April 26, 1932. C. R. KEITH 1,855,576

FREQUENCY TRANSLATING SYSTEM

Filed April 9, 1929

Fig. 1

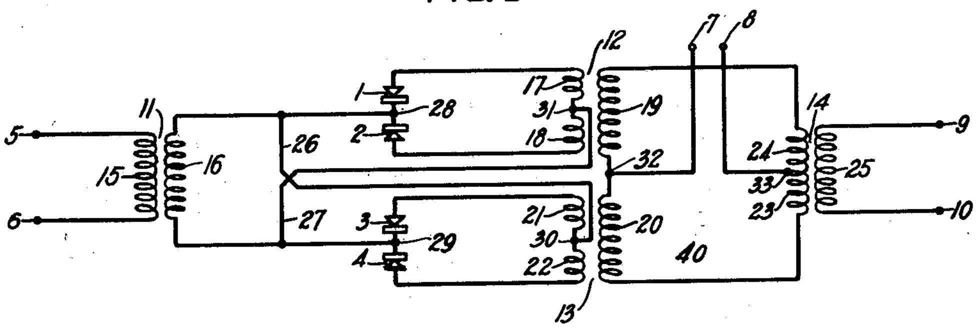


Fig. 2

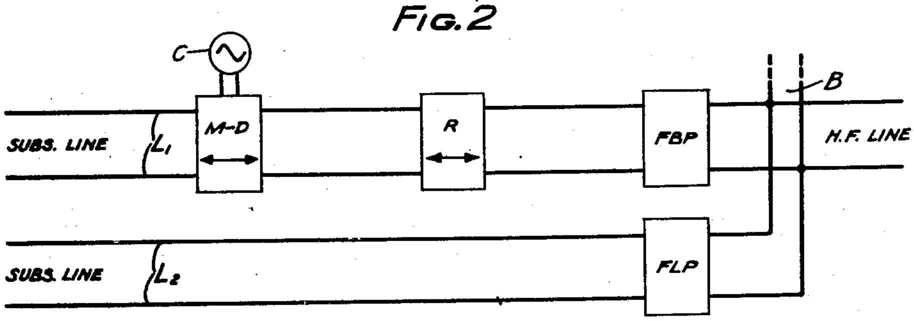
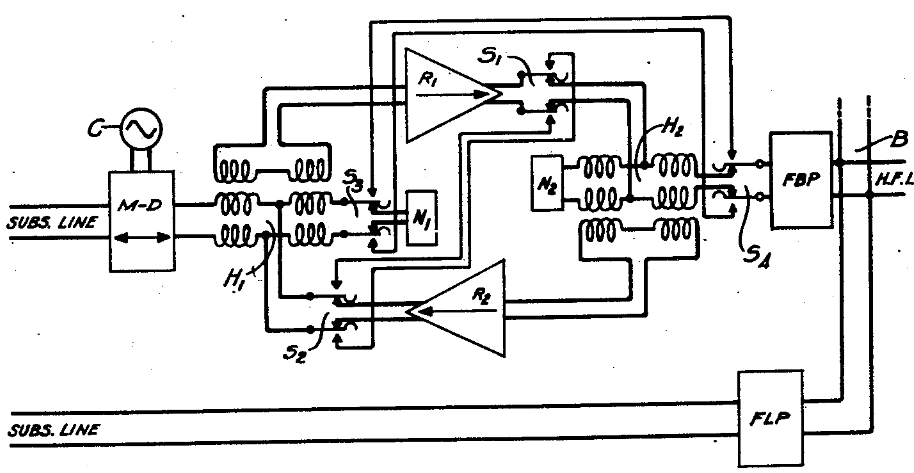


Fig. 3



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FREQUENCY TRANSLATING SYSTEM

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This invention relates to frequency translation of electric waves and particularly to a system which may be operated to effect modulation and detection.

An object of the invention is to effect modulation and detection in a system including rectifiers, and particularly copper oxide rectifiers.

Another object is to prevent undesired currents, either impressed upon or developed by the normal operation of the modulator, from being transmitted to circuits external to but associated with the modulator.

In accordance with the present invention the modulating system comprises at least four rectifying elements arranged in pairs and having each pair connected in push-pull or balanced relation. The push-pull pairs are interconnected in such manner as to provide a system having but one pair of terminals, at each side of the system, for connection to an external circuit. A source of carrier waves is associated with the modulator.

Since the rectifying-modulating system has only two pairs of binding posts or terminals through which connection is made to external circuits at the respective sides thereof, it is possible to utilize the system for combining a carrier wave with a modulating current supplied by a source over the external circuit connected to one pair of terminals and to detect a modulated wave supplied by another source over the external circuit connected to the other pair of terminals, without requiring the use of switching means for changing over from one function to the other.

The use of a double balanced circuit tends to prevent waves or currents impressed upon the rectifiers through one of the external circuits from being transmitted to the other external circuit and the other wave source. It also permits the elements of the circuit to be so connected as to balance out certain distorting currents, produced by the normal operation of the rectifiers, which would tend to flow through the external circuits and the wave source.

The invention will be more fully described hereinafter with reference to the drawings in which Fig. 1 shows a double balanced system for effecting modulation and detection in accordance with the invention, and Figs. 2 and 3 show portions of a carrier wave multiplex system embodying a combined modulator and detector.

The system shown in Fig. 1 employs four rectifying units or wave detecting devices 1, 2, 3 and 4. Any device which has a different degree of conductivity for currents in the two directions therethrough may be used. A device which has high conductivity in one direction and practically none in the other is preferable. For this purpose a rectifier composed of one or more discs of copper, each disc coated with copper oxide on one surface and separated from adjacent discs by lead spacers, has proved to be well suited. To facilitate balancing the system, it is generally convenient to use four substantially identical rectifiers.

Three pairs of terminals, 5—6, 7—8 and 9—10 are shown, although only two pairs are intended for connection to external circuits. The third pair is provided for connection to a source supplying carrier waves to the modulator-detector.

For reasons which will be set forth hereinafter and when the circuit is used for the purpose of combining a carrier wave with a modulating current to produce side-bands, it is often preferable to connect the carrier source to one of the terminal pairs 7—8 or 9—10. The second of these pairs, 9—10 or 7—8, is connected to a load circuit, transmission line or antenna system adapted for the transmission of a modulated carrier wave. The remaining pair 5—6 is connected to a source of signaling or modulating current.

For purposes of disclosing one embodiment of the invention, the circuit of Fig. 1 will be described on the basis that it is to be used for the purpose of combining a signal or modulating current with a carrier wave to produce a signal modulated wave and on the assumption that the carrier source is connected to terminals 7—8, that the modulated wave is to be supplied to an external circuit through terminals 9—10, and that the source of modulating current is connected to terminals 5—6.

The various pairs of terminals are connected to the rectifying devices by means of the transformers 11, 12, 13 and 14 and the current leads 26 and 27.

The transformer 11 includes a primary winding 15 and a secondary winding 16. The ends of winding 15 are connected to the terminals 5 and 6 respectively.

Transformer 12 includes a balanced pair of windings 17 and 18, and a third winding 19. Transformer 13 includes a balanced pair of windings 21 and 22, and a third winding 20. These windings are also balanced in the additional pairs 17—22, 18—21, 17—21, 18—22, and 19—20. It is generally convenient and conducive to complete balancing to make transformers 12 and 13 substantially identical.

Transformer 14 includes a pair of balanced windings 23—24 and a third winding 25, the terminals of the latter winding being connected to terminals 9 and 10.

Rectifying devices 1 and 2, conductively opposed, are connected in series with the windings 17 and 18. Rectifying devices 3 and 4, also conductively in opposition, are connected in series with windings 21 and 22.

The two ends of the winding 16 are connected respectively to the junction 28 of devices 1 and 2 and the junction 29 of devices 3 and 4. Lead 26 provides a direct connection between the junction 28 and the common terminal 30 of windings 21 and 22. Lead 27 provides a direct connection between the junction 29 and the common terminal 31 of windings 17 and 18.

The windings 19, 20, 23 and 24, connected in series, comprise a coupling circuit generally designated hereinafter by reference numeral 40. Terminal 7 is connected to the junction 32 of windings 19 and 20 and terminal 8 is connected to the junction 33 of windings 23 and 24.

The system shown in Fig. 1 is so balanced that the sources of modulating current and carrier wave, connected respectively to the terminal pairs 5—6 and 7—8, are substantially prevented from transmitting current of their respective frequencies into circuits connected to the other pairs of terminals.

For example, modulating currents from the source connected to terminal pair 5—6, flowing in winding 15 will, during one-half cycle, set up a current upwardly through winding 16 into lead 26 and returning to winding 16 by two parallel paths comprising, respectively, winding 21 in series with rectifier 3 and winding 22 in series with rectifier 4. Since windings 21 and 22 are balanced, no appreciable current is induced in circuit 40 during this half cycle.

During the remaining half cycle a current is set up in a direction downwardly through winding 16 into lead 27 and returning to winding 16 by two parallel paths comprising, respectively, winding 17 in series with rectifier 1 and winding 18 in series with rectifier 2. Windings 17 and 18 being balanced, no appreciable current is induced in circuit 40 during the second half cycle.

Since no appreciable currents are set up in circuit 40 during either of the half cycles of the modulating current, no appreciable amount of modulating current is transmitted to either pair of terminals 7—8 or 9—10 associated with that circuit.

On the other hand, waves supplied by the source through terminals 7—8 cause carrier currents to flow through two parallel paths comprising, respectively, windings 19 and 24 in series and windings 20 and 23 in series. Due to the fact that windings 23 and 24 are balanced, no appreciable carrier current is transmitted to the terminal pair 9—10.

Furthermore, during one-half cycle of the carrier wave, the carrier currents in windings 19 and 20 set up electromotive forces in windings 17 and 22 in such directions as to aid each other in producing a current flow in the circuit through winding 17, rectifier 1, lead 26, winding 22, rectifier 4 and lead 27 back to winding 17. By virtue of the balance between windings 17 and 22, there is no difference of potential at carrier frequency between the leads 26 and 27, so that no appreciable carrier current flow is produced in winding 16, which is connected across the leads 26 and 27. Therefore, no appreciable current is induced in winding 15 and transmitted to the terminal pair 5—6.

Similarly, during the remaining half cycle of the carrier wave, the carrier currents in windings 19 and 20 set up electromotive forces in windings 18 and 21 in such directions as to aid each other in producing current flow in the circuit through winding 18, rectifier 2, lead 26, winding 21, rectifier 3 and lead 27 back to winding 18. Due to the balance between windings 18 and 21, the carrier frequency potential of the leads 26 and 27 continue to remain equal to each other and therefore no appreciable carrier current flow is produced in winding 16 and transmitted to terminal pair 5—6.

Since no appreciable currents are transmitted to either pair of terminals 5—6 or 9—10 during either of the half cycles of the carrier wave, it follows that no appreciable carrier currents are directly transmitted from the source, connected to terminals 7—8, to either of the other pairs of terminals.

Currents from the carrier and modulating sources are, however, transmitted through the paths traced above to the rectifying devices 1 to 4 inclusive, wherein they are combined to produce a modulated wave.

The modulated wave comprises components in various phases. Certain of these components transmitted through transformers 12 and 13 and circuit 40 to the windings

23 and 24, are in such phase relationship in these windings that they additively affect the winding 25. However, other components which tend to produce distortion are balanced out in transformers 12 and 13 or; if transmitted to circuit 40, are opposed to one another in windings 23 and 24 and do not induce appreciable current flow in winding 25.

In a similar manner, certain of the current components produced by the rectifying devices and flowing through the windings of the transformers 11, 12 and 13, are in such phase relationships that they are additively effective in the circuits associated with terminals 5—6, 7—8 and 9—10, while certain other components, which cause distortion, are subtantially prevented from inducing currents therein.

While in describing the operation of the system of Fig. 1, it has been assumed that the carrier wave source is connected to terminals 7—8, the source of modulating current to terminals 5—6, and the load circuit to terminals 9—10, it is not necessary that the connections be made as assumed.

In general, the carrier wave source may be connected to any desired pair of terminals, 5—6, 7—8, or 9—10, the source of modulating current may be connected to either of the remaining two pairs, and the load circuit may then be connected to the third pair of terminals.

In many practical cases the carrier wave and the side bands produced by modulation lie relatively close together in respect to frequency. In such cases, the modulating current generally comprises components having frequencies comparatively remote from the frequency range of the carrier and side bands.

It is often advantageous, therefore, to connect the carrier source and the load circuit to which the modulated wave is to be supplied to the terminals 7—8 and 9—10, as assumed above. The transformers 12 and 13, which are employed to connect the carrier and side band circuits to the rectifiers, may then be designed expressly for use in the frequency range occupied by the carrier and side bands. There is then no necessity for any transformer in the system to transmit efficiently current components lying in bands separated by a relatively wide frequency interval.

In the example discussed above, the terminals 5 and 6 are connected to the source of modulating current and transformer 11 is designed solely for use in the frequency range of the modulating current.

While the system of Fig. 1 has been described as a modulating system it is obvious that the same system may be employed as a detector or demodulator, since the process of detection or demodulation does not differ essentially from the process of modulation, as is well known.

To effect demodulation in the system of Fig. 1, a source of modulated waves is applied to one pair of terminals and the carrier source is applied to another pair. The demodulated or detected currents are then supplied, through the third pair of terminals to a load circuit, transmission line, or the like.

Preferably, the carrier source is connected either to pair 7—8 or pair 9—10. The second pair, whether 9—10 or 7—8, is connected to the source of modulated waves. The remaining pair 5—6 is connected to the load circuit.

Assuming the source of modulated waves to be connected to the pair 9—10, modulated waves are transmitted to circuit 40 from this source by transformer 14. On account of the balance existing between windings 19 and 20 and also between windings 23 and 24, the modulated waves will cause equal potentials to be applied to the terminals 7 and 8. The source is, therefore, prevented from producing an appreciable current flow in a circuit connected to the terminals 7—8.

The source of modulated waves is likewise prevented from producing appreciable current flow in a circuit connected to terminals 5 and 6, by virtue of the balance between certain windings of transformers 12 and 13.

During one-half cycle of the modulated wave, the modulated currents in windings 19 and 20 set up electromotive forces in windings 17 and 21 in such directions as to aid each other in producing a current flow in the circuit through winding 17, rectifier 1, lead 26, winding 21, rectifier 3, and lead 27 back to winding 17. By virtue of the balance between windings 17 and 21, potentials developed in the leads 26 and 27 remain equal to each other, so that no appreciable current flow is produced in winding 16, bridged across leads 26 and 27. Therefore no appreciable current is induced in winding 15 and transmitted to circuit connected to terminals 5—6.

During the remaining half cycle of the modulated wave, the modulated currents in windings 19 and 20 set up electromotive forces in windings 18 and 22 in such directions as to aid each other in producing current flow in the circuit through winding 18, rectifier 2, lead 26, winding 22, rectifier 4 and lead 27 back to winding 18. Due to balance between windings 18 and 22, potential applied to the leads 26 and 27 continue to remain equal to each other and, therefore, no appreciable current flow is produced in winding 16 and transmitted through transformer 11 to terminals 5—6.

Since no appreciable currents are transmitted to either pair of terminals 5—6 or 7—8 during either of the half cycles of the modulated wave, it follows that no appreciable modulated currents are directly transmitted from the source, connected to terminal pair 9—10, to either of the other pairs of terminals.

It follows generally from the above description that a source of current, connected to any one of the three pairs of terminals 5—6, 7—8 or 9—10, is substantially shielded from currents transmitted from a source connected to one of the remaining pairs of terminals.

Also, currents supplied by a source connected to any one of the terminal pairs will induce currents which are supplied to at least two of the rectifying devices.

Furthermore, no wave filters are necessary to prevent direct transmission of currents from one source into a circuit connected to another source of current.

Fig. 2 represents diagrammatically a portion of one terminal of a carrier wave multiplex transmission system, showing means for connecting two lines, for example, two telephone subscribers' lines, to a main line suitable for high frequency transmission. M—D is a combined modulator and detector of the type shown in Fig. 1. The subscriber's line L_1 constitutes a source of modulating current. R is a two-way repeater or amplifier which constitutes a means for transmitting a modulated carrier wave.

The three pairs of terminals of the modulator-detector are connected respectively to the subscriber's line L_1, the carrier wave generator C and the repeater R, either in the preferred order hereinbefore recommended or in any other desired order. The repeater R is also connected through a band pass filter FBP to the high frequency line.

A second subscriber's line L_2 is connected to the same high frequency line through a low pass filter FLP.

The system of Fig. 2 may be operated either to modulate a carrier wave, supplied by generator C in accordance with a signaling current from the subscriber's line L_1, to produce a modulated carrier wave which is repeated by R and transmitted through filter FBP to the high frequency line, or it may be used to receive from the high frequency line a modulated wave which is selectively transmitted through the filter FBP, amplified in repeater R and detected in the modulator detector M—D to produce a signal current which is supplied to the line L_1. In accordance with well known principles of multiplex practice, the subscriber's line L_2 may be used at the same time to transmit telephone or telegraph signals without employing a carrier wave.

Fig. 3 shows a portion of a multiplex system embodying a particular form of two-way amplifier or repeater which may be used in place of the repeater R in the system of Fig. 2.

With the exception of the amplifier, Fig. 3 is identical with Fig. 2, and for that reason only the amplifier will now be described.

The amplifying system of Fig. 3 comprises two repeating elements R_1 and R_2 associated with the hybrid coils H_1 and H_2. The hybrid coils are balanced by means of networks N_1 and N_2.

The amplifier R_1 is employed to amplify a modulated wave produced by the modulator-detector M—D, while the amplifier R_2 is employed for amplifying modulated waves incoming from the high frequency line.

As is well known in the art, one amplifier, for example R_1, may serve to amplify all the modulated waves, whether incoming or outgoing. In this case, the output leads of amplifier R_1 are connected to the hybrid coil H_1, in place of the output leads of amplifier R_2, and the associated network N_1 is replaced by direct connections to the filter FBP. This may be done by throwing all of the double-pole, double-throw keys or switches S_1, S_2, S_3, S_4, out of engagement with their respective inner pairs of contacts and into engagement with their respective outer pairs of contacts. Amplifier R_2, hybrid coil H_2 and network N_2 are thereby disconnected.

Branch circuits B, B are provided in the systems of Figs. 2 and 3 for connecting the high frequency line to additional carrier wave communication channels (not shown) which may be operated, if desired, in conjunction with the apparatus which has been described.

What is claimed is:

1. A frequency translating system comprising at least four rectifying elements, said elements being balanced in pairs and one of said pairs being associated with another of said pairs in balanced relation, a plurality of circuits for supplying said rectifying elements with currents to be translated and a load circuit for utilizing translated currents; said current supplying circuits and said load circuit being connected respectively to said rectifying elements, and said balanced arrangement being effective to prevent direct transmission between any two of said aforementioned circuits.

2. A frequency translating system comprising at least four substantially unidirectional conductors, said conductors being arranged in pairs and in conductive opposition to each other in each pair, one of said pairs being associated with another of said pairs in balanced relation, a plurality of circuits for supplying said unidirectional conductors with currents to be translated and a load circuit for utilizing translated currents; said current supplying circuits and said load circuit being connected respectively to said unidirectional conductors and said balanced arrangement being effective to prevent direct transmission between any two of said aforementioned circuits.

3. A combined modulating and detecting system comprising a source of carrier waves,

a load circuit including an associated source of modulating current, a second load circuit including an associated source of modulated waves to be detected, at least four rectifying elements, means connecting each of said load circuits and each of said sources respectively with all of said rectifying elements whereby said elements are effective to cause modulation of said carrier waves and detection of said modulated waves, said connecting means being balanced to prevent direct transmission between any two of said sources.

4. A combined modulating and detecting system comprising a source of carrier waves, a load circuit including an associated source of modulating current, a second load circuit including an associated source of modulated waves to be detected, at least four rectifying elements, means connecting each of said load circuits and each of said sources with all of said rectifying elements, whereby said elements are effective to cause modulation of said carrier waves and detection of said modulated waves, with incidental generation of distorting currents, said connecting means being balanced to prevent direct transmission between any two of said sources and to reduce the transmission of said distorting currents into said load circuits.

5. A terminal circuit for a high frequency signaling system comprising a subscriber's line, a high frequency line, a source of carrier waves and a combined modulator detector including at least four rectifying elements connected in balanced arrangement whereby direct transmission between said lines and between said source and each of said lines is prevented.

In witness whereof, I hereunto subscribe my name this 4th day of April, 1929.

CLYDE R. KEITH.