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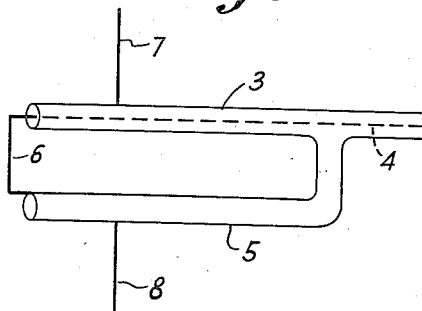
E. C. CORK ET AL

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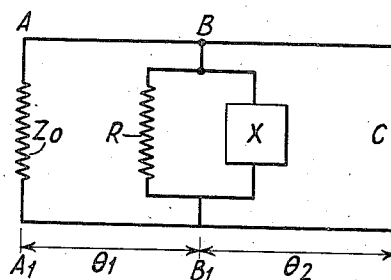
FEEDER AND THE LIKE FOR ELECTRIC CURRENTS OF HIGH FREQUENCY

Filed Sept. 16, 1936

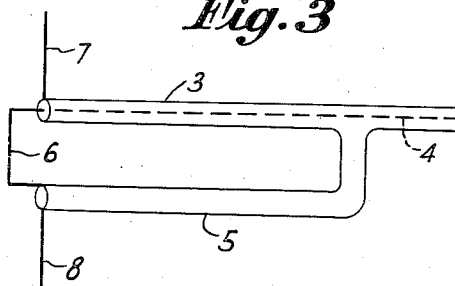
*Fig. 1*



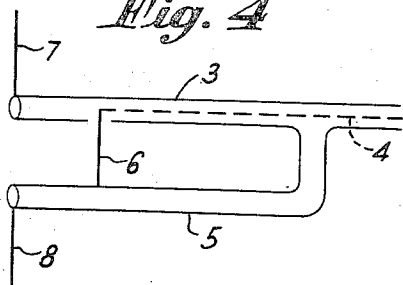
*Fig. 2*



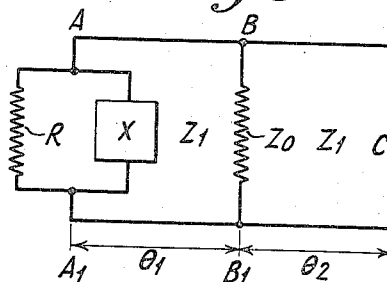
*Fig. 3*



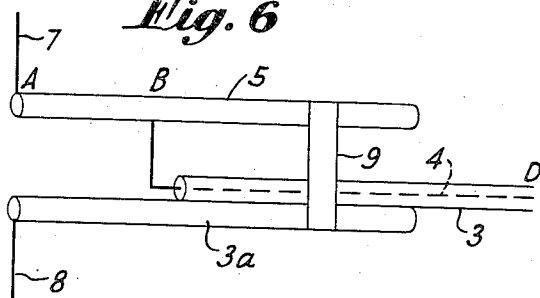
*Fig. 4*



*Fig. 5*



*Fig. 6*



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## UNITED STATES PATENT OFFICE

2,138,906

FEEDER AND THE LIKE FOR ELECTRIC  
CURRENTS OF HIGH FREQUENCY

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Application September 16, 1936, Serial No. 100,986  
In Great Britain September 17, 1935

10 Claims. (Cl. 250—33)

This invention relates to aerial systems for electric currents of high frequency such as are encountered in television and like transmission or receiving systems.

5 In the specification of British Patent 438,506, there is described a feeder system in which, in one embodiment, a quarter wavelength rejector circuit is provided at the end of a concentric feeder which is connected to a dipole aerial for the purpose of changing an unbalanced concen-  
10 tric line to a balanced aerial system. This balancing effect is obtained when equal current is fed into the two portions of the aerial the rejector circuit serving to cancel or reduce the current  
15 flowing along the outside of the sheath of the feeder.

It is generally desirable to match the impedance of the aerial to that of the feeder and hitherto it has been customary to employ a suitable form of transformer for this purpose. In many cases the length of the aerial for high frequency transmission or reception is one-half of the operating wavelength, but in some cases, in order to avoid excessive size of aerial or for other  
25 reasons, it may be desirable to employ an aerial of less length than half of the operating wavelength. In this case and in the case in which the aerial is of a length greater than one-half of the operating wavelength, the impedance of  
30 the aerial at the point to which the feeder is attached contains a reactive component. The magnitude of the reactive component also depends upon the folding or shaping, if any, of the aerial. In order, therefore, to obtain efficient transfer of  
35 energy between the feeder and aerial and to prevent reflection at the point of connection, it is necessary to match the aerial to the feeder which necessitates that the system shall be tuned, since the impedance of the feeder is, in general, almost  
40 purely resistive. Since the feeder resistance is also in general different in value from the resistive component of the aerial impedance, a transforming device becomes necessary, as stated above. If the aerial is tuned to a length which  
45 is a multiple of the operating wavelength, a transforming device is still generally required for matching purposes.

In the specification of the aforementioned patent, a transforming device is disclosed in which  
50 one of the conductors of the feeder is provided for part of its length equal to a quarter of the operating wavelength and adjacent the aerial end of the feeder, with a radius greater or less than the radius of the main part of the conductor so  
55 that such portion has a characteristic impedance

different from that of the main part of the feeder, such characteristic impedance being arranged to give impedance matching between the feeder and the aerial attached thereto.

It is the chief object of the present invention to provide an improved high frequency aerial system employing a rejector circuit as described in the specification of the above-numbered patent and in which impedance matching is obtained in a simple, but nevertheless effective manner.  
10

According to the invention, a high frequency aerial system is provided in which a dipole aerial is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath, the two portions of the aerial being effectively connected to the sheath and auxiliary conductor, and wherein, for the purpose of matching the impedance of the aerial to that of the feeder, the auxiliary line comprising the sheath and auxiliary conductor is arranged to function as a transformer. The auxiliary conductor functions in the manner described in the specification of the above numbered patent as a rejector, and also functions, in conjunction with the sheath of the feeder, as a transformer for matching purposes, so that the use of a separate transforming device, such as the transformer disclosed in the  
25 aforesaid specification, or another form of transformer, is avoided. The required transforming action may be obtained by connecting a dipole aerial to points on the sheath of the feeder and the auxiliary conductor at a suitable distance from the end of the feeder, or by connecting the  
30 aerial to the ends of the feeder and auxiliary conductor and by adjusting the length of the auxiliary conductor. Other examples of the invention will be hereinafter described.  
35

In order that the said invention may be clearly understood and readily carried into effect, the same will now be more fully described with reference to the accompanying drawing, in which:  
40

Fig. 1 illustrates an aerial system constructed in accordance with one embodiment of the invention;  
45

Fig. 2 represents the equivalent electrical circuit of the arrangement shown in Fig. 1;  
50

Fig. 3 illustrates a further aerial system in accordance with the invention;

Figs. 4 and 5 illustrate, respectively, another embodiment of the invention and the equivalent electrical circuit; and  
55

Fig. 6 illustrates a modification of the system shown in Fig. 4.

Referring now more particularly to Fig. 1 of the accompanying drawing, the aerial system comprises a concentric feeder including a tubular sheath 3 and an inner conductor 4, the feeder at the right hand end of Fig. 1 being adapted to be connected to a short wave wireless transmitter or receiver. At the other, or aerial end of the feeder, an auxiliary conductor 5 is attached to the sheath 3, the conductor 5 preferably being of the same external cross section and shape as the sheath 3, but may be otherwise constructed as described, for example, in the specification of the aforesaid patent. The auxiliary conductor, as shown, projects perpendicularly a short distance, for example, one or two inches from the sheath 3, and is then bent to lie parallel to the sheath 3, the free end of the auxiliary conductor being located adjacent the end of the sheath 3. Although the auxiliary conductor is shown mounted parallel to the feeder, this is not an essential requirement. The free end of the auxiliary conductor 5 is conductively connected by a conductor 6 to the inner conductor of the feeder. The sheath of the feeder and the auxiliary conductor form an auxiliary transmission line shorted at one end and connected to the feeder. The arrangement shown in Fig. 1 is illustrated in conjunction with a dipole aerial and the portions 7 and 8 of the aerial are connected to the sheath 3 and the auxiliary conductor 5 at points located at a suitable distance from the end of the feeder.

Corresponding to any point of attachment of the aerial, there exists at the free end of the feeder an impedance which is a function of the impedance of the aerial and its point of attachment. By suitable choice of the impedance of the aerial with respect to its point of attachment, or of the point of attachment with respect to the impedance of the aerial, it can be arranged that the effective impedance at the aerial end of the feeder is equal to the characteristic impedance of the feeder. The impedance looking along the feeder from the end thereof which is connected to the transmitter or receiver is then equal to the characteristic impedance of the feeder. The action of the auxiliary conductor in conjunction with the sheath of the feeder is, therefore, that of a transformer.

For the purpose of determining the required dimensions of the system shown in Fig. 1, reference will now be made to the equivalent electrical circuit shown in Fig. 2. The aerial impedance in this figure has been converted in well known manner to the equivalent circuit of resistance R and reactance X in parallel, and is connected across the rejector at the points BB'.

Let  $Z_1$  be the characteristic impedance across the sheath 3 and auxiliary conductor 5, constituting the rejector, considered as part of a continuous line.

Let  $Z_0$  be the characteristic impedance between the inner conductor and the sheath of the feeder.

Points AA' are connected to the feeder, which is a substantially pure resistance of value  $Z_0$ . To match and tune the aerial it is necessary to make the impedance at the terminals BB', without the equivalent aerial circuit connected, equal to a resistance R in parallel with a reactance  $-X$ , in order to match the resistance R of the antenna and tune out the reactance  $+X$  of the antenna. This is done by correct choice of the electrical lengths  $\theta_1$  and  $\theta_2$  of the portions AB and BC of

the rejector. It is understood, of course, that

$$\theta_1 = 2\pi \frac{AB}{\lambda}$$

and

$$\theta_2 = 2\pi \frac{BC}{\lambda}$$

where  $\lambda$  is the working wave-length.

The impedance of the line  $\theta_1$ , terminated by  $Z_0$  at A is equivalent to a parallel arrangement of resistance  $R_1$  and reactance  $X_1$ , where

$$R_1 = Z_0 \left\{ \cos^2 \theta_1 + \frac{Z_1^2}{Z_0^2} \sin^2 \theta_1 \right\} \quad (1)$$

$$X_1 = \frac{\cos^2 \theta_1 + \frac{|Z_1|^2}{Z_0^2} \sin^2 \theta_1}{\frac{\sin 2 \theta_1}{2 Z_1} \left\{ \frac{|Z_1|^2}{Z_0^2} - 1 \right\}} \quad (2)$$

Similarly the reactance of the shorted line  $\theta_2$  is

$$X_2 = Z_1 \tan \theta_2 \quad (3)$$

The conditions for tuning and matching are respectively:

$$\frac{1}{X} + \frac{1}{X_1} + \frac{1}{X_2} = 0 \quad (4)$$

$$R_1 = R \quad (5)$$

From Equations 1 and 5 we obtain:

$$\sin^2 \theta_1 = \frac{\frac{R}{Z_0} - 1}{\frac{|Z_1|^2}{Z_0^2} - 1} \quad (6)$$

For a given value of equivalent aerial resistance R and some value of  $Z_1$ , Equation 6 determines  $\theta_1$ , and hence the distance from A at which the aerial is to be connected. Substituting this value of  $\theta_1$  in Equation 2 the value of  $X_1$  at BB' is found. Inserting this and X in Equation 4  $X_2$  is found and from 3 the value of  $\theta_2$  that is to say the length BC for the assumed value of  $Z_1$  is determined.

A consideration of Equation 6 shows that since  $\sin^2 \theta_1$  can vary between the values 0 and 1, R must lie between the limits  $Z_0$  and  $Z_1^2/Z_0$ .

In the above  $Z_1$  has an assumed value and  $\theta_1$  and  $\theta_2$  are determined. A special case arises when

$$\theta_1 + \theta_2 = \frac{\pi}{2} \quad (7)$$

in other words when the length AC is one-quarter of the working wave-length. In this case  $\theta_1$  and  $Z_1$  have certain values. It can be shown that if the aerial has the impedance

$$r - jx = Z_0 \cos^2 \theta_1 - j Z_1 \cos \theta_1 \sin \theta_1 \quad (8)$$

and is connected across BB' at the electrical distance  $\theta_1$  from A, then the impedance at the open end A is resistive and equal in value to  $Z_0$ . Hence

$$\theta_1 \text{ is given by } \cos^2 \theta_1 = r/Z_0$$

and

$$Z_1 \text{ is given by } Z_1 = \frac{-X_2}{\cos \theta_1 \sin \theta_1}$$

The above formulae assume that the losses in the rejector line are negligible, and it is well known that at the high frequencies to which the system is applicable this condition is closely approximated.

An alternative arrangement is shown in Fig. 3 of the drawing in which the two portions of the aerial are connected to the free ends of the sheath 3 and the auxiliary conductor 5. Compared with the equivalent electrical circuit of

Fig. 2, Fig. 3 represents a case in which  $\theta_1=0$ . Let  $r+jx$  be the impedance of the aerial.

The equivalent parallel resistance  $R$  and reactance  $X$  of the aerial are given by:

$$R = \frac{r^2 + x^2}{r} = r + \frac{x^2}{r}$$

and

$$X = \frac{r^2 + x^2}{x}$$

In order that  $R$  may be equal to  $Z_0$ ,  $x$  must be adjusted by altering the length of the aerial. Alteration of the length of the aerial has a large effect on the value of  $x$ , but only a relatively small effect on the value of  $r$ . Hence the length must be adjusted to give  $x^2=r(Z_0-r)$ . The resultant parallel reactance of the aerial is then

$$X = Z_0 \left\{ \frac{r}{Z_0 - r} \right\}^{\frac{1}{2}}$$

The length of the rejector portion is then chosen to have a reactance  $-X$ . If  $\theta$  is the electrical length required, as in Equation 3,

$$\begin{aligned} \tan \theta &= -\frac{X}{Z_1} \\ &= -\frac{Z_0 \left\{ \frac{r}{Z_0 - r} \right\}^{\frac{1}{2}}}{Z_1} \end{aligned}$$

It is obvious that since  $R > r$ , the method of Fig. 3 is only possible if  $r < Z_0$ . This is the case that is most likely to occur in practice since the radiation resistance  $r$  of a dipole decreases rapidly with a decrease in length from the approximate value of 70 ohms at half a wave-length, and a common value for the characteristic impedance  $Z_0$  of the feeder is 100 ohms.

In the system of Fig. 1 transformations are limited to aerials with effective parallel resistances between  $Z_0$  and  $Z_1^2/Z_0$ . In Fig. 4 is shown an alternative scheme in which the aerial and feeder points of connection are interchanged with respect to those of Fig. 1. In this case the portions 7 and 8 of the aerial are connected to the free end of the sheath 3 and auxiliary conductor 5 and the central conductor 4 is tapped by virtue of conductor 6 onto auxiliary conductor 5 at a predetermined distance along its length. By this arrangement aerials having an effective parallel resistance outside the above range and any value of reactance can be transformed. This arrangement will also transform aerials with resistances within the above range provided that the reactance is greater than a value dependent on the resistance.

The equivalent electrical circuit is shown in Fig. 5 and it is possible to calculate the value of  $\theta_1$  for values of  $R$ ,  $X$  and  $Z_1$ , i. e., the length  $AB$  is determined. The length of  $BC$  is again calculated to cancel the resultant reactance at  $BB'$ .

In practice, it is merely necessary to select the tapping point  $BB'$  so that the parallel resistance across  $BB'$  without the central conductor of the feeder connected to  $B'$  is equal to  $Z_0$ . The length  $BC$  is then chosen to annul the parallel reactance.

A simpler practical arrangement is shown in Fig. 6. A length of feeder 3 a whole number of half wavelengths long, and therefore acting as a 1/1 transformer, is slidably connected to the conductors 3a and 5 forming the line of characteristic impedance  $Z_1$ . The distance  $AB$  is adjusted until the equivalent parallel resistance measured at  $D$  is equal to the feeder impedance  $Z_0$ . A shorting member 9 which is the equivalent of the perpendicular portion of the auxiliary conductor

clamped in position, is then adjusted until the parallel reactance at  $D$  is tuned out. The feeder is thus matched and may, therefore, be continued for any length.

The term "concentric feeder" employed here- in means a feeder of the kind in which one or more conductors are surrounded by an outer conductor in the form of a sheath. The sheath may, for example, act as one conductor of a two wire feeder or as an electrostatic shield for the inner conductor or conductors.

What is claimed is:

1. A high frequency aerial system in which a dipole aerial is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath at a point intermediate the ends of said sheath, the two portions of the aerial being effectively connected to the sheath and the auxiliary conductor at predetermined points on the lengths thereof away from their open ends for the purpose of matching the impedance of the aerial to that of the feeder.

2. A high frequency aerial system in which a dipole aerial having a complex load impedance is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath, the two portions of the aerial being effectively connected to the sheath and auxiliary conductor, said auxiliary conductor comprising two parallel conducting tubes open at least at one end, the two portions of the aerial being effectively connected to said tubes at said open end thereof, a short-circuiting strap connected across said tubes for adjusting the effective length thereof, said inner conductor being connected to one of said tubes at a predetermined point along its length between said strap and said open end, whereby the impedance of said aerial is matched to the impedance of said feeder.

3. A high frequency aerial system in which a dipole aerial having a complex load impedance is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath at a point intermediate the ends of said sheath, the two portions of the aerial being effectively connected to the sheath and the auxiliary conductor at predetermined points in the lengths thereof away from their open ends, and a connection joining the open end of said auxiliary conductor and said inner conductor, whereby the impedance of said aerial is matched to that of said feeder.

4. A high frequency aerial system in which a dipole aerial having a complex load impedance is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath at a point intermediate the ends of said sheath, the two portions of the aerial being effectively connected to the sheath and auxiliary conductor at the open ends thereof, said inner conductor being connected to the auxiliary conductor at a predetermined point along its predetermined length away from its open end, said auxiliary conductor and said sheath having such lengths and being so constructed as to form a tank circuit and functioning in the manner of a trans-

former for the purpose of matching the impedance of the aerial to that of the feeder.

5 5. A high frequency aerial system comprising a dipole aerial having a complex load impedance, a concentric feeder having an inner conductor surrounded by a sheath, and a line for matching the impedance of said aerial to that of said feeder, said line constituting an auxiliary conductor and the outer surface of said sheath, said auxiliary conductor being coupled at predetermined points in its length both to said inner conductor and to said sheath, the two portions of said aerial being effectively coupled both to said sheath and to said auxiliary conductor, whereby the impedance of said aerial is matched to that of said feeder.

10 6. A high frequency aerial system in which a dipole aerial is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath at a point intermediate the ends of said sheath, the two portions of the aerial being effectively connected to the sheath and the auxiliary conductor at predetermined points on the lengths thereof away from their open ends for the purpose of matching the impedance of the aerial to that of the feeder, the lengths of said sheath and auxiliary conductor to the left and right of said predetermined points being so chosen as to make the aerial conductance equal to the conductance between the predetermined points and the aerial susceptance equal and opposite to the susceptance between the predetermined points.

15 35 7. A high frequency aerial system in which a dipole aerial is fed by a concentric feeder comprising an inner conductor surrounded by a sheath and in which a rejector circuit is employed comprising an auxiliary conductor attached at one end to the sheath at a point intermediate the ends of said sheath, the two portions of the aerial being effectively connected to the sheath and the auxiliary conductor at predetermined points on the lengths thereof away from their open ends for the purpose of matching the impedance of the aerial to that of the feeder, said aerial having an

effective parallel resistance in the range between  $Z_0$  and  $Z_1^2/Z_0$ , where  $Z_0$  is the characteristic impedance between the inner conductor and sheath of the concentric feeder and  $Z_1$  is the value of the characteristic impedance across the sheath of the feeder and the auxiliary conductor.

8. Means for matching a balanced complex load impedance to a coaxial line having a certain characteristic impedance, comprising a section of two-conductor line, one end of which is open and the other end of which is short circuited, part of said two-conductor line acting as the outer conductor of a portion of said coaxial line, connections from one of said impedances to the open end of said two-conductor line and connections from the other impedance to a pair of points on said two-conductor line between which the admittance is equal to the conjugate of the admittance of said last named impedance, the length of said two-conductor line being so chosen as to provide such a point.

9. Means for matching a balanced complex load impedance to a coaxial line having a certain characteristic impedance, comprising a section of two-conductor line, one end of which is open and the other end of which is short circuited, a part of said two-conductor line having electrically the same potential as the outer conductor of said coaxial line, connections from one of said impedances to one end of said two-conductor line and connections from the other impedance to a pair of points on said two-conductor line between which the admittance is equal to the conjugate of said admittance to said last named impedance, the length of said two-conductor line being so chosen as to provide such a point.

10. A symmetrical tank circuit devoid of concentrated reactance, connections for energizing it from an unbalanced line, connections from said tank circuit to a balanced load circuit, the tuning of said tank circuit and the points of connection being so chosen as to match the impedance of said line to said load.

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