

Feb. 5, 1946.

M. FUCHS

2,393,981

SHIELDED LOOP ANTENNA

Filed Nov. 6, 1943

2 Sheets-Sheet 1

Fig. 1.

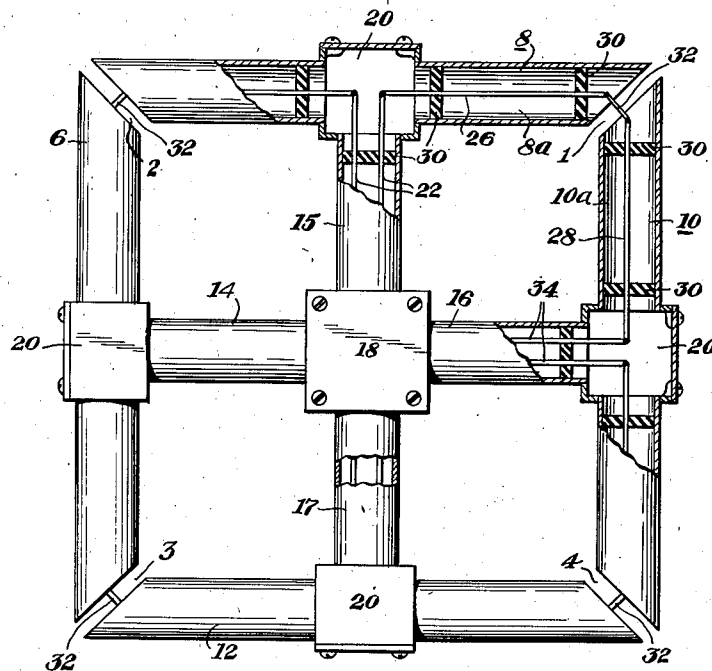
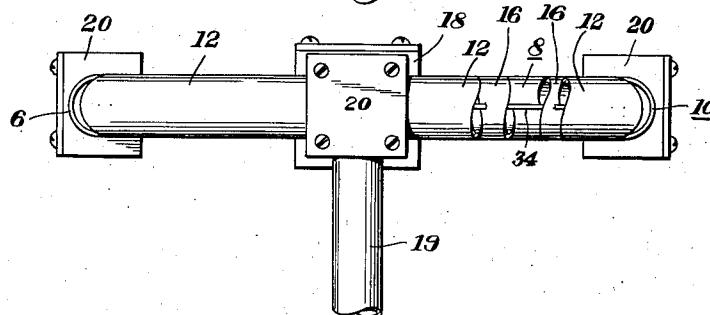


Fig. 2.



INVENTOR.
MORTON FUCHS
BY *R. P. Morris*
ATTORNEY

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M. FUCHS

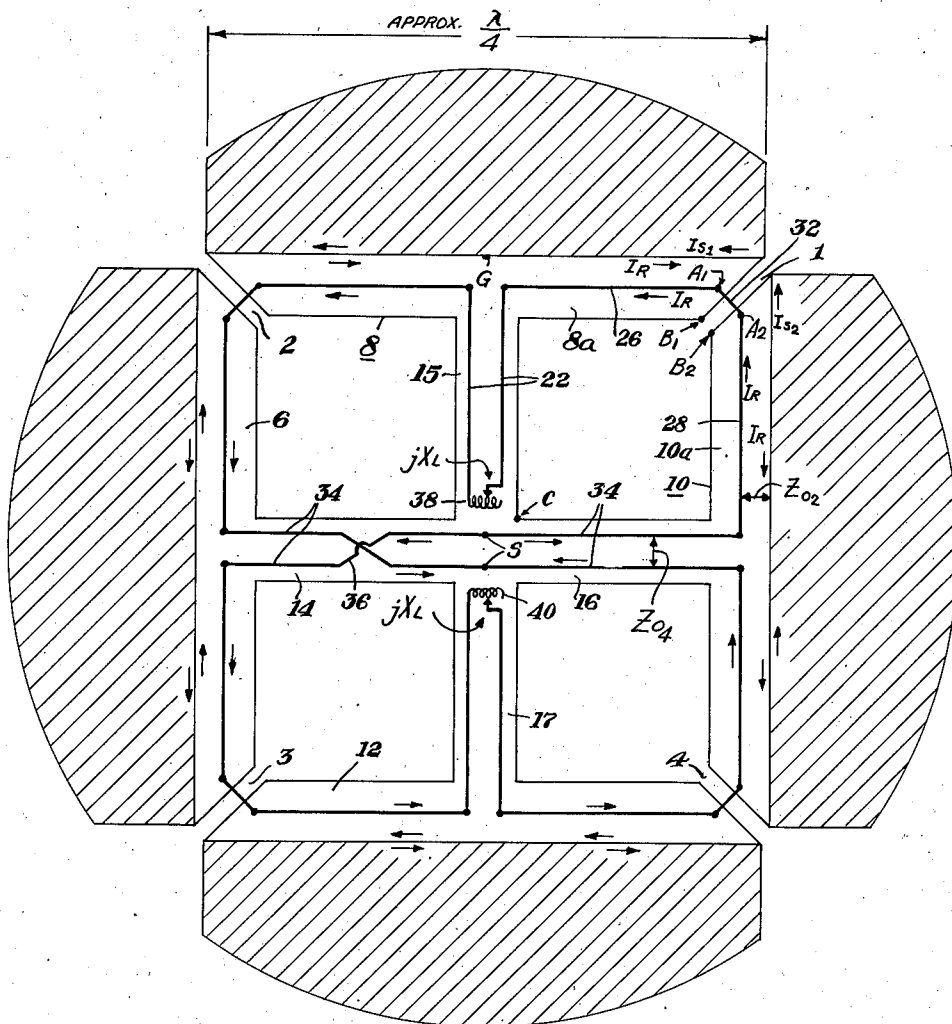
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Fig. 3.



INVENTOR.
MORTON FUCHS

BY

R. F. Morris

ATTORNEY

UNITED STATES PATENT OFFICE

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SHIELDED LOOP ANTENNA

Morton Fuchs, New York, N. Y., assignor to
Federal Telephone and Radio Corporation, New
York, N. Y., a corporation of Delaware

Application November 6, 1943, Serial No. 509,251

9 Claims. (Cl. 250—33)

The present invention relates to antennas, particularly those of the shielded loop type.

In United States Patent No. 2,289,856, issued July 14, 1942, to Andrew Alford, is shown an antenna unit having a plurality of radiating members several of which are directly energized through a connection to the transmission line, and the remainder of which receive their power from the energized members through a capacitive coupling arrangement. These radiating members of the patent are either of the single wire type or may consist of hollow metal tubes.

Such an antenna has the disadvantages that any unbalanced currents that may be picked up from, say, a neighboring power generator, will not be appreciably attenuated in the antenna, but will be passed along to the transmission line to produce undesirable effects on the output of the transmitter or receiver. Furthermore, the antenna shown in the above-mentioned patent is difficult to tune, since there is no convenient way of adjusting the impedances of the radiating members to match the impedance of the line.

Accordingly the present invention has as an object the provision of an antenna which will be receptive only to balanced currents.

A further object of the invention is to provide a shielded loop antenna which may be connected to a dual transmission line, and which incorporates means for adjusting the coupling between the line and the antenna conductors.

An additional object of the invention is to provide an antenna having a large radiation resistance and a consequent high degree of energy radiation.

Other objects and advantages will be apparent from the following description of a preferred form of the invention made with reference to the accompanying drawings, in which:

Figs. 1 and 2 are respectively plan and front elevational views of a preferred form of antenna in accordance with the present invention; and

Fig. 3 is a circuit diagram of the antenna shown in Figs. 1 and 2, also showing the current distribution pattern.

In the antenna unit of Figs. 1 and 2, four coplanar radiating members consisting of coaxial conductor sections 6, 8, 10 and 12 are arranged in the form of a square or other symmetrical substantially closed pattern. The ends of these conductor sections 6, 8, 10, 12 are spaced apart to provide gaps 1, 2, 3, and 4 therebetween, the width of the gaps being small compared to the diameter of the members. Four supporting arms 14, 15, 16 and 17 are respectively connected to

the mid-points of the conductor sections by means of a plurality of junction boxes 20, the conductor sections being split at their mid-points to permit such connection. Junction boxes 20 are provided in conventional fashion with demountable cover plates so that access may be had to the interior thereof. The inwardly-projecting ends of supporting arms 14, 15, 16 and 17 are connected to a central junction box 18 which has a demountable cover plate in the manner of boxes 20. This central junction box 18 is supported by a pole or mast 19, which may also be a shielded dual line for feeding the antenna, so that the antenna unit lies preferably in a horizontal position.

Since the four radiating members 6, 8, 10, 12 are similarly proportioned and symmetrically positioned, a description of a portion of the antenna unit will suffice to illustrate the constructional details, such portion being shown in section in Fig. 1. As above stated, radiating members 6, 8, 10 and 12 may constitute sections of a coaxial line, and each section is divided by the junction boxes 20 into two portions of equal length as shown. One portion of the member 8, designated as 8a, encloses an inner conductor 26, while one portion of member 10, designated as 10a, encloses an inner conductor 28.

The supporting arms 14, 15, 16 and 17, on the other hand, each contain two conductors, and preferably comprise sections of a shielded dual transmission line. Arm 15 contains a pair of leads 22, while arm 16 similarly contains a pair of leads 34. A plurality of spacers 30 are employed to position inner conductors 22, 26, 28 and 34. The extremities of the inner conductors of adjacent members are joined by connecting wires, the connector 32, for example, joining the conductors 26 and 28 so as to provide an unbroken current path between the conductors and across the gap, this connection being made by some preferred means such as soldering.

Connections are also made within junction boxes 20 between the two sections of the inner conductor of each radiating member and the dual conductors of its supporting arm, each coaxial conductor section being joined by soldering or other suitable means to one of the dual conductors, as for example, one of the dual conductors 22 being joined to the inner conductor 26 of radiating member portion 8a, and one of the dual conductors 34 being joined to the inner conductor 28 of radiating member portion 10a. Similar connections are made between the dual conductors of supporting tubes 14 and 17 and

the inner conductors of radiating members 6 and 12 respectively.

In the circuit diagram of Fig. 3 is shown a pair of adjustable inductances 38 and 40 respectively terminating lines 22 and the dual line enclosed within arm 17. Although elements 38 and 40 have been illustrated as inductance coils, it will be understood that other terminating devices for the lines within arms 15 and 17 may be substituted therefor, the only requirement being that the effective electrical length of the lines 26 and 22, for example, from the gap 1 to the terminating device be between 90° and 180°. The purpose of this requirement will later become apparent, but it might be mentioned that this electrical length of between 90° and 180° acts to transform a selected inductive reactance 38 at the terminus of the dual lines enclosed by arms 15 and 17 to a capacitive reactance between the inner conductor and the shield at the gaps between the ends of the radiating members.

Inductances 38 and 40 are adapted to be mounted in any desired manner within central junction box 18, and which mounting means are not shown. The midpoint of line 34 has two transmission line connections S located within junction box 18. The section of dual line 34 enclosed within supporting arm 14 is transposed as shown at 36.

It is well known that a coaxial line with a continuous shield between generator and load will not radiate. However, if the terminating impedance does not connect directly to the end of the shield, but is instead connected to some point on the outside of the shield, then current will flow on the outside of the shield and the line will radiate. The provision of an open ended shield, one end of which is grounded or serves as a connection point for completing the circuit of the terminating impedance, meets this later requirement. This effect may be introduced into a coaxial line by providing a gap in the shield conductor intermediate its ends. In this case each of the members beyond the gap may be considered as the impedance or load connected between the inner conductor of the other member and a point at the far end of the shield for this other member.

The current from transmission line terminals S, if transposed at 36, will flow in the same direction around the periphery of the antenna unit as shown by the arrows. Now it is known that the current on the inside of the shield flows in an opposite direction to the current in the line. By Kirchhoff's law the current flowing from one end on the outside of the shield must be equal to the current flowing toward that end in the opposite direction on the inside of the shield. Therefore, the directions of the currents in the inner conductor and on the outside of the shield are the same, and a circular radiation pattern will result.

The four radiating sections 6, 8, 10, 12 may be considered as approximately $\lambda/4$ (λ being the wavelength of the operating frequency) sections of a coaxial line, with gaps or openings in the shield at the corners of the square. In order that the current distribution be maintained properly in these radiating sections 6, 8, 10, 12, it is essential that they be terminated at their free ends in an effective capacitive reactance.

The purpose of inductive members 38 and 40 will now be apparent. It has been stated that the effective electrical length of lines 26 and 22, for example, from the gap to member 38 be between

90° and 180°. If line 22, as in this example, be terminated in an inductance, then this inductance will be transformed by lines 26 and 22 into an effective capacitive reactance between the inner conductor 26 and the shield at the gap between the radiating sections 6, 10. Thus the radiating members 6, 8, 10, 12 have the effect of "loaded" lines, and the radiation pattern produced will be substantially circular as shown in Fig. 3.

The following mathematical analysis is presented to more clearly bring out the operation of one form of applicant's antenna, although it will be clearly understood that it is given merely by way of example, and that the invention is not intended to be limited to the specific analysis set forth.

Since the two portions of radiating member 8 are of equal and opposite polarity, point G is at ground or neutral potential, and point C is likewise a neutral point. Let the subscripts to the voltage V designate the voltages between the points indicated, and in a similar manner let the subscripts to the impedance Z designate the impedance between such points. Also let the terminals of conductors 26 and 28 at the gap between members 8 and 10 be designated as A₁ and A₂ respectively, and let the adjacent ends of the shields of these members 8 and 10 be respectively designated as B₁ and B₂, as illustrated.

In order to demonstrate that the impedance of each shield appears in series with the line, or that

$$Z_{A_2 B_2} = Z_{A_1 B_1} + Z_{B_1 C} + Z_{B_2 C}$$

it will first be shown that the impedance $Z_{A_1 C}$ is the sum of impedances $Z_{A_1 B_1}$ and $Z_{B_1 C}$ or that

$$Z_{A_1 C} = Z_{A_1 B_1} + Z_{B_1 C} \quad (1)$$

when looking from the gap along conductor 26 toward point G.

This can be shown as follows:

$$Z_{A_1 C} = \frac{V_{A_1 C}}{I_R} \quad (2)$$

and

$$V_{A_1 C} = V_{A_1 B_1} + V_{B_1 C} \quad (3)$$

where I_R is the current flowing in the inner conductors 26 and 28.

Since

$$V_{A_1 B_1} = I_R Z_{A_1 B_1}$$

and

$$V_{B_1 C} = I_{S_1} Z_{B_1 C}$$

where I_{S_1} is the current on the outside of shield 8a, then substituting in (3)

$$V_{A_1 C} = I_R Z_{A_1 B_1} + I_{S_1} Z_{B_1 C}$$

Now, $I_R = I_{S_1}$, so that

$$V_{A_1 C} = I_R Z_{A_1 B_1} + I_R Z_{B_1 C} = I_R (Z_{A_1 B_1} + Z_{B_1 C}) \quad (4)$$

Substituting (4) in (2)

$$Z_{A_1 C} = \frac{V_{A_1 C}}{I_R} = \frac{I_R (Z_{A_1 B_1} + Z_{B_1 C})}{I_R} = Z_{A_1 B_1} + Z_{B_1 C}$$

or Equation 1.

Now it will be shown that

$$Z_{A_2 B_2} = Z_{A_1 B_1} + Z_{B_1 C} + Z_{B_2 C} \quad (5)$$

or that the impedance of each shield appears in series with the line. It can be assumed that

$$Z_{A_2B_2} = \frac{V_{A_2B_2}}{I_R} \quad (6)$$

and since

$$V_{A_1A_2} = 0$$

$$V_{A_1C} = V_{A_2C}$$

therefore

$$V_{A_2B_2} + V_{B_2C} = V_{A_1C} \quad (7)$$

Also

$$V_{A_1C} = I_R(Z_{A_1B_1} + Z_{B_1C}) \quad (8)$$

and since the current I_{S_2} on the outside of shield 10a flows out of Z_{B_2C} , then

$$V_{B_2C} = -I_{S_2}Z_{B_2C}$$

Since $I_{S_2} = I_R$, then

$$V_{B_2C} = -I_RZ_{B_2C} \quad (9)$$

Substituting (8) and (9) in (7)

$$\begin{aligned} V_{A_2B_2} &= V_{A_1C} - V_{B_2C} = I_R(Z_{A_1B_1} + Z_{B_1C}) - (-I_RZ_{B_2C}) \\ &= I_R(Z_{A_1B_1} + Z_{B_1C}) + I_RZ_{B_2C} \\ &= I_R(Z_{A_1B_1} + Z_{B_1C} + Z_{B_2C}) \end{aligned} \quad (10)$$

Substituting (10) in (6)

$$\begin{aligned} Z_{A_2B_2} &= \frac{V_{A_2B_2}}{I_R} = \frac{I_R(Z_{A_1B_1} + Z_{B_1C} + Z_{B_2C})}{I_R} \\ &= Z_{A_1B_1} + Z_{B_1C} + Z_{B_2C} \end{aligned}$$

and since the radiating elements of the loop are of the same size and shape,

$$Z_{B_1C} = Z_{B_2C}$$

Therefore

$$Z_{A_2B_2} = Z_{A_1B_1} + Z_{B_1C} + Z_{B_2C} = Z_{A_1B_1} + 2Z_{B_1C} \quad (11)$$

thus proving Equation 5.

It will now be shown that line 28 is terminated in a pure resistance. It has been stated that $Z_{A_1B_1}$ is the input impedance into line 22. Line 22 is terminated as shown in Fig. 3 by an element 38 which is chosen to present an inductive reactance jX_L at the terminus of the line. Since it has been previously stated that the combined length of conductors 26 and 22 from the gap to point C is electrically of the order of a quarter-wavelength of the operating frequency, this condition is utilized to transform inductive reactance jX_L into a capacitive reactance $-jX_C$, where

$$Z_{A_1B_1} = -jX_C \quad (12)$$

It has likewise been stated that both points G and C are at ground or neutral potential. Therefore Z_{B_1C} is an inductance X with a resistance component R produced by radiation, or

$$Z_{B_1C} = jX + R \quad (13)$$

Substituting Equations 12 and 13 in Equation 11

$$Z_{A_2B_2} = -jX_C + 2jX + 2R \quad (14)$$

If now jX_L is adjusted until $jX_C = 2jX$ these terms will cancel and

$$Z_{A_2B_2} = 2R \quad (15)$$

or in other words, line 28 will be terminated in a pure resistance $2R$.

It has been shown that the impedance $Z_{A_2B_2}$ is transformed back to input point S. If Z_{0_4} is made equal to $2Z_{0_2}$, where Z_{0_2} is the surge

impedance of line 28 with respect to the shield, and Z_{0_4} is the surge impedance of the dual line 34 before it divides, then at S the impedance $Z_{A_2B_2}$ will be transformed to

$$\frac{(Z_{0_4})^2}{2R} \quad (16)$$

and the input impedance Z_{in} of the antenna will be equal to two of these impedances (16) in parallel, or

$$Z_{in} = \frac{Z_{0_4}}{4R} \quad (17)$$

Although the invention has been described in connection with a transmitting antenna, it will be obvious that the structure disclosed will be suitable for use in receiving systems or as a single antenna for both purposes.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of my invention as set forth in the objects of my invention and the accompanying claims.

I claim:

1. A radio translating system including a radio antenna comprising a plurality of radiating members in the form of coaxial conductor sections positioned with ends spaced to provide small gaps therebetween and arranged to form a substantially closed coplanar periphery, each of said radiating members being short with respect to the operating wavelength, connections between the inner conductors of said coaxial sections across the gap between adjacent ends of said sections, a plurality of inwardly-projecting supporting arms in the form of shielded dual transmission lines substantially coplanar with said radiating members and respectively attached substantially at the mid-points thereof, the inner conductor of each of said coaxial sections being centrally broken and each of the resulting conductor portions being connected respectively to one of the conductors of the dual line attached to said section, whereby the inner conductors of the coaxial sections and the dual line conductors of said antenna form a plurality of individual substantially closed loops, a central mounting enclosing a pair of input terminals to said antenna and rigidly positioning said supporting arms, connections between the dual line conductors of two oppositely-positioned arms and said input terminals, the dual line conductors in one of said input connected arms being transposed, a pair of inductances respectively terminating the inwardly-projecting ends of the dual line conductors of the remainder of said arms, and means for transforming the inductive reactance produced by said inductances into a capacitive reactance between the inner conductors of the sections connected to the remainder of said arms and their respective shields at said gaps, whereby the radiant action of said system is substantially uniform in all directions about said periphery and has everywhere a polarization substantially parallel to said plane.

2. A radio translating system according to claim 1, wherein the electrical length of each of said radiating members is in the order of one-quarter wavelength at the operating frequency.

3. A radio antenna system including four shielded conductor sections positioned in coplanar relation with the ends of the shields adjacent to form a substantially closed periphery

with a gap between the adjacent ends of said shields, the ends of the conductors of each section being respectively joined to the ends of the conductors of adjacent sections, the conductors of each section being broken at substantially the midpoints of each section, four pairs of leads, one of said pairs connected to the conductor portions of each of said sections and projecting inwardly toward the center of said periphery, one pair of leads being transposed, means for transmitting energy over two oppositely-disposed pairs of leads including said transposed pair of leads, and means for terminating the remaining two pairs of leads in such a manner that the effective electrical length of any single lead of said remaining pairs added to the effective electrical length of the conductor portion to which it is connected will be between 90° and 180° .

4. A radio antenna system according to claim 3 in which said four pairs of leads comprise four shielded dual transmission line portions.

5. A radio antenna system according to claim 3 in which said means for terminating said remaining two pairs of leads comprises a pair of inductances respectively connected to the said remaining two pairs of leads.

6. A radio antenna system according to claim 3, further comprising a metal antenna supporting means, and a plurality of metallic arms connected substantially at the mid-points of each of said shielded conductor sections for mounting said conductor sections on said supporting means, said leads being enclosed within said arms.

7. A shielded loop antenna comprising a plurality of radiant acting coaxial conductors of substantially equal electrical length positioned with ends spaced to provide small gaps therebetween

and arranged to form a substantially closed coplanar periphery, the ends of the inner conductors being joined together across the gaps between the ends of said coaxial conductors, an input connection at substantially the central axis of said coplanar periphery, means for supplying energy from said input connection to each of said coaxial conductors with different relative polarities such that current will circulate about said periphery in the same sense at all points, and means for extending the effective electrical length of each of said radiant acting coaxial conductors so as to produce a substantially circular radiation pattern from said antenna.

8. A radio antenna including a plurality of hollow tubular radiating members arranged in coplanar relation and in a substantially closed pattern with the ends thereof spaced to provide small gaps therebetween, a plurality of conductors coaxially positioned respectively within said radiating members, connections between said conductors across said gaps, an input connection to said antenna, means for energising said inner conductors from said input connection to supply energy to the outer surfaces of said tubular radiating members, and adjustable reactance means coupled to said conductors intermediate said gaps for producing a capacitive reactance between said conductors and their respective enclosing radiating members at said gaps, whereby the effective electrical length of said radiating members will be extended.

9. A shielded loop antenna according to claim 7 in which the terminating impedance between the end of any one of said inner conductors and its shield is equal to a pure resistance.

MORTON FUCHS.