Sept. 26, 1939.

J. PLEBANSKI

2,174,166

ELECTRICAL CIRCUITS

Filed Feb. 24, 1938

3 Sheets-Sheet 1

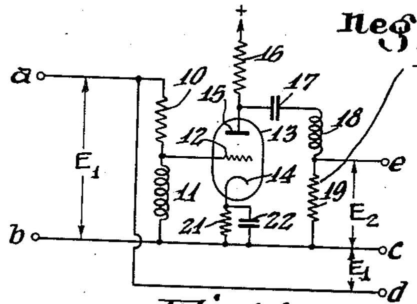

Fig. 1

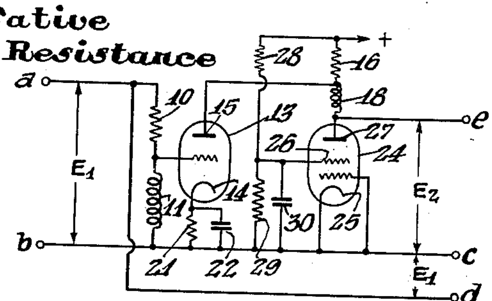

Fig. 2

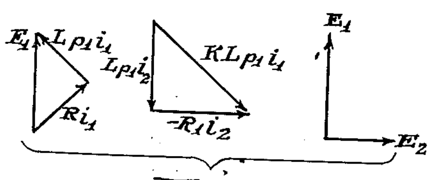

Fig. 3

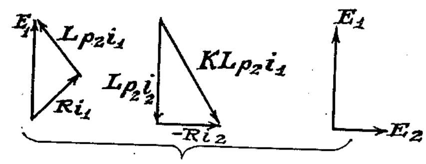

Fig. 4

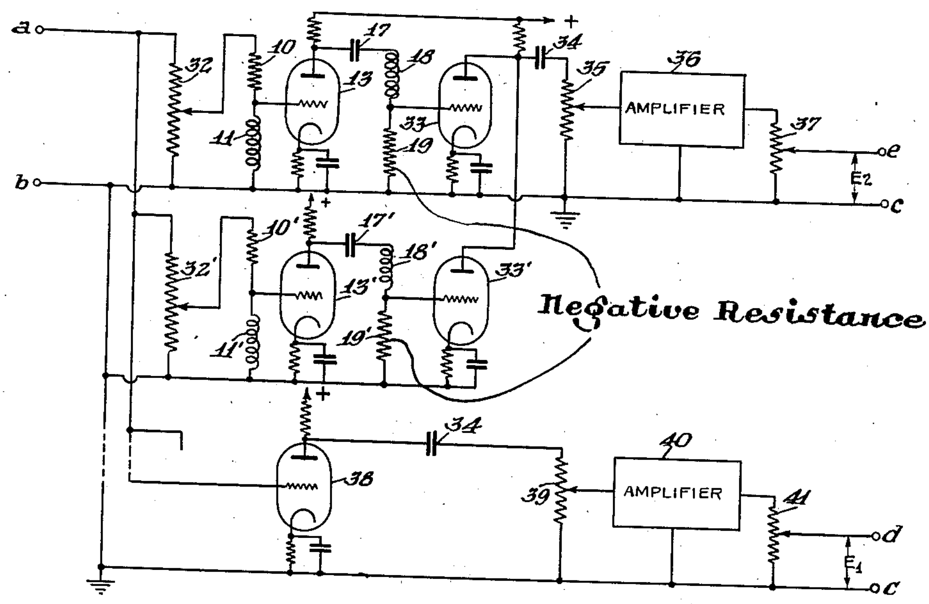

Fig. 5

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ELECTRICAL CIRCUITS

Filed Feb. 24, 1938 3 Sheets-Sheet 2

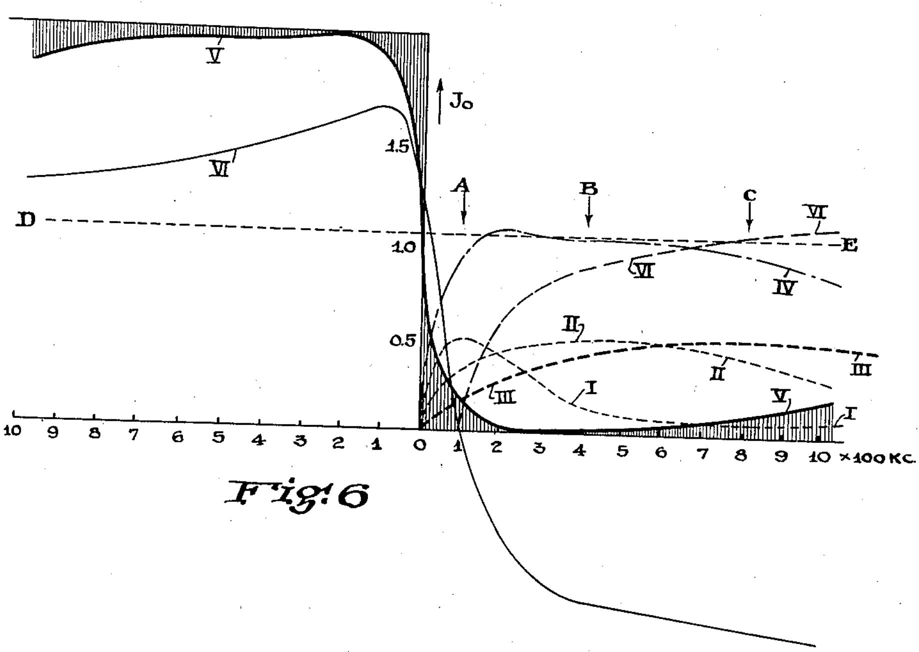

Fig. 6

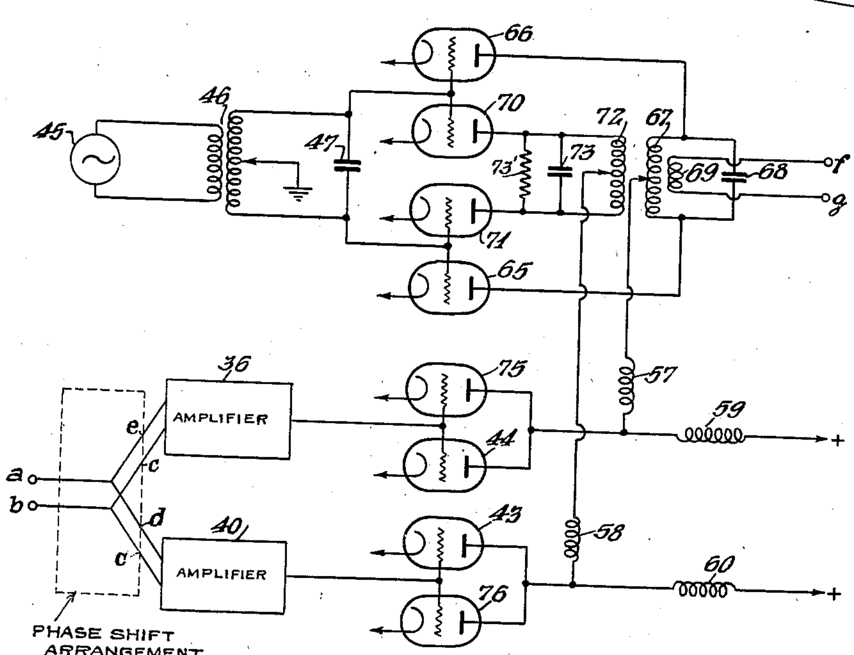

Fig. 8

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ELECTRICAL CIRCUITS

Filed Feb. 24, 1938 3 Sheets-Sheet 3

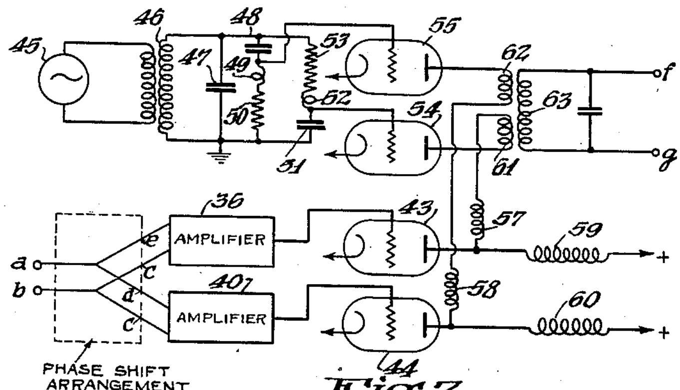

Fig: 7

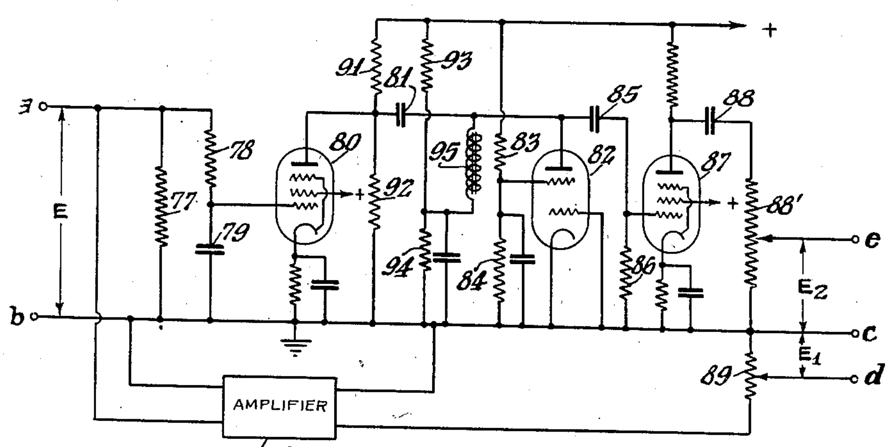

Fig: 10

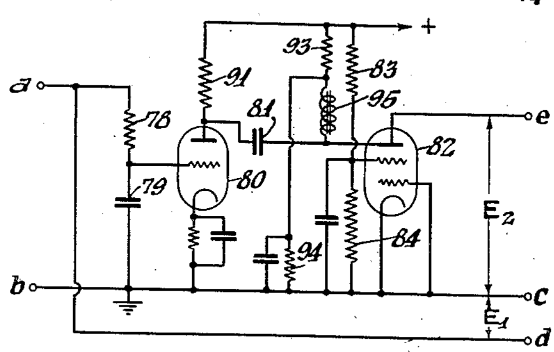

Fig: 9

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2,174,166

UNITED STATES PATENT OFFICE

2,174,166

ELECTRICAL CIRCUITS

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Application February 24, 1938, Serial No. 192,278
In Poland March 10, 1937

15 Claims. (Cl. 178—44)

The present invention relates to a system for and a method of simultaneously shifting the phases of a plurality of alternating currents such as the components of a signal current or potential wave in radio or other signalling systems.

The invention, while not limited thereto, has special use in one side band carrier signal transmission and reception for radio telephony, television and other signalling purposes. The advantages of single side band transmission, such as reduced transmitting power, improved transmitting channel facilities, and others are well known and are especially useful in the transmission of television signals by enabling the attainment of greater gain in the image or video signal amplifier, an increased number of scanning lines or greater detail of the picture for a given transmitting channel, and other desirable features well known.

However, owing to the extended signal frequency bands in television comprising from 500 to 1000 kc. and more, difficulties have been experienced in the past in employing the methods and systems for single side band transmission as known in other carrier signalling systems such as in carrier telephony wherein the side bands comprise a range of only about 5 to 10 kc.

One of the well known methods of side band suppression in carrier signal transmission is based on the addition or subtraction of two modulating products wherein the carrier and modulating frequencies are shifted in phase by 90° as illustrated by the following theoretical expressions well understood by those versed in the art:

$$(1)\quad A \sin wt + B \sin pt \sin wt = A \sin wt + \frac{B}{2}\cos(w-p)t - \frac{B}{2}\cos(w+p)t$$

$$(2)\quad A \cos wt + B \cos pt \cos wt = A \cos wt + \frac{B}{2}\cos(w-p)t + \frac{B}{2}\cos(w+p)t$$

wherein A represents the amplitude of the carrier current, B represents the amplitude of the modulating currents, $w/2\pi$ represents the carrier frequency and $p/2\pi$ represents the modulating frequency. Various systems and methods have been proposed for one side band elimination based on the above principle, all of which however suffer from the disadvantage that it is difficult to shift the phases of all components of an extended modulating frequency band or complex modulating signal wave equally by 90° or to adapt the system for modulating signals comprising an extended band of frequencies such as in television and other signalling systems. By the known arrangements and methods, practically a phase shift for a single modulated frequency only can be obtained.

The above difficulties are substantially overcome by the novel method and system proposed by the invention, according to which the quadrature or 90° phase shift of a plurality of alternating currents is effected by utilizing the potential drop across nonreactive and reactive impedances in series in conjunction with a compensating or equalizing system, resulting in the attainment of an exact 90° phase shift for each of a large number of frequencies such as those forming the components of a complex modulating current or potential wave and resulting in turn in a complete elimination of one side band of the modulated carrier output in systems operating on the principle as represented by the above Equations 1 and 2.

Accordingly it is an object of the invention to provide a novel method of and system for shifting the phase of alternating or oscillating currents, preferably intermediate frequency or high frequency currents, by a predetermined angle independently of the frequency of said currents.

Another object is to shift the phase angle of alternating or oscillating currents by 90° independently of and substantially without requiring additional adjustments for different frequencies of such currents.

A further object is to shift the phases of a plurality of alternating or oscillating currents simultaneously by equal angles without substantially affecting the relative amplitudes of such currents.

Still another object is to shift the phases of a plurality of alternating or oscillating currents simultaneously by 90° without substantially affecting the relative amplitudes of such currents.

Another object is the provision of a phase shift arrangement or network for alternating or oscillating currents adapted to shift the phases by a predetermined angle substantially independently of the frequency of such currents.

Still another object is the provision of a quadrature phase shift arrangement or network for alternating or oscillating currents adapted to shift the phase angles substantially independently of the frequency effective over a wide band of operating frequencies and without substantially affecting the relative amplitudes of such currents.

The above and further objects of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification, and wherein:

Figures 1 and 2 represent basic phase shifting circuits constructed in accordance with the invention,

Figures 3 and 4 show vector diagrams explanatory of the function and operation of the circuits according to Figures 1 and 2.

Figure 5 shows a system comprising a plurality of arrangements according to the invention to obtain a phase shift for an extended band of alternating or oscillating currents without substantially affecting the amplitude relation of such currents.

Figure 6 shows diagrams explanatory of the function and operation of the system shown in Figure 5,

Figures 7 and 8 illustrate by way of example single side band modulating systems embodying the improvements of the invention,

Figures 9 and 10 represent modified phase shifting networks constructed according to the invention.

Like reference characters identify like parts throughout the different views of the drawings.

Referring to Figure 1, there is shown a single phase shift circuit or network of the type proposed by the invention. The input current or potential E_1 whose phase angle is to be shifted and which may be the modulating current or potential in a carrier transmission system, is impressed through a pair of input terminals a and b upon a series network comprising a non-reactive or ohmic impedance **10** and a reactive impedance, in the example illustrated, an inductance **11**. A portion of the input energy is applied directly, that is, without phase shift, to the output terminals c, d as shown. The reactive potential drop developed across the inductance **11** being in quadrature to the potential drop across the resistance **10**, is impressed upon the grid-cathode path of an amplifying valve **13** having a cathode **14**, grid **12**, and a plate or anode **15**. The anode of the valve is connected to the positive pole of a high tension source indicated by the plus symbol through a load impedance such as a resistance **16**. There is further shown a second series network comprised of a self-inductance **18** and a non-reactive impedance or resistance **19** connected across the anode-cathode path of valve **13** directly or in series with a relatively large coupling capacity shown at **17**. Item **21** represents a resistance in the cathode lead of the valve shunted by a by-pass condenser **22** to provide adequate grid biasing potential in a manner well known. According to the present invention the non-reactive impedance or resistance **19** is of the "negative" type and may consist for instance of an oscillating detector crystal or a discharge valve connected and operated with a drooping or "negative" anode current-voltage characteristic such as shown in Figure 2.

In the latter, the resistance **19** is replaced by a screen grid type valve **24** having a cathode **25**, a control grid, which in the example illustrated is tied to the cathode, a screen grid **26**, and an anode or plate **27**. The anode current characteristic of the tube is rendered "negative" in a known manner by properly biasing the screen grid **26** to a positive potential derived from the junction point of a pair of resistances **28** and **29** connected between the positive pole of the high tension source and the cathode, resistance **29** being by-passed by a condenser **30**. As is understood, any other known device providing a "negative" resistance path may be employed for the purposes of this invention.

In an arrangement of the type described it can be shown that for certain relations between the inductances **11** and **18** and between the numerical values of the resistances **10** and **19**, the phase shift between the voltage E_2 developed across the resistance **19** or the valve **24** and the input voltage E_1 is exactly 90° substantially independently of the frequency and without substantially affecting the relative amplitudes of current comprising a substantial band of input frequencies. This is further explained by reference to the vector diagrams shown in Figures 3 and 4, wherein the inductances **11** and **18** and the numerical values of the resistances **10** and **19** are assumed to be equal to each other.

Referring to Figure 3, the left-hand diagram represents the potentials in the input circuit, Ri_1 representing the nonreactive potential drop across the resistance **10** and Lp_1i_1 representing the reactive voltage drop across the inductance **11**, whereby R represents the numerical value of the resistances, L the value of the self-inductances, i_1 the current flowing in the circuit and $p_1/2\pi$ is the frequency of the current. The potential drop Lp_1i_1 is repeated by the valve **13** whereby a potential KLp_1i_1 is obtained in the output circuit as shown in the central diagram of Figure 3, K being a constant including the amplification factor of the valve. This output or anode potential is equal to the vector sum of the potential drops developed across the inductance **18** and the "negative" resistance **19** as represented by Lp_1i_2 and $-Ri_2$ in the central diagram of Figure 3. Since the resistance R of **19** is negative, the rotation of the vectors has to be assumed in an opposite direction to the rotation of the vectors in the left-hand diagram of Figure 3 or in other words, the non-reactive potential leads the impressed potential and the inductive potential drop lags the impressed potential contrary to the case of a positive resistance. From the diagrams it is readily seen that the output potentials E_1 and E_2, which latter corresponds to the potential drop across the resistance **19**, are in phase quadrature to each other as desired.

Referring to Figure 4, there are shown the equivalent diagrams for a different frequency $p_2/2\pi$. In Figure 3 the frequency $p_1/2\pi$ was assumed to be of such a value that the inductive and ohmic potential drops across the resistance **10** and inductance **11**, respectively, were equal to each other. In the case of Figure 4, for a different frequency these potential drops will be no longer equal as shown in the drawings. However, if the values of the inductances **11** and **18** and the numerical values of the resistances **10** and **19** remain the same, the potentials E_1 and E_2 will also remain in exact phase quadrature; that is, they are independent of the frequency, as illustrated by the vector diagram according to Figure 4.

By theoretical analysis, the value for E_2 is found as follows:

$$(3)\quad E_2=-Ri_2=-\frac{KRLE_1}{R^2+p^2L^2}\sin\left(pt+\operatorname{arctg}\frac{R}{pL}+\operatorname{arctg}\frac{Lp}{R}\right)=-\frac{KRLpE_1}{R^2+p^2L^2}\sin(pt+90°)$$

wherein equal numerical values for the inductive and non-reactive impedances (R and L) have been assumed.

The same result is obtained if capacitative reactances in the form of condensers having a capacity C are provided in place of the inductances **11** and **18** such as shown at **79** and **81**, respectively, in Figures 9 and 10. In the latter case the expression for the output potential E_2 is found as follows:

$$(4)\quad E_2=-Ri_2=-\frac{KRE_1}{Cp(R^2+1/C^2p^2)}\sin\left(pt-\text{arctg}\frac{1}{RCp}-\text{arctg } RCp\right)$$
$$=-\frac{KRE_1}{Cp(R^2+1/C^2p^2)}\sin(pt-90^\circ)$$

In general, it is not necessary that the numerical values of the inductances **11** and **18** or other reactances used and of the resistances **10** and **19** be equal. For this general case the phase angle between the potentials E_1 and E_2 is found by analysis as follows:

$$(5)\quad \varphi=\text{arctg}\frac{R_1}{pL_1}+\text{arctg}\frac{pL_2}{R_2}=\text{arctg}\frac{R_1/pL_1+L_2p/R_2}{1-R_1/L_1p.L_2p/R_2}=\text{arctg}\frac{R_1/L_1p+L_2p/R_2}{1-R_1/L_1\times L_2/R_2}$$

wherein R_1 is the value of resistance **10**, R_2 the value of resistance **19**, L_1 is the value of inductance **11** and L_2 the value of inductance **18**. From the latter it is seen that in order to obtain a 90° or quadrature phase angle; that is for $\varphi=90°$, $\text{tg}\varphi$ must be equal to infinity or:

$$(6)\quad 1-\frac{R_1L_2}{L_1R_2}=0,\ \text{or}\ \frac{L_2}{L_1}=\frac{R_2}{R_1}$$

It is seen therefor, that for certain ratios between the reactive and non-reactive impedances, the angle φ will always be 90° independently of the frequency.

There is thus described generally by the invention, a system for shifting the phase angles of a plurality of alternating or oscillating currents such as the frequency components of a modulating current or potential wave by substantially equal amounts such as by 90° according to the example illustrated. To this end, the input potential is impressed upon a series network comprising a reactive and non-reactive or ohmic impedance to produce potentials of reactive and non-reactive character. The potential drop of one character developed across the one of said impedances is translated preferably uni-directionally such as through an amplifying valve and the translated potential impressed upon a second similar series network comprising a reactive and non-reactive or ohmic impedance, one of said non-reactive impedances being of the "negative" type. By choosing suitable ratios between the reactive and non-reactive impedances of said networks, the potential of opposite character derived from said second network will have a predetermined phase relation to the input potential substantially independently of the frequency and without substantial relative amplitude change for a substantial number of input currents or potentials covering an extended frequency range. By choosing equal ratios between the reactive and non-reactive impedance of said networks, a quadrature phase shift is obtained in the same manner as described and explained above. As is understood, the valve **13** may be omitted and the potential directly applied from the inductance **11** to the network **18**, **19**. Alternatively, the non-reactive potential developed by the resistance **10** may be transmitted and impressed upon the network **18** and **19** and the output potential derived from the inductance **18** for obtaining the same results. In all cases the phase of the potential E_1 is first rotated by a predetermined angle in one direction by the aid of a first series network **10**, **11** and thereafter the phase is further rotated in the same direction through a second series network (**18**, **19**) by an angle complementary to the first angle with or without additional 180° phase shift therebetween when using a vacuum valve as a transmitting element, or direct transmission, respectively, with the final result of a quadrature phase angle rotation substantially independently of the frequency of the input current or potential.

The above described phase shift will be exactly 90° or any other angle only if the inductances **11** and **18** in Figures 1 and 2 have no energy or current loss. If they have a slight resistance this can be compensated by a relatively large condenser placed in series with the resistance which condenser has a low reactance thereby to compensate for the resistance in the inductance. Similarly where condensers are used in place of the inductances, a small inductance may be provided in series with the resistance, such as shown in Figure 7. Alternatively, wire wound resistances may be used having a slight inductance for obtaining the same purpose.

Referring to Figure 6 of the drawings, there is shown at I a curve representing the amplitudes of the output potential E_2 as a function of the frequency obtained in arrangements of the type shown by Figures 1 and 2 for input potentials of constant amplitude. In the example illustrated the numerical values of reactive and ohmic resistances were chosen to be equal for a frequency of 100 kc. As is seen from this curve, the amplitudes of the phase shifted potentials remain practically constant over a band of about 500 kc. In order to extend the constant amplitude range over the entire modulating band, a plurality of arrangements according to Figures 1 and 2 may be connected in parallel, each being designed in such a manner as to have a different peak frequency; that is, a frequency for which $Lp=R$. In the figure there are shown the curves for three such arrangements I, II, III which when added will yield a resultant over-all fidelity curve shown at IV approaching more nearly the ideal curve or line D—E. As is understood, the curve IV may be further improved to approach the ideal by employing more than three arrangements designed with proper relative peak frequencies. For the curve IV the side bands in a single side band modulating system based on the principle according to the above Equations I and II, will appear as shown by curve V. On the left of the figure there is shown the side band to be transmitted and on the right the side band to be eliminated. It is evident that by using an arrangement according to the invention a substantially complete side band suppression can be effected with relatively simple means with high fidelity and substantially without amplitude and phase distortion. There is shown for comparison a curve VI obtained by the orthodox methods known in the art employing a single series network comprising a reactive and non-reactive impedance such as an ohmic resistance and a condenser. In the latter case, as is seen, practically only one modulation frequency, in the example illustrated the 100 kc. frequency, will disappear in the right-hand side band. In addition there is a phase change around 100 kc. resulting in distortion and other drawbacks well understood. The "negative" portion of the right side band has been shown as "positive" for better comparison (curve VI).

Referring to Figure 5, there are shown two phase shifting arrangements of the type according to Figure 1 connected in parallel, like elements in the two arrangements being designated by like primed numerals. The arrangements shown schematically comprise the valves **13** and **13'**, respectively, with input series networks **10**, **11** and **10'**, **11'**, output series networks **18**, **19** and **18'**, **19'** substantially similar as shown in the previous figures. There are further shown input potentiometer resistance **32** and **32'** for properly adjusting the amplitude of the input potentials. The phase shifted output potentials supplied from the "negative" resistances **19** and **19'** are impressed, respectively, upon the input of amplifying valves **33**, **33'**, the output of the latter being combined by directly connecting the plates of the valves. The combined output is impressed through a coupling condenser **34** and variable coupling resistance **35** upon a further amplifier **36** having a variable output resistance or potentiometer **37** connected to output terminals *c* and *e*. In order to compensate for the additional phase shift caused by the valves **13**, **33** and **13'**, **33'**, and the intercoupling elements therebetween, the in-phase potential transmitted to the output potentials *c* and *d* is similarly amplified by like amplifiers comprising a preamplifying valve **38** having a variable output resistance **39** and an amplifier **40** similar to amplifier **36** with a variable output resistance or potentiometer **41** connected to the terminals *c* and *d*.

Referring to Figure 7, there is shown a complete single side band modulating circuit for television or similar signal systems. Amplifiers **36** and **40** and associate phase shift arrangement may be similar to Figure 5 and serve to impress quadrature modulating potentials upon the grids of a pair of modulating valves **43** and **44**, respectively. The output potentials of the latter serve to modulate a pair of carrier current components having a 90° or quadrature phase relation in the manner illustrated by the above Equations 1 and 2. The quadrature carrier currents are derived from a source or oscillator **45** feeding a transformer **46** having a secondary tuned by a condenser **47**. There are connected across the secondary of the transformer **46**, a pair of circuit branches each comprising in series a capacity **48** and **51**, a small inductance **49** and **52**, and a nonreactive or ohmic impedance **50** and **53**, respectively. The potential at the junction between the condenser **48** and the inductance **49** is impressed upon the grid of a first power amplifier valve **55** and the potential at the junction between the condenser **51** and inductance **52** is impressed upon the grid of a second power amplifying valve **54**. By thus deriving the control potentials for the valves **54** and **55** from the reactive and non-reactive potential drops, respectively, developed in the branch circuit across the secondary of transformer **46**, the valves **54** and **55** are excited by quadrature potentials thereby producing quadrature currents in the output or plate circuits thereof. These output currents are modulated in accordance with the modulating potentials developed at the anodes of the valves **43** and **44**. To this end the anode of valve **43** is connected to the anode of valve **54** through an inductance **57** having a high impedance for the modulating current variations and a coupling coil **61**. Similarly the anode of valve **44** is connected to the anode of valve **55** through an inductance **58** and a coupling coil **62**. Items **59** and **60** are choke coils arranged in a known manner in the leads to the high tension source indicated by the plus sign. The coils **61** and **62** are coupled to a common tuned output circuit comprising an inductance **63** whereby a single side band modulated carrier current is obtained at the terminal *f* and *g* in a manner as is readily understood from the above. As is understood, any other known modulating method may be employed for the purpose of the invention differing from the anode or plate modulation shown for illustration.

Referring to Figure 8, there is shown a modified single side band modulating system. According to this embodiment the tuned secondary of the transformer **46** is arranged to excite two pairs of push-pull connected valves, the first pair comprising the valves **65** and **66** having a common resonant output circuit comprising inductance **67** shunted by a capacity **68**. The second pair comprises the valves **70** and **71** having a common tuned output circuit comprising an inductance **72** shunted by capacity **73**. The circuits **67**, **68** and **72**, **73** are mutually coupled with each other in such a manner that the currents flowing in the circuits have a 90° or quadrature phase relation. The tubes are modulated in push-pull by connecting the choke coils **57** and **58** to the central tap points of the inductances **67** and **72**, respectively. Item **69** is an inductance coil coupled with either of the inductances **67** and **72** and connected to the output terminals *f*, *g*. There are further shown in Figure 8 a pair of additional modulating valves **75** and **76** connected in parallel to the modulating valves **44** and **43**, respectively, to increase the modulating power in a manner well understood. Otherwise the circuit according to Figure 8 is substantially similar to Figure 7.

Referring to Figure 9, there is illustrated a modification of the invention wherein the inductances in the previous figures are replaced by capacitative reactances. In this embodiment the input potential is impressed from terminals *a*, *b* upon a series network comprising a resistance **78** and a capacity **79**. The reactive potential drop developed across the capacity **79** is impressed upon the grid cathode path of a valve **80**, the anode of which is connected to a series network comprising a capacity **81** and a "negative" resistance in the form of a valve **82** substantially similar as shown in the previous figures. The anode of valve **80** is connected to the high tension supply source through an output or load impedance **91**. The valve **82** has its screen grid properly biased by a connection to the junction of a pair of resistances **83** and **84** connected between the positive pole of the high tension source and the cathode or ground. The anode of valve **82** is connected to the positive pole of the high tension source through a choke coil of high inductance and a resistance **93**, the latter being further connected to ground through a resistance **94**. The various elements of the circuit have to be chosen in such a manner as to prevent the valve **82** from producing self-sustained oscillations. The value of the choke coil **95** should be sufficiently high in order to insure an exact quadrature phase shift including the lower frequencies. The resistance 91 and impedance of the valve 80 should be chosen so as to introduce sufficient damping for the valve 82 to prevent the generation of oscillations.

Referring to Figure 10, there is illustrated an arrangement substantially similar to Figure 9 wherein the phase shifted potential supplied by the "negative" resistance valve 82 is impressed through a coupling condenser 85 and coupling resistance 86 upon the grid of a further amplifying valve 87, the output of which is applied to terminals *c* and *e* through a coupling condenser 88 and variable coupling resistance 88'. In an arrangement of this type in order to compensate for the additional phase shift incurred by the reactances of the valves 80 and 87 and inter coupling elements 81, 85 and 88, a substantially similar amplifier 90 is preferably provided between the input terminals *a*, *b* and the output terminals *c*, *d*, with variable output resistance or potentiometer 89 for adjusting the amplitude of the non-shifted or in-phase output potential E_1. Item 77 represents an input coupling resistance across terminals *a*—*b* and 92 is a resistance connected between the anode and cathode of valve 80 to steady the anode potential thereof.

It will be evident from the above that the invention is not limited to the specific arrangements of elements and methods disclosed herein for illustration, but that the underlying principle and concept of the invention is susceptible of numerous variations and modifications coming within the broadest scope of the invention as defined in the appended claims. Accordingly, the specification and drawings are intended to be regarded in an illustrative rather than in a limiting sense.

I claim:

1. In an electrical system, a first and a second network, each of said networks comprising a reactive impedance and a non-reactive impedance in series to develop potentials of reactive and non-reactive character by an input voltage impressed thereon, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, means for impressing an input voltage upon the first of said networks, means for deriving potential of one character from the first network and for impressing the derived potential upon the second network, and further means for deriving output potential of opposite character from said second network.

2. In an electrical system, a first and second network, each of said networks comprising a reactive impedance and a non-reactive impedance in series to develop potentials of reactive and non-reactive character by an input voltage impressed thereon, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, means for impressing an input voltage upon one of said networks, means for deriving potential of one character from said first network, means for amplifying the derived potential and for impressing the amplified potential upon said second network, and further means for deriving output potential of opposite character from said second network.

3. In an electrical system, a first and a second network, each of said networks comprising a reactive impedance and a non-reactive impedance in series, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, means for impressing an input voltage upon said first network, means for deriving reactive potential from said first network and for impressing the derived potential upon said second network, and further means for deriving non-reactive output potential from said second network.

4. In an electrical system, a first and a second network, each of said networks comprising a reactance and a resistance in series, the resistance of said second network having a negative current-voltage characteristic, means for impressing an alternating potential upon said first network, means for impressing potential upon said second network derived from the reactance of said first network, and further means for deriving output potential from the resistance of said second network.

5. In an electrical system, a first and a second network, each of said networks comprising a reactance and a resistance in series, the resistance of one of said networks having a negative current-voltage characteristic, means for impressing input potential upon said first network, means for deriving reactive potential from said first network, means for amplifying the derived potential and for impressing the amplified potential upon said second network, and further means for deriving output potential from the resistance of said second network.

6. In an electrical system, a first and a second network, each of said networks comprising a reactive and a non-reactive impedance in series to develop potentials of reactive and non-reactive character by an input voltage impressed thereon, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, the ratio between the reactive and the non-reactive impedances of said first network being equal to the ratio between the reactive and non-reactive impedances of said second network, means for impressing an input potential upon said first network, means for deriving voltage drop of one character from said first network and for impressing the derived voltage upon said second network, and further means for deriving output potential of opposite character from said second network.

7. In an electrical system, a first and a second network, each of said networks comprising a reactive impedance and a non-reactive impedance in series, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, the ratio between the reactive and non-reactive impedances of said first network being equal to the ratio between the reactive and non-reactive impedances of said second network, means for impressing an input potential upon said first network, means for deriving reactive potential from said first network and for impressing the derived potential upon said second network, and further means for deriving non-reactive output potential from said second network.

8. In an electrical system, a first and a second network, each of said networks comprising a reactive and a non-reactive impedance in series, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, the ratio between the reactive and non-reactive impedances of said first network being substantially equal to the ratio between the reactive and non-reactive impedances of said second network, means for impressing an input potential upon said first network, means for deriving reactive potential from said first network, means for

amplifying the derived potential and for impressing the amplified potential upon said second network, and further means for deriving non-reactive output potential from said second network.

9. In an electrical system, a first and a second network, each of said networks comprising a reactive impedance and a non-reactive impedance in series to develop potentials of reactive and non-reactive character by an input potential impressed thereon, the non-reactive impedance of one of said networks having a negative current-voltage characteristic, the reactive and non-reactive impedances of the first network being equal to the respective reactive and non-reactive impedances of the second network, means for impressing an input potential upon said first network, means for deriving potential of one character from said first network and for impressing the derived potential upon said second network, and further means for deriving output potential of opposite character from said second network.

10. In a phase shifting system, a first network comprising a positive resistance and a reactive impedance in series, means for impressing an input voltage upon said network, an electron valve having an input and an output, means for impressing the voltage developed by said reactive impedance upon the input of said valve, a second network comprising a negative resistance and a reactive impedance in series, said second network being connected to the output of said valve, and means for deriving output potential from said negative resistance.

11. A system as claimed in the preceding claim, wherein said negative resistance consists of an electron valve with a negative output current-voltage characteristic, and means for preventing self-oscillations of said last mentioned valve.

12. In a system as claimed in claim 10, wherein said negative resistance consists of an electron valve having a cathode and an anode and at least one positively biased grid to produce a negative output current-voltage characteristic, and means for preventing self-oscillations of said last mentioned valve.

13. In a system as claimed in claim 10, wherein said negative resistance consists of an electron valve comprising a cathode and anode and at least one biased grid electrode to provide a negative output current-voltage characteristic, both of said valves having their anodes connected to the same high tension source, and a high ohmic inductance inserted in the anode lead of said last mentioned valve.

14. In a system as claimed in claim 10, wherein the ratio of the reactive impedances of said networks is equal to the ratio of the numerical values of said positive and negative resistances.

15. A phase shifting system having an input and an output, a plurality of channels connected between said input and said output, each of said channels comprising a first and a second network, each of said networks comprising a reactive and a non-reactive impedance in series to produce potentials of reactive and non-reactive character by a voltage impressed thereon, the non-reactive impedances of one of said networks in each channel having a negative current-voltage characteristic, means for deriving potential of one character from the first network in each channel, and for impressing the derived potential upon the second network in each channel, means for applying voltage from said input circuit to all of said first networks in each channel, means for deriving and transferring reactive potential of different character from the second network in each channel upon said output, the reactive impedances and the numerical values of the non-reactive impedances of said first and second networks in each channel being equal to each other in respect to a different frequency for each of said channels.

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