Jan. 30, 1940. E. C. CORK ET AL 2,188,389

ELECTRICAL HIGH FREQUENCY SIGNALING SYSTEM

Filed Nov. 13, 1936 2 Sheets-Sheet 1

Fig. 1

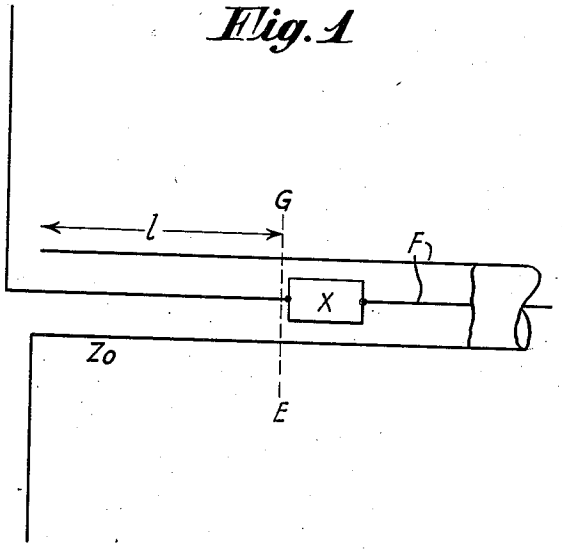


Fig. 2

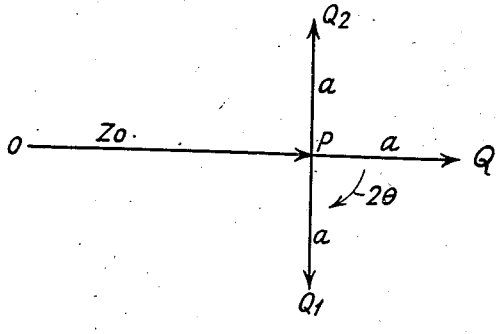
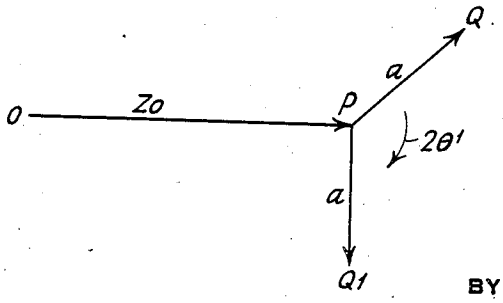


Fig. 3



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Fig. 4

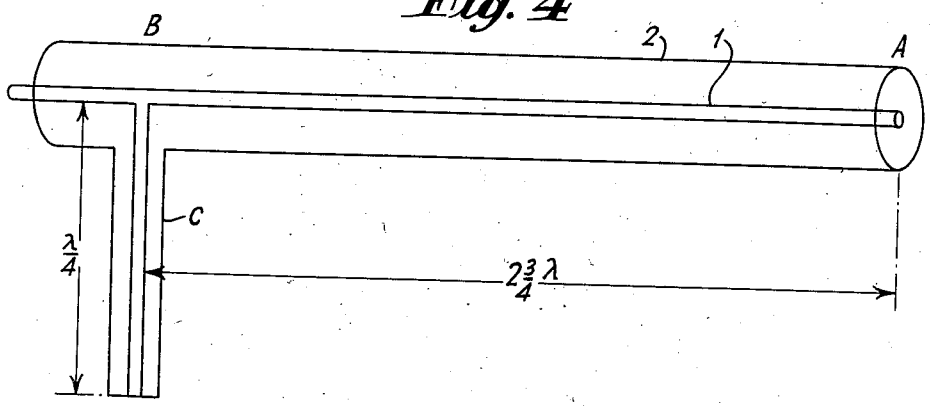
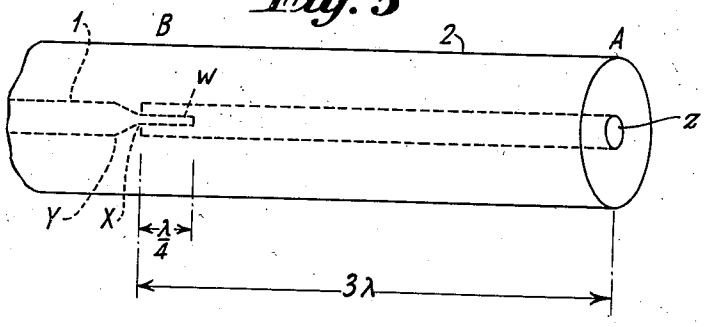


Fig. 5



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ELECTRICAL HIGH FREQUENCY SIGNALING SYSTEM

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Application November 13, 1936, Serial No. 110,652
In Great Britain November 21, 1935

8 Claims. (Cl. 250—33)

This invention relates to high frequency signaling systems and is particularly concerned with feeder systems for short wave transmitting aerials. In the case of a short wave transmitter feeding an aerial through a transmission line it is usual to match the resistive impedance of the aerial to the characteristic impedance of the feeder and further, if possible, to match this characteristic impedance to the impedance of the transmitter.

When transmitting signals with a wide side band such as television signals, it is impracticable 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; in fact the parallel resistance thrown on the transmitter by the aerial seen through the feeder is usually much lower than the impedance of the transmitter in order to damp sufficiently the transmitter tuned circuit. Any small errors or variations in the impedance of the aerial as seen through the feeder then affect the output. If these errors vary with frequency, the response of the transmitter will also not be uniform, and will vary with the impedance of the aerial as seen through the feeder.

Now, if the feeder is long and the aerial impedance does not match the characteristic impedance of the feeder, serious variations of impedance seen by the transmitter may take place within the working range, and these variations of impedance will cause variations in the response of the transmitter. Such failure of matching, between the aerial and the feeder, may be due to the variation of the aerial impedance with frequency.

Even if the reactance of the aerial is small, or is neutralized by suitable circuits, the radiation resistance will, in general, vary with frequency. The aerial is usually matched to the feeder at the carrier 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 an error in the impedance as seen by the transmitter. The phase angle of currents reflected at the aerial end of the feeder when they reach the transmitter depends on the length of the feeder having regard to the width of the band of modulation frequencies. If the feeder is approximately an integral number of half wavelengths long at a side band frequency and a different integral number of half wavelengths long at the carrier frequency, then at some frequency or frequencies between the carrier frequency and the side band frequency the feeder will be an integral number of one-quarter wavelengths long and will act as a transformer so that the impedance at the transmitter end will be different from the impedance at the side band or carrier frequency.

The response characteristic of the aerial, instead of showing merely a droop towards the extreme side band frequencies will also exhibit alternate rises and falls.

If L is the length of the feeder and f_o and f_1 are the carrier and side band frequencies, respectively, the numbers of standing half waves in the feeder at these two frequencies are

$$\frac{2f_oL}{o} \text{ and } \frac{2f_1L}{o}$$

where o is the velocity of propagation of waves in the feeder and approximating to the velocity of light. The feeder is defined as being electrically long with respect to the highest modulation frequency if

$$2\left(\frac{f_1-f_o}{o}\right)L \geqq 1$$

Thus, if $(f_1-f_o)=\pm 2$ megacycles, the undesired effect will occur when L is greater than about 75 meters. With a long feeder and a wide frequency band it is therefore important that the impedance seen by the transmitter should be a substantially pure resistance over the working band of frequencies.

If a line is terminated by an impedance differing from its characteristic impedance by an impedance Z, it is well known that the input impedance is dependent upon the electrical length of the line. Hence, it is possible to choose an electrical length of feeder or line terminated at one end with an aerial the impedance of which varies with frequency such that the impedance looking into the other end at one frequency is equal to an assigned value R and a reactance X. It is further possible at another frequency to choose another electrical length which will give the same resistance and another reactance. This condition of a constant resistance R can be satisfied at a number of frequencies by the same physical length of line owing to the variation of electrical length with frequency. The reactance variations are a function of the aerial impedance, but if the aerial impedance deviations from the characteristic impedance of the feeder are equal in magnitude, the reactances are equal, and the line length can be chosen to make them equal and opposite. There is, therefore, obtained as the input impedance a resistance R at the mean frequency and at two side frequencies an equal re-

sistance R, with equal and opposite reactances. These reactances may be annulled by the corresponding reactances at the side frequencies of a circuit tuned to the mean frequency. By compensating in this way for the impedance deviations at two frequencies towards the extremes of the band, it is usually found that the deviations at all frequencies over the band are substantially compensated.

It is the object of the present invention to provide a high frequency signaling system in which irregularities in the response characteristic of an aerial, feeder and transmitter, are reduced.

According to the present invention, in a method of transforming impedance, the value of which varies with frequency, to a substantially constant resistance over a range of frequencies, the deviations of the impedance at frequencies in the said range from said constant resistance are transformed by the use of a length of transmission line which converts the deviations in impedance to deviations in reactance which are then substantially annulled by the provision of reactive circuits. In applying the invention to a high frequency signaling system including a feeder associated with a load which varies in impedance over a range of frequencies, the deviations in impedance from an arbitrarily selected impedance are converted to variations in reactance which are neutralized or substantially reduced by the provision of reactive circuits. Thus in a short wave transmitting system including an aerial connected by a feeder to a transmitter, a section of feeder is given such a length and such electrical constants that it transforms variations of impedance of the aerial into variations of reactance which are neutralized or reduced by the reactive circuits.

In order that the invention may be more clearly understood and readily carried into effect, reference will now be made to the accompanying drawings which include explanatory diagrams, a diagrammatic representation of a system embodying the invention, and two examples of concentric feeders embodying the invention.

Fig. 1 of the drawings shows diagrammatically a dipole aerial and feeder to which the invention is applied;

Figs. 2 and 3 are given merely for the purpose of exposition and show vector diagrams of the impedances entering into consideration in the design of aerial systems in accordance with the invention; and

Figs. 4 and 5 show constructional forms of concentric feeder.

Fig. 1 shows diagrammatically the invention applied to a dipole aerial system. A reactive circuit represented by the rectangle X is connected at a point in a concentric feeder F at a distance represented by l from the aerial end of the feeder. In the case shown, this length of feeder l has a characteristic impedance Z_0 which is equal to the substantially resistive impedance of the aerial at the mean frequency of the band of frequencies transmitted by the aerial.

For the sake of simplicity, a case will be considered in which the reactance of the aerial is negligibly small at the mean frequency and remains negligibly small over the range of frequencies transmitted by the aerial. The mean frequency, in the case under consideration, is the carrier frequency and the range of frequencies transmitted will be determined by the upper and lower side bands resulting from an amplitude modulation of the carrier. If now the radiation resistance of the aerial varies substantially linearly with frequency above and below the value at the carrier frequency, the electrical length l is made one-eighth of the wavelength at the carrier frequency.

Assuming that the resistance deviation is equal in magnitude to a at two frequencies equally different from the carrier frequency and that a is small compared with the characteristic impedance, the input impedance at EG of the line l of characteristic impedance Z_0 terminated by the impedance Z_0, a is

$$Z=Z+ae^{-2j\theta}$$

For any given values of Z_0, θ and a where θ is the electrical length of the line, Z may be obtained by setting off vectors OP and PQ, respectively equal to Z_0 and a as in Fig. 2 of the drawings, and rotating the vector PQ through an angle -2θ to PQ_1, Z is then given by the vector OQ_1. Thus, it will be seen that in order to convert the variation of resistance a into a variation of reactance only, 2θ must be equivalent to 90°, that is to say $\theta=45°$. Hence the length l is required to be one-eighth of a wavelength long. This length l can also be increased from one-eighth of a wavelength by any number of half wavelengths.

The operation of the system is unaltered in the vicinity of the carrier frequency but owing to the variation of the electric length of the line with frequency from the required value of $n\pi+45°$, the resistance variation is not converted to a pure reactance variation. It is obvious that this effect of the changing electrical length of the line is small if the line is merely the necessary one-eighth of a wavelength long. It will be seen that the variable radiation resistance has been replaced at the section EG in Fig. 1, by a constant resistance in series with a variable reactance. The increase of resistance for frequencies above the carrier frequency has been replaced by a reactance of one sign and the decrease of resistance for frequencies below the carrier frequency has been replaced by a reactance of opposite sign. The variations of reactance can thus be neutralized at EG by the insertion of suitable reactive circuits.

Since the variation of radiation resistance has been assumed to be linear with frequency, the resultant variation of reactance will also be linear and thus can be neutralized throughout the range of frequencies by the similar variation of the reactance in the neighbourhood of the carrier frequency, of an inductance and condenser connected in series in the central conductor of the feeder, the inductance and condenser being tuned to the carrier frequency. The ratio inductance/capacity is, of course, so chosen that the slope of the reactance/frequency curve is equal and opposite to that of the varying reactance to be annulled.

If the reactance of the aerial is not negligible but also varies linearly with frequency through zero at the carrier frequency, the impedance of the aerial will be represented by a constant resistance in series with an impedance of constant phase angle varying linearly with frequency. This impedance is represented at one frequency by the vector PQ (Fig. 3). Applying the general considerations of Fig. 2 to Fig. 3, it will be seen that the previous length l must be increased to l', corresponding to the angle $2\theta'$ of this figure.

Assume now that it is required to minimize the impedance variations of an aerial and feeder sys-

tem in which the aerial has the impedance characteristic given in the following table:

Frequency, megacycles	Resistance, ohms	Reactance, ohms
43	82	0
45	75	0
47	82	0

In applying the invention, it is possible to use a length of line such that the input resistance can be made substantially constant and equal to 75 ohms at the above frequencies, the reactance passing through zero at 45 megacycles. This may be attained by using a line of 75 ohms characteristic impedance which is matched at 45 megacycles.

Referring again to Fig. 2 of the drawings, the vector PQ represents the increase of resistance at 43 and 47 megacycles. The length of line is so chosen that on account of the difference in its electrical length at 43 and 47 megacycles the vector PQ is in one case rotated to position PQ_1 and in the other case to position PQ_2. Thus the line must be an odd number of one-eighth wavelengths long at both 43 and 47 megacycles. To obtain, in addition, the transformation to positive and negative reactances at 43 and 47 megacycles, respectively, the electrical lengths at the two frequencies must be different by a quarter of a wavelength. Also, in order that the reactance may be capacitative at 43 megacycles, so that it may be annulled by a parallel circuit tuned to 45 megacycles, which is inductive at frequencies below resonance, the electrical length of the line must be one-eighth of a wavelength greater than a half wavelength. Hence, the physical length must be such that the electrical length is

$$(4n+1)\frac{\lambda}{8}$$

at 43 megacycles, and

$$(4n+3)\frac{\lambda'}{8}$$

at 47 megacycles where λ and λ' are the corresponding wavelengths. Hence

$$\frac{4n+3}{4n+1}=\frac{47}{43}$$

which is satisfied by

$$n=\frac{41}{8}$$

Since, however, n is required to be an integer, the best compromise is realized by $n=5$ which corresponds to 2¾ wavelengths at 45 megacycles.

Referring now to Fig. 4 of the drawings, a portion of feeder is shown having a characteristic impedance of 75 ohms and consisting of an inner conductor 1 arranged concentrically within an outer conductor 2, the end A of the feeder being connected to an aerial or other impedance. At the point B which is distant from A by 2¾ of the wavelength of the mid-frequency is connected a correcting circuit in the form of a projecting portion C of a feeder equal in length to one-quarter of this wavelength, having a characteristic impedance of 56.6 ohms which in this case is the value required such that the slope of the reactance frequency curve of the portion C is that required to effect the desired correction. The inner and outer conductors are connected together at the end of the portion C.

Fig. 5 shows an alternative correcting impedance in the form of a series circuit comprising overlapping tubular sections of inner conductor. Since in this correcting circuit the reactance increases algebraically through zero with increasing frequency, the variation of input reactance of the feeder at the point of connection of the tuned circuit must decrease with frequency. This may be obtained by using a feeder differing in length by one-quarter of a wavelength from the previous value, that is to say, a feeder three wavelengths long. As shown in the drawings, the terminating end of the inner conductor is three wavelengths long at the mid-frequency, and its end overlaps a portion W of the continuation of the inner conductor, the cross-section of which is reduced for a distance equal to one-quarter of a wavelength. The inside surface of the tube XZ forms with this reduced portion an open circuited quarter wavelength line which acts in a manner similar to a series tuned circuit inserted between the points XY. It is necessary that this effective tuned circuit should have the correct slope of reactance frequency characteristic to compensate the input reactance of the feeder section. This may be obtained by a suitable choice of the characteristic impedance of the quarter wavelength tuned line and of the number of multiples of quarter wavelengths of this line.

If the impedance variations are not merely resistive, but contain a reactive component, that is to say, if the impedance of the aerial at 43 or 47 megacycles is represented by the vector OQ in Fig. 3, the necessary length of line is correspondingly modified.

A further case arises in which the variations of resistance at 43 and 47 megacycles are not equal and also variations of reactance at these frequencies are not equal but the variations in impedance are equal in magnitude but are of differing phase angle. The variations of impedance may then be represented by vectors of equal length inclined to one another in place of the vector PQ in Fig. 3. It will be realized that a length of line can be chosen to convert these impedance variations into equal and opposite reactances suitable for cancellation by the method described with reference to Figs. 4 and 5.

In the case in which variations in impedance are unequal for equal changes of frequency, the method of the invention may be applied to convert the impedance differences into reactance differences which will, of course, not be of the same magnitude. Cancellation of these reactances will then require the use of reactive circuits more complicated than simple series and parallel tuned circuits.

The methods of Figs. 4 and 5 may be combined for special purposes, as in cases in which the reactance values are non-symmetrical. Further, should the correction not be adequate, the process may be repeated to further improve the characteristic.

What is claimed is:

1. A short wave aerial system for transmitting a carrier wave modulated by signals covering a wide band of frequencies, comprising an aerial having a small effective reactance and a feeder coupling said aerial to a radio transmitter, said feeder having such a length and such electrical constants that it transforms the variations of radiation resistance of said aerial into variations of reactance, and means connected to said feeder for neutralizing or substantially reducing said variations of reactance.

2. A system in accordance with claim 1, characterized in this that said means constitutes an inductance and a condenser connected in series in said feeder, said inductance and condenser being tuned to the frequency of the carrier wave, the ratio of inductance to capacity being so chosen that the slope of the reactance versus frequency curve is equal and opposite to that of the varying reactance to be annulled.

3. A short wave aerial system for transmitting a carrier wave modulated by signals covering a wide band of frequencies comprising an aerial and a feeder coupling said aerial to a radio transmitter, said feeder having such a length and such electrical constants that it transforms the variations of radiation resistance of said aerial into variations of reactance, and means connected to said feeder for neutralizing or substantially reducing said variations of reactance, said means comprising a parallel circuit of inductance and capacity connecting in parallel with the conductors of said feeder.

4. A short wave aerial system comprising a dipole, a first section of balanced feeder coupled to the dipole of a length such that it transforms variations in radiation resistance of said dipole connected to it at one end to variations in inductive reactance at its other end, a second section of balanced feeder coupling said last end of said first section to a radio transmitter adapted to transmit a carrier modulated by signals covering a wide band of frequencies, and means at the junction point of said two sections of balanced feeder for neutralizing the variations of reactance.

5. A short wave aerial system in accordance with claim 4, characterized in this, that the length of said first section of balanced feeder is one-eighth of the operating wavelength at the mean frequency to be transmitted, said first section having a characteristic impedance equal to the radiation resistance of said dipole.

6. A short wave aerial system in accordance with claim 4, characterized in this that said means comprises, in effect, a section of line having an electrical length equal to one-quarter wavelength at the mean operating frequency.

7. A high frequency system comprising a load which varies in impedance over a range of frequencies, a feeder connected to said load, said feeder having such constants as to convert deviations in impedance of said load from an arbitrarily selected impedance into variations in reactance, and means connected to said feeder for neutralizing variations in reactance, whereby there is obtained a constant input impedance looking into said feeder.

8. A high frequency system comprising a load which varies in impedance over a range of frequencies, a feeder connected to said load, said feeder having such constants as to convert deviations in impedance of said load from an arbitrarily selected impedance into variations in reactance, and a reactive circuit including a lumped reactance connected to said feeder for neutralizing variations in reactance, whereby there is obtained a constant input impedance looking into said feeder.

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