Feb. 6, 1945. C. B. WATTS, JR 2,368,693

MODULATION SYSTEM

Filed July 4, 1942

FIG. 1

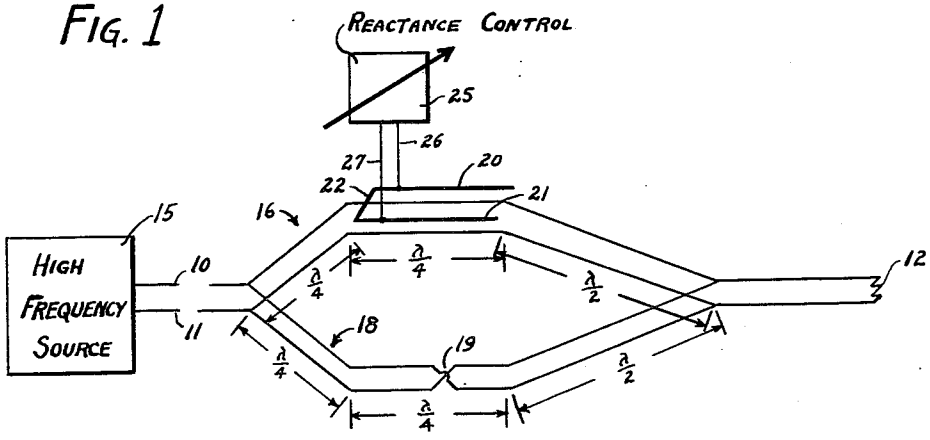


FIG. 2

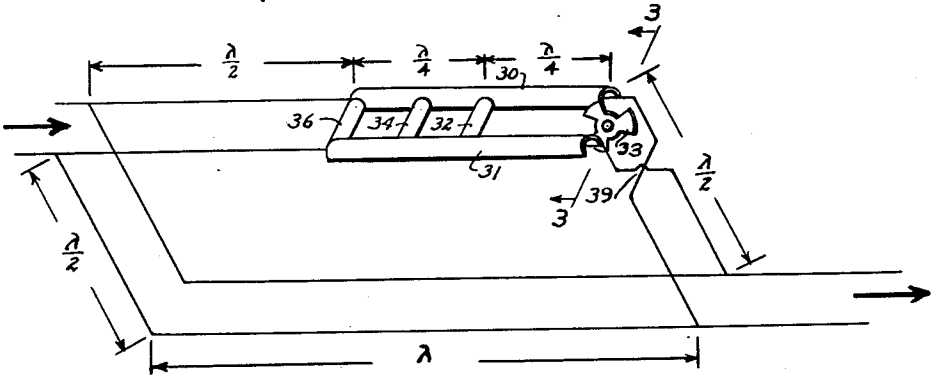
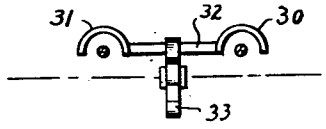


FIG. 3



INVENTOR
CHESTER B. WATTS JR.
BY Paul R Adams
ATTORNEY

Patented Feb. 6, 1945 2,368,693

UNITED STATES PATENT OFFICE

2,368,693

MODULATION SYSTEM

Chester B. Watts, Jr., East Orange, N. J., assignor to Federal Telephone and Radio Corporation, a corporation of Delaware

Application July 4, 1942, Serial No. 449,829

11 Claims. (Cl. 179—171.5)

This invention relates to modulators and more particularly to modulation systems having a coupled network capable of effecting broad frequency band operation.

It is known, as set forth in the patent to Andrew Alford, No. 2,159,648, dated May 23, 1939, that a network comprising a two-wire line one quarter wavelength long short circuited at one end and open circulited at the other end and located adjacent a transmission line, the network will operate as a current cut-off for the line when tuned to resonance at the frequency of the current carried by the line. That is to say, the resonant condition of the network produces large voltages in the transmission line which effectively block or prevent the flow of the current at such frequency past the point where the network is coupled. However, when such a network is slightly detuned from the frequency of the energy carried by the transmission line, it will have substantially no effect upon the transmission along the line of the current having that frequency. It is this phenomenon that is employed for modulation purposes in the patent to Andrew Alford, No. 2,244,756, dated June 10, 1941.

The modulation feature disclosed in the Patent No. 2,244,756, is effected by alternately tuning and detuning the network to effect the desired control of the current carried by the transmission line. This alternate tuning and detuning is accomplished by varying the reactance of the network.

It is clear that the coupling coefficient of the resonant network varies inversely to the distance between the conductors of the network and the conductors of the transmission line. As hereinbefore suggested, the network is usually loosely coupled to the line, and the blocking control of the network therefore required close tuning; thus, should the frequency of the blocked current vary from the frequency at which the network is tuned the resonance voltages will rapidly decrease and permit the flow of current. In other words, the effective blocking of current is limited to a very narrow wave band and the effective blocking of a current along the transmission line is dependent upon the maintenance of a substantially constant frequency. It is not always possible, however, to obtain a source of high frequency current, the frequency of which is constant. The frequency of most such sources drifts somewhat from time to time. Furthermore, there are circuits in which the carrier frequencies are purposely varied or wobbled as disclosed in the patent to Alford, No. 2,241,897, dated May 13, 1941. Still other circuits are intended for broad frequency bands such as where modulation is imposed upon a carrier frequency.

Such systems as hereinbefore described are quite satisfactory for tuning relatively narrow frequency bands. Where the frequency of the current to be modulated drifts or is purposely varied, the tuning of a modulating network to the frequency band of the current may not effect sufficient blocking of the current to produce a detectable difference in the transmission thereof for signal modulation purposes.

I have discovered a modulation network system wherein even a slight current blocking effect by a network produces a detectable signal. Thus in accordance with my discovery, I am able to produce detectable and therefore effective modulation over a relatively wide frequency band.

I accomplish this in accordance with my invention by providing a loop circuit in the transmission line, the two sides of the loop circuit being equal in length electrically with the conductors of one of the sides transposed, and a resonance network coupled to one of the sides of the loop. When the network is untuned, it has substantially no effect upon the current and the current carried by the transmission line is divided equally between the two sides of the loop, and since the conductors of one of the sides are transposed, the two components of the current carried by the two sides neutralize at the output side of the loop. When the network is tuned to resonance at or near the frequency of the current carried by the transmission line, it tends to block the passage of current in the side of the loop with which the network is coupled. This blocking of the current in one side of the loop results in an unbalanced flow of current in the two sides of the loop. Thus, whenever the network is tuned sufficiently to alter the flow of current in the side of the loop with which the network is coupled, an unbalanced flow results thereby producing an output flow proportional to the blocking effect of the network.

It will be clear, therefore, that when the network is untuned, no resulting output flow will result and when the network is tuned, a resulting output flow will result.

This feature of my invention is thus distinguished from prior modulation network systems which cause a decrease in current flow upon the resonance tuning of the coupled network. In existing prior network systems, a current flow exists until the network is tuned to resonance at the frequency of the current and should the

frequency of the current drift from the frequency to which the network is tunable, the effect of the network is very small and an effected decrease in current may be difficult to observe as signal modulation.

In my modulating system there is no current flow when the network is untuned. When the network is tuned, even though partially, the resonance effect produces a resultant output flow of current which is readily observable as a signal.

The effective width of frequency band modulation of my invention may be expanded by increasing the capacity relationship between the conductors of the network and the conductors of the transmission line similarly as disclosed in a copending application of Andrew Alford, Serial No. 453,866, filed August 6, 1942. That is to say, the effective frequency band of my modulation system may be enlarged by increasing in size or cross-wise dimensions and/or by changing the shape of the network conductors so that the conductors are wider than and have overlapping or partially encompassing relationship either horizontally, vertically, or otherwise with the conductors of the transmission line with which the network is associated. The coupled network may also be extended for a quarter wavelength beyond the shorted end thereof and such extension short-circuited at one or more points therealong to avoid objectionable standing waves in the transmission line when the network is detuned similarly as disclosed in the aforementioned copending Andrew Alford application.

One of the objects of this invention, therefore, is to provide a wide frequency band modulation network system and a feature of the invention is a modulation network system which, when the network is untuned, it prevents passage of current and when tuned to resonance at or near the frequency of the applied current, it produces an output flow of current from the loop.

The above object and others ancillary thereto will become more apparent upon reference to the following detailed description to be read in connection with the accompanying drawing in which,

Fig. 1 is a schematic illustration showing one form of this invention;

Fig. 2 is a schematic illustration of an additional form of the invention; and

Fig. 3 is an end view of the coupling shown in Fig. 2 taken along line 3—3 of Fig. 2.

Referring to Fig. 1 of the drawing, a two-wire transmission line 10, 11 is shown connecting a load 12, which may be an antenna, through a loop circuit to a source of high frequency current 15. The loop circuit comprises two sides 16 and 18 which are substantially equal in length electrically. Each side may be in the order of one wavelength long or multiples of one-half wavelength in addition. The conductors of one side of the loop are transposed as at 19. When the two sides of the loop are unaffected by extraneous influences, the current from the source 15 divides substantially equally between the two sides 16 and 18 of the loop and the two components thereof, being in opposite phase due to the transposition of conductors at 19, neutralize each other. Thus, normally no output current will be delivered to the load 12.

To one side of the loop circuit is coupled a resonance network comprising two parallel conductors 20 and 21 substantially a quarter wavelength long and short circuited at one end by a conductor 22, the opposite end of the parallel conductors 20, 21 being open circuited. The reactance of the network is preferably such that the network normally will not become resonant to the frequency of the current carried by the transmission line. In order to tune the network to resonance condition, a variable control 25 may be provided to vary the reactance of the network. The reactance control may comprise any suitable reactance variation means such as a form of variable condenser. As shown in Figs. 2 and 3 for example, the reactance control may comprise a slotted condenser disc movable relative to the open ends of the conductors 20 and 21. The reactance variation means may comprise a similar condenser arrangement located remote to the coupling and connected thereto by the leads 26 and 27.

The effect of the coupled network, when tuned, being substantially to produce in the line to which it is coupled at a point near the open end of the coupled network a condition of high impedance; the open end of the network should be preferably located a half wavelength or multiples thereof from both the input and the output terminals of the loop. The reason for this is that the side of the loop containing the coupled network, when tuned, will then represent a relatively high impedance bridged across the other side of the loop (that is, the side doing the transmitting) and thus a condition of high efficiency of power transfer may be achieved.

In contrast, for example, the open end of the coupled section should not be placed a quarter wavelength or odd multiple thereof from the input terminals of the loop for in that case a virtual short circuit would be placed across these terminals, and the efficiency of power transfer would be very low whether the coupled network is tuned or detuned.

It does not matter toward which end of the loop circuit the open end of the coupled network faces.

In Figs. 2 and 3 I have shown a network having conductors 30 and 31 the cross-sections of which are extended so as to partially encircle or encompass the conductors of the line. This encompassing relationship of the conductors of the network relative to the line greatly increases the capacity and therefore in effect more tightly couples the network to the line without bringing closer together the coupled conductors. While the conductors 30 and 31 of the network are shown to be arcuate in cross-section, it will be understood that they may be of any other suitable shape so as to provide an extended cross-wise or encompassing area adjacent the conductors of the transmission line.

This increased capacity relationship between the network conductors and the line conductors increases correspondingly the width of the frequency band effectively blocked or partially blocked by resonance tuning of the network.

When the network is tuned for a given frequency, for example, the establishment of high voltages in the transmission line due to the resonant condition of the network effectively blocks currents of frequencies within a short range above and below the given frequency. Thus, when the carrier current of the transmission line drifts or is wobbled or modulated within the effective frequency band of the network, such variation will not pass beyond the current blocking function of the network.

The tuning and detuning of the network shown in Figs. 2 and 3 are accomplished by the provi-

sion of a slotted condenser plate 33 disposed between the open ends of the conductors 30 and 31 and driven by any suitable source of power such as an electric motor. The number of slots and the speed of rotation determines the modulation frequency of the system, that is, the rate of tuning and detuning of the network and, therefore, the blocking and unblocking of the flow of current in the side of the loop circuit with which the network is coupled. As hereinbefore described, the tuning and detuning of the coupled network controls the flow of current from the output side of the loop. The loop circuit shown in Fig. 2 is in the order of half wavelengths, each side being one and a half wavelength long. It is immaterial which side of the loop contains the transposition and as shown in Fig. 2, the transposition 39 may be located in the same side of the loop with which the network is coupled.

As disclosed in the aforementioned Andrew Alford application, the conductors 30 and 31 of the network may be extended beyond the short circuiting conductor 32 for a distance of approximately one quarter wavelength. This extension is short circuited at spaced points therealong by conductors 34 and 36. No particular spacing of the short circuiting conductors is necessary other than to avoid an unshorted length of line approximating a quarter wavelength. This short circuited extension of the network provides in addition to the active quarter wavelength section, an inactive quarter wavelength, the overall length of the network being substantially a half wavelength. Such overall length of network has the same surge impedance effect as if the transmission line had inserted therein an enlarged conductor section a half wavelength long. It is known that while such an enlarged conductor section will produce reflections at the ends thereof, that such reflections balance each other so that while standing waves may occur in the enlarged conductor section of the line, no standing waves will be produced in the line beyond the ends of the enlarged section. It follows, therefore, that standing waves will not occur in the transmission line beyond the ends of the network when the network is not tuned to or near the frequency of the current carried by the transmission line. Thus, even though the conductors of the network provide increased capacity with respect to the line of the loop circuit, they do not produce any net impedance effect upon the line when the network is untuned and therefore, do not alter the equal division of current between the two sides of the loop. A modulator construction in accordance with my invention will thus produce a modulating effect by producing an output flow of impulses in accordance with the tuning and detuning of the coupled network. It will also be clear that this manner of modulation increases the width of the effective detectable frequency band.

While I have shown two forms of loop and coupling network arrangements, I recognize that many different variations in the arrangement as well as the selection of reactance control means for the network may be made without departing from the invention. It will be understood, therefore, that the forms herein shown and described are to be regarded as illustrative of the invention only and not as restricting the appended claims.

What I claim is:

1. A modulating network system for high frequency transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to multiples of a half wavelength and the conductors of one side of the loop being transposed, a quarter wavelength network tunable to the frequency of the current carried by the line, said network being coupled to one side of said loop at a point one-half wavelength or multiples thereof from both the input and output terminals of said loop, so that when the network is untuned the current divides equally between the two sides and the two components thereof neutralize, and when the network is tuned the components of the current flowing through the two sides become unbalanced thereby resulting in an output current.

2. A modulating network system for high frequency transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to multiples of a wavelength and the conductors of one side of the loop being transposed, a network coupled to one of the sides of said loop at a point one-half wavelength or multiples thereof from both the input and output terminals of said loop, and means to vary the reactance of said network to tune and detune the network in relation to the frequency of the current carried by the line, the detuning of the network permitting substantially equal division of current between the two sides of the loop whereby the two components neutralize each other, and the tuning of the network operating to unbalance the division of current flowing through the two sides thereby resulting in an output current.

3. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to multiples of a half wavelength and the conductors of one side of the loop being transposed, a network including two parallel conductors substantially a quarter wavelength long open circuited at one end and short circuited at the other end, the open circuited end of said network being coupled to one of the sides of said loop at a point one-half wavelength or multiples thereof from both the input and output terminals of said loop, and means to vary the reactance of said network to tune and detune the network in relation to the frequency of the current carried by the line, the detuning of the network permitting substantially equal division of current between the two sides of the loop whereby the two components neutralize each other, and the tuning of the network operating to unbalance the division of current flowing through the two sides thereby resulting in an output current.

4. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to multiples of a half wavelength and the conductors of one side of the loop being transposed, a network including two parallel conductors substantially a quarter wavelength long open circuited at one end and short circuited at the other end, the open circuited end of said network being coupled to one of said sides at a point one-half wavelength or multiples thereof from both the input and output terminals of said loop, and means to vary the

reactance of said network to control the flow of output current from said loop, said means comprising a condenser element movable relative to the space between the parallel conductors of said network.

5. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically and in the order of one wavelength, a network tunable to the frequency of the current carried by the line, including two parallel conductors substantially a quarter wavelength long open circuited at one end and short circuited at the other end, the open circuited end of said network being coupled to one of the sides of said loop at a point midway between the input and output ends thereof, so that when the network is untuned the current is divided equally by the two sides and the two components thereof neutralized, and when the network is tuned causing the current to flow unequally through the two sides thereby resulting in an output current.

6. A modulating network system for high frequency transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to one wavelength, a network tunable to the frequency of the current carried by the line, said network being coupled to one of the sides of said loop at substantially the midpoint thereof, and means to vary the reactance of said network to tune and detune the network in relation to the frequency band of the current carried by the line.

7. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically and the conductors of one side of the loop being transposed, a network tunable to the frequency of the current carried by said line, said network including two parallel conductors substantially a quarter wavelength long open circuited at one end and short circuited at the other end, each of the network conductors being substantially arcuate in cross-section and at least partially encompassing one of the line conductors of one of the sides of said loop.

8. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically and the conductors of one side of the loop being transposed, a network including two parallel conductors substantially a quarter wavelength long open circuit at one end and short circuited at the other end, each of the network conductors being substantially arcuate in cross-section and at least partially encompassing one of the line conductors of one of the sides of said loop, and means including a rotatable slotted condenser plate operable relative with respect to said parallel conductors to effect alternate tuning and detuning of the network with respect to a given frequency band.

9. A modulating network system for high frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically and the conductors of one side of the loop being transposed, a network coupled to one of the sides of said loop comprising a section having a pair of substantially quarter wavelength long parallel conductors open circuited at one end and short circuited at the other end and a second section having parallel conductors forming a continuation of the first mentioned section beyond the short circuited end thereof for a length in the order of substantially a quarter wavelength, and means short circuiting the conductors of the second section so that the impedance effect upon the one side of the loop by the network when untuned is equal to substantially a half wavelength of line of dissimilar impedance.

10. A modulating network for a transmission line connecting a load to a source of high frequency current comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically to one wavelength, a network tunable to the frequency of the current carried by said line, said network including two parallel conductors substantially a quarter wavelength long open circuited at one end and short circuited at the other end, said network being coupled to one of the sides of said loop at substantially the midpoint thereof.

11. A modulating network system for high-frequency two-conductor transmission lines comprising a loop circuit connectable in said line, the two sides of the loop being substantially equal in length electrically and the conductors of one side of the loop being transposed, a network tunable to the frequency of the current carried by said line, said network including two parallel conductors substantially a quarter wave-length long, open circuited at one end and short circuited at the other end, and respectively encompassing at least partially the line conductors of one of the sides of said loop.

CHESTER B. WATTS, JR.