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ELECTRICAL APPARATUS ADAPTED TO OPERATE AT VERY HIGH FREQUENCIES

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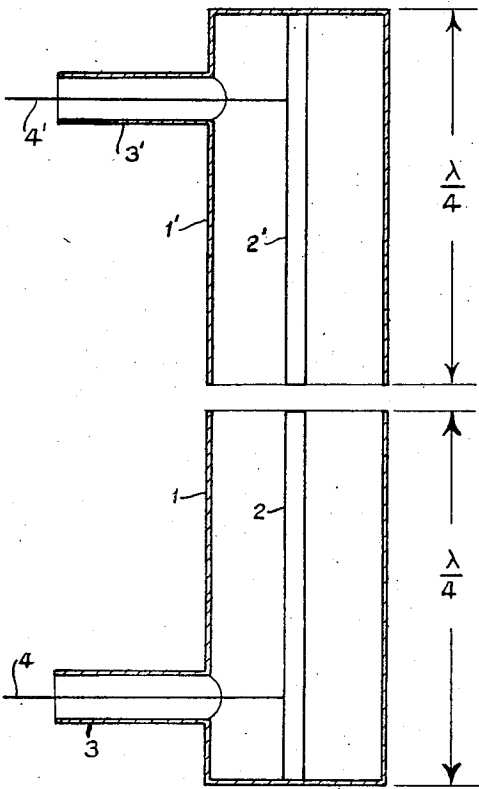


FIG. 1.

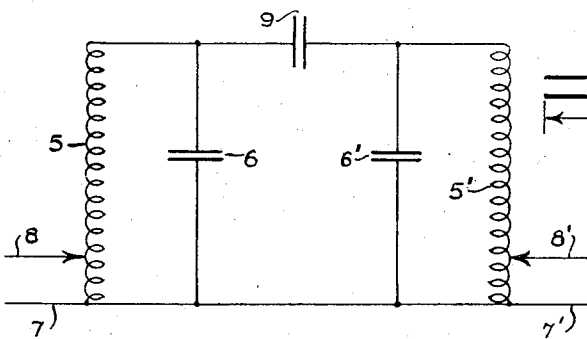


FIG. 2.

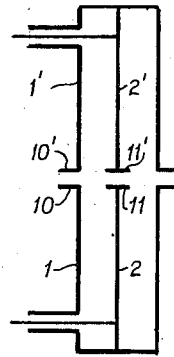


FIG. 3.

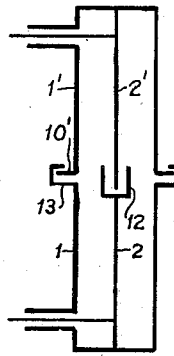


FIG. 4.

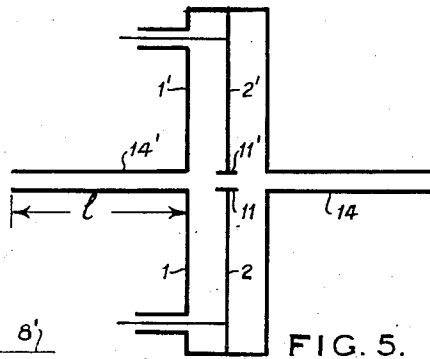


FIG. 5.

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ELECTRICAL APPARATUS ADAPTED TO
OPERATE AT VERY HIGH FREQUENCIESDennis Clark Espley, North Wembley, England,
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8 Claims. (Cl. 178-44)

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This invention relates to electrical apparatus of the type adapted to operate at frequencies so high that the dimensions of the apparatus are greater than or not very much less than the wavelength corresponding to the frequency of operation, and especially to such apparatus adapted to transmit or receive or both transmit and receive wavelengths between 50 and 1 cm.

It is sometimes desirable that the direction to which the apparatus emits radiation, or from which it receives radiation, should be easily variable; it may then be desirable that one part of the apparatus should be rotatable relatively to another part with which it is in electrical connection. Connection through slip rings or other rubbing contacts is undesirable at these high frequencies; the object of this invention is to provide a suitable form of connection.

The invention depends upon a principle which will now be explained with reference to the accompanying drawing, in which

Figure 1 shows one form of the improved connection permitting relative movement of two concentric lines,

Figure 2 is a diagram of a circuit comparable to the connection shown in Figure 1, and

Figures 3, 4 and 5 show respectively three modifications of the arrangement shown in Figure 1.

Figure 1 shows a concentric line with outer conductor 1 and inner conductor 2, these conductors being joined at a closed end, but not connected at the open end; the length of the line is $\lambda/4$, where λ denotes the wavelength corresponding to a frequency at which the apparatus is adapted to operate. Near the closed end there enters a side concentric line with outer conductor 3 and inner conductor 4, connected respectively to the outer and inner conductors 1 and 2. It is known that this arrangement is equivalent in many respects to one half of the band-pass filter section shown in Figure 2, consisting of an inductor 5 tuned by a condenser 6, oscillations having the frequency to which the combination is tuned being injected by the leads 7 and 8 both near one end of the inductance. It is further known that if leads 7' and 8' are connected correspondingly to the other half of the section, consisting of inductor 5' and condenser 6', the transfer impedance between 7, 8 and 7', 8' is much less than if these leads were connected directly through the condenser 9, joining the two halves of the section; in other words the condenser 9 acts as if it were a condenser of much larger capacity connecting the leads directly. Indeed, if ideal filter sections could be constructed

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and strictly sinusoidal voltages applied to them, the transmission loss between 7, 8 and 7', 8' would be zero, however small the capacity of the condenser 9.

Suppose then that a system 1', 2', 3', 4' similar to 1, 2, 3, 4 in Figure 1 is placed with its open end opposite to that of 1, 2, 3, 4. The arrangement is then analogous to that of Figure 2, the capacities between the conductors 1, 1' and 2, 2' playing the same part as the condenser 9. Accordingly, though the systems 1, 2, 3, 4, 1', 2', 3', 4' are only connected through small capacities, they behave, in respect of the leads 3, 4, 3', 4' as if they were connected by a much larger capacity; if the side line 3, 4 is near enough to the closed end of 1, 2, this apparent capacity will be so great that the connection of 3, 4 to 3', 4' is almost equivalent to a conductive connection.

The object of this invention is attained by introducing the lines to be connected into the concentric lines 1, 2, 1', 2', and these concentric lines are arranged with their open ends facing each other so that they are rotatable relatively to each other about their common axis. One of the said lines to be connected leads to a directional aerial and the other to an oscillator (or receiver) from (or to) which oscillations pass to (or from) the aerial. Of course the same apparatus may be used for both receiving and transmitting.

It is not necessary that the concentric lines should have a closed end near the entry of the side line or that its length should be $\lambda/4$. The necessary and sufficient condition is that the side line should enter near a voltage node and that the distance from this voltage node to the open end presented to the open end of the other concentric line should be $p \lambda/4$, where p is an odd integer. Thus the position of the voltage node in Figure 1 would be unchanged, and consequently the operation of the arrangement, if the closed end of a line 1, 2 or 1', 2' were replaced by a line open at each end and of length $p \lambda/4$, where p is an odd integer.

Again the side lines need not make metallic connection with the main lines; the necessary coupling may be made in known manner by a magnetic loop.

It will be observed that the principle of the invention, heretofore explained with reference to Figure 2 and underlying the invention, depends on the fact that the impedance between the open ends of lines 1, 2, 1', 2' in Figure 1 is a pure capacitive reactance large compared with the input impedance of a side line. In principle there is no upper limit to the magnitude of this im-

pedance; but in practice it is desirable to reduce it as far as possible, for thereby the width of the frequency band that can be transmitted without appreciable loss is increased. It can be reduced, for example as shown in Figure 3, by providing the ends of the members of the lines with flanges 10, 10' and 11, 11' facing each other. Alternatively the said impedance may be reduced by longitudinally overlapping the ends of the members of the lines as shown in Figure 4, where a sleeve 12 connected to the member 2 surrounds the free end of the member 2', and a flange 10' on the member 1' is partly enclosed in a channel-section ring 13 on the member 1. If there were no limit to the reduction that could be effected by such means, the problem to which the invention relates would not arise; it is to be assumed therefore that a limit is imposed.

Now the reactance in question may be regarded as the sum of two reactances in series, namely that between the inner members of the lines and that between the outer members of the lines. The limit is likely to arise from the former rather than the latter; thus a limit is imposed on the width of the flange that can be attached to the inner member by the internal diameter of the outer member; but no limit may be imposed on a flange attached to the outer member. Thus, as shown in Figure 5, a pair of flanges 14 and 14' attached to the outer members constitute a resonator which may have zero input impedance, so that the second of the two said reactances is abolished. It is even possible to adjust these flanges so that the input impedance imparted to them is an inductive reactance and partially neutralises the capacitive reactance between the inner members. The input impedance to this resonator is negative, zero or positive according as the dimension l is respectively between $\lambda/4$ and 0, equal to $\lambda/4$, or between $\lambda/4$ and $\lambda/2$. All such methods of reducing the impedance between the lines may be adopted in apparatus according to the invention so long as the condition is fulfilled that the resultant impedance between the two lines is substantially a pure capacitive reactance large compared with the input impedance of either side line.

In view of the specification of my patent application Serial No. 397,016, filed June 7, 1941, it is desirable to point out that the principle there described for reducing to zero the impedance between corresponding members of a pair of relatively rotating coaxial lines may be applicable to the outer members when it is not applicable to the inner members. For since the characteristic impedance of a concentric line depends on the ratio between the diameters of the members, a clearance permissible between a pair of outer members forming a concentric line would often not be permissible between a pair of inner members.

Finally it is to be observed that it is generally desirable, if other considerations permit, to fill the space between the pair of concentric lines (together probably with the interior of the lines) with a dielectric liquid of high dielectric strength. For thereby the minimum clearances permissible are reduced, and the capacity corresponding to any given clearance increases.

I claim:

1. Electrical apparatus of the type specified comprising a pair of concentric lines, wherein each said concentric line is fed by a side line, wherein the distance of the entry of each said side line from an open end of the associated concentric

line is so adjusted that at some frequency at which the apparatus is adapted to operate, corresponding to a wavelength λ , the said entry is near a voltage node whose distance from the said open end is $p\lambda/4$, where p is an odd integer, and wherein the said pair of concentric lines are co-axially arranged in such a manner that they are rotatable relatively to each other about their common axis and that the impedance between their said open ends which face one another is substantially a pure capacitive reactance large compared with the input impedance to either side line.

2. Electrical apparatus of the type specified comprising a pair of concentric lines each of which is $\lambda/4$ long, where λ denotes the wavelength corresponding to a frequency at which the apparatus is adapted to operate, and each of which has one end open and the other end closed, wherein each said concentric line is fed by a side line entering near said closed end, and wherein the said pair of concentric lines are co-axially arranged in such a manner that they are rotatable relatively to each other about their common axis and that the impedance between their said open ends which face one another is substantially a pure capacitive reactance large compared with the input impedance to either side line.

3. Electrical apparatus of the type specified comprising a pair of concentric lines, wherein each said concentric line is fed by a side line, wherein the distance of the entry of each said side line from an open end of the associated concentric line is so adjusted that at some frequency at which the apparatus is adapted to operate, corresponding to a wavelength λ , the said entry is near a voltage node whose distance from the said open end is $p\lambda/4$, where p is an odd integer, wherein the said pair of concentric lines are co-axially arranged in such a manner that they are rotatable relatively to each other about their common axis and that the impedance between their said open ends which face one another is substantially a pure capacitive reactance large compared with the input impedance to either side line, and wherein the capacity between a member of one of said concentric lines and a member of the other of said concentric lines is increased, as compared with the capacity between the bare ends of said members, by the attachment of said ends of portions which overlap each other.

4. Apparatus as claimed in claim 3, wherein said portions that are attached to the ends of said members of the concentric lines overlap each other in directions transverse to the common axis of said concentric lines.

5. Apparatus as claimed in claim 3, wherein said portions that are attached to the ends of said members of the concentric lines overlap each other in directions parallel to the common axis of said concentric lines.

6. Electrical apparatus of the type specified comprising a pair of concentric lines, wherein each said concentric line is fed by a side line, wherein the distance of the entry of each said side line from an open end of the associated concentric line is so adjusted that at some frequency at which the apparatus is adapted to operate, corresponding to a wavelength λ , the said entry is near a voltage node whose distance from the said open end is $p\lambda/4$, where p is an odd integer, wherein the said pair of concentric lines are co-axially arranged in such a manner that they are

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rotatable relatively to each other about their common axis and that the impedance between their said open ends which face one another is substantially a pure capacitative reactance large compared with the input impedance to either side line, and wherein the outer members of said concentric lines comprise co-operating subsidiary portions serving to render the reactance between said outer members much smaller than the reactance between the inner members of said concentric lines.

7. Apparatus as claimed in claim 6, wherein said subsidiary portions serve to render the reactance between said outer members inductive.

8. In electrical apparatus for operation at high frequency and including a directional aerial and

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a line associated with said aerial, the provision of a coupling in said line for permitting rotation of said aerial relative to other elements of the apparatus, said coupling including two co-axially disposed concentric lines having open ends facing one another, wherein said concentric lines are fed respectively by two side lines entering said concentric lines in the neighbourhood of voltage nodes at a distance from said open ends equal to $p\lambda/4$, where p denotes an odd integer and λ the wavelength corresponding to the said frequency, the impedance between said open ends being substantially a pure capacitative reactance large compared with the input impedance to either of said side lines.

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