March 22, 1938. A. D. BLUMLEIN ET AL 2,111,743

AERIAL SYSTEM

Filed Oct. 7, 1936 2 Sheets-Sheet 1

Fig. 1

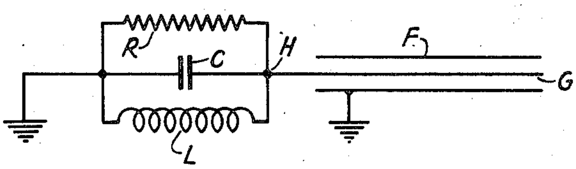



Fig. 2

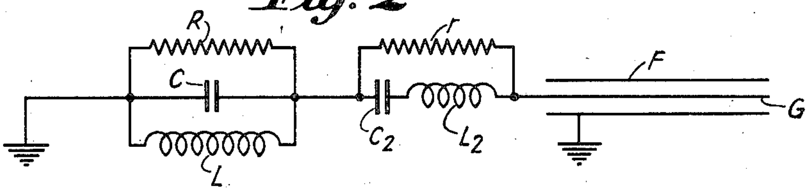



Fig. 3

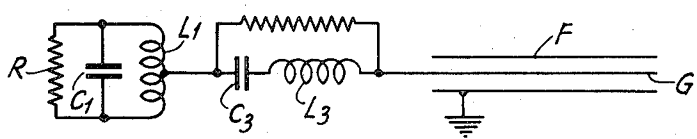



Fig. 4

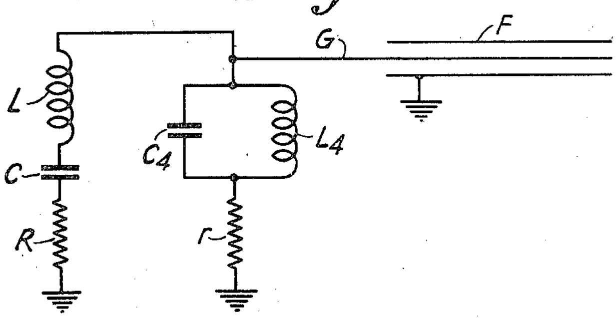
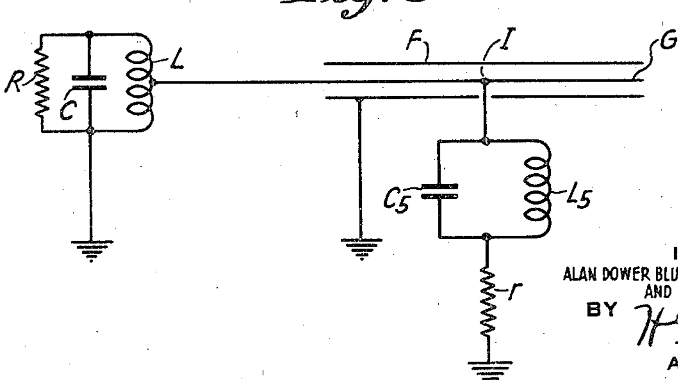



Fig. 5

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AERIAL SYSTEM

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Fig. 6

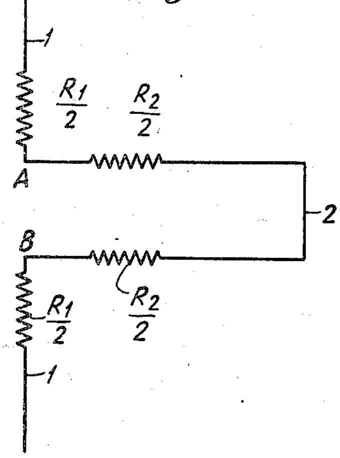



Fig. 7

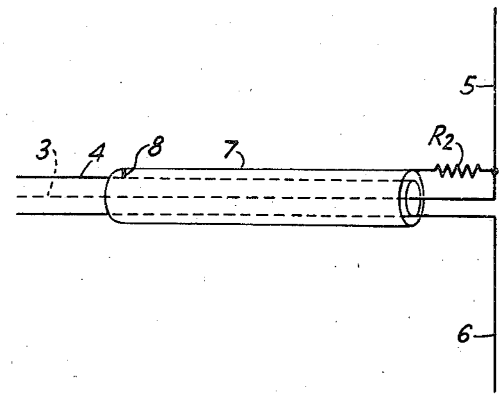



Fig. 8

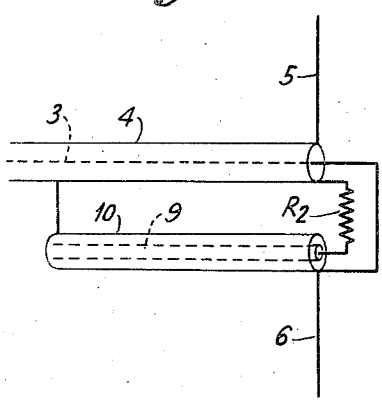



Fig. 9

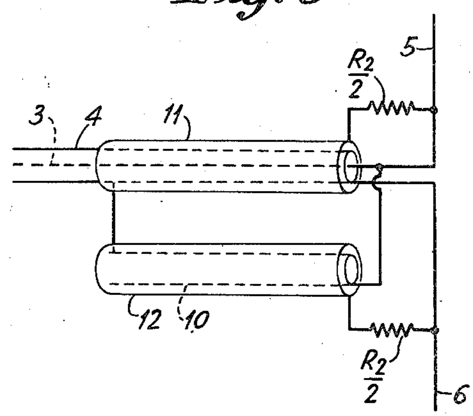
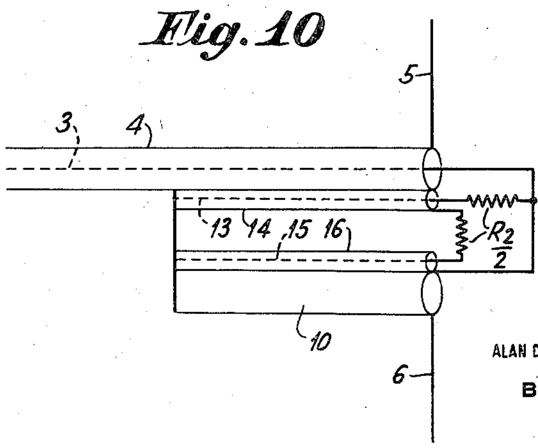



Fig. 10

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# UNITED STATES PATENT OFFICE

2,111,743

## AERIAL SYSTEM

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9 Claims. (Cl. 250—17)

This invention relates to aerial and feeder systems for short wave transmitting apparatus and has particular reference to aerial systems for use with signal frequencies of the order employed in television transmission systems.

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 may be impracticable to match the transmitter impedance to the feeder impedance and also to the aerial impedance, and at the same time obtain the necessary band width; in fact the load thrown on the transmitter by the aerial seen through the feeder may be much lower than the impedance of the transmitter. Any small errors or variations in the impedance of the aerial as seen through the feeder then affect the output. If these errors are variable 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 electrically 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 of frequencies 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 maladjustment or to the variation of the aerial impedance with frequency. Even if the aerial has a natural frequency response curve adequately wide for the band in question, at small departures from the tuning frequency of the aerial, considerable reactance may be present. For example, if an aerial has a natural band width of ±5 megacycles per second, the band width being taken as the width of the band within which the response does not fall more than 3 decibels below the maximum, then, at 5 megacycles per second from its tuned frequency, the reactance of the aerial will equal its resistance. At one megacycle per second from the tuned frequency, the reactance will be approximately one-fifth of (or five times if considered in parallel) the resistance. This is a 20% error in matching impedance.

It is well known that if a feeder is not correctly terminated, standing waves occur in the feeder and the impedance at the transmitter input will vary for any given aerial impedance and frequency with the length of the feeder. If the feeder is approximately an integral number of half wavelengths long at the side band frequency, the impedance at the transmitter end of the feeder will also be in error by 20%. If at the carrier frequency the feeder is a different integral number of half wavelengths long, then at some frequency or frequencies between the carrier frequency and the one megacycle side band frequency, the feeder will be an integral number of one-quarter wavelengths long and will act as a transformer so that at these frequencies the impedance at the transmitter end will be less than the impedance at the 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 $f_0$ and $f_1$ are the carrier and side band frequencies respectively, the numbers of standing waves in the feeder at these two frequencies are:

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

where $c$ 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

$$2\frac{(f_1-f_o)}{c}L \geqq 1$$

Thus, if $(f_1-f_0)=\pm 2$ megacycles, the undesired effect will occur when L is greater than about 75 meters.

It is the object of the invention to provide means for preventing variations of the impedance presented to a transmitter connected with an aerial by an electrically long feeder and so obtaining a substantially even response over a desired range of frequencies.

According to the present invention, in a short wave transmitting system, variation in reactance of the aerial is corrected by the insertion at or near the aerial of circuits which convert the impedance of the aerial system to a substantially constant resistance. In particular systems, according to the invention, the aerial, by the addition of reactance with or without resistance, presents a substantially constant terminating resistance to the feeder at all important frequencies within a working range of frequencies.

In order that the invention may be more clearly understood and readily carried into effect, some aerial and feeder systems embodying the invention will now be described by way of example with reference to the accompanying drawings, wherein Figs. 1 and 6 are given for purposes of exposition and Figs. 2 to 5, inclusive, and 7 to 10, inclusive, illustrate various applications of the invention considered, respectively, first from the angle of equivalent constants for the antenna circuits, and then actual antenna constructions.

Referring to the drawings, Fig. 1 illustrates diagrammatically a known dipole aerial system fed from a potential antinode, in this case one end of the aerial. The aerial as represented includes a resistance R, a condenser C, and an inductance L connected in shunt with one another between earth and a common point. A concentric feeder F of characteristic impedance Z is connected at one end to a transmitter (not shown) and at its other end has its central conductor G connected to a point H which is one end of the aerial. The outer conductor of the feeder F is earthed. R, C and L represent the resistance, capacity and inductance, respectively, of the aerial. It will be seen that at frequencies off resonance, even when the reactance of L and C is still considerably greater than R, the feeder of impedance Z, assumed to be substantially resistive, will not be correctly terminated by the aerial. Fig. 2 illustrates the application of the invention to the aerial system shown in Fig. 1. An inductance $L_2$ and condenser $C_2$ are connected in series between the aerial and the feeder. Condenser $C_2$ and inductance $L_2$ are shunted by the resistance $r$ equal in magnitude to the resistance of the feeder and have the values

$$C_2=\frac{L^2}{R} \text{ and } L_2=C_2R^2$$

Under these conditions the impedance facing the feeder will be invariant with frequency and equal to R, i. e., equal to Z. If only comparatively small departures from the resonant frequency of the aerial are considered, the resistance $r$ may be omitted altogether since the variation of resistance presented to the feeder will not be serious and the only effect which it is necessary to correct is the reactance introduced by L and C. This can be corrected for small departures from resonance by the reactances $L_2$ and $C_2$.

If the impedance of the feeder does not match the impedance of the aerial directly, i. e., if Z is not equal to R, which is usual in practice when the end fed aerial is one-half of a wavelength long, it is necessary to insert a transformer between the feeder and aerial. This may take the form of a tuned circuit connected between the earth and the end of the aerial, the central conductor of the feeder being connected to a tapping point on the inductance of the tuned circuit while the sheath of the feeder is earthed. The inductance and capacity of the tuned circuit are in parallel with the corresponding inductance and capacity of the equivalent aerial circuit. The resultant inductance and capacity are shown by $L_1$ and $C_1$ in Fig. 3, which shows the application of the invention to the aerial and transformer system. The inductance $L_3$ and condenser $C_3$ are connected in series between the aerial end of the central core G of the feeder F, and the tapping point on the inductance $L_1$. The resistance $r$, equal in magnitude to the resistance of the feeder, shunts the condenser $C_3$ and inductance $L_3$ as in Fig. 2. If it is assumed that the transformer ratio is the square root of $n$, where $n$ is equal to

$$\frac{R}{Z}$$

then the apparent inductance value of $L_1$ at the tapping point will be

$$\frac{L_1}{n}$$

and the apparent value of $C_1$ at the same point will be $nC$. $L_3$ is then made equal to $nC_1Z^2$, and $C_3$ is made equal to

$$\frac{L_1}{nZ^2}$$

Under these conditions, assuming a perfect transformer, the impedance facing the feeder will be equal to Z. As in the case of the arrangement shown in Fig. 2, the resistance $r$ may be omitted if only small departures from the resonant frequency of the aerial are considered. Correction for the reactance introduced by $L_1$ and $C_1$ for small departures from resonance can be corrected by the reactances $L_3$ and $C_3$. In this case $L_3$ may be composed of the leakage inductance of the transformer so that in some cases only $C_3$ need be added.

Fig. 4 illustrates the case of an aerial fed at its centre, the aerial system being represented by an inductance L, a condenser C and a resistance R, connected in series with one another and between the aerial end of the feeder F and earth. It is assumed that the feeder impedance has been made equal to R. The present invention is shown applied to this arrangement by the addition of a shunt load comprising an inductance $L_4$ and capacity $C_4$ and resistance $r$. The lower terminal of resistance $r$ is earthed and its upper terminal is connected to one terminal of condenser $C_4$ and to one terminal of inductance $L_4$. The other terminals of the inductance $L_4$ and condenser $C_4$ are connected to the aerial end of the central conductor G. In this case it is arranged that

$$\frac{L_4}{C}$$

is equal to $R^2$,

$$\frac{L}{C_4}$$

is equal to $R^2$ and $r$ is equal to R. This is a counterpart of the arrangement described with reference to Fig. 3, and again, as a first approximation, resistance $r$ may be omitted and for this purpose may be short circuited.

Fig. 5 shows another method of applying the invention to the aerial system described with reference to Fig. 3. The tapping point on the inductance L remains directly connected to the end of the central conductor G of the feeder F, and a shunt load is connected between the central conductor G of the feeder and earth at a point I located a quarter wavelength or an odd number of quarter wavelengths from the aerial end of the feeder. The shunt load is of the type described with reference to Fig. 4. Thus, an inductance $L_5$ and capacity $C_5$ are connected at one end to the central conductor G and their other ends are earthed through resistance $r$. In this case $L_5$ is equal to

$$\frac{L}{n}$$

and $C_5$ is equal to $nC$. As before, as a first approximation close to resonance $r$ may be effectively omitted by short circuiting it. If this type of correction is employed, it is advisable to put the correcting circuit only a small number of quarter wavelengths away from the aerial, if correction over a wide frequency band is required. By putting the load a quarter wavelength away, the impedance errors are inverted so that the type of circuit required is altered.

Further applications of the invention are illustrated in Figs. 7, 8, 9 and 10, and will be more clearly understood when considered in relation to the following explanation of Fig. 6. In this figure a dipole aerial **1** is represented diagrammatically and includes a parallel line circuit **2**. If it is assumed that the dipole aerial is a line of characteristic impedance $Z_A$ and of a length $\theta_a$ with a radiation resistance $R_1$ in series, and that the line **2** has an impedance $Z_o$, an electrical length $\theta$ and has in series a resistance $R_2$, then the impedance between the points A and B may be obtained by the following equation:—

$$Z=\frac{(R_1R_2+Z_oZ_A\cot\theta_A\tan\theta)+j\left(R_1Z_o\tan\theta-\frac{R_2Z_A}{\tan\theta_A}\right)}{R_1+R_2+j\left(Z_o\tan\theta-\frac{Z_A}{\tan\theta_A}\right)}$$

If, in this equation is inserted:

$$R_1=R_2=\sqrt{-Z_oZ_A}=R$$

and $\tan\theta_A=\tan\theta$, then $Z=R$, from which it is seen that the reactance variation has disappeared.

Referring to Fig. 7, a concentric feeder having inner and outer conductors **3** and **4** is connected to a dipole aerial **5, 6**. The parallel line corresponding with the line **2** in Fig. 6 is constituted by an outer sheath **7** enclosing the sheath **4** of the feeder. The sheath **7** is connected directly to the sheath **4** at a point **8** approximately one electrical quarter of a wavelength from the aerial **5, 6**.

In Fig. 8 a symmetrical arrangement is shown in which the parallel line is formed by adding an inner conductor **9** to a hollow line **10** used normally as a dummy line serving the same purpose as an interference suppressing line of the kind described in the specification of British Patent No. 438,506. This interference suppressing line renders the end of the feeder connected to the aerial electrically symmetrical with respect to earth, and also acts so that interference picked up by and propagated along the outside of the feeder acts equally on each half of the dipole aerial so that no potential difference due to interference is established between the conductors of the feeders **3, 4**.

In Fig. 9 a symmetrical arrangement is shown, but in this case two parallel lines **11** and **12** are used as the correcting lines, the dummy line **10** shown in Fig. 8 being retained.

In Fig. 10 a further symmetrical arrangement is shown but in this case two auxiliary concentric lines having inner and outer conductors **13** and **14**, and **15** and **16**, respectively, are used for correction purposes.

It will be understood that the invention may be carried out in further ways which will occur to those skilled in the art, and it is further to be understood that the invention may be applied to aerials of other types than dipoles, the correction in certain cases being made at the junction of the aerial and its feeder.

What is claimed is:

1. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling said aerial to said source, and a circuit coupled to said feeder near the coupling point of said aerial and feeder for presenting a substantially pure resistance to said feeder over a range of frequencies which said aerial is adapted to radiate.

2. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling said aerial to said source, and a circuit coupled to said feeder near the coupling point of said aerial and feeder for presenting a substantially pure resistance of constant magnitude to said feeder over a range of frequencies which said aerial is adapted to radiate.

3. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling said aerial to said source, and a circuit inserted in series between said aerial and feeder and located near the coupling point of said aerial and feeder for presenting to said feeder a substantially pure resistance over a range of frequencies which said aerial is adapted to radiate.

4. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling said aerial to said source, and a circuit including a concentrated reactance coupled to said feeder near the coupling point of said aerial and feeder for presenting a substantially pure resistance to said feeder over a range of frequencies which said aerial is adapted to radiate.

5. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling said aerial to said source, and a circuit including a capacitance and an inductance effectively arranged in series inserted between said aerial and feeder near the coupling point of said aerial and feeder, said capacitance and inductance having such values as to present to said feeder a substantially pure terminating resistance over a range of frequencies.

6. In a short wave transmitting system, an aerial, a source of energy, a feeder a plurality of wavelengths long at the operating frequencies coupling one end of said aerial to said source, and a circuit including a capacitance and an inductance effectively arranged in series inserted between said aerial and feeder near the coupling point of said aerial and feeder, said capacitance and inductance having such values as to present to said feeder a substantially pure terminating resistance over a range of frequencies.

7. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling the center of said aerial to said source, and a circuit including a capacitance and an inductance effectively arranged in parallel coupled between said feeder and ground at a point near the coupling point of said aerial and feeder, said capacitance and inductance having such values as to present to said feeder a substantially pure terminating resistance over a range of frequencies which said aerial is adapted to radiate.

8. In a short wave transmitting system, an aerial, a source of high frequency energy, a feeder coupling the center of said aerial to said source, and a circuit including a capacitance and inductance effectively arranged in parallel coupled between said feeder and ground at a point a multiple of a quarter wavelength, including unity, from the coupling point of said aerial and

feeder, said capacitance and inductance having such values as to present to said feeder a substantially pure terminating resistance over a range of frequencies which said aerial is adapted to radiate.

9. A system in accordance with claim 5, characterized in this that said capacitance and inductance are substantially uniformly distributed and in the form of portions of concentric transmission lines.

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