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 APPARATUS FOR INSULATINGLY TERMINATING
 CONCENTRIC CONDUCTOR RESONATORS
 Filed July 22, 1949

2,630,487

Fig. 1.

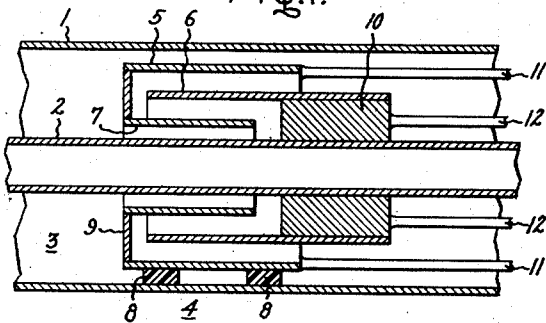


Fig. 2.

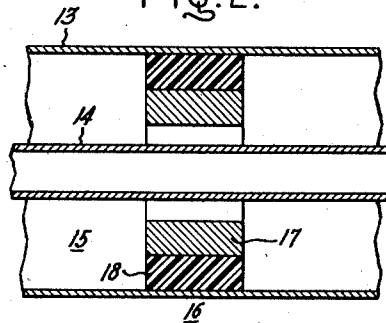


Fig. 3.

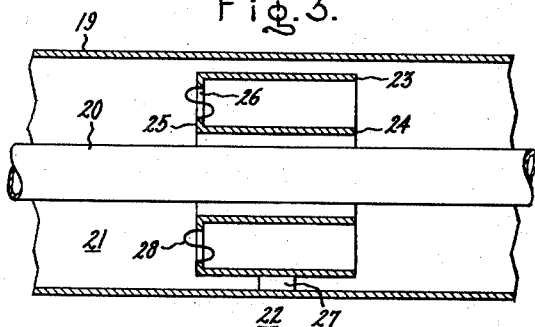


Fig. 4.

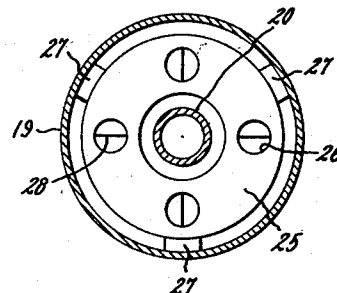


Fig. 5.

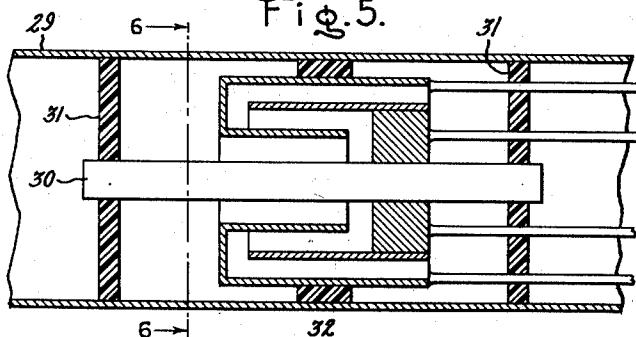
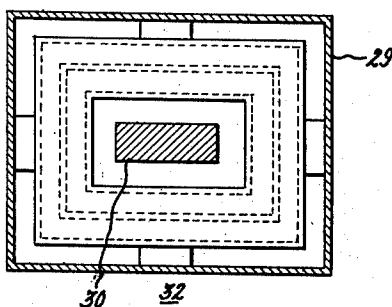


Fig. 6.



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APPARATUS FOR INSULATINGLY TERMINATING CONCENTRIC CONDUCTOR RESONATORS

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Application July 22, 1949, Serial No. 106,284

1 Claim. (Cl. 178—44)

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My invention relates to ultra high frequency resonators having a space-resonant cavity defined between a pair of concentric conductors and has particular reference to apparatus for insulatingly terminating such resonators.

It is known that a space-resonant cavity defined between a tubular outer conductor and a centrally situated inner conductor may be excited by a suitable exciting means, such as an electron discharge device, to establish transverse electromagnetic waves between the inner and outer conductors. The desired electrical length of the concentric conductor resonator is commonly established by providing a proper terminating means between the conductors such as a short circuiting plunger or a capacitive choke. Where it is desired to overcome mechanical difficulties encountered with a short circuiting plunger and also to insulate the conductors from each other for direct current or low frequency potentials, the choke type of terminating means is generally preferred.

Such chokes have usually consisted essentially of a conductive barrier interposed between the concentric conductors and insulatingly spaced from one of them. To minimize energy leakage from the space-resonant cavity along the choke transmission line section defined between the choke means and the opposing resonator conductor surface, the spacing between these surfaces is made as small as practical. While this practice has the desired effect of increasing the electromagnetic wave reflection due to the increased ratio between the characteristic impedance of the concentric line resonator and that of the choke transmission line section, a limit is reached when the spacing is insufficient to withstand the potentials between the opposing surfaces. In addition the resulting capacity between the conductors at the terminating means may limit the minimum spacing in some applications.

It is an object of my invention to provide an improved insulating terminating arrangement for apparatus of the nature described having a minimum amount of leakage.

It is a further object of my invention to provide an insulating terminating means for such apparatus offering relatively low capacitance between the transmission line conductors.

Another object of my invention is to provide an improved apparatus for blocking the propagation of energy along the space between a pair of concentric conductors, which is effective over a range of frequencies.

My invention is characterized by the use of a choke for insulatingly terminating a concentric

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conductor resonator in which part of the electromagnetic wave energy tending to travel beyond the terminating means is cancelled by another such part of the wave energy of equal amplitude and opposite phase. This result is achieved by interposing one or more concentric conductors between the resonator conductors so as to provide a plurality of concentric choke transmission line sections extending from the cavity side of the terminating means to the back side, one or more of the transmission line sections being so arranged that electromagnetic waves which tend to propagate through it reach the back side of the choke a half-wave length out of phase with the other choke transmission line waves reaching the back side of the choke. Such a terminating means constructed according to my invention reflects all of the wave energy at the resonator frequency but insulates the resonator conductors for direct current or low frequency potentials. My invention may also be considered as a blocking filter for blocking the propagation of wave energy of a particular frequency along the space between the concentric conductors of an ultra high frequency system.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 is a sectional view of an embodiment of my invention, as employed to terminate a concentric conductor resonator, Fig. 2 represents a modification, Fig. 3 represents another modification, Fig. 4 represents an end view of the modification shown in Fig. 3, Fig. 5 is a view of a wave guide employing the embodiment shown in Fig. 1 and Fig. 6 is a cross-sectional view taken along line 6—6 of Fig. 5.

Referring now to Fig. 1 a concentric conductor resonator is partially shown in which an outer conductor 1 and an inner conductor 2 define between them a space 3 which is resonant when the resonator is properly excited, as by an electron discharge device. The concentric conductors are insulatingly terminated by a terminating means 4 comprising a choke constructed according to my invention. As shown in the figure, three conductive choke sleeves 5, 6, and 7, suitably made of brass or copper, are concentrically arranged between the conductors 1 and 2 of the resonator. The outer choke sleeve 5 is insulatingly and slidably supported from the wall of the outer resonator conductor 1 in any suitable manner such as by interposing between the conductive sur-

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faces a number of circumferentially spaced dielectric spacers 8 made of an insulating material such as polystyrene, the spacers being preferably cemented to the choke sleeve 5 and slidably engaging the inner surface of conductor 1.

As will be further described hereinafter a first concentric transmission line section extending from the space-resonant region 3 to the back side of the cavity at the other end of the choke is defined between opposing surfaces of the outer choke sleeve 5 and the outer resonator conductor 1. A second concentric transmission line section having a multiple reversed path and ends co-extensive with those of the first section is defined between the inner resonator conductor 2 and the choke sleeves. To form this section the inner and outer choke sleeves 5 and 7 are conductively connected at the cavity side of the choke, as by an annular brass or copper disk 9 so that the inner sleeve 7 is spaced from the inner resonator conductor and supported from the outer sleeve 5. The intermediate choke sleeve 6 is conductively supported from the inner resonator conductor 1 by a suitable means such as an annular brass or copper member 10 to which the sleeve 6 is soldered. The annular member 10 is slidably mounted on inner resonator conductor 2, and if desired, spring contact fingers may be provided on the member 10 to assure adequate contact with conductor 2. Actuating rods 11, extending from the back side of the cavity, may be connected to the outer choke sleeve 5 in order to facilitate adjustment of the position of choke sleeves 5 and 7 along the concentric conductors 1 and 2, and similar rods 12 may be connected to the slidable member 10 to adjust the position of choke sleeve 6 with respect to the other choke sleeves. The second transmission line section thus formed extends from the cavity side of the choke between the opposing surfaces of the conductor 2 and the choke sleeve 7, along the opposing surfaces of choke sleeves 7 and 6, and then along the opposing surfaces of choke sleeves 6 and 5 to terminate at the back side of the choke. By means of actuating rods 11 and 12 the length of the transmission line section formed by the sleeves and the inner conductor may be varied over a limited range.

In order that the electromagnetic waves tending to propagate through each of the choke transmission line sections may arrive at the back side of the choke at 180° phase difference, the length of the choke sleeves and their relative positions as determined by the actuating rods 11 and 12 are chosen so that the folded and reversed transmission line section is one half wave length or an odd numbered multiple thereof longer than the shorter transmission line section. In operation the resonator is first tuned to the desired frequency by sliding the assembly comprising choke sleeves 5 and 7 to the desired position by means of actuating rods 11, the annular disk 9 connecting sleeves 5 and 7 approximately defining the end of the cavity since a portion of the electromagnetic waves within the cavity are reflected from its conductive surfaces. The intermediate sleeve 6 is then slidably adjusted along the inner conductor by means of actuating rods 12 in order that the length of the folded transmission line section may be adjusted for the desired difference in length between the two transmission line sections.

In order that the electromagnetic waves arriv-

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ing at the ends of the two transmission line sections have the same magnitude, the relative diameters of the choke sleeves are chosen to provide approximately the same characteristic impedances for the two choke transmission line sections, the characteristic impedance of the longer section being somewhat greater to compensate for the greater wave attenuation associated with that section. Since the electromagnetic waves arriving at the ends of the transmission line sections are of equal amplitude and opposite phase, they cancel each other and thus prevent energy leakage. The transmission line sections may be considered collectively as presenting a short-circuit impedance to the wave energy in the cavity, just as if a short-circuiting plunger was interposed between the concentric resonator conductors. Since the choke operation depends upon the difference in electrical length of the two concentric transmission line sections, the length of the outer choke sleeve 5 with respect to the wave length at the frequency of the resonator energy is not in itself significant nor is the insulating spacing between the inner and outer choke sleeves and the resonator conductors a measure of choke leakage. Hence a relatively large choke transmission line spacing may be employed, resulting in a decrease in capacity between the resonator conductors and a corresponding increase in dielectric strength of the insulation therebetween. It is obvious that without departing from the spirit of my invention that a further number of choke sleeves may be employed to obtain the desired difference in electrical length between a pair of choke transmission line sections or that a greater number of choke transmission line sections may be employed and still obtain complete wave reflection by cancellation.

In a modification of my invention illustrated in Fig. 2 a simplified choke construction suitable for operation at a predetermined frequency is employed in a concentric conductor resonator having an outer conductor 13 and an inner conductor 14 which define between them a space-resonant cavity 15. To suitably terminate the resonator a choke means 16 is employed which offers two co-extensive concentric transmission line sections extending from the cavity to the back side of the choke. A conductive choke sleeve 17, suitably made of brass or copper, is concentrically interposed between the resonator conductors 13 and 14 and spaced from each to provide an outer transmission line section between the opposing surfaces of the sleeve 17 and outer resonator conductor 13 and an inner section between the opposing surfaces of the sleeve 17 and inner conductor 14.

Since the velocity of propagation of an electromagnetic wave through an insulating medium varies inversely with the square root of the dielectric constant of that medium, the electrical lengths of the choke transmission line sections may be made to differ by one half wave length or an odd multiple thereof at the resonator frequency by selecting insulating media for the two sections which have suitably differing dielectric constants. With this consideration in mind an annular insulating member 18 of a low-loss dielectric such as polystyrene, may be concentrically interposed between one of the resonator conductors and the conductive choke sleeve 17, the member 18 also serving to support the choke sleeve. The dielectric in the other choke trans-

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mission line section may suitably consist of the air usually constituting the insulating medium between the resonator conductors. Accordingly, electromagnetic waves from the resonator cavity tend to propagate more slowly through the choke transmission line section having the polystyrene insulation since it has a higher dielectric constant than has the air. By choosing the proper length of choke sleeve 17 and dielectric member 18 relative to wave length at the frequency of the resonator energy, the electromagnetic waves arriving at the ends of the respective transmission line paths will be 180° or one-half wavelength out of phase with each other and thus cancel.

In general, if E_1 and E_2 represent the waves, which are to cancel,

$$E_1 = E_{01} \sin \left(\omega t + \frac{2\pi l}{\lambda} \sqrt{\epsilon_1} \right)$$

and

$$E_2 = E_{02} \sin \left(\omega t + \frac{2\pi l}{\lambda} \sqrt{\epsilon_2} \right)$$

Here E_{01} and E_{02} are the wave amplitudes at the beginning of the respective choke transmission line sections, and ϵ_1 and ϵ_2 are the specific dielectric constants of the insulating media of the respective sections. The physical length of the choke transmission line section is l , being the same for each section in the modification of my invention shown in Fig. 2. Symbols t and λ represent time and wavelength, respectively. The condition required for cancellation and proper operation of the choke can be seen to be

$$E_1 + E_2 = 0$$

Consequently if it is desired to find the proper value of l , and E_{01} , E_{02} , and ϵ_1 , and ϵ_2 are given, then the simple case where E_{01} equals E_{02} (this being the condition of similar excitation of electromagnetic waves in the adjacent choke transmission line sections when the sections are designed to have the same characteristic impedance) is represented by

$$(2n-1)\pi + \omega t + \frac{2\pi l \sqrt{\epsilon_1}}{\lambda} = \omega t + \frac{2\pi l \sqrt{\epsilon_2}}{\lambda}$$

where n represents any integer, $2n-1$ thus representing any odd-numbered integer, and λ the wavelength in vacuum. Solving,

$$\frac{l}{\lambda} = \frac{2n-1}{2[\sqrt{\epsilon_2} - \sqrt{\epsilon_1}]}$$

For example for $n = 1$, $\epsilon_1 = 1$ for air, and $\epsilon_2 \approx 4.0$ for quartz,

$$l \approx 0.5\lambda$$

Of course, if it is desired to establish a choke sleeve length in terms of wave length, such as l as

$$\frac{\lambda}{4}$$

for example, then dielectric media having the proper values of ϵ_1 and ϵ_2 may be selected.

In the modification of a choke embodying my invention shown in Fig. 3, lumped circuit constants comprising S-shaped coupling loops are employed to provide a transmission line wave in part of the choke which cancels opposite phase transmission line waves produced in another part of the choke. This modification is shown as employed in a concentric conductor resonator having an outer conductor 19 and an inner conductor 20 which define between them

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a space-resonant cavity 21. To suitably terminate the resonator a choke means 22 is employed which comprises a pair of conducting sleeves 23 and 24 concentrically interposed between resonator conductors 19 and 20 and insulatingly spaced from them.

As further shown in the end view of the choke from the cavity end depicted in Fig. 4, the choke sleeves at the cavity end of the choke are connected by an annular member 25 having a plurality of apertures 26. The choke sleeve assembly is insulatingly supported from the resonator conductors by suitable means, such as a number of circumferentially-positioned dielectric spacer members 27 interposed between the opposing surfaces of the outer sleeve choke 23 and the outer resonator conductor 19. In this choke structure a pair of transmission line sections is defined respectively between opposing surfaces of the outer choke sleeve 23 and the outer resonator conductor 19 and between the opposing surfaces of inner choke sleeve 24 and the inner resonator conductor 20. Since the choke transmission line sections are co-extensive and employ the same dielectric medium the waves tending to propagate from the space-resonant region 21 along these transmission line sections to the back side of the choke will be of the same phase and cumulative in amplitude.

To provide cancellation waves a third transmission line section co-extensive with the first two sections defined between opposing surfaces of the choke sleeves 23 and 24 is coupled to the space-resonant region 21 at each aperture 26 in the member 25 by a radially aligned S-shaped coupling conductor 28. Each coupling conductor 28 may suitably consist of copper wire having its ends connected to the edges of the annular member 25 at an aperture 26 with one of its loops extending into the space resonant region 21 and the other extending in the third transmission line section. Each of the coupling conductors 28 thus couples a portion of the wave energy in the space-resonant region 21 to the transmission line section defined between the coupling sleeves but excites transmission line waves therein of opposite phase than the waves in the first two transmission line sections. The mechanics of this phase inversion may be perhaps most readily perceived by considering the magnetic field in the space-resonant region 21 as inducing a current in that portion of the coupling loop 28 extending into the space-resonant region 21, which current sets up a corresponding but opposing field around that loop of the coupling conductor extending into the space between the choke sleeves 22 and 23. By selecting a suitable number of coupling apertures 26 and coupling conductors 28 therefor, a transmission line wave in the third transmission line section may be established with an amplitude equal to the combined amplitudes of the transmission line waves in the first two transmission line sections but out of phase with the latter waves by 180° or one-half wave length. Thus it may be seen that the transmission line waves arriving at the back side of the choke will cancel each other for complete reflection and thus prevent energy leakage beyond the choke. Since the relative characteristics impedances of the first two transmission line sections may be chosen in any manner so long as the combined amplitude of their waves simultaneously reaching the back side of the choke is equal to the amplitude of the out-of-phase waves, it is obvious that one of the first

two sections may be eliminated without departing from the spirit of my invention.

In Fig. 5 I have shown how a choke constructed according to my invention may be used to insulatingly terminate a hollow metallic wave guide. For example, in a wave guide 29 having a rectangular cross-section, as may be better seen in the cross-section view shown in Fig. 6, a centrally disposed inner conductor 30 is positioned along a length of the wave guide where the choke means is to be located, thus converting the wave guide to a concentric transmission line section for a portion of the wave guide length. Suitable insulating means 31 such as a number of dielectric spacer slabs are interposed between the inner surface of the wave guide 29 and the inner conductor 30, which preferably has a rectangular cross-section corresponding to that of the wave guide. Between the inner and outer conductors of the concentric transmission line thus formed, a choke 32 such as that embodiment of my invention described in Fig. 1 is interposed to insulatingly terminate the concentric line section of the wave guide and thus insulatingly terminate the wave guide 28 itself. This type of installation may be desired in such instances where a discharge device or other circuit means is to be employed in the wave guide and insulated therefrom for application of direct current potentials. The cross-section configuration of the choke sleeves should correspond with that of the wave guide 29, which in this example is rectangular, as shown in Fig. 6.

As in the design and operation of the embodiment of my invention shown in Fig. 1, the same advantages of low choke capacitance and adequate insulation between the resonator conductors may be obtained with chokes constructed as shown in Figs. 2-6 since the same basic principle of operation is employed.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claim to cover all such equivalent variations as come within the

true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

In an ultra-high frequency system comprising a pair of concentric conductors, means for insulatingly terminating said conductors to block wave propagation along the space between them which comprises a pair of concentrically disposed conductive members interposed between said conductors, a first transmission line section being defined between one of said conductors and one of said conductive members, a conductive annulus secured to corresponding ends of said conductive members so as to close the annular space therebetween, an annular metallic member disposed in axially slidable relationship with respect to the other of said conductors, a third concentric conductive member having one end thereof secured to said annular member and having the other end thereof interposed between said pair of conductive members, said third conductive member being spaced from said pair of conductive members and said conductive annulus, a double reverse second transmission line section being defined between the other conductor and said other of said pair of conductive members and between said third conductive member and said pair of conductive members, said second section having an effective electrical length differing by one-half wavelength of an odd multiple thereof from the electrical length of said first section at the frequency of electromagnetic waves traveling therethrough.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,226,479	Pupp	Dec. 24, 1940
2,258,148	Schussler	Oct. 7, 1941
2,451,876	Salisbury	Oct. 19, 1948
2,456,803	Wheeler	Dec. 21, 1948
2,463,415	Nims	Mar. 1, 1949
2,594,895	Feiker	Apr. 29, 1952