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RADIO TRANSMITTER SYNCHRONIZATION

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Fig. 1

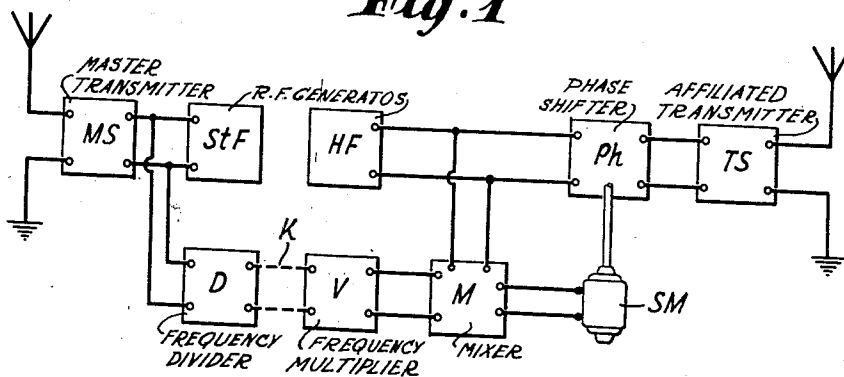
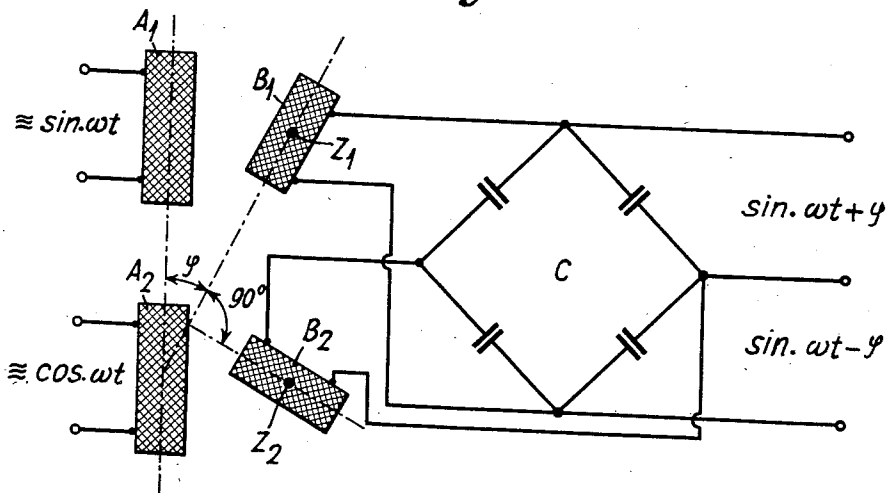


Fig. 2



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RADIO TRANSMITTER SYNCHRONIZATION

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10 Claims. (Cl. 250—2)

This invention relates to means which are adapted to automatically synchronize radio frequency transmitters.

In the operation of chain broadcasting, that is to say, of systems in which several broadcasting stations work upon one and the same wave, beats are set up as a result of slight discrepancies in the frequencies of the various stations. These irregularities must be prevented by synchronization of the various transmitters with each other by the aid of a standard (reference) frequency. As far as I am aware, the synchronizing methods known in the prior art usually operate in such a way that a standard frequency is transmitted from a master or key station, either directly or after frequency division, through cables to the various affiliated stations of the system. At the latter stations the incoming frequency serves either for the synchronization of an A. F. generator whose frequency thereafter is multiplied, or else the incoming synchronizing or pilot frequency is first multiplied and then used for the synchronization of the radio frequency generator.

A characteristic feature of the present invention is that the various transmitter stations to be synchronized are controlled or monitored by independently oscillating radio frequency generators of high constancy and stability, such as crystal or piezo-electric stabilized transmitters and that the frequency of each transmitter is caused to come in step with the frequency of another or master transmitter in which the phase of the generated frequency per unit of time is rotated an angle of 360 degrees as many times as corresponds to the phase difference between the master transmitter and the pilot transmitter of the transmitter to be synchronized. In other words, it is not the frequency of the radio frequency generator of the transmitter that is varied by the standard frequency in the present method, but the generated frequency is synchronized with the standard frequency in a stage following the generator stage by addition or subtraction of a few cycles. This is accomplishable, for instance, by transmitting the standard frequency either by way of cables, after division in the master or key transmitter and re-multiplication thereof in the subsidiary or affiliated stations, or else by a short-wave connection to the subsidiary or affiliated stations where the same is mixed with the frequency of the radio frequency generator or oscillator in the affiliated station. The difference between them is filtered out and used to actuate a phase shifter or rotator. An exemplified embodiment of this arrangement will be described

further below. The said phase rotating device causes the phase of the frequency generated in the affiliated station to rotate an angle of 360 degrees as many times as corresponds to the frequency difference. As a result the output frequency of the phase shifter will be raised or lowered an amount equal to the said difference of frequency.

In order to insure the correct sense of frequency change in the affiliated transmitter, it is also necessary to determine the sign of the departure between the standard frequency and the frequency generated in the affiliated or subsidiary station. To this end, the mean frequency of the radio frequency generator is detuned in relation to the standard or reference frequency in a definite sense by an amount which is greater than the greatest possible departure of the radio frequency transmitter from the said mean frequency. For instance, if this departure or drift which, for instance, may be due to temperature fluctuations, etc., amounts to ± 5 cycles, then the radio frequency generator is adjusted to a mean frequency which is 10 cycles per second higher than the reference or standard wave. Under such conditions it is quite certain that the differential frequency must be added to the frequency of the radio frequency generator in order to reach the standard frequency. Of course, it will be understood that it would be just as feasible to choose the mean frequency of the radio frequency generator higher than the standard frequency by a corresponding amount and the phase shifter device operated in such a way that the phase lags constantly a convenient amount.

An exemplified embodiment of an arrangement adapted to carry the above method into effect is schematically shown in Figure 1, while Figure 2 shows schematically a phase shifter which may be used in the circuit of Figure 1. In Figure 1 the reference or standard frequency StF is generated in the radio frequency generator. This standard frequency is, firstly, fed to the master transmitter MS and, secondly, after frequency division in D it is sent by way of the cable K to the affiliated or subsidiary station. At the latter, the standard frequency is restored in the frequency multiplier V , and then mixed in the mixing stage M with the frequency generated in the radio frequency oscillator HF of the affiliated broadcast station. An alternating current of the differential frequency drives the synchronous motor SM which actuates the phase shifter Ph in which the frequency coming from the radio

frequency generator HF is synchronized by constant leading or lagging of the phase and is then fed to the affiliated station TS.

- An arrangement adapted to cause phase shift of the kind which will be advantageous for carrying the present method into effect shall be described in what follows by reference to Figure 2. Referring to Figure 2, A₁ and A₂ denote two coils independent of each other upon which oscillations of equal amplitude *a* and of an angular velocity (cyclic frequency) ω are impressed with a phase displacement angle of 90 degrees. It is readily feasible to insure this fixed phase angle by the aid of conventional circuit means. The oscillations arising in A₁ and A₂ may then be represented by the equations:

$$^sA_1 = a \sin \omega t$$

$$^sA_2 = a \cos \omega t$$

- Inside the field of the coil A₁ is revolvably mounted a coil B₁, and inside the field of coil A₂ similarly a coil B₂ in such a way that the maximum degree of coupling which is attained with a given parallel position of the coils A₁ and B₁, and of A₂ and B₂ will in both instances be of the same amount *b*. The coils B₁ and B₂ are so inter-coupled mechanically that the angles which they form with the corresponding coils A₁, A₂ will always differ an angle of 90 degrees from one another. For instance, this may be accomplished by mounting the coils B₁ and B₂ upon a common shaft (indicated in the drawing by Z₁, Z₂) so that they are displaced an angle of 90 degrees in reference to or inside the coils A₁ and A₂ placed parallel to each other. Thus, if the coils A₁ and B₁ comprise an angle ϕ , then the coils A₂ and B₂ comprise an angle of 90 degrees $+\phi$. The degree of coupling between A₁ and B₁, on the one hand, and between A₂ and B₂, on the other hand, therefore is always as the cosine of an angle is to the sine of the angle. They are represented by the equations:

$$^sB_1 = ab \cos \phi \sin \omega t$$

$$^sB_2 = ab \sin \phi \cos \omega t$$

By forming the sum or difference of these two quantities there thus results—

$$^sB_1 \pm ^sB_2 = ab (\cos \phi \sin \omega t \pm \sin \phi \cos \omega t) = ab \sin (\omega t \pm \phi)$$

- In other words, there results an oscillation of constant amplitude, the phase of which may be shifted any desired angle by turning the shaft Z₁, Z₂.

- The formation of the sum and difference of the two potentials $^sB_1$ and $^sB_2$ must be effected without reaction between the circuits. For this purpose, the two coils B₁ and B₂ are connected to the diagonals of a balanced bridge arrangement C. Then from one arm may be taken off the potential of phase $+\phi$, and from the other arm the potential of phase $-\phi$, when the coils A₁ and B₁ enclose an angle ϕ .

- Non-reactive coupling of the coils B₁ and B₂ with the output circuits may alternatively be established by connecting the coils in series in the grid circuit of an amplifier tube rather than by a bridge scheme as hereinbefore described. All that is necessary in this connection is to make sure so that no grid current will flow in order that perfect freedom from reaction may be insured.

- Occasionally, it may be more favorable to mount the primary coils at right angles to each other, and the secondary coils parallel to each

other so as to be rotatable. It will also be understood that in lieu of the fixedly arranged primary (stator) coils and the rotatably journaled secondary (rotor) coil, conditions may be inversed in that the former may be made rotatable and the latter fixed.

To insure slight frequency shifts of the kind used in the method hereinbefore disclosed, the shaft upon which the secondary coils B₁ and B₂ are mounted is rotated. This causes a constant shift of the phase, and this corresponds to a frequency shift equal in amount to the frequency of rotation of the shaft.

The shaft of the phase shifter device here described is preferably driven from a synchronous motor whose speed is controlled by the differential frequency between the standard or reference frequency and the frequency generated in the affiliated transmitting station.

The arrangement designed to insure a phase rotation or phase shift as here described may moreover be used in all cases where small frequency shifts are to be produced or where by simple ways and means phase shifts through angles up to 360 degrees are to be produced. To this latter end the shaft Z is not continuously driven from a motor, but is preferably furnished with a rotary knob and a dial or scale. The angle through which the shaft must be turned corresponds to the angle by which the phase is shifted.

I claim:

1. A system for insuring synchronism of a subsidiary transmitter with a master transmitter each of which includes an independent radio frequency oscillator of high frequency stability, means for transmitting the frequency generated at said master transmitter to said subsidiary transmitter, means for comparing the generator frequency at said subsidiary transmitter with the frequency received from said master transmitter and means for continuously rotating the phase of the frequency generated at the subsidiary transmitter in accordance with the result of said comparison.

2. A system for insuring synchronism of a subsidiary transmitter with a master transmitter each of which includes an independent radio frequency oscillator of high frequency stability, means for transmitting the frequency generated at said master transmitter to said subsidiary transmitter, means for comparing the generator frequency at said subsidiary transmitter with the frequency received from said master transmitter and means for rotating the phase of the frequency generated at the subsidiary transmitter in accordance with the result of said comparison.

3. The method of synchronizing a subsidiary transmitter with a master transmitter each of which includes an independent radio frequency oscillator of high frequency stability which comprises comparing the frequency of said master transmitter with said subsidiary transmitter, obtaining a differential frequency proportional to the result of said comparison and rotating the phase of the wave generated at said subsidiary transmitter an amount proportional to the differential frequency.

4. The method of synchronizing a subsidiary transmitter with a master transmitter each of which includes an independent radio frequency oscillator of high frequency stability which comprises comparing the frequency of the master transmitter with said subsidiary transmitter and

rotating the phase of the wave generated at said subsidiary transmitter an amount proportional to the result of said comparison.

5 5. Arrangement as claimed in claim 1 with the characteristic feature that the control frequency of master and subsidiary transmitter are detuned in relation to each other such an amount that the differential frequency between both always preserves the same sign.

10 6. Arrangement adapted to phase shifting as claimed in claim 1 characterized by the use of two pairs of coupled coils being independent of each other, the coupling coefficients or degrees of which are variable in different senses by rotation of the coils in reference to each other
15 by the agency of a joint drive, the primary coils thereof being impressed with radio frequency potentials of like frequency, but of dissimilar phase, while the secondary coils thereof operate
20 upon a joint output circuit, with preclusion of mutual reaction.

7. A system for insuring synchronism of a subsidiary transmitter with a master transmitter each of which includes an independent radio
25 frequency oscillator of high frequency stability, means for transmitting the frequency generated at said master transmitter to said subsidiary transmitter, means for generating a differential frequency in response to a difference between the
30 generated frequency at said subsidiary transmitter with the frequency received from said master transmitter, means for rotating the phase of the frequency generated at the subsidiary transmitter and a motor for said last means
35 controlled by said differential frequency.

8. A system as set forth in claim 7 in which said phase rotating means comprises a pair of primary coils supplied with radio frequency of

like periodicity but dissimilar phase, a pair of secondary coils each in inductive relationship with one of said primary coils, said secondary coils being mounted on a shaft for rotation whereby the coupling between each primary and
5 its associated secondary may be simultaneously varied and means for combining the output from said secondary coils without interaction.

9. A system as set forth in claim 7 in which said phase rotating means comprises a pair of
10 primary coils supplied with radio frequency of like periodicity but with a phase displacement of 90 degrees with reference to each other, a pair of secondary coils each in inductive relationship with one of said primary coils, said secondary
15 coils being mounted at an angle of 90 degrees with respect to one another on a shaft for rotation whereby the coupling between each primary and its associated secondary may be simultaneously varied and means for combining the output
20 from said secondary coils without interaction.

10. A system as set forth in claim 7 in which said phase rotating means comprises a pair of primary coils supplied with radio frequency of
25 like periodicity but with a phase displacement of 90 degrees with reference to each other, a pair of secondary coils each in inductive relationship with one of said primary coils, said secondary coils being mounted at an angle of 90
30 degrees with respect to one another on a shaft for rotation whereby the coupling between each primary and its associated secondary may be simultaneously varied and bridge circuit means for connecting each of said coils to a diagonal of said bridge and an output circuit connected
35 to one arm of said bridge.

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