Aug. 22, 1961 D. A. WATKINS 2,997,618

BAR-STRAPPED MULTIFILAR HELIX FOR TRAVELING-WAVE TUBE

Filed July 21, 1959

FIG_1

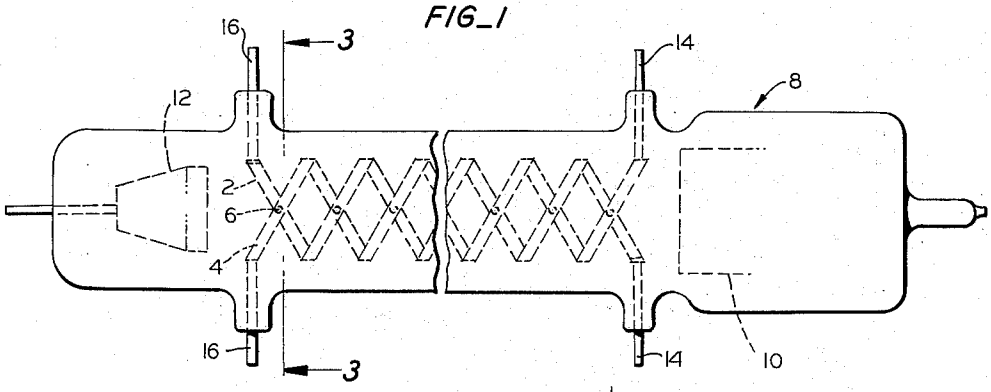


FIG_2

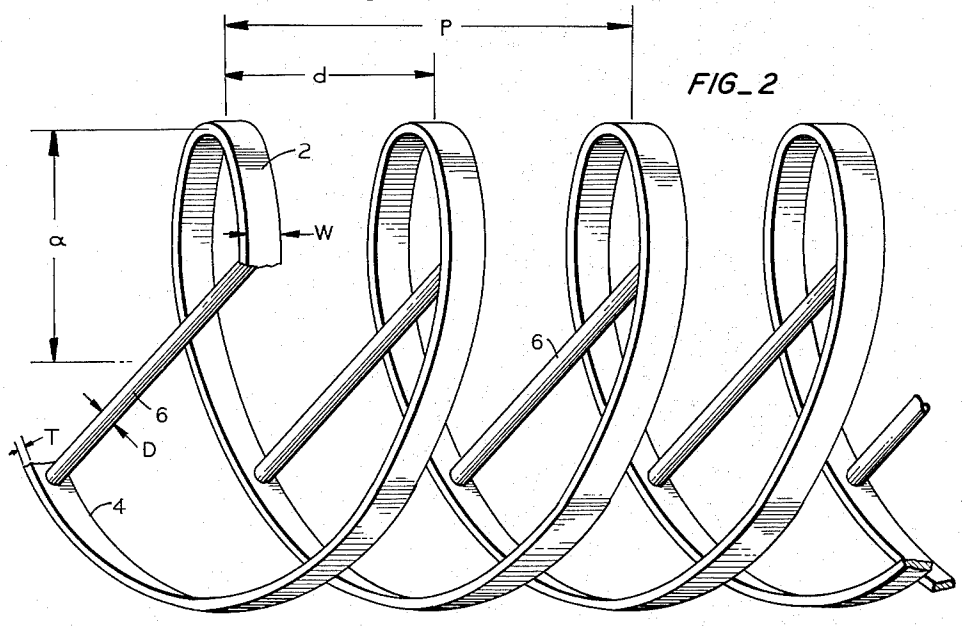
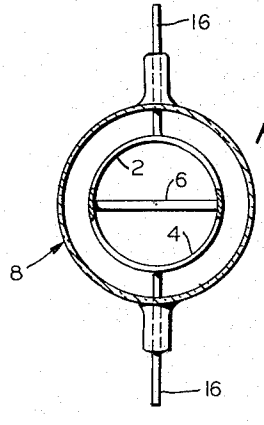


FIG_3



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BAR-STRAPPED MULTIFILAR HELIX FOR TRAVELING-WAVE TUBE

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4 Claims. (Cl. 315—3.6)

This invention relates to a slow-wave structure for use in traveling-wave tube amplifiers, and more particularly to a bar-strapped multifilar helix.

An object of this invention is to provide a slow-wave structure, which used with an appropriate high-voltage electron beam (for example 10 to 40 kilovolts) will form a traveling-wave tube amplifier with the following characteristics: large 3-db bandwidth (about 2:1); and the tube will be relatively free from self-oscillation caused by beam-interaction with a backward space-harmonic of the structure having a velocity nearly synchronous with the electron beam, as compared with a single helix having a similar beam configuration and equal pitch and diameter. By the aforementioned description of bandwidth is meant to those skilled in the art that the frequences at the 3-db down points on the response curve are in the ratio of 2:1.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein:

FIG. 1 is a more or less schematic drawing of a traveling-wave tube showing one preferred embodiment of the invention;

FIG. 2 is an enlarged axonometric view of a bar-strapped bifilar helix removed from the tube of FIG. 1 and partially broken away; and

FIG. 3 is a cross-section taken along the line 3—3 in FIG. 1.

Reference is now made to the drawing. The particular multifilar helix illustrated is a bifilar helix made of two helices 2 and 4 of uniform conducting tape of width W and thickness T. Each has the form of a helix of constant pitch p (the axial distance in which the conductor makes one complete rotation about the axis), constant pitch angle Ψ (the complement of the angle between an element of the cylindrical surface in which the helix lines and the helical direction in that surface), and constant mean radius a. The helices are spaced equally from each other along their common axis.

The helices are connected together electrically (strapped) every distance d by means of identical conducting bars 6 (or wires, rods, etc.), shown in FIG. 2 to be of circular cross-section with diameter D. The axes of the bars lie along diameters of the cross-section of the helix cylinder.

The helices and bars may be the same piece of metal formed into the shape described, or they may be separate pieces of metal formed as described and connected together to afford electrical connection and physical support between the separate pieces.

The spacing d between bars is shown in FIG. 2 to be equal to half the pitch distance p. Other spacings are possible, in which case the bars would not be aligned with each other, in general, but would each be rotated about the axis of the structure from adjacent bars by some constant angle which depends upon d and Ψ.

The cross-sectional shapes of the conductors which form the helices and of the bars of secondary importance to the configurations of the conductors and their spacings relative to each other.

Thus, other cross-sectional shapes (e.g., circular, oval, rectangular, etc.) of conductors would produce structures of quite similar characteristics.

The traveling-wave tube in which the helix of this invention is used is indicated generally at 8 and is of conventional construction, including an electron gun 10, a collector 12, input terminals 14, and output terminals 16. The electron beam can travel in two segments, either inside the helix or outside of it, being directed in such a manner as to avoid hitting the bar straps or supporting structure. The helix can be supported by dielectric supporting rods inside of it (omitted for the sake of clarity) or can be supported by the connecting terminals alone if the tube is disposed with its axis vertical.

An understanding of the operation of this invention can perhaps best be had by review of the operation of an unstrapped bifilar helix. The unstrapped bifilar helix has an infinity of possible modes of propagation, two of which are important here. The "symmetric" or "push-push" mode is characterized by fields at the two helices being in phase with each other. It has a forward space-harmonic (designated as a fundamental or 0 space-harmonic) which is useful for forward wave amplifiers, and a strong —2 backward space-harmonic which can cause oscillations when its velocity is nearly synchronous with the electron beam and therefore also nearly synchronous with the velocity of the fundamental space-harmonic.

An "anti-symmetric" or "push-pull" mode is also possible, for which the fields at the two helices are 180° out of phase at any axial position, even at very low frequencies. This mode has a strong —1 backward space-harmonic which can cause oscillations under the same near-synchronous condition with the beam and therefore also with the fundamental space-harmonic. The —1 and the 0 space-harmonics are synchronous at or near the frequency for which the circumference of the structure is equal to one-half of a free-space wavelength. Recalling that a is the mean radius of the structure, the terminology common in the art defines ka as the circumference measured in free-spaced wavelengths. Thus, the aforementioned synchronism of the —1 and 0 space-harmonics, can be said to occur near $ka=0.5$. Synchronism between the —2 and the 0 space-harmonics occurs at or near $ka=1.0$.

The straps of the present invention connect the two helices together electrically, thereby forcing them to be in phase and prevent a "push-pull" mode with its —1 space-harmonic from propagating. The straps, because of their periodic perturbation of the unstrapped structure, also cause a stop band in the "symmetric" mode. By suitable choice of the strap spacing d there is produced a stop band which results in considerably higher beam currents being required for oscillation in the strapped structure than for interaction with the —2 space-harmonic of the unstrapped structure. The stop band is needed at about $ka=1.0$, which allows forward-wave interaction (traveling-wave tube operation) up through $ka=0.5$ and higher. Operation through such a high value of ka is one requirement for broadband amplification in a high power tube, the other requirement of the structure being low dispersion. Measurements have shown that the diametrically strapped bifilar helix has very little more dispersion than a sheath helix of the same velocity up to $ka=0.8$.

Although the illustrated multifilar helix is a bifilar helix, multifilar helices using more than two such identical helices assembled along a common axis, equally spaced from one another, can be used. As the helices become more numerous, the width of each one would need to become smaller, so that the individual helices do not touch each other. Diametric strapping of a multifilar helix having more than two separate helices would require more than the number of straps shown in the illustrated embodiment. They could meet at the axis

of the structure and all lie in the same transverse plane, or they can be staggered along the axis. Bar strapping can also be accomplished without the bar passing through the axis of the structure. Thus, the bars could connect only adjacent helices, so that the bars form a polygon in a transverse plane, or they could be staggered along the axis of the structure. Whatever the form of strapping, it must be periodic in the axial direction.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A slow-wave structure for use in traveling-wave tubes comprising a multifilar helix including a plurality of separate helices, each separate helix having the same constant pitch, the same constant pitch angle, and the same constant mean radius; said helices being spaced equally from each other along a common axis; and a plurality of conducting bars, spaced periodically from each other along the direction of the axis of the multifilar helix; each bar electrically connecting the helices together, lying across a diameter of the multifilar helix, and intersecting the axis of the multifilar helix.

2. The slow-wave structure of claim 1 wherein the multifilar helix is a bifilar helix.

3. The slow-wave structure of claim 2 wherein the conducting bars are spaced from each other a distance equal to half the pitch distance of each separate helix.

4. In a traveling-wave tube, an electron gun, a collector for electrons, and a slow-wave structure; said slow-wave structure being the structure of claim 1.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,997,618 August 22, 1961

Dean A. Watkins

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 14, after "which" insert -- when --; line 48, for "lines" read -- lies --; same column 1, line 69, after "bars" insert -- are --; column 2, line 39, for "free-spaced" read -- free-space --.

Signed and sealed this 6th day of March 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents