Dec. 23, 1941. E. C. CORK ET AL 2,267,445

ELECTRIC HIGH FREQUENCY SIGNALING SYSTEM

Filed April 21, 1938

Fig. 1

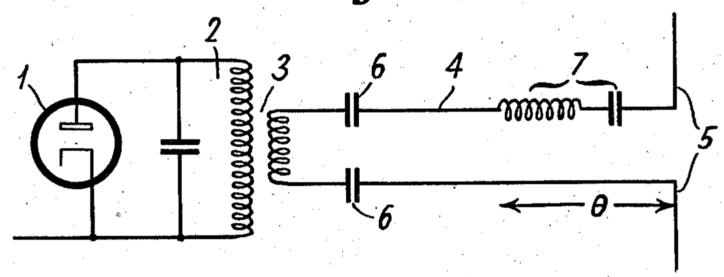


Fig. 2

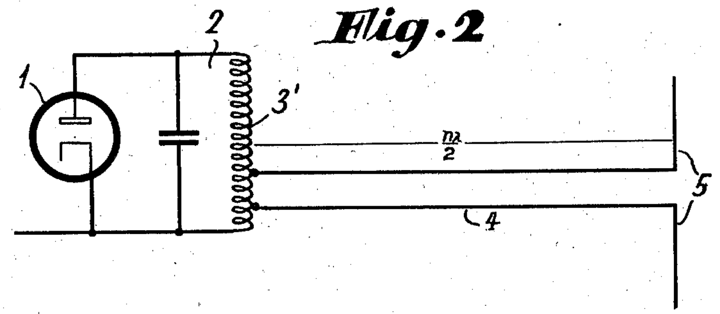


Fig. 3

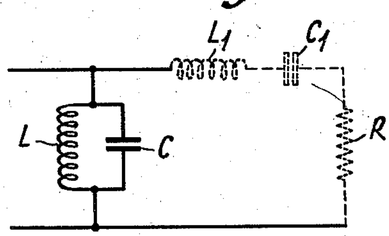
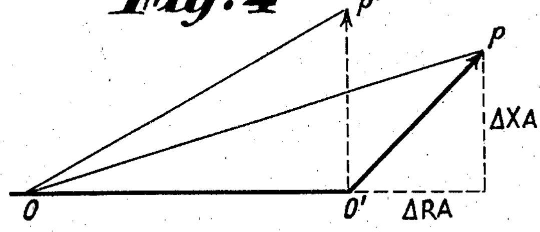


Fig. 4



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Patented Dec. 23, 1941

2,267,445

UNITED STATES PATENT OFFICE

2,267,445

ELECTRIC HIGH FREQUENCY SIGNALING SYSTEM

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Application April 21, 1938, Serial No. 203,244
In Great Britain May 1, 1937

4 Claims. (Cl. 250—33)

The present invention relates to high frequency signaling systems and more specifically to such systems which are required to transmit a wide band of signals.

In the complete specification of British applications Nos. 32,339/35 and 16,998/36 (Patent No. 469,245), it is explained that in high frequency signaling systems such as television systems, it is generally impractical to match the transmitter impedance to the input impedance of the feeder terminated by the aerial and at the same time obtain the necessary band width.

It is pointed out in our prior specification that even if the reactance of the aerial is small or is neutralized by suitable circuits the radiation resistance of the aerial will, in general, vary with frequency. The aerial is usually matched to the feeder at the aerial frequency, but due to the variation of the radiation resistance with frequency, the aerial will not be matched at side band frequencies. This mismatching causes variation in the impedance presented to the transmitter by the aerial system, and hence variations in the radiated power over the wide band of frequencies constituting the side bands of a television transmitter.

The phase angle of current reflected at the aerial end of the feeder when it reaches the transmitter depends on the length of the feeder having regard to the width of the band of modulation frequencies.

In the aforesaid prior specification, methods are described of substantially eliminating the variation of the aerial impedance with frequency so that there is at all relevant frequencies a substantially constant resistance, by means of lengths of line and resonant circuits, so that it can be connected to the associated transmitter by any length of transmission line.

Where it is necessary for the transmitting system as a whole to have a band pass characteristic, the constant resistance aerial provided by the methods of the above applications would be coupled to the final tuned (tank) circuit of the transmitter by a further tuned circuit. Such arrangement would thus include two tuned circuits associated with the feeder, one of the tuned circuits being inserted at the transmitter end of the feeder to compensate for the reactance change of the tank circuit of the transmitter, and the other tuned circuit being inserted towards the aerial end of the feeder to annul reactance change due to the aerial.

Now the relative variations of the impedance of the aerial and of the tank circuit of the transmitter are of the same order of magnitude and for this reason in some cases a simplification of the band-pass arrangement can be effected, in that the variation of the impedance of the aerial may be caused to appear from the transmitter as a reactance variation of opposite sense to that of the variation in the reactance of the transmitter itself, whereby variations in the impedance of the aerial with changing frequency tend to compensate the variations in the output impedance of the transmitter; thus, if the length of the feeder is correctly chosen, the tuned circuits provided in the feeder described in the prior case may be omitted.

Thus, according to the present invention, a radio signal transmitting or receiving arrangement more especially for use on short waves is provided comprising a radio transmitter or receiver so associated with an aerial that for a band of frequencies in the pass range of the arrangement, the variation of the impedance of the aerial as viewed from the transmitter or receiver appears as a reactance variation substantially opposite in sense to the variation in the reactance of the transmitter or receiver itself, whereby variations in the impedance of the aerial with changing frequency tend to compensate the variations in the output impedance of the transmitter.

In the preferred arrangement according to the invention the variation of the impedance of the aerial as viewed from the transmitter appears as a reactance substantially equal in value to the variation of the reactance of the transmitter over said band of frequencies.

In certain circumstances, in an arrangement according to the invention, a transmitter and its aerial may be connected without the interposition of a feeder, or a simple half wave length feeder may be provided.

The nature of the invention and the method of carrying the same into effect will be more clearly understood from the following description in detail reference being made to the accompanying drawing in which:

Figure 1 shows a schematic diagram of a band-pass aerial system embodying the invention described in our prior specification above referred to.

Figure 2 is a similar representation of an arrangment according to the present invention.

Figure 3 is an explanatory equivalent circuit of the arrangement of Figure 2.

Figure 4 is a vector diagram applicable to the arrangement of Figure 2.

Referring to Figure 1, it will be seen that the output circuit of a transmitter including tube **1** and tank circuit **2** is shown connected over transformer **3** to feeder **4** which is directly coupled to dipole aerial **5**. In order to compensate for the variation in the reactance of the tank circuit of the transmitter the secondary winding of the transformer **3** is associated with condensers **6**, which form a resonant combination with the said secondary winding, and in order to compensate for the variation in aerial reactance the series tuned combination **7** of inductive and capacity elements is provided.

Now the changes in the magnitude of the reactances which are compensated in the above arrangement are of the same order, and in accordance with the present invention, instead of providing tuned combinations **3**, **6**, **6**, and **7**, the length of the feeder is chosen so that the reactive change of the aerial may have the effect of a series tuned circuit located at the point where the feeder is connected to the transmitter. For example, referring to Figure 2, aerial **5** is shown connected over feeder **4** to tappings on the inductance **3'** of the tank circuit **2** of the transmitter the inductance **3'** thus serving as an auto-transformer.

Figure 3 shows the equivalent circuit in this case. In this figure, the tank circuit **2** of Figure 2 is represented by the tuned circuit comprising inductance L and capacity C, while L', and C', and R represent the equivalent circuit of the feeder and aerial.

In such a circuit the constant K band-pass condition is given by

$$R^2=\frac{L_1}{C}=\frac{L}{C_1}$$

and $LC\omega_0 2=1$ where ω_0 is the angular velocity, corresponding to the midfrequency f_0 of the band. The circuit comprising elements L_1, C_1 and R_1 must therefore have an impedance

$$Z=\frac{R+j2\Delta fR^2\omega_0 C}{f_0}$$

$$=R+j-4\pi\Delta fR^2C \quad \text{------------(1)}$$

where Δf is the amount by which the frequency departs from mid-band frequency.

Now consider the input impedance to the feeder when terminated by the aerial impedance.

If the aerial is tuned to the mid-band frequency, the aerial impedance will at any frequency within the band be given by

$$Z_A=R_A+\left\{\frac{dR_A}{df}\right\}\Delta f+j\left\{\frac{dX_A}{df}\right\}\Delta f$$

where R_A is the aerial resistance at mid-band frequency and X_A the aerial reactance, the latter being zero at mid-band frequency.

The input impedance of the feeder at any given frequency may be obtained from the vector diagram of Figure 4 in which line OO' is a vectorial representation of the characteristic impedance of the feeder which is made equal to R_A, and the vector O'P is the resultant change of impedance due to the increments of resistance and reactance ΔR_A and ΔX_A respectively, of the aerial, when the signal frequency departs from the mid-frequency of the band by the amount Δf.

The input impedance to the feeder of length θ when terminated by the impedance Z_A which has been represented by the vector OP, is given by the vector OP' which has been obtained by rotating O'P about O' through an angle -2θ. Where 2θ is such that OP rotates to a position at right angles to OO' the change of aerial impedance from the resistive tuned value will appear as a reactance of magnitude O'P': the angle 2θ is given by the equation—

$$2\theta=360\text{ dgs.}-\cot^{-1}\frac{\left\{\frac{dX_A}{df}\right\}}{\left\{\frac{dR_A}{df}\right\}} \quad \text{--------(2)}$$

The aerial impedance viewed from the transmitter will then be given by the expression

$$R_A+j\left\{\left\{\frac{dR_A}{df}\right\}^2+\left\{\frac{dX_A}{df}\right\}^2\right\}^{\frac{1}{2}}f \quad \text{--------(3)}$$

Equation 3 can satisfy the bandpass condition given by Equation 1 if

$$4\pi R^2C=\left\{\left\{\frac{dR_A}{df}\right\}^2+\left\{\frac{dX_A}{df}\right\}^2\right\}_{\frac{1}{2}} \quad \text{--------(4)}$$

Now for a half wave dipole aerial with a tuned impedance at mid-band frequency of 72 ohms

$$\frac{dR_A}{df}$$

is approximately

$$\frac{72}{f}\pi$$

and

$$\frac{dX_A}{df}$$

is approximately

$$\frac{Z_{(OA)}\pi}{f}$$

where Z_{OA} is the characteristic impedance of the aerial. Hence the value of Z_{OA} for a given value of C can be found and the electrical length of feeder required to produce the apparent rotation of OP is given from the Equation 3 as

$$2\phi=n\ 360-\cot^{-1}\frac{Z_{OA}}{72} \quad \text{--------------(5)}$$

where n is any integer, including zero. It is apparent from the form of this equation that the same physical length of line approximately satisfies the equation over a band of frequencies.

By way of example, it may be noted that in the case given if $C=109$ $\mu\mu$f. the characteristic impedance of the aerial $Z_{OA}=72$ ohms, and for $C=440$ $\mu\mu$f., $Z_{OA}=400$ ohms. These are the approximate limits over which the aerial may conveniently be varied.

It will be noted that the physical length of line required to satisfy Equation 5 is slightly dependent on frequency, since the electrical length required is constant. In practice, therefore, a single feeder will not be effective equally at all frequencies within a band and the best compromise in the choice of length is that which the input resistance is passing through a stationary value with varying frequency. This limitation on the use of the invention becomes more rigorous the greater the length of the feeder, so that the invention is most suitable for application to transmitters in which the line connecting the feeder to the aerial is short, as for example, in an aeroplane transmitter. In many cases, this restriction on the use of the invention makes it preferable to use an arrangement such as that shown in Figure 1 of the drawing.

Certain special cases of the application of the invention are of interest. For example, if the variation of the resistance with frequency

$$\left\{\frac{dR_A}{df}\right\}$$

is zero or negligibly small compared with the variation

$$\left\{\frac{dX_A}{df}\right\}$$

as for example in a condensed array, the Equation 4 above becomes

$$4\pi R^2 C=\left\{\frac{dX_A}{df}\right\}$$

and the electrical length of the feeder required is given by $\theta=n$ 180 degs. where n is any integer including zero. The simplest case is that in which n and consequently θ is zero, in which case the transmitter would be directly connected to the aerial but if a direct connection is inconvenient, half or full wave lengths of feeder may be inserted.

This case has an application to the compensation of a load resistance with some residual reactance.

In the above description it has been assumed that it is desirable to produce a constant K type of bandpass for the circuit. It may be preferred to use filters of different types, for example, such as that which produces double humping. A set of conditions for the application of the invention may be determined in the manner described above for any particular case. The invention will, of course, be applicable in any case where it is possible to transform the variation of the impedance of an aerial to substantially a linear reactance variation of the correct magnitude.

In the arrangement described above, the feeder is chosen to match the aerial impedance, so that the input impedance to the line is equal to the tuned aerial resistance. If it is desired to work into a different impedance, an unmatched line may be used of suitable impedance and electrical length, so that it acts as a transformer and produces the desired bandpass action. The invention is not only applicable at the transmitting end of signaling system, but is equally applicable to a receiver.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. In combination, an aerial having an impedance comprising a reactance which varies with the frequency of a wave applied thereto and a substantially constant resistance, a feeder connected to said antenna and a coupling circuit connected to said feeder for coupling a source of high frequency oscillations to said aerial, the reactance of said coupling circuit varying with the frequency of a wave applied thereto, said feeder having an electrical length equal to a half wave length of the operating frequency so that the reactance variation of said aerial viewed from said coupling circuit is substantially opposite in sense to the reactance variation of said coupling circuit whereby said variations compensate for each other.

2. In combination, an aerial having an impedance comprising a reactance which varies with the frequency of a wave applied thereto and a substantially constant resistance, a feeder connected to said antenna and an output circuit of a transmitter connected to said feeder, the reactance of said output circuit varying with the frequency of a wave applied thereto, said feeder having an electrical length equal to a half wave length of the operating frequency so that the reactance variation of said aerial viewed from said output circuit is substantially opposite in sense to the reactance variation of said output circuit whereby said variations compensate for each other.

3. A broad band transmitting arrangement including an aerial having an impedance comprising a reactance which varies with the frequency of a wave applied thereto and a substantially constant resistance, a feeder connected to said antenna and an output circuit of a transmitter connected to said feeder for coupling said transmitter to said aerial, the reactance of said output circuit varying with the frequency of the wave appearing therein, said feeder having an electrical length equal to a multiple including unity of a half wave length at the middle frequency of said band so that the reactance variation of said aerial viewed from said output circuit is substantially opposite in sense to the variation in reactance of said output circuit whereby said variations compensate for each other.

4. A broad band antenna arrangement including an aerial having an impedance comprising a reactance which varies with the frequency of a wave applied thereto and a substantially constant resistance, a feeder connected to said antenna and a coupling circuit connected to said feeder for coupling a transducer to said aerial, the reactance of said coupling circuit varying with the frequency of the wave applied thereto, said feeder having an electrical length equal to a multiple including unity of a half wave length at the middle frequency of said band so that the reactance variation of said aerial viewed from said coupling circuit is substantially opposite in sense to the variation in reactance of said coupling circuit whereby said variations compensate for each other.

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