Jan. 9, 1940. J. PLEBANSKI 2,186,146

SIDE BAND SUPPRESSION SYSTEM

Filed Sept. 8, 1938

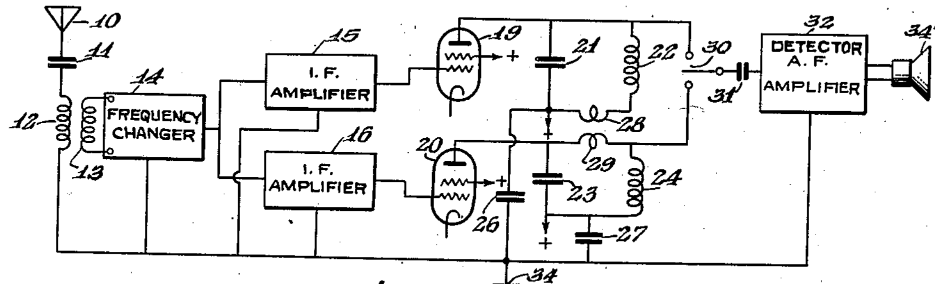

Fig: 1

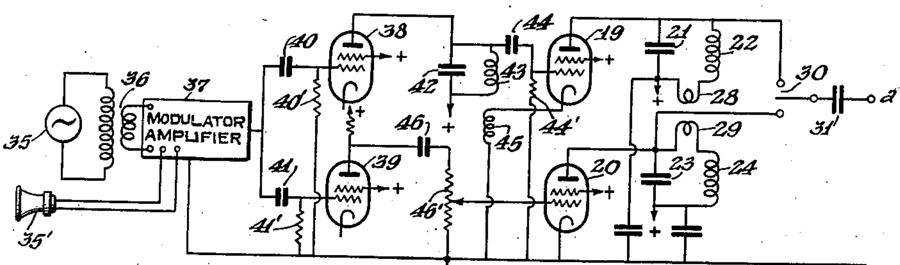

Fig: 3

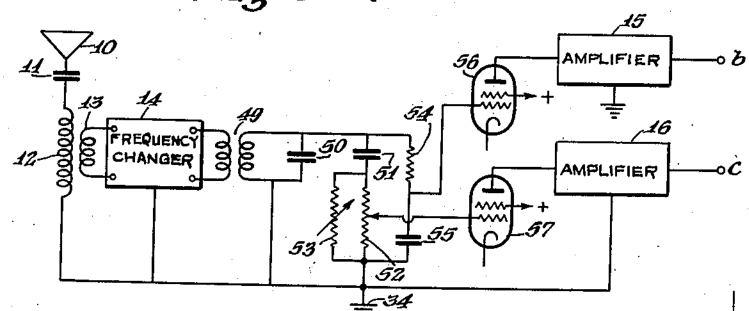

Fig: 6

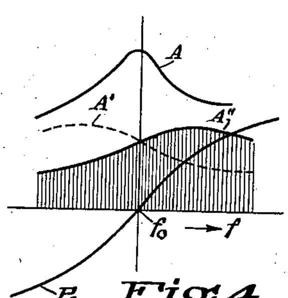

Fig: 4

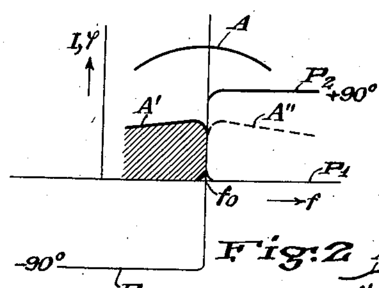

Fig: 2

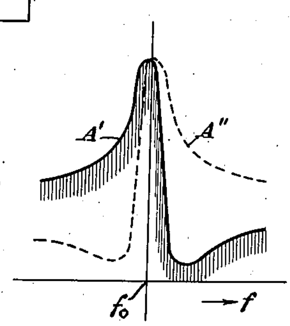

Fig: 5

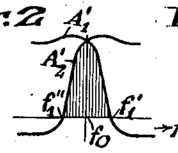

Fig: 8

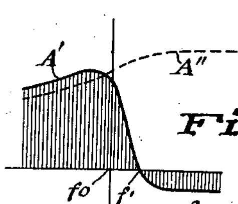

Fig: 7

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SIDE BAND SUPPRESSION SYSTEM

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14 Claims. (Cl. 178—44)

The present invention relates to systems for translating modulated carrier signals and more particularly to an improved circuit for and method of suppressing one of the modulation side bands in the transmission or reception of signals of this character.

An object of the invention is to provide a simple and efficient means and a method for selecting the upper or lower side band of a modulated carrier signal.

A more specific object is to provide a simple and efficient circuit arrangement in a radio receiver for eliminating or minimizing interference due to overlapping of the modulation side bands of adjacent signalling channels experienced in the reception of broadcast signals or the like.

Another object is the reduction or suppression of disturbing heterodyning signals or beat notes in a radio receiver caused by an adjacent carrier wave.

The above and further objects and advantages of the invention will become more apparent from the following description of several practical embodiments thereof taken with reference to the accompanying drawing forming part of this specification and wherein

Figure 1 is a circuit diagram for a radio receiver embodying a side band selecting system in accordance with the invention,

Figure 2 shows a set of response curves explanatory of the design and operation of the circuit according to Figure 1,

Figure 3 illustrates a preferred practical embodiment of a system constructed in accordance with the invention,

Figures 4 and 5 are theoretical diagrams explanatory of the design and operation of Figure 3,

Figure 6 illustrates a modification of Figures 1 and 3,

Figure 7 shows a diagram explanatory of the effects and results obtained by means of a system according to Figure 6, and

Figure 8 shows a diagram illustrating a further modification of the invention.

Similar reference characters identify similar parts and magnitudes throughout the different views of the drawing.

Referring more particularly to Figure 1, there is shown an antenna 10 connected in a known manner to ground 34 through a series coupling condenser 11 and a coupling coil 12. The latter is arranged in inductive relation with a secondary coil 13 connected to the input of a frequency changer or mixer device 14 as provided in the conventional type of superheterodyne receiver. In this manner a modulated high frequency signal received by the antenna is converted into a signal of intermediate or beat frequency portions of which are applied to a pair of separate intermediate frequency amplifiers 15 and 16, respectively. The output signal of the amplifier 15 is impressed upon the grid of a further amplifying tube 19 including in its output a resonant circuit comprised of an induction coil 22 shunted by a condenser 21 in series with a coupling coil 28. Similarly the output signal of the amplifier 16 is impressed upon the grid of an amplifying tube 20 including in its output a resonant circuit comprised of an induction coil 24 shunted by a condenser 23 in series with a coupling coil 29. The anodes of tubes 19 and 20 are supplied with high potential from a source indicated by the plus symbols in a manner well known, and the resonant circuits are returned to ground or cathode for high frequency through condensers 26 and 27, respectively. The high potential ends of the resonant circuits are further connected each to one of a pair of fixed contacts of a switch 30 having a movable contact connected to a detector and audio frequency amplifier 32 through a coupling condenser 31. The output of the audio amplifier may serve to supply a translating device such as a loud speaker 34'. The resonant circuits 21, 22, 28 and 23, 24, 29 are tuned to the signal frequency, that is in the example illustrated the intermediate or beat frequency of the receiver. By properly adjusting the coupling between the resonant circuits 21, 22, 28 and 23, 24, 29 through the coils 28 and 29, either of the modluation side bands of the impressed input signal may be selected and applied to the detector or audio frequency amplifier by connecting the switch 30 in the upper or lower position, respectively. As is understood, the received high frequency signal may be directly applied to the amplifier tubes 19 and 20 or tuned circuits 21, 22 or 23, 24, respectively, i. e. in the manner of a straight high frequency receiver without changing to an intermediate frequency as shown in the example illustrated.

In order to obtain the above effect, that is to suppress either of the modulation side bands in the circuits 21, 22, 28 and 23, 24, 29 the amplifiers 15 and 16 or translating channels have to be designed with predetermined characteristics as explained in greater detail in the following.

The amplitude response characteristic of the amplifier 15, that is the amplitude of the output current I input as a function of frequency is shown at A in Figure 2, that is the amplitude response is substantially constant throughout the modulation frequency band. Similarly, the phase characteristics of this amplifier is assumed to be constant such as shown at P_1 in Figure 2, or in other words no substantial phase displacement occurs during the passage of the signals from the input to the output. The amplifier 16 on the other hand is designed to have an amplitude response characteristic similar to the amplifier 15, that is as shown at A in Figure 2, and a phase response characteristic differing substantially from the phase response characteristic of the amplifier 15 as shown at P_2 in Figure 2. According to the latter which represents an ideal condition, the time phase of all frequencies below the resonant frequency f_0 (lower side band) is $-90°$ and the phase of all the frequencies above the resonant frequency f_0 (upper side band) is $+90°$ or, in other words, all frequencies of the left side band are shifted by $-90°$ in respect to the same frequencies in the amplifier 15 and all frequencies of the right side band are shifted by $+90°$ in respect to the corresponding frequencies in the amplifier 15. Theoretically the currents developed in the two resonant circuits 21, 22, 28 and 23, 24, 29 may be represented by the following equations:

$$I_1=\frac{E_1R_2}{Z}\sin(\omega t+\varphi_1)-\frac{E_2\omega M}{Z}\cos(\omega t+\varphi_2) \quad (1)$$

$$I_2=\frac{E_2R_1}{Z}\sin(\omega t+\varphi_2)-\frac{E_1\omega M}{Z}\cos(\omega t+\varphi_1) \quad (2)$$

whereby it is assumed that the electromotive force developed in the first circuit is equal to $E_1 \sin(\omega t+\varphi_{11})$ and the electromotive force developed in the second circuit is equal to $E_2 \sin(\omega t+\varphi_2)$ and wherein R_1 and R_2 represent the total loss resistances of the respective circuits, M represents the mutual inductance between the coils 28 and 29,

$$\frac{\omega}{2\pi}$$

is the signal frequency, in the example illustrated the intermediate or beat frequency of the receiver and Z is a factor depending on various design constants of the two circuits.

From the above equations it is seen that by using amplifiers with the proper phase characteristics the upper modulation side band will be suppressed and the lower side band augmented in one of the resonant circuits 21, 22, 28 and 23, 24, 29 (to about twice the original amplitude) and vice versa in the other circuit the lower modulation side band will be suppressed and the upper side band augmented. This is shown by the curves A′ and A″ in Figure 2, the former representing the lower and the latter the upper side band. Thus, by placing the switch 30 in either its upper or lower position, either one of the modulation side bands can be selected and impressed upon the detector and audio amplifier to suit any existing requirements.

The invention by reason of the relative simplicity of the circuit and its adjustment has great advantages over the existing methods of side band suppression or selection requiring filters with sharp cut-off characteristics, the latter being complicated in design and as a result thereof bulky and costly. In the case of transmitters or modulators, it has become known to suppress one side band by modulating each of a pair of carrier waves having a quadrature phase relation by a corresponding pair of modulating waves also having a quadrature relation and by adding or subtracting the output products, whereby one of the modulation side bands is suppressed or neutralized. Systems of this type, however, are also expensive and complicated both in design and operation due primarily to the fact that a 90° phase shift of both the carrier and the components of the modulating signal is required. Especially, in the case of the latter great difficulties are experienced in equally shifting by 90° the phase of all the components in an extended band of modulating frequencies such as an audio or video frequency signal band. These difficulties are completely avoided by the present invention which merely requires the dividing of a modulated carrier into two components, passing the components through channels of predetermined phase and amplitude characteristics and exciting a pair of mutually coupled resonant circuits in the manner described hereinbefore.

Referring to Figure 3, there is illustrated a preferred practical circuit arrangement for obtaining an amplitude and phase characteristic in the signal channels feeding the coupled resonant circuits. Although Figure 3 is described with reference to a transmitter, it is understood that the arrangement shown equally applies to a receiver or any other system for translating modulated carrier energy.

Referring more particularly to Figure 3, there is shown at 35 a generator or oscillator producing high frequency currents. The latter are applied to a modulator 37 of any known type through a coupling transformer 36. There is further impressed upon the modulator 37 a modulating signal current or potential generated by a microphone 35′ or the like to produce a modulated carrier output, portions of which are applied to the grids of a pair of amplifier tubes 38 and 39 through grid coupling condensers 40 and 41, the tubes 38 and 39 being provided with the usual grid-leak resistances 40′ and 41′, respectively. The amplified output current of tube 38 is applied to a reonant circuit comprised of an induction coil 43 shunted by a condenser 42 and coupled to the grid of a further amplifying tube 19 through a grid coupling condenser 44 and grid leak resistance 44′ substantially similar to Figure 1.

Contrary to the tube 38, the output circuits of the tube 39 contains a resistance capacity coupling arrangement comprising in the example shown a coupling condenser 46 in series with a coupling resistance 46′. A suitable tap point of the latter is connected to the grid of the tube 30. The coupled resonant circuits 21, 22, 28 and 23, 24, 29 connected in the output circuits of the tubes 19 and 20 and the side band selecting switch 30 are substantially similar to the arrangement shown in Figure 1.

Referring to Figure 4 showing diagrams explanatory of the function of Figure 3, curve A represents the amplitude transmission characteristic of the upper channel determined substantially by the tuned circuit 42, 43 while P_2 represents the phase characteristic which differs from the ideal characteristic in Figure 2 by a more gradual change of the phase from $-90°$ to $+90°$ in place of the sudden phase reversal in the ideal condition. Accordingly, the side bands are not completely suppressed as in the case of Figure 2, but substantially weakened as seen from the characteristic curves A′ and

A'' in Figure 4. If the tuned circuit 42, 43 has a low damping which may be obtained by regeneration through the feed-back coil 45 connected in the output circuit of the tube 19 and arranged in inductive coupling relation with the coil 43, the side band characteristics A' and A'' will assume a shape such as shown in Figure 5. In order to adjust the relative amplitudes of the exciting potentials impressed upon the tuned circuits 21, 22, 28 and 23, 24, 29, suitable regulating means are provided such as an input resistance 46' having a variable tap connected to the control grid of the tube 20 as described hereinabove. It has further been found advantageous to keep the amplification of the tubes 39 and 20 at a low value whereby by proper adjustment of the reaction coil 45 and the potentiometer 46' it is possible to obtain side band characteristics of varying shape and degree of suppression of the side bands or any desired part thereof.

In arrangements of the type described, designed and adjusted so as to produce side band characteristics as shown in Figures 4 and 5, the latter are symmetrical for the upper and lower side band in respect to the carrier frequency, whereby either of the side bands may be selected for transmission or reception by means of switch 30 as shown in Figures 1 and 3. The selected side band may be applied to any output or utilization circuit connected to point *a* in a manner well understood from the above.

A characteristic of the circuit shown in Figure 3 is the fact that if the damping of the resonant circuit 42, 43 is decreased one of the side bands will be reduced to a greater extent while the lower frequencies in the other side band will be accentuated which may be useful in some cases. Furthermore, by adjusting the system in such a manner that the carrier amplitude is substantially greater than the side band amplitudes as shown in Figure 5 (by varying the degree of regeneration through coil 45 and adjustment of potentiometer 46') the demodulation in a subsequent detector is substantially improved especially when employing linear detection.

Referring to Figure 6, there is shown a modification of the invention especially suited although not limitatively for suppression of disturbing heterodyning signals produced by beating between two adjacent carrier frequencies. According to this embodiment, means are provided for producing an additional fixed phase shift between the potentials exciting the coupled side band suppression circuits through the amplifiers 15 and 16. In the example illustrated this is obtained by the provision of a phase shifting circuit arrangement connected between the frequency changing or mixer stage 14 and the amplifiers 15 and 16 and comprising an output transformer 49 of the frequency changer 14 having a secondary tuned to the intermediate frequency by a parallel condenser 50. The phase shifting arrangement comprises a pair of series networks connected across the transformer secondary, the first of said networks being comprised of a condenser 51 in series with a resistance 52, the latter being shunted in the example shown by a variable resistance 53, and the second of said networks comprising an ohmic resistance 54 in series with a condenser 55. There are further provided a pair of amplifying tubes 56 and 57, the input control grid of the former being connected to junction between the resistance 54 and condenser 55 and the input grid of the latter being connected to a variable tap point of the resistance 52. The amplified output currents of the tubes 56 and 57 are impressed upon the amplifiers 15 and 16 for further amplification and the output terminals of the latter *b* and *c* are connected to a side band elimination system of substantially the same type as shown in Figures 1 and 3, but omitted in Figure 6 for ease of illustration. By means of the network 51—55, it is possible to effect a phase shift between the potentials impressed upon tubes 56 and 57 from 0 to 180° to suit any existing requirements. Thus, when using a phase shift of about 45° between the exciting potentials and employing amplifiers having amplitude and phase characteristics of the type shown in Figure 4, the resultant side band characteristics in the coupled resonant circuits 21, 22, 28 and 23, 24, 29 will be as shown in Figure 7. From the latter it is seen that the side band characteristics A' and A'' are no longer symmetrical and that a complete suppression takes place for a definite frequency f' above or below the resonant frequency f_0 depending on which of the circuits is used or the position of the switch 30. The frequency f' for which complete suppression takes place can be controlled by regulating the resistances 52 and 53, that is by adjusting both the initial phase shift and relative amplitude of the exciting potentials exciting the coupled resonant circuits 21, 22, 28 and 23, 24, 29 or alternatively by slightly detuning the receiver in one or the other direction such as by varying the local oscillating frequency in the case of a superheterodyne receiver. As is understood, the arrangement according to Figure 6 is not limited to superheterodyne receivers, but may be used with equal advantage in straight high frequency receivers or in connection with any modulated carrier system.

It will be evident from the foregoing that the present invention provides a simple means and method for suppressing one side band in a modulated carrier signal and has great advantages compared with known methods and circuits of side band elimination requiring filters with sharp cut-off characteristics or other circuit arrangements complicated both in construction and adjustment. In accordance with the present invention relatively simple translating circuits are required merely having predetermined amplitude and phase characteristics. It is further seen from the above that the invention may be used with equal advantage for side band suppression on both long and short waves, thereby greatly extending the use and possibilities of this method of modulated signal energy transmission.

The curves shown in Figures 4, 5 and 7 are actually plotted in connection with experiments conducted by applicant with coupled circuits having a rather high damping (R=100 ohms) in order to avoid a substantial attenuation of the side band frequencies. The resistances R_1 and R_2 of the circuits were equal to each other and to the mutual coupling reactance ωM. Both coupling circuits were tuned to the carrier frequency of 130 kc. The phase shifting circuit 42, 43 had a total loss resistance of 100 ohms in the case of Figure 4 and 10 ohms in the case of Figure 5. All the curves shown encompass approximately ± 10 kc. at both sides of the carrier frequency f_0.

The invention has special use for improving the selectivity of wireless receivers by enabling it to eliminate interference due to overlapping side bands of adjacent transmitting channels known as "monkey chatter" or disturbing beat notes between adjacent channels. Since such interferences are usually caused by one of the side bands only, it is possible to eliminate this interference by selecting either of the side bands such as by placing the switch **30** in the one or the other position.

The curves shown in Figures 4, 5 and 7 are plotted without taking into consideration the overall sensitivity of the circuits. The latter can be obtained by multiplying the amplitudes of the curves shown with the corresponding amplitudes of the selectivity curves for the remaining parts of the apparatus such as a receiver or transmitter.

The invention may be further used advantageously for providing ultra-selective circuits, that is circuits having extremely sharp cut-off frequencies at both sides of the resonant frequency. For this purpose two arrangements of the type disclosed are connected in cascade and adjusted in such a manner that the cut-off frequency f_1' in the first arrangement is above and the cut-off frequency f_1'' of the second circuit is below the resonant frequency f_0 as shown in Figure 8 in such a manner that the overall side band characteristic A_1' and A_2' overlap resulting in a narrow frequency band characteristic with sharp cut-off frequencies shown by the hatched area in the drawing. In this manner, a resultant band-pass characteristic of extreme selectivity is obtained.

It will be evident from the above that the invention is not limited to the specific circuits and arrangements shown and disclosed hereafter for illustration but that the underlying thought and principle thereof are susceptible of numerous variations and modifications coming within the broad scope and spirit of the invention as defined in the appended claims.

The specification and drawing are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. A translation system for modulated carrier energy comprising a pair of transmitting channels having substantially constant input-output amplitude response over a range encompassed by the modulation side bands, means for applying substantially equal portions of said energy to the inputs of said channels, one of said channels having a substantially constant input-output phase characteristic in dependence upon frequency and the other channel adapted to change the phase of the modulation frequencies below and above the carrier frequency between the limits of −90° to +90°, respectively, resonant circuits tuned to the carrier frequency connected to the outputs of said channels, mutual reactive coupling means between said resonant circuits, and a utilization circuit connected to one of said resonant circuits.

2. A translation system for modulated carrier energy comprising a pair of transmission channels having substantially constant input-output amplitude response over the modulation side band range, means for impressing substantially equal amounts of said energy upon the inputs of said channels, one of said channels having a substantially constant input-output phase characteristic in dependence upon frequency and the other channel adapted to change the phase of modulation frequencies below and above the carrier between the limits of −90° to +90°, respectively, resonant circuits tuned to the carrier frequency connected to the outputs of said channels, mutual reactive coupling means between said resonant circuits, a utilization circuit, and switching means for selectively connecting said utilization circuit to either of said resonant circuits.

3. A translation system for modulated carrier energy comprising a pair of amplifying channels each comprising at least two amplifying stages in cascade, a resonant circuit tuned to the carrier frequency forming a coupling element between successive amplifying stages in said first channel, a resistance-capacity network forming a coupling element between successive amplifying stages in said second channel, a pair of further resonant circuits tuned to the carrier frequency and each connected to the output of one of said channels, inductive coupling means between said resonant circuits, and a utilization circuit connected to one of said resonant circuits.

4. A translation system for modulated carrier energy comprising a pair of amplifying channels each comprising at least two amplifying stages in cascade, a resonant circuit tuned to the carrier frequency forming a coupling element between successive stages in said first channel, a resistance-capacity network forming a coupling element between successive stages in said second channel, a pair of further resonant circuits tuned to the carrier frequency and each connected to the output of one of said channels, a coupling transformer interconnecting said resonant circuits, the ohmic impedances of said last resonant circuits being substantially equal to each other and to the mutual reactance of said coupling transformer to effect suppression of the upper and lower modulation side bands, respectively, in each of said resonant circuits respectively, and a utilization circuit energized from one of said resonant circuits.

5. A system as claimed in claim 4 including means for adjusting the relative amplitude of the energies impressed upon said last resonant circuits.

6. A system as claimed in claim 4 including means for reacting upon said first mentioned resonant circuit with currents derived from a point at a relatively higher level of amplification in said first amplifier.

7. A system as claimed in claim 4 including means for regeneratively reacting upon said first resonant circuit with currents derived from a point at a higher amplification level in said first amplifier.

8. A translation system for modulated carrier energy comprising a pair of transmitting channels having substantially constant amplitude response over the modulation frequency range to be transmitted, one of said channels being substantially aperiodic and the other channel including a resonant circuit tuned to the carrier frequency and adapted to effect a phase shift between the lower and upper side band frequencies between the limits from −90° to +90°, respectively, a pair of further resonant circuits each connected to the output of one of said channels, mutual reactive coupling means between said last resonant circuits, and a utilization circuit energized from one of said last resonant circuits.

9. A system as claimed in claim 8 including means for selectively connecting said utilization circuit to either of said last resonant circuits.

10. A system as claimed in claim 8 including means for initially adjusting the relative phase of the energies impressed upon said transmitting channels.

11. A translation system for modulated carrier energy comprising an aperiodic amplifier, a periodic amplifier comprising at least one resonant circuit tuned to the carrier frequency, means for impressing equal portions of the energy to be translated upon said amplifiers, a pair of further resonant circuits tuned to the carrier frequency and connected each to the output of one of said amplifiers, mutual reactive coupling means between said last resonant circuits, and a utilization circuit energized from one of said resonant circuits.

12. In a system as claimed in claim 11 including means for adjusting both the relative amplitude and phase of the energies impressed upon said amplifiers.

13. A translation system for modulated signal energy comprising a pair of transmitting circuits, means for feeding portions of the energy to be translated to said circuits, one of said circuits adapted to maintain the time phase position of the individual frequency components of the energy transmitted substantially constant and the other circuit adapted to effect a phase shift in opposite directions for the upper and lower side band frequencies, respectively, of the components of like frequency of the energy being transmitted therethrough, a pair of resonant circuits tuned to the carrier frequency and connected each to the output of one of said transmitting circuits, mutual reactive coupling means between said resonant circuits, and an output circuit connected to at least one of said resonant circuits.

14. A system as claimed in claim 13 including means for initially adjusting the relative time phase between corresponding components of like frequency of said energy portions before impression upon said transmitting circuits.

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