

May 2, 1961

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2,982,703

SIGNAL TRANSMISSION ELEMENT AND METHOD OF MANUFACTURING SAME

Original Filed March 2, 1955

FIG. 1.

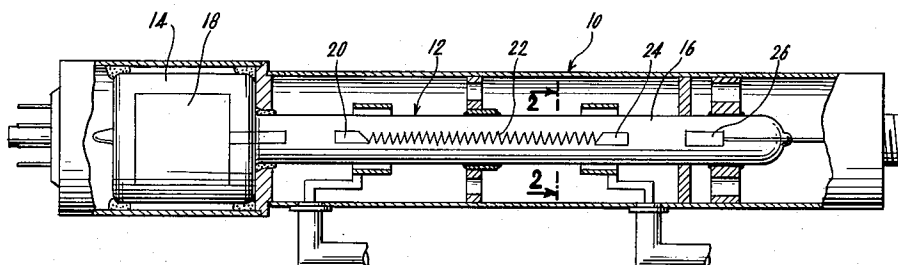


FIG. 3.

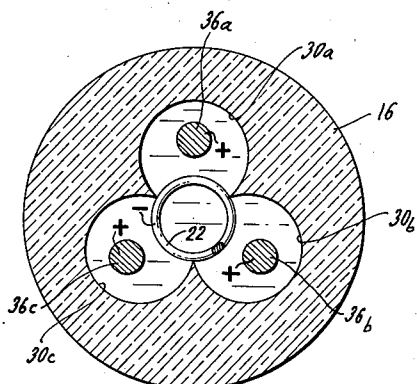


FIG. 2.

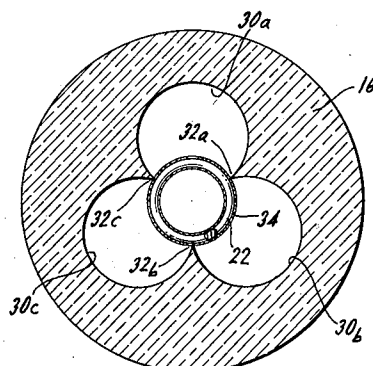


FIG. 4.

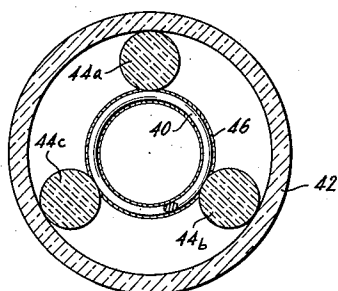
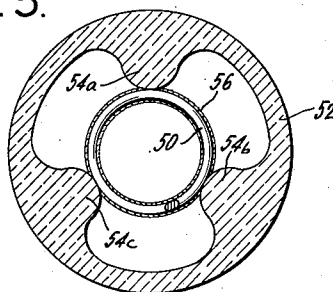


FIG. 5.



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SIGNAL TRANSMISSION ELEMENT AND METHOD OF MANUFACTURING SAME

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Original application Mar. 2, 1955, Ser. No. 491,716.
Divided and this application Sept. 10, 1958, Ser. No. 765,266

6 Claims. (Cl. 204—16)

This application is a division of application Serial No. 491,716 filed March 2, 1955, now abandoned.

The present invention relates to encased and supported impedance and signal transmission elements, and more particularly to an improved process for fabricating such elements, and to resultant electrical devices incorporating such elements and exhibiting enhanced mechanical and electrical properties. Specifically, the present invention is concerned with an improved method of manufacturing traveling wave tubes and like devices incorporating a helical wire conductor, and to traveling wave tubes having improved characteristics, prominently reliability and ruggedness.

The impedance and signal-transmission characteristics of coils, helices and the like, all of which are useful as circuit components and as parts of electrical and electronic devices, frequently depend upon the distribution of the turns of the coils and/or the materials in proximity to the coil. For example, the signal-transmission properties of a helical conductor changes with variations in interturn spacing and the presence of dielectric material in contact with or between respective turns.

Accordingly, it is an object of the present invention to provide an improved method of supporting and encasing coils and helices. To advantage, ruggedized coil assemblies may be constructed which have a fixed turn distribution and exceptionally desirable electrical and mechanical properties.

In one form, the invention may be best demonstrated in its application to the manufacture of the well-known traveling wave tube which is essentially an electron beam tube employing an electron gun. The electron gun, similar to those commonly found in cathode ray tubes, forms and projects an electron beam axially of and within a surrounding wire helical conductor, which helical conductor is excited by a high frequency input signal at one end thereof. During travel of the input signal along the helical conductor toward the output end, there is interaction between the electron beam and the input signal. This interaction results in amplification of a broad band of input frequencies which are available at the output end of the helical conductor.

Such known traveling wave tubes include an elongated wire helix, usually encased within a vitreous envelope or sleeve throughout its length and approximately assembled with input and output coupling devices. The assembly of the helix and the vitreous envelope or sleeve usually is of relatively small diameter and is comparatively long. Such assemblies may be characterized as including many hundreds of turns in relation to the length of the helix. The accomplishment of energy transfer between the beam and the helix often necessitates the use of as many as 800 turns for a helix length of approximately 15 inches and with a helix diameter of the order of $\frac{1}{40}$ of an inch.

The support of the relatively small diameter helix within the elongated, slender vitreous sheath or envelope presents a rather troublesome problem, particularly since

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the assembly has critical electrical properties which may vary greatly and in a random fashion depending upon the mounting of the helix. Of primary importance is the fixing of the respective turns of the helix in relation to each other in accordance with a preestablished pitch, whether the pitch be uniform or variable. Such fixing of the turn distribution of the helix should be accomplished without adversely affecting the electrical properties of the helix, as by establishing microwave mismatches or causing prohibitive standing wave ratios.

An ideal mount for the helical signal-transmitting conductor of the microwave tube would be to suspend the helical conductor within the evacuated envelope in proper axial orientation with respect to the electron beam, but with no supporting structures in immediate proximity to the conductor, such that the traveling waves are not unintentionally damped. As an approach to these optimum supporting conditions, it has been suggested that the supporting structure for the helix include circumferentially spaced contacts to the helix throughout its length, provided either by integral portions of the vitreous sleeve or by separate mounting rods which make line contact with the helix. Such line contact or equivalent supporting structure assures a minimum amount of dielectric material in close proximity to the helical conductor. This assures minimum dielectric loading, and provides an adequate mechanical mount. Although such support in many instances assures the required mechanical support for the helix, it is not infrequent that the turn distribution of the helix changes, as for example when the tube is impacted or subjected to shock excitation. A more idealized mount for the helical signal-transmission conductor would be one in which each turn of the helix were fixed or locked in relation to the supporting structure. However, the realization of this further objective is difficult, in part due to the size and physical geometry of the helix and its supporting sleeve, and the problems of dielectric loading.

Accordingly, it is a further object of the present invention to provide an improved method of manufacturing encased signal transmission helices which provides for mechanical fixing or locking of the successive turns of the helix within its encasing support. Specifically, the present invention provides an improved process for the mounting of an encased helical conductor for a traveling wave tube in which the mounting or support provides minimum dielectric loading, yet assures mechanical locking of the successive turns of the helix throughout its length.

As applied to the manufacture of a microwave tube including a wire helix and supporting means defining a bore for receiving the wire helix, the present method involves the initial assembly of the wire helix within the bore and the formation on at least the outer surface of the helix of an integral shell. The integral shell or skin increases the diameter of the wire helix in relation to the diameter of the bore defined by the supporting means whereby the turns of the wire helix are fixed in position. Advantageously the integral shell or skin is a thin electrolytically deposited layer of metal deposited on the exposed outer surfaces of the wire helix, which thin shell or skin builds up the diameter of the wire helix. The supporting means which define the bore may take the form of integral flutings formed internally of the vitreous supporting sleeve or separate ceramic spacers having tangential contacts with the inner surface of a glass sleeve and with the outer periphery of the wire helix.

In accordance with the present method, the tubing for the helix may be produced to comparatively high precision; likewise, the helix can be wound with high precision as to its outer diameter such that the helix fits snugly into the bore provided by the tubing. When the

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helix is positioned within the tubing in accordance with the present method, a rugged mechanical lock is provided between the helix and tubing throughout the entire length of the helix by electrochemically growing at least the outer diameter of the helix until each turn of the helix becomes tightly held within the supporting structure. Such ruggedization may be accomplished by the deposition of only a few thousandths of an inch of material onto the original helix, without adversely affecting the helix transmission properties.

Numerous advantages may be attributed to the described method, including the ability to mount the helix within its supporting structure without mechanically forcing the helix such that the most delicate helix may be handled without danger of introducing permanent distortions likely to affect microwave transmission properties. Further, by appropriately selecting the plating material in relation to the core or body of the helix, it is possible to transform the usually high-loss core materials to a somewhat lower impedance at the microwave frequencies. For example, employing a body of tungsten or molybdenum and a plating of copper appreciably reduces the radio frequency losses in that the skin or coating provides a low impedance to high frequencies.

The above brief description as well as further objects, features and advantages of the present invention will be best appreciated by reference to the following detailed description of the presently preferred process and articles attainable thereby, when taken in conjunction with the accompanying drawing wherein:

Fig. 1 is an elevational view, with parts broken away, showing a typical traveling wave tube assembly processed in accordance with features of the present invention;

Fig. 2 is a sectional view, on a greatly enlarged scale, taken substantially along the line 2—2 of Fig. 1 and showing the details of a ruggedized helix assembly obtainable in accordance with the present invention;

Fig. 3 is a sectional view, similar to Fig. 2, but showing the helix-mount assembly during processing;

Fig. 4 is a sectional view showing a modified form of helix-mount assembly in accordance with the present invention; and

Fig. 5 is a sectional view, on an enlarged scale, showing a still further modified helix-mount assembly in accordance with the present invention.

In that the invention may be best demonstrated as applied to the well-known traveling wave tube 10, in Fig. 1 there is shown such an illustrative traveling wave tube which includes a vitreous body 12 having an enlarged end or bulb 14 and an elongated slender sheath, sleeve or tube 16. Within the bulb or enlarged end 14 is the well known electron gun assembly 18 which is arranged to produce a beam to be axially directed along the sleeve. The gun assembly 18 includes the usual filamentary heater, electron-emitting cathode and beam-forming elements. Within the sleeve 16 is an electrode assembly including an input probe 20, a helical conductor 22 of a uniform and variable pitch and an output probe 24. The helical conductor 22 has appropriate electrical connections to the input probe 20 and to the output probe 24. Beyond the output probe 24 is a collector 26 for the electron beam having appropriate external terminal or connection. As is well understood, electrical connections are provided for establishing operating potentials for the tube 10 and a magnetic field is arranged about the sleeve 16 for focusing the electron beam. The slender tubing 16 in the region of the helix 22 should be of a highly refractory material, such as fused quartz or similar non-porous, low loss material of comparable refractory merit. Usually the tubing 16 is joined by graduated seals of different types of glasses to the bulb end 14 and to the collector end 26 of the electrode assembly. Further, the bulb end and the collector end are suitable for sealing to metal terminals. In that the

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present invention is not concerned specifically with this broadly old traveling wave tube which is shown to illustrate an important application of the invention, further detailed description of the traveling wave tube construction will be dispensed with, except as is necessary for an understanding of the present process.

In accordance with the present invention, the helix 22 is mechanically locked to the vitreous tube or sleeve 16 throughout the length of the tube or sleeve by a construction which assures minimum dielectric loading, yet adequate mechanical support and rigidity. As seen in Fig. 2, the cross-section of the sleeve or tubing 16 is of a special configuration, that is, of clover-leaf cross-section. The interior of the fluted sleeve is made up of three longitudinally extending circular bores 30a, 30b and 30c having their center lines lying at the apices of an equilateral triangle. The bores 30a, 30b provide convex surfaces which converge toward a tangential intersection which defines a thin or knife-supporting edge 32a having line contact with the outer periphery of the helical conductor 22. Similarly, the bores 30b, 30c intersect at a further knife-supporting edge 32b and the bores 30c, 30a intersect at a still further knife-supporting edge 32c. The fluted tubing may be produced with high precision such that the bore diameter defined by the knife edge supports 32a, 32b, 32c lies within prescribed tolerances. Such tubing and its manufacturing is described in co-pending application Serial No. 466,525, filed November 3, 1954, in the name of Vincent C. De Maria and assigned to the assignee of the present invention. The helix 22 is wound with high precision such that a snug but slip fit is achieved upon axial insertion of the helix 22 within the vitreous support 16. With this fluted or clover-leaf cross-section, line contact supports are provided for the helix 22 which assures comparatively low dielectric loading. Further, in that the envelope may be formed very accurately in diameter and exceptionally straight axially, it is possible to readily orient the small diameter helix in relation to the electron beam.

The assembly of the slip-fitted helical conductor 22 within the fluted tubing 16 is mechanically interconnected by an electroplated coating 34 which is deposited on the exposed surfaces of the helix 22 throughout its length. As will be subsequently appreciated, the coating on the outer periphery of the helix builds up quicker than the coating on the inner periphery of the helix, such that a negligible amount of material is deposited on the inner surfaces of the helix. The electrodeposited coating builds up or grows the outer diameter of the helix 22 in relation to the bore diameter defined by the knife edged supports 32a, 32b, 32c such that the respective turns of the helix 22 are fixed in relation to the supporting structure. Such fixing or helix ruggedization may be accomplished by the deposition of only a few thousandths of an inch of material onto the helix.

The process for forming the integral electroplated coating on at least the outer surfaces of the wire helix will be described in conjunction with Fig. 3. Electrodes 36a, 36b and 36c are inserted within the respective bores 30a, 30b, 30c and are supported by appropriate external clamps axially of their associated bores. Such electrodes, which are to serve as anodes in the electro-depositing of material onto the helix 22, are kept from shorting against the helix, serving as the cathode, by being placed under tension by appropriate external spring loading and are maintained straight axially of the respective bores. Thereafter, the assembly shown in Fig. 3 is immersed in an appropriate plating solution and electro-deposition is brought about by application of proper operating potentials to the electrodes and to the cathode. Plating is continued for a period sufficient to build up the required coating, skin or layer on at least the outer surfaces of the wire helix to assure fixing of the respective turns of the helix in relation to the support.

In an illustrative plating operation, anodes of 20 mil

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copper wire are employed with a tungsten helix having an outside diameter of 62 mils. A high-speed all potassium plating solution is employed which contains essentially copper cyanide, potassium thiocyanate, potassium hydroxide and free potassium cyanate. The temperature of the plating solution is maintained at 80° C. and the current flow is selected at a density of 100 amperes per square foot. An appropriate time of plating is found to be 15 to 20 minutes which is sufficient to build up the necessary skin on the exposed surfaces of the helical conductor.

The resultant helix-support assembly, as shown in Fig. 2, includes a structure in which each turn of the helix is locked in relation to the supporting edges 32a, 32b, 32c. The support is achieved without mechanically forcing or distorting the helix in effecting the initial assembly and with the use of minimum low-loss materials in immediate proximity to the helix. Further, the composite helix, which may have a core of tungsten or molybdenum and a coating of copper as described in the illustrative embodiment, is one having comparatively low radio frequency loss in that the copper plating is comparatively low impedance at the microwave frequencies.

Turning now to Fig. 4, there is shown an alternative helix-support assembly attainable in accordance with the present invention. In this embodiment, a helix 40 is mounted within a tube or sleeve 42 of vitreous material through the use of circumferentially spaced and longitudinally extending insulating rods 44a, 44b, 44c. Such rods may be of appropriate ceramic material and are proportioned in relation to the inner diameter of the sleeve 42 and the outer diameter of the helix 40 to provide tangential contacts between the respective rods and the inner wall of the tube and the outer periphery of the helix along radii emanating from the center of the helix. Such mount with ceramic spacer rods has been heretofore described in the art. However, in accordance with the present invention, an electrodeposited skin or layer 46 is formed on at least the outer surfaces of the helix 40 to build up the outer diameter of the helix in relation to the bore defined by the ceramic spacer rods 44a, 44b, 44c. The procedure for applying the plating is as described previously, and accordingly further description will be dispensed with.

Referring now to Fig. 5, there is shown a still further helix-support assembly attainable in accordance with the present invention. In the form illustrated in Fig. 5, the vitreous support 50 is formed with integral circumferentially spaced inwardly extending projections 54a, 54b and 54c. These projections make line contact with the helix 50. Although more vitreous material is in proximity to the helix 50 in the embodiment illustrated in Fig. 5, as compared to the embodiment illustrated in Fig. 2, it should be appreciated that the drawings are to a greatly enlarged scale and there is still a comparatively small amount of low loss material in close proximity to the helix 50. After the initial assembly as aforesaid, the electrodeposited skin or coating 56 is applied to at least the outer surfaces of the helix 50 to lock the turns of the helix 50 to the support 52.

A latitude of variation is intended in the apparatus shown in Fig. 3 and in the supporting structures assembled with the helix. For example, if space requirements permit, the electrodes may be made of special configurations to assure adequate throw power and uniform deposition of the material throughout the circumferential extent of the helix. Further, other integral or separate mounting structures are contemplated for use with the vitreous sleeve to provide a mount for the helix with minimum low loss materials in close proximity to or between turns of the helix.

Further modifications and varied applications of the foregoing invention will occur to those skilled in the art, and accordingly the appended claims should be con-

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strued broadly, as is consistent with the spirit and scope of the present invention.

What I claim is:

1. In the manufacture of a helix assembly including a conducting wire helix and a non-conducting vitreous sleeve receiving said wire helix and having supporting portions circumferentially engaging said wire helix throughout its length, the steps including electroplating a thin layer of metal onto at least the exposed outer surfaces of said wire helix throughout its length whereby the outer diameter of the exposed outer surface is built up in relation to the supporting portions of said vitreous sleeve to lock the turns of said wire helix against movement relative to said sleeve.

2. In the manufacture of a helix assembly including a conducting wire helix, a non-conducting vitreous sleeve receiving said wire helix, spaced apart supporting means of insulating material circumferentially engaging said wire helix throughout its length, the steps including placing metal electrodes in the spaces between the supporting means and extending through the length of said wire helix, applying a potential difference between said metal electrodes as anodes and said wire helix as a cathode to electroplate a thin layer of metal onto at least the exposed outer surfaces of said wire helix throughout its length whereby the outer diameter of the exposed outer surface is built up in relation to said supporting means to lock the turns of said wire helix against movement relative to said supporting means.

3. In the manufacture of a microwave tube including a conducting helical signal-transmission element and non-conducting supporting means defining a circular bore for snugly receiving said element and having line contacts with the outer periphery thereof substantially throughout the length of said element, the steps including assembling said element within said bore of said supporting means, and electrodepositing a metallic layer on the outer periphery of said element adjacent said line contacts thereby building the section throughout the length of said element at opposite sides of said line contacts whereby said element is fixed in position.

4. A method for producing a traveling wave tube assembly wherein a helically shaped conductive element which extends in a given direction is mounted within an electrically non-conductive hollow structure extending in the same direction, the inner surface of said structure defining a plurality of separate lands and valleys which extend in said direction, said method comprising the steps of inserting said element within said structure with a snug but slip fit between said element and said lands; and depositing a metal layer upon the outer surface of said element throughout its length to a thickness at which said element is mechanically locked to said lands.

5. A method for producing a travelling wave tube assembly wherein a helically shaped conducting element which extends in a given direction is mounted within an electrically non-conductive hollow structure extending in the same direction, said structure including a hollow cylinder and a plurality of insulator rods separated from each other and extending in said direction, each rod being secured to the inner surface of said cylinder, the inner surface of said structure defining a plurality of separate lands constituted by said rods and valleys constituted by the portions of the inner surface of said cylinder between said rods which extend in said direction, said method comprising the steps of inserting said element within said structure with a snug but slip fit between said element and said lands; and depositing a metal layer upon the outer surface of said element throughout its length to a thickness at which said element is mechanically locked to said lands.

6. A method for producing a traveling wave tube assembly wherein a helically shaped conducting element which extends in a given direction is mounted within an electrically non-conductive hollow member extending in

the same direction, said member having a cross sectional shape at which the inner surface of said member defines a plurality of separate lands and valleys which extend in said direction, said method comprising the steps of inserting said element within said member with a snug but slip fit between said element and said lands; and depositing a metal layer upon the outer surface of said element throughout its length to a thickness at which said element is mechanically locked to said lands.

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