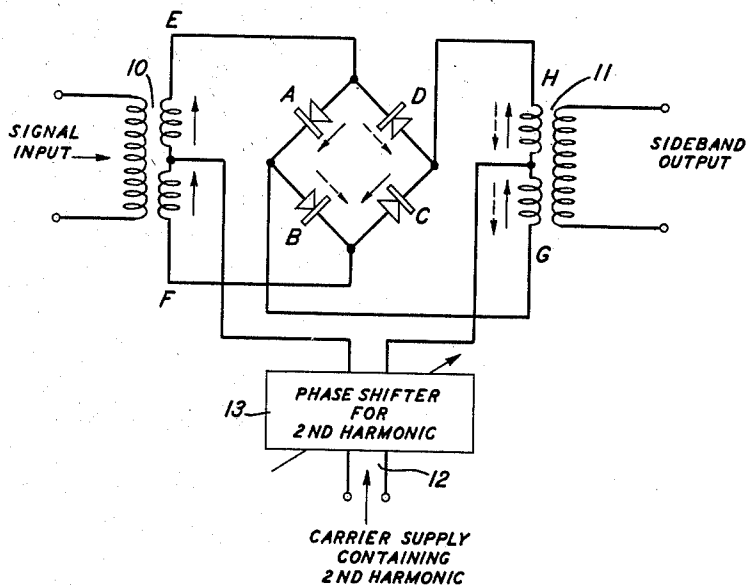


FIG. 2

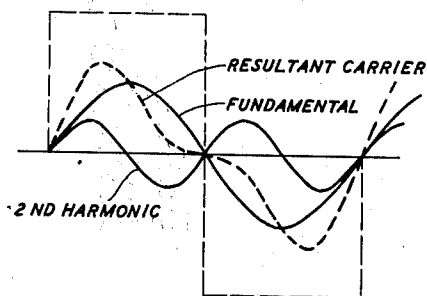
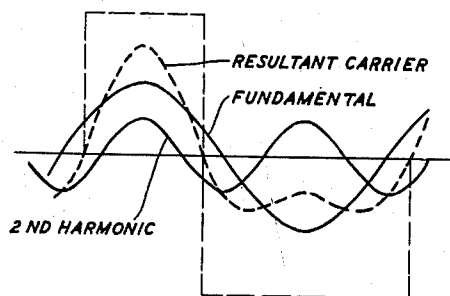


FIG. 3



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CARRIER WAVE MODULATION

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1 Claim. (Cl. 179—171.5)

The present invention relates to the modulation of carrier waves by a signal or other relatively low frequency waves and relates especially to the reduction of signal leak or direct transmission of signal currents through the modulator into the side-band output circuit or load circuit.

Signal leak becomes a particular problem in systems in which the signal and side-band frequencies coincide, since filtering can be used in cases where the signal and side-bands have different frequencies. One instance that may be cited as an example in which filtering cannot be used to suppress signal leak would be a speech frequency inverting circuit in which the inverted side-band frequencies are to coincide with or overlap the speech band.

The commonest cause of signal leak is, of course, circuit unbalance and effort is always made to secure as perfect a balance as possible by choosing the modulator elements to match as closely as possible and making the transformers as symmetrical as possible. After all possible precautions have been taken in balancing the circuit, there remains a possible source of signal leak in the presence of second harmonics in the carrier supply which, depending upon their phase, may have the effect of lengthening the conductivity period of the modulator in one-half cycle of the applied carrier and shortening the conductivity period in the next half cycle. This results in a net rectifying effect which is equivalent to producing some side-band output based on direct current, that is, some of the original signal, thus producing signal leak.

In accordance with the present invention this source of dissymmetry in the operation giving rise to signal leak is eliminated by producing the requisite phase shift in the second harmonic of the carrier supply relative to the fundamental carrier frequency component.

The nature and objects of the invention will be more fully understood from the following detailed description in connection with the attached drawing, in which:

Fig. 1 is a schematic circuit diagram of a double balanced ring modulator incorporating the improvement of the present invention; and

Figs. 2 and 3 are graphs of wave forms illustrating the effect of phase relations between the fundamental and second harmonic of the carrier wave.

Referring first to Fig. 1, the ring modulator containing the four elements, A, B, C and D is connected in a double balanced circuit of known configuration comprising an input transformer

10 and an output transformer 11 for connecting respectively, to the signal input circuit and a side-band output circuit or load.

The windings of the transformers 10 and 11 adjacent the ring are supplied with center taps between which is connected the carrier supply source assumed to be connected to circuit 12. In accordance with the present invention a phase shifter 13 is connected in the circuit 12 for introducing relatively greater phase shift for the second harmonic than for the fundamental frequency component of the carrier current. Ideally, the phase shifter 13 may be regarded as introducing phase shift for only the second harmonic component.

In the usual operation of the circuit of Fig. 1, not considering for the moment the improvement feature of the present invention, the amplitude of the carrier wave would be chosen to be large compared with the maximum amplitude of the signal wave. The effect of this is to cause the ring A, B, C, D to operate as a switch which is opened and closed under control of the carrier wave so as to transmit some of the signal input wave through to the side-band output circuit in respectively reversed polarity in successive half cycles of the applied carrier wave. For example, when the carrier wave is in such direction as to make the impedance of elements A and C low and the impedance of elements B and D high, current flows around the circuit in the direction E, A, G, H, C, F, thus producing current flow in the primary winding of output transformer 11 in the direction indicated by the solid arrows, assuming the signal input wave has the polarity indicated by the solid arrows adjacent input transformer 10. When the carrier wave reverses in polarity, elements B and D are made to have low impedance and elements A and C high impedance. Current then flows in the direction E, D, H, G, B, F, thus sending current through the primary winding of the output transformer 11 in the direction of the dotted arrows. There is thus a reversal of direction of current flow in the transformer winding GH whenever the carrier current reverses direction and the amplitude of such current flow is proportional to the signal. The duration of the current flow is determined by the duration of the low conductivity periods of the modulator elements involved and this in turn depends upon the duration of the time in which a voltage of sufficiently high value is applied to them from the carrier supply source.

If the duration of the conductivity condition in one-half cycle of the applied carrier wave is

slightly different from the duration of the conductivity in the alternate half cycle, a residual direct current component of the carrier is produced by rectification and this causes a proportionate amount of the signal to be transferred to the side-band output circuit as signal leak. Such a dissymmetry between alternate half cycles of the carrier waves may be caused, for example, by the presence of second harmonic in the carrier supply.

Figs. 2 and 3 represent, with some exaggeration for purposes of illustration, two extreme cases in which (Fig. 2) the second harmonic component has such phase as to pass through zero at the same instant as the fundamental carrier component and (Fig. 3) the second harmonic has been shifted 90 degrees with respect to the case shown in Fig. 2. The dotted lines in each case represent the resultant carrier that is actually applied to the ring circuit, this being obtained by direct addition of the fundamental and second harmonic components. The broken line rectangular curve having opposite polarity portions represents the conductivity duration of the ring modulator in the corresponding direction. Comparison of Figs. 2 and 3 shows that the conductivity period is equal in the positive and negative directions in Fig. 2, whereas in Fig. 3 the conductivity in the positive direction is shorter than that in the negative direction. The condition illustrated in Fig. 2, therefore, is such as to produce no signal leak by rectification of the carrier wave, while the condition illustrated in Fig. 3 is such as to produce a signal leak, since there is a net resultant direct current component produced by rectification.

The relations indicated in Fig. 3 may be changed to those illustrated in Fig. 2 by shifting the phase of the second harmonic component relative to the fundamental. This may be done by inserting the phase shifter 13 of Fig. 1, which may be in the form of an all-pass network of the lattice type with inverse reactive networks in the series and shunt branches and with impedance

matching the output circuit of the oscillator. The attenuation of the network should be low at the carrier frequency, and the phase shift at the second harmonic of the carrier frequency relative to that at the carrier frequency is preferably variable to permit the introduction of any desired amount of phase shift difference throughout a range of at least 90 degrees. If it is known in any particular case that the phase relations shown in Fig. 3 exist, then, of course, a simple 90-degree phase shifting circuit for the second harmonic component may be used at 13.

While the conditions illustrated in Figs. 2 and 3 are exaggerated, the presence of even a small amount of second harmonic component will produce a corresponding unsymmetrical effect in the resultant applied carrier wave. Where the suppression of the second harmonic cannot be or has not been made sufficiently complete by filtering to eliminate the effect, a phase shifter 13 may be used with or without a purifying filter or as part of a purifying filter to secure a more perfect result.

What is claimed is:

25 In a signal modulating circuit, a ring modulator, a source of signal currents and a load connected to points in said ring such as to be in conjugate relation to each other, a source of carrier waves connected between mid-points in said source and load respectively, said carrier wave source delivering a relatively small amount of second harmonic current with the carrier wave, and means for controlling direct signal transmission to said load due to inequality in conduction times of said ring in successive carrier half cycles comprising a phase shifter between said ring and said source of carrier waves for producing phase shift in the second harmonic relative to the fundamental carrier wave of such amount as to cause the carrier wave fundamental and second harmonic components applied to the ring to pass through zero coincidentally.

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