Jan. 6, 1942. W. LUTZENBERGER 2,268,837

MODULATOR ARRANGEMENT

Filed May 20, 1939

Fig. 1a

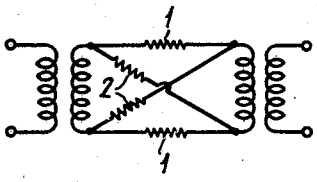


Fig. 1b

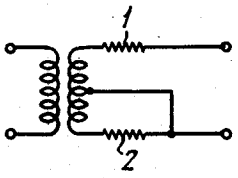


Fig. 1c

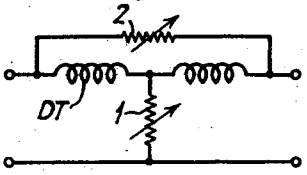


Fig. 2

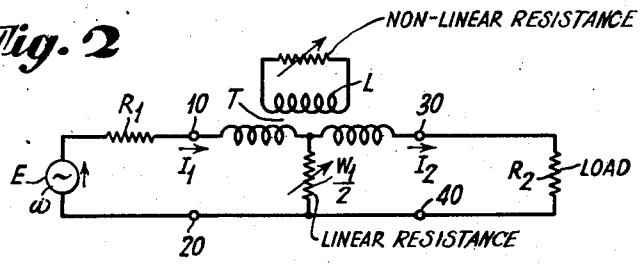


Fig. 3a

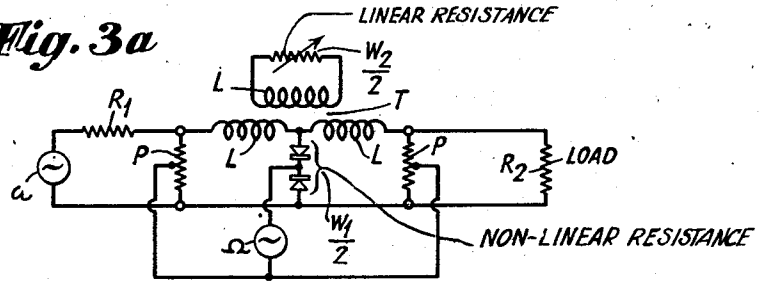


Fig. 3b

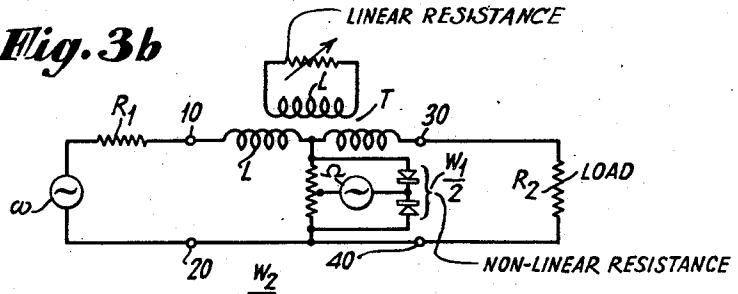
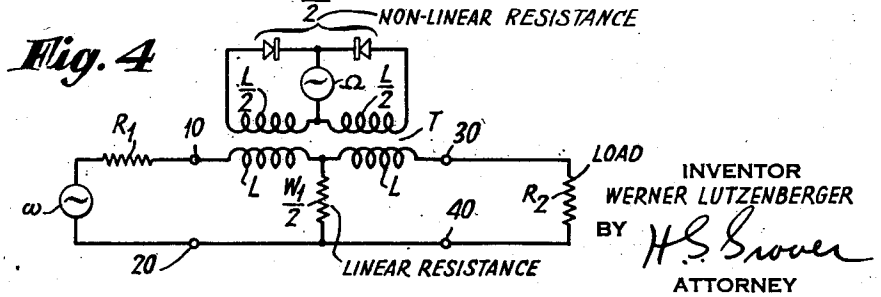


Fig. 4



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MODULATOR ARRANGEMENT

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In Germany May 21, 1938

1 Claim. (Cl. 179—171.5)

The invention relates to modulator arrangements and demodulator arrangements with non-linear resistors, more especially with dry-contact rectifiers or diodes such as employed in the carrier current field and measurements to move a frequency or a frequency band into another position in the frequency spectrum. The frequency or the frequency band to be converted is applied hereby to the modulator and more especially across a filter arrangement and the non-linear resistor or resistors are controlled by a carrier frequency providing the desired frequency displacement. The converted signal may then be derived at the output terminals.

Often it is desired to have solely the converted frequency in the output of the arrangement whereby at least the signal frequency and the carrier frequency are suppressed. To suppress one of these frequencies as well as other undesirable modulation products in the modulator output, circuit arrangements have become known which were obtained by connecting two non-linear circuits. On these so-called push-pull modulators it is often necessary to employ compensation methods to suppress the signal frequency or the carrier frequency still appearing in the output, more especially in the case where the carrier frequency employed is relatively low. It is known to this end to apply the signal frequency and the carrier frequency respectively in suitable phase and amplitude to the output of the modulation arrangement. But this is a cumbersome method and requires considerable means as well as an additional consumption of power.

The conditions are much more favorable when using the known double push-pull arrangements, more especially an arrangement as has become known under the designation ring modulator. In the case of the ring modulator obtained by the interconnecting of four non-linear circuits and four non-linear resistors there is obtained a decoupling of all terminal pairs. The output of the modulator arrangement no longer contains the carrier frequency and signal frequency as well as other undesirable modulation products. It is for these reasons and for other advantages that the ring modulator is now generally in use.

However, there is still a disadvantage inherent to ring modulator arrangements and to all double push-pull arrangements, namely, that it is necessary to utilize possibly four non-linear resistors all having the same characteristic so as to completely suppress in the output the carrier frequency and the signal frequency. It is possible to avoid the necessity of having completely non-linear resistors in that in accordance with other known proposals the resistors are chosen in accordance with certain other laws. But also in this case the requirements in usable dry contact rectifiers in a production series is rather low so that it is often necessary to resort to compensation methods for suppressing a residual potential of the carrier frequency and/or of the signal frequency still existing in the output. Hence, an arrangement would be much more favorable which with a smaller number of non-linear resistors would already assure a suppression of the carrier frequency and signal push-pull modulators are, however, not suited to this end since, as already stated, only one of the two frequencies is thereby suppressed in the modulator output.

In describing my invention reference will be made to the attached drawing wherein Figures 1*a*, 1*b* and 1*c* inclusive are basic diagrams used to illustrate my invention while Figures 2, 3*a*, 3*b* and 4 illustrate schematically four different embodiments of my novel modulator in which the voltage modulated and modulating voltages are suppressed in the output.

In accordance with the invention the modulator arrangement is designed as a bridge circuit such that the one-half of the branches of the bridge is formed by non-linear resistors while the other half is formed by linear resistors, more especially by ohmic resistors. Bridge circuits are meant hereby to be the actual bridge circuits according to Figure 1*a*, as well as the equivalents thereof. Thus, Figure 1*b* shows a differential bridge arrangement and Figure 1*c* shows a bridged T-circuit. The non-linear resistors are designated by 1 in the Figures 1*a* to 1*c* and the linear resistors are designated by 2, or vice versa. In the bridged T-circuit, according to Figure 1*c* by means of which the present invention will be elucidated, there is placed in a series branch a differential transformer winding DT and between the transformer winding center and the other series branch a resistor 1. The differential transformer has a further resistor 2 inductively coupled therewith. One of the resistors is formed by one or several non-linear resistors which can be controlled between a maximum value and minimum value and the other resistor is formed by one or several linear resistors. As non-linear resistors dry, contact rectifiers or diodes are chosen in particular. With the modulator constructed in accordance with the present invention, a modulation arrangement is realized having only one-half of the non-linear resistors as compared with the push-pull and double push-pull arrangements required for the same results as regards the suppression of the carrier frequency and signal frequency in the modulator output. The resistance value of the constant resistance is chosen hereby between the two limit values of the controllable non-linear resistance, and more

especially this value is chosen equal to the geometrical mean value of the said limit values.

The principal circuit of the modulator arrangement according to the invention is shown in Figure 2. There is connected to the input terminals 10, 20 the signal current source ω through the resistor R_1. The signal voltage is represented by E. The terminals 30, 40 of the arrangement have the load R_2 connected thereto. The modulator arrangement consists of the differential transformer T, the resistance

$$\frac{W_1}{2}$$

placed in the parallel branch and the inductively coupled resistance

$$\frac{W_2}{2}$$

It is assumed that $R_1=R_2=R$. The output current I_2 of the modulator arrangement is then established by the equation:

$$I_2=\frac{E}{2}\frac{W_1-W_2}{(R+W_1)(R+W_2)}$$

Now if one of the resistances, such as for instance the resistance

$$\frac{W_2}{2}$$

varies periodically between the highest resistance value

$$\frac{S}{2}$$

and the lowest resistance value

$$\frac{D}{2}$$

and if the resistance value of the other resistor is constant and lies between these two limit resistance values and chosen more especially to be:

$$\frac{W_1}{2}=\frac{1}{2}\sqrt{DS}=\text{const.}$$

the output current changes its polarity periodically. There follows under the assumption that $R=W_1=\sqrt{DS}$ that:

$$I_2=\frac{E}{4\sqrt{DS}}\frac{\sqrt{DS}-W_2}{\sqrt{DS}+W_2}$$

For the lowest resistance value of

$$\frac{W_2}{2},\ \frac{W_2}{2}=\frac{D}{2}$$

there is:

$$I_2=\frac{E}{4\sqrt{DS}}\frac{\sqrt{S}-\sqrt{D}}{\sqrt{S}+\sqrt{D}}=\frac{E}{4\sqrt{DS}}\frac{\sqrt{M}-1}{\sqrt{M}+1}\approx\frac{E}{4\sqrt{DS}}$$

for

$$M=\frac{S}{D}\gg 1$$

For the highest resistance value

$$\frac{W_2}{2}=\frac{S}{2}$$

there is accordingly:

$$I_2=\frac{E}{4\sqrt{DS}}\frac{\sqrt{S}-\sqrt{D}}{\sqrt{S}+\sqrt{D}}=\frac{E}{4\sqrt{DS}}\frac{\sqrt{M}-1}{\sqrt{M}+1}\approx-\frac{E}{4\sqrt{DS}}$$

for

$$M=\frac{S}{D}\gg 1$$

The equations show that the arrangement operates as periodic polarity changer. The signal frequency does not appear in the output if the equation $R=W_1=\sqrt{DS}$ is fulfilled. An advantage exists however if the resistor

$$\frac{W_1}{2}$$

is variable whereby its value which can only be calculated approximately can be so adjusted that the signal frequency disappears entirely in the output. Just as in the case of constituting the resistor

$$\frac{W_2}{2}$$

by a non-linear resistance which varies periodically between a maximum value and a minimum value, also the resistor

$$\frac{W_1}{1}$$

can be formed by a non-linear resistance and

$$\frac{W_2}{2}$$

by a constant resistance whose value is to be chosen in accordance with the points outlined in connection with

$$\frac{W_1}{1}$$

For controlling the non-linear resistance formed, for instance, by a dry contact rectifier or by a diode, a carrier frequency of preferably rectangular pattern is utilized in accordance with the desired displacement of the signal. When employing but one non-linear resistance element this arrangement is however not yet sufficient to suppress the carrier frequency in the output without using a special compensation circuit. The arrangement behaves just as a push-pull modulator arrangement but requires only one-half of the non-linear resistance elements.

In the example of construction, according to Figure 3*a*, an arrangement is shown in which the non-linear resistance is formed by two dry contact rectifiers or diodes connected in push-pull. The carrier frequency source Ω is placed between the connection point of the two resistance elements and the centers of two inductances or resistances P arranged on both sides of the arrangement, or according to the example of construction of Figure 3*b*, the said carrier frequency source is placed at the center of an impedance bridging the detector elements. This arrangement which differs from a push-pull modulator on account of the use of the differential transformer and of the resistor

$$\frac{W_2}{2}$$

coupled inductively therewith, has the advantage over the push-pull modulator that as regards the suppression of the carrier frequency and signal frequency in the output, it behaves in the same manner as a double push-pull modulator. The circuit can be simplified if, according to the example shown in Figure 4, the resistor

$$\frac{W_2}{2}$$

is a controllable non-linear resistor, more especially if it is formed of two dry contact rectifiers or diodes placed in push-pull. The carrier frequency source Ω is connected in this case between the connection point of the two resistance elements and the center of the transformer wind-

ing. Therefore, in this case only a single transformer is required.

The arrangement according to the invention which could be termed suitably a bridge modulator to distinguish it from the known arrangements requires, as already pointed out, only one half of the non-linear resistors as compared with the known modulators for the same results in regard to the decoupling of the modulator output from the signal frequency terminals and carrier frequency terminals. The examples of construction, according to Figures 2 and 3, have the further advantage over the ring modulator in that they can be easily constructed also when employing tubes. A double push-pull modulator utilizing tubes requires, however, as is known, a considerable number of means. Moreover, the tubes employed can be united in a single vessel. Also duo-diodes may be employed in a manner known as such.

The damping during operation, of the bridge modulator according to the invention is the same as that of the ordinary push-pull modulator as can be proven by calculation. As compared with the push-pull modulator, the further advantage exists that in the bridge modulator the variations of the input signal current I_1 are substantially smaller such as can be seen from the following. The input current (Figure 2) is:

$$I_1 = E\frac{W_1+W_2+2R_2}{2W_1W_2+2R_1R_2+W_1(R_1+R_2)+W_2(R_1+R_2)}$$

and if $R_1=R_2=R$;

$$I_1 = E\frac{R+\frac{1}{2}(W_1+W_2)}{(R+W_1)(R+W_2)}$$

For $R=W_1=\sqrt{DS}$ there will be:

$$I_1=\frac{E}{4\sqrt{DS}}\frac{3\sqrt{DS}+W_2}{\sqrt{DS}+W_2}$$

For $W_2=D$, there will be:

$$I_1=\frac{E}{4\sqrt{DS}}\frac{3\sqrt{M}+1}{\sqrt{M}+1}\approx\frac{3}{4}\frac{E}{\sqrt{DS}}$$

whereby $M\gg1$;

For $W_2=S$ there is:

$$I_1=\frac{E}{4\sqrt{DS}}\frac{3+\sqrt{M}}{1+\sqrt{M}}\approx\frac{1}{4}\frac{E}{\sqrt{DS}}$$

whereby $M\gg1$

I_1 therefore varies only in the proportion 3:1 while I_1 varies in case of the push-pull connection according to

$$\sqrt{\frac{S}{D}}$$

What is claimed is:

In a system for intermodulating two alternating voltages of different frequencies to obtain voltages of other frequencies related to the frequencies of said two voltages and substantially suppressing voltages of the frequency of the frequencies of the two original voltages, a two-wire line having input terminals and output terminals connected with a load impedance, a transformer having a first winding and having a differential secondary winding connected in series with one wire of said line, a resistance coupled in shunt to said first winding, a non-linear controllable resistance variable between two values connecting a point between the windings of said differential secondary winding to the other side of said line, said first resistance having a value intermediate the limits of variation of said controllable resistance, means for impressing one of said voltages on the input terminals of said line and means for varying the value of said controllable resistance in accordance with the other of said voltages.

WERNER LUTZENBERGER.