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WAVE SHIELDING ARRANGEMENT

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Fig. 1

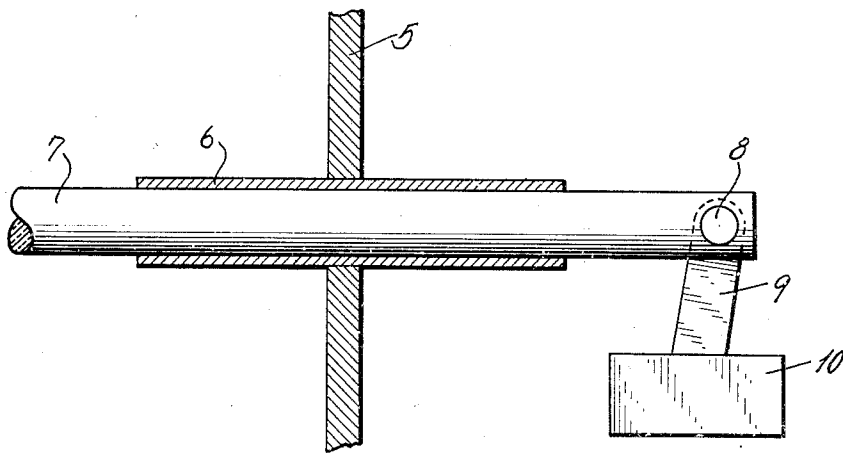
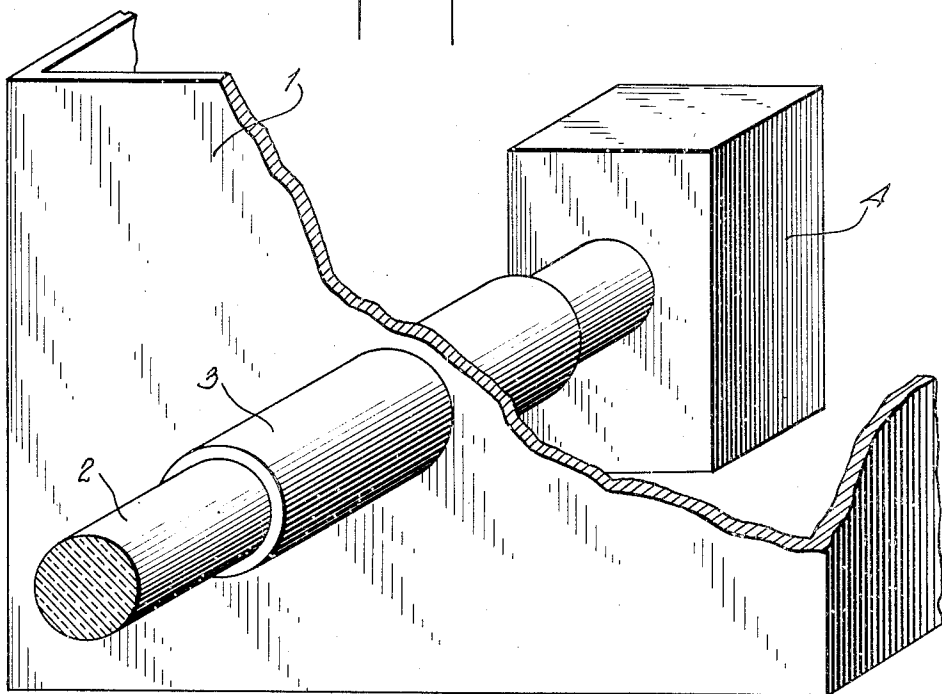


Fig. 2.

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WAVE SHIELDING ARRANGEMENT

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1 Claim. (Cl. 178-44)

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This invention refers to shielding methods for preventing the uncontrolled transmission of radio frequency energy from one circuit unit to another.

In the practical design of high frequency devices, such as radio and television receivers and transmitters, radio direction finders, saw-tooth generators, pulse formers and counters, or of high frequency test equipment, such as signal generators, cathode ray tube oscillographs and capacity bridges, the designer is often confronted with the problem of confining the fields generated by some of the circuit elements to the smallest possible region around these circuit elements. This is usually necessary for the purpose of preventing undesired back-coupling between circuit-units which must operate independently of each other, or for separating the various stages of amplification of different frequencies and wave shapes.

Such a separation of high frequency fields and the elimination of uncontrolled transmission between various circuit units, which may or may not be inter-related in their operation, is generally carried out by surrounding selected combinations of circuit elements by metal containers, through which the electromagnetic fields cannot penetrate.

The effectiveness of shielding depends substantially on the practical possibilities of providing a completely closed metallic surface around the circuit elements under consideration. It is not in general possible to isolate a component unit of a circuit forming part of an amplifier, transmitter, saw-tooth generator or other high frequency device into a completely closed metal cavity. Openings must be provided for leading-in the power supplies and transmission lines to the input and output ends of the devices enclosed in the metal shields. In addition, other openings must be provided for the passage of mechanically movable control shafts for tuning, wave band switches, gain controls, widths of pass band filters or couplings between the various circuit elements enclosed in the metal shield and for many other control purposes. The openings needed for the connection of permanent power supply leads and transmission lines are usually not quite as difficult to protect by supplementary shielding members, which may be soldered or welded over the openings after the required circuit connections have been installed. This is, however, not true for those openings in the metal walls which must be provided for passing movable mechanical control members from a region outside the metal enclosure to one or several of the controllable circuit elements inside the enclosure. These control members consist mostly of shafts which transfer a mechanical torque, or carry out a translational motion along its axis.

In certain cases it is possible to use movable

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metal shafts passing through the openings of the shielding walls, and a tight fitting metal bearing, supplemented by bushings stuffed with metal filings or powder, steel wool or similar loose conducting material will result in a satisfactory shielding of the remainder openings. This type of bearing is, however, not adaptable when voltage differences must be maintained between the the circuit element to be adjusted, and the shielding metal container. If it is required to pass a fast rotating shaft through an opening, as for rotating condenser plates for the purpose of periodic variations of the frequency of a resonant circuit, frictional bearings must be avoided.

In the region of ultra high frequencies, metallic shielding containers are particularly effective, because of the extremely small penetration of these very high frequency fields into the surface of a good conductor. On the other hand, any opening in a metal container represents an effective radiator of very high frequency electromagnetic energy. The efficiency of the opening in a metal wall as a radiator is, within limits, proportional to its area, and a difficult problem presents itself whenever it is necessary to pass a movable insulating shaft of appreciable thickness through the wall of a shielding metal container. The resulting undesired transmission of electromagnetic high frequency energy through such an opening is called leakage.

It is therefore a main object of my invention to provide a mechanical coupling through the opening in a shielded metal container including means for preventing the leakage of a high frequency field.

A feature of the invention refers to a mechanical coupler for the control of high frequency devices enclosed in a metal container, including a movable shaft made of a solid dielectric and means to attenuate the passage of a wide band of frequencies through the opening through which the shaft passes.

It is another object of the invention to provide improved shielding means for the free mechanical rotation of a shaft passing through an opening in a metal wall.

It is another object of the invention to provide improved shielding means for the free mechanical longitudinal motion of a shaft passing through an opening in a metal wall.

A still further object of the invention refers to a mechanical coupling means for a control shaft passing through an opening in a metal shielding wall, including means to prevent the leakage of high frequency fields above a desired maximum wave length.

A feature of the invention refers to the construction of a mechanical coupler passing through the opening in a metal shielding wall, which sim-

ulates the properties of a high attenuation wave transmission line.

Another feature of the invention refers to the construction of a mechanical coupler passing through a metal shielding wall including means for using the high pass filter properties of metallic wave guides.

According to another feature of the invention means are provided including a cylindrical metal bushing, which prevent the transmission of high frequency energy through the opening in a metal shielding wall filled or substantially filled with a dielectric material.

Other features of the invention will be discussed as the disclosure proceeds.

The invention will now be described in connection with the drawing, in which

Fig. 1 represents a perspective view of one embodiment of the invention.

Fig. 2 is a longitudinal section of a mechanical coupler according to another embodiment of the invention.

In Fig. 1, numeral 1 represents the wall of a metal shielding box or shield partly broken away, so as to make visible an adjustable device or circuit element 4 enclosed in the shielding box, which circuit element is to be controlled mechanically by means of a cylindrical shaft 2 constituted of dielectric or electric insulation material. Shaft 2 is surrounded interiorly and exteriorly of wall 1 by a metallic bushing 3 of cylindrical cross section. The inner diameter of the outer conductor must be chosen according to practical considerations in connection with the equations given on columns 4 and 5. If desired, separate bearings such as ball bearings or roller bearings, may be provided for the rotation of shaft 2 so as to insure rotation of the shaft in the bushing with minimum friction. These bearings do not form a necessary part of the invention and for simplicity are omitted from the drawing.

The dimensions of the shaft and of the bushing are so chosen, that their combination represents a wave guide which can only transmit frequencies which are higher than those produced or converted by the circuit element 4 to be shielded by the metal container.

An analysis of the nature of propagation of high frequency electromagnetic waves in hollow metal pipes or "wave guides" has been given in various papers beginning in 1936, and this theory has been built up and supplemented, rather recently. The analysis up to 1942 has indicated that in a metal pipe of a given cross section there exists a critical minimum frequency below which no wave propagation can take place. This result was based on certain simplifying assumptions, which substantially amount to a restriction to "perfect" metals; i. e., metals having infinite conductivity. The finite value of the conductivity of real metals was introduced in the earlier wave guide analysis only for the purpose of determining the attenuation of the waves propagated through the wave guide; i. e., for waves of a frequency above the theoretical cut-off frequency.

As shown by G. E. Linder in his article, "Attenuation of electromagnetic fields in pipes smaller than the critical size," (Proceedings of the I. R. E., December 1942, vol. 30, pp. 554-556), electromagnetic fields of frequencies below the so-called cut-off frequencies in wave guides of given cross sections are actually propagated in hollow metal pipes of finite conductivity. Their

attenuation is, however, so high, that the propagation of waves of these frequencies could not be experimentally discovered for a long period of time. Linder's conclusions are based on a more thorough analysis of the propagation of high frequency fields in wave guides in the critical region, which takes into consideration the finite value of the conductivity of the metals known as good conductors. In the meantime, Linder's calculations have obtained practical significance, as the practical technique of wave guides has advanced. Today, metal pipe wave guides below critical dimensions find important applications as attenuators, in particular in signal generators which are designed for measureable output amplitudes varying over an attenuation range up to 50 or 100 decibels.

As shown in the theory of propagation of H. F. fields in wave guides, there are a large number of modes of waves that may be propagated. The important modes are the so-called dominant modes, whose "cut-off frequencies" are lower than the "cut-off frequencies" of all other modes that may be derived from them. The cut-off frequencies of the dominant modes are related in a simple way to the cross-sectional dimensions of the metal pipes, and it is therefore customary to compare a characteristic length related to the cross section of the metal pipes with the corresponding longest wave length, which is capable of propagation.

In the case of hollow metal pipes with circular cylindrical cross section, the radius or the diameter of the inner circular metal boundary of the wave guide is a convenient parameter for comparing their cross sectional dimensions with the cut-off wave length.

This maximum or cut-off wave length (capable of propagation without extreme attenuation) in cylindrical pipes of circular cross section has been found by Southworth to be proportional to the inner diameter of the metal pipe and to the square root of the dielectric constant of the material filling the interior of the pipe. The proportionality factor depends on the "mode" of the propagation. For the "dominant" modes, it is a fractional number near unity, but differing in value depending on the character of the dominant mode. The higher modes (derivable from the dominant modes) have longer cut-off wave lengths, and are not of great practical importance at the present time.

The longest cut-off wave length, λ_0 , of all the modes that may be propagated in a cylindrical wave guide of diameter d and dielectric constant K is the one corresponding to the mode known as the $TE_{1,1}$ mode is given as

$$\lambda_0 = 1.71\sqrt{K} \quad (1)$$

while in the simplified theory no propagation takes place through the guide for frequencies corresponding to a longer wave length λ , it has been shown by Linder, that for waves for which $\lambda > \lambda_0$, propagation actually does take place but that such a wave has an attenuation

$$\alpha = 16.0\sqrt{1 - (\lambda_0/\lambda)^2} \text{ db per cm. of radius} \quad (2)$$

For values of λ large compared to the theoretical cut-off wave length as given by Equation 1, the attenuation for a length of wave guide equal to its radius $r, = d/2$ approaches therefore a constant value of 16 db. The corresponding attenuation for other modes of high frequency wave in cylindrical wave guides is still higher than that given by Equation 2, and it is therefore not of in-

terest to consider the other modes of wave propagation of signals of a given frequency through cylindrical wave guides in connection with the present invention. It has also been found experimentally that the attenuation for frequencies below the cut-off frequency is of the same order of magnitude in wave guides of rectangular cross section.

The foregoing theory is, according to the invention, embodied in the construction of the supplementary shielding of an opening in a metal shielding box passing a movable shaft of dielectric material.

As an example consider a shaft of 1 cm. diameter, dielectric constant $K=9$; the cut-off wave length λ_0 for such a shaft becomes, according to Equation 1

$$\lambda_0=5.13 \text{ cm.}$$

The attenuation of a length of metal wave guide equal to 0.5 cm. for a wave of wave length

$$\lambda=2\lambda_0=10.26 \text{ cm.}$$

is given from Equation 2 as

$$\alpha=16.0\sqrt{1-\frac{1}{4}}\text{db}=13.8\text{db}$$

As shown in the figure, the metal bushing surrounding the dielectric shaft and the shaft itself are made many times longer than the diameter. The bushing extends preferably, but not necessarily, in both directions from the opening in the metal wall, and substantially perpendicular to this wall.

Assuming the numerical values of the example given above, a signal of wave length $\lambda=10.26$ cm. will be attenuated 138 db for a total length of the metal bushing 3 in Figure 1 equal to 5 cm. This is based on the assumption that dielectric shaft 2 completely fills the interior of bushing 3. The attenuation will be still higher if the dielectric shaft fills only part of the bushing, as the value of the average dielectric constant will then become smaller.

This numerical example shows that this method of shielding an opening in a shielding container is very effective for all wave length above twice the cut-off wave length calculated from Equation 1 for a given diameter of the bushing and the dielectric constant of the shaft moving in the bushing.

In order to obtain a desired attenuation for a high frequency field produced by a circuit element 4 of a given wave length λ , it is possible to calculate the proper diameter and length of the bushing from Equations 1 and 2.

Obviously it is of no importance, whether the mechanical motion of shaft 2 in the bushing is a rotation around or a translation parallel to the

axis of the shaft. Figure 2 shows an arrangement in which shaft 7 is moved parallel to itself, as may be desired e. g., for changing the length of a transmission line section for tuning. Metal tube 6 encasing shaft 7 and penetrating shield 5 forms a slide bearing for the shaft, this shaft being connected by pin 8 and link 9 to adjustable device 10.

The invention is, however, not restricted to the modes of transmission of high frequency fields through cylindrical wave guides. As explained above, the invention contemplates broadly utilizing the propagation and attenuation characteristics of hollow metal pipe conductors or wave guides of any cross section for the purpose of preventing the leakage of high frequency fields through openings in metallic shielding containers. In particular, the invention refers to the methods of shielding openings in such containers, through which passes a mechanically movable control member made of a dielectric material.

One of the outstanding advantages of my new shielding and choking method is the fact that the attenuation for any given bushing may be very accurately predicted. Conversely, a choke joint of the type described in this specification can be accurately designed by calculation for any attenuation that may be desired in any practical problem.

What is claimed is:

In a wave-shielding system, an adjustable device to be shielded, a shield entirely enclosing said device, an operating shaft of insulation material penetrating said shield and mechanically connected to said device, and a tubular conductor united with said shield and forming an encasing bearing for said shaft, said tubular conductor and shaft constituting a transmission line of the wave-guide type having a cut-off frequency above any operating frequency of said system and of a length to provide a predetermined high attenuation to all frequencies of the system.

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