United States Patent

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[54] **HELICAL RESONATOR HAVING VARIABLE CAPACITOR WHICH INCLUDES WINDINGS OF REDUCED DIAMETER AS ONE PLATE THEREOF**
8 Claims, 3 Drawing Figs.

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[51] Int. Cl. **H10s,** H03h 7/10
[50] **Field of Search** 333/83, 82, 5; 334/41–45, 68, 76, 85, 73; 336/205, 207, 208; 331/96–102; 330/53–56

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ABSTRACT: A helical resonator is comprised of a coil embedded in a plastic core which has been injection molded thereabout and a conductive housing. Windings at one end of the coil have a reduced diameter with respect to the diameter of the rest of the windings of the coil to provide one plate of an equivalent variable capacitor. The other plate is partially formed by a wall of the housing which is adjacent to the windings of reduced diameter. A screw extends through the foregoing wall into a hollow portion in the core enclosed by the windings of reduced diameter. Adjustment of the screw controls the resonant frequency of the cavity.

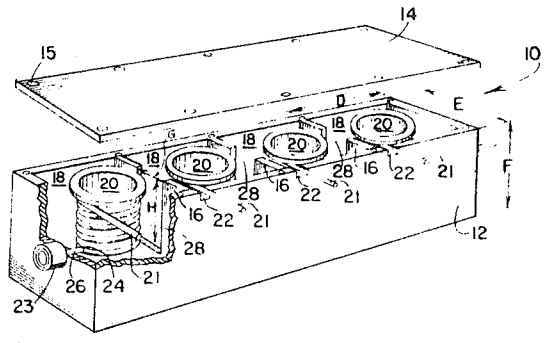
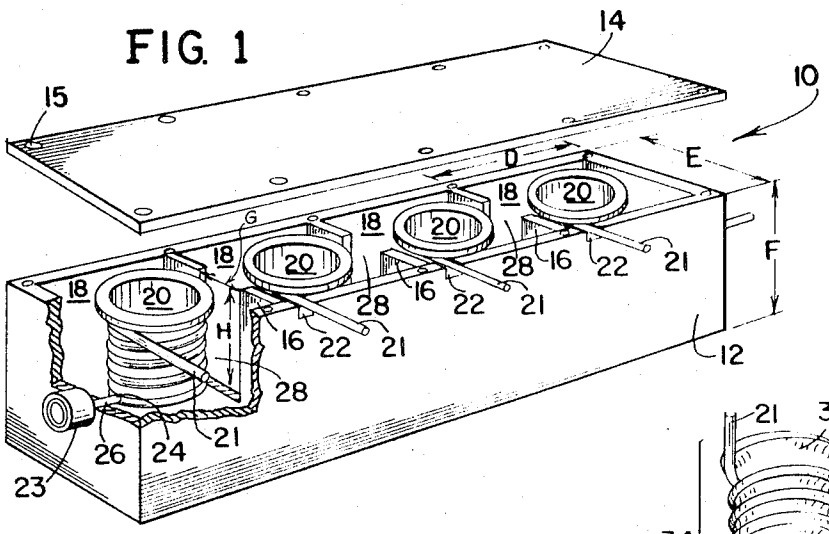


FIG. 1



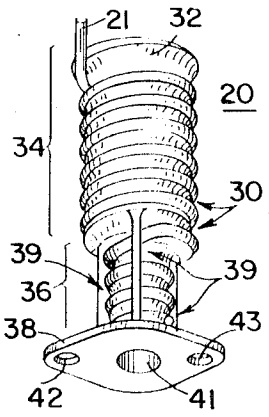
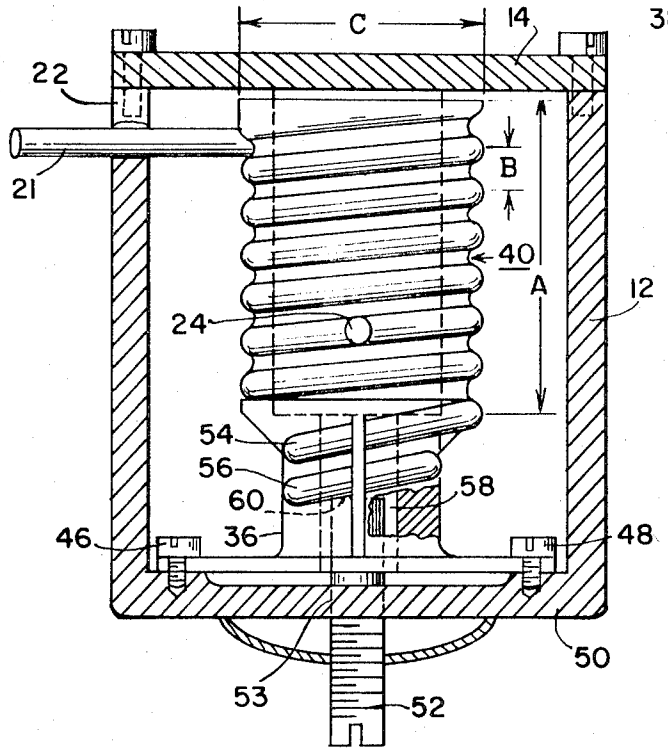


FIG. 2

FIG. 3



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HELICAL RESONATOR HAVING VARIABLE CAPACITOR WHICH INCLUDES WINDINGS OF REDUCED DIAMETER AS ONE PLATE THEREOF

BACKGROUND OF THE INVENTION

Radio equipment and other electronic apparatus operating at high frequencies have utilized helical resonators as tuning elements to select signals within desired frequency ranges. Such resonators may be comprised of an inductive element in the form of a helical coil and a capacitive element formed by the proximity of the coil to a metallic enclosure surrounding the helical coil. The grounded or low impedance end of the coil is directly connected to the metal enclosure and the high impedance end is capacitively coupled to the enclosure. The resonant frequency of the resonator is a function of the physical dimensions of the coil, the capacitive structure, and the distance between the high impedance end of the coil and the enclosure. Since it is desirable to adjust the resonant frequency of the resonator, some prior art helical resonators have included a member which is in electrical contact with the enclosure and which can be moved with respect to the high impedance end of the helical coil thereby varying the equivalent capacitance of the composite structure.

The structure of prior art helical resonators, however, has been found to be either inadequate or unduly expensive in some applications. In one prior art embodiment, for instance, a helical coil is wound around and supported by a ceramic form. The combination of the form and coil is positioned in a metallic enclosure. One plate of a variable tuning capacitor thereof is comprised of an annular element, the position of which is adjustable with respect to the high impedance end of the coil by means of a threaded shaft in engagement with the enclosure. The other plate is comprised of a metal tab which is soldered to the high impedance end of the coil. This tab provides sufficient capacitive coupling between the coil and the annular element so that movement of the annular element can produce an appreciable change in the resonant frequency of the structure.

Although the foregoing embodiment works well in most applications, if the helical resonator is included in a mobile receiver, for instance, which may be subjected to mechanical vibration, the coil of the helical resonator has a tendency to vibrate like a coil spring about the ceramic form. This vibration produces corresponding changes in the inductance which undesirably modulate the radio frequency (RF) electrical signal passing therethrough. Since this modulation may be at audio frequency, it can result in an undesirable "ringing" sound which emanates from the speaker of the receiver. Moreover, it is possible for the physical dimensions of the coil to undesirably change in response to the temperature variations to which mobile or portable equipment is often subjected thereby tending to detune the resonator. Furthermore, the electrical connection between the tab and the high impedance end of the coil produce an electrical discontinuity in the coil thereby increasing the insertion loss of the resonator.

To overcome the problems created by vibration and changes in dimension with temperature of the coil, it has been proposed that the ceramic coil form could be manufactured with grooves therein corresponding to the turns of the helical coil. After being positioned in the grooves, the turns of the coil could be anchored in place on the form with cement. Although these precautions may satisfactorily solve the particular problems associated with vibration, the resulting resonator is disadvantageous because it is relatively expensive and complex.

SUMMARY OF THE INVENTION

Hence, it is an object of the present invention to provide a simple, inexpensive and rugged structure for a helical resonator.

Another object of the invention is to provide a simple and inexpensive mechanism for effectively capacitively tuning a helical resonator.

A further object of the invention is to provide a helical resonator including a minimum number of parts which can be quickly and easily assembled.

A still further object of the invention is to provide an inexpensive helical resonator which is suitable for use in portable electronic equipment which is subjected to vibration and temperature change.

In brief, the helical resonator of one embodiment of the invention is comprised of a conductive housing which surrounds a coil mounted in a plastic form that has been injection molded thereabout. The coil is embedded in the plastic form to prevent vibration of the coil. The windings at one end of the coil have a reduced diameter with respect to the diameter of the rest of the windings. The other end of the coil is grounded to a portion of the conductive cavity. The form has a flange integral therewith which is located adjacent to the windings of reduced diameter for mounting the coil on an inside surface of a wall of the housing. This wall and the windings form an equivalent capacitor which is tuned by a screw passing through the wall into a hollow area enclosed by the windings of reduced diameter. Adjustment of the screw varies the resonant frequency of the helical resonator.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partially exploded view of an RF coupling circuit or preselector utilizing a plurality of helical resonators which are in the form of one embodiment of the invention;

FIG. 2 is a perspective view of one of the coils included in the coupling circuit of FIG. 1; and

FIG. 3 is a cross-sectional view of the RF coupling circuit of FIG. 1 showing the physical relation of a coil to a cavity and tuning element.

DESCRIPTION THE PREFERRED EMBODIMENT

In FIG. 1 there is depicted an RF coupling circuit **10** which may be utilized, for instance, to preselect signals within a predetermined frequency band passing therethrough from an antenna to the first RF amplifier stage of a receiver by reducing the amplitude of all Rf signals outside of the desired passband. The coupling circuit includes a conductive housing comprised of a metallic or conductive lower portion **12** and a metallic upper portion or plate **14**. Plate **14** is fastened onto lower portion **12** by screws passing through holes **15**. Lower portion **12** includes a plurality of walls or partitions **16** which divide up the space therein to form a plurality of cavities **18**. A helical coil **20** is disposed within each cavity **18**. The top or low impedance end **21** of each coil is conveniently grounded by soldering it to notches **22** in the sidewall of housing **12** which may be positioned at convenient points along the sidewall with respect to the cavity. An electrical connection for applying an input signal to a coil at one end of coupling circuit **10** or deriving an output signal from a coil at the other end is made through a standard RF connector which passes through the end wall of the lower portion, such as connector **23**. The portion of connector **23**, which is located inside of cavity **18**, is directly connected to a selected point **24** on coil **20** through connecting wire **26**. The exact point of connection on the coil is chosen to provide impedance matching between the external circuitry and coupling circuit **10**. An aperture or window **28** is provided in each partition **16** to allow energy to be transferred between cavities **18** through magnetic field coupling. The coupling to and from RF coupling circuit **10**, as well as between the helical resonating sections thereof, is very efficient thus permitting the use of a plurality of sections without the need for amplifying means interposed therebetween. The number of sections depends on the overall desired frequency response characteristic of the coupling circuit.

Referring now to FIG. 2, helical inductor **20** which is suitable for use in coupling circuit **10** is illustrated as being comprised of several turns **30** made in a single piece of heavy copper wire. The inside portions of windings **30** are embedded

in tubular insulating plastic support core **32**. The outside portions of winding **30** are exposed to facilitate soldering of connecting wires, such as connecting wire **26**, thereto. Plastic form **32**, which may be injection molded about prewound coil **20**, is formed into a single supporting structure comprised of an upper portion **34** having a circular cross section of a given diameter, a lower portion **36** having a smaller diameter, and a flange portion **38** at one end thereof. Plastic ribs **39** extend from flange **38** across the lower portion **36** to the lower edge of upper portion **34**. These ribs may be molded at quadrature with respect to each other about the lower portion to add strength and rigidity to unit **40** comprised of coil **20** and form **32**. The inside of form **32** is hollow as shown in FIG. **3** to reduce electrical losses. Flange **38** includes aperture or hole **41** which extends into the hollow inner portion of the core. Holes **42** and **43** are provided through flange **38** to facilitate the mounting of coil **20** in any one of cavities **18**.

Form **32** may be molded from polypropylene which is an inexpensive, lightweight plastic having relatively low water absorption characteristics, and exhibits low loss to high radio frequencies. Since turns **30** of coil **20** are embedded or injection molded into the plastic of form **32**, coil **20** cannot oscillate when subjected to mechanical vibration. Unit **40**, therefore, is free from the problem, inherent in most prior art resonators, wherein vibration or oscillation of the coils produces a change in inductance therein which provides undesirable modulation of the RF signal passing therethrough at an audiofrequency. Unit **40** is inexpensive, rugged, and can be quickly and easily fabricated. Furthermore, unit **40** is suitable for use in portable electronic equipment subject to vibration.

FIG. **3**, which shows a cross-sectional view of the coupling circuit of FIG. **1**, illustrates the mounting of unit **40**. In particular, self-tapping screws **46** and **48** pass through holes **42** and **43** to fasten flange **38** to base portion **50** of housing **10**. Low impedance end **21** of coil **20** is grounded by soldering it in groove **22**. A resonant structure is formed by the interreaction of inductor **20**, which may be considered as electrically analogous to the inner conductor of a quarter wave coaxial transmission line, and the metallic walls of housing **12**, which may be considered as analogous the outer conductor of the coaxial line. This coaxial line may be thought of as being end loaded by an equivalent capacitor connected from the center conductor or coil to the outer conductor or walls. One plate of this equivalent capacitor is comprised of turns **54** and **56** at the high impedance end of the coil which have reduced diameter with respect to the other turns of coil **20**. The other plate is comprised of base portion **50** of housing **10** and screw **52** which extends through tapped portion **53** of base **50** into hollow portion **58** of core **32**. The distance between end **60** of screw **52** and winding **56** is a measure of the thickness of the dielectric of the capacitor. Hence, as screw **52** is adjusted so that it protrudes further into hollow portion **58**, the effective plate area is increased and the thickness of the dielectric is decreased, both of which contribute to an increase in the capacitance of the equivalent capacitor. This change in equivalent capacitance varies the resonant frequency of the helical resonator.

Because of the proximity of windings **54** and **56** to tuning screw **52**, adjustment of tuning screw **52** effectively controls the value of the equivalent capacitor. Hence, one turn of screw **52** provides a relatively large change in the resonant frequency. The helical resonator of this embodiment, therefore, provides a simple and inexpensive mechanism comprised of turns **56** and **58** and screw **52** which effectively tunes the resonant frequency. Moreover, the structure of coil **20** has an advantage compared with prior art structures in that essentially no electrical discontinuity is created by the gradual decrease or "necking down" of the diameter of coil **20** to form the aforementioned plate for the equivalent capacitor. The cost and difficulties encountered in manufacturing and assembling the resonator of the embodiment of the invention are substantially less than that required for prior art structures. Furthermore, since the plate formed by windings **54** and **56** is relatively close to the plate formed by base **50**, the thermal expansion or contraction of the plastic of the form therebetween will cause a minimum detuning of the resonator with changes in ambient temperature.

The following table gives information pertinent to the construction of a helical resonator which has been made in accordance with the teaching of this invention and which has been tested and found suitable for use in a commercial radio preselector operable in the frequency range from 150 megacycles to 180 megacycles.

Coil **20** is made from No. 11 copper wire
A=1.12 inches
B=0.155 inch
C=0.8 inch
D=1.25 inches
E=1.25 inches
F=1.75 inches
G=0.29 inch
H=0.65 inch

What has been described, therefore, is a simple, rugged and inexpensive structure for a helical resonator which is suitable for use in mobile or portable RF apparatus which is subjected to vibration, moisture and temperature change.

I claim:

1. A helical resonator for passing radiofreqnency signals within a predetermined frequency range, such helical resonator including in combination:

a helical coil comprised of conductive windings, said windings having a first cross-sectional diameter along a first portion of said coil and a second cross-sectional diameter which is less than said first cross-sectional diameter along a second portion of said coil including an endmost windings;

a conductive member forming a cavity enclosing said coil to form a resonant structure;

a coupling surface forming part of said conductive member which is positioned in a plane that is essentially parallel to said endmost winding, said surface thereby forming a first plate and said endmost winding forming a second plate of an equivalent capacitor with the distance between said coupling surface and said endmost winding being the thickness of the dielectric of said capacitor;

movable conductive means having a portion extending through said coupling surface toward said endmost winding of the coil, said means being adjustable to vary said portion thus changing the effective surface area of said first plate and the thickness of said dielectric to change the capacitance of said equivalent capacitor thereby adjusting the resonant frequency of the helical resonator.

2. The helical resonator of claim **1** wherein said conductive windings are made of copper.

3. The helical resonator of claim **1** further including a form for supporting said coil, said form having a first cross-sectional diameter extending along a first portion thereof corresponding to said first cross-sectional diameter of the coil;

said form further having a second cross-sectional diameter along a second portion thereof corresponding to said second cross-sectional diameter of the coil;

flange means integral with one end of said second portion of the form, said flange means being connected to said coupling surface thereby mounting said coil thereon;

said second portion of the form having a hollow area;

said flange means having an aperture opening into said hollow area; and

said movable conductive means being adjustable to extend through said aperture into said hollow area.

4. The helical resonator of claim **3** wherein said coupling surface has a tapped hole extending therethrough to said aperture and wherein said movable conductive means is a screw in engagement with said hole and extending through said hole and said aperture into said hollow area.

5. The helical resonator of claim **3** wherein said form including said flange is comprised of a plastic material which is molded about said coil;

said windings of said coil being partially embedded in the plastic material to prevent oscillation of the windings with respect to the form.

6. The helical resonator of claim 5 wherein said plastic is polypropylene.

7. A coil structure for use in a helical resonator having an adjustable tuning member, said coil structure including in combination:

a coil having a longitudinal axis and with a first portion having a plurality of helical windings, each of a first diameter and with a second portion extending along the axis away from said first portion and having at least one helical winding of a second diameter, said second portion including an endmost winding;

a cylindrical form for supporting said coil having first, second and third integral parts, said first part having a first diameter supporting said first portion of said coil, said second part extending from said first part and having a second diameter supporting said second portion of said coil, said third part extending from said second part and forming a flange for mounting said coil; and

said flange having an aperture therein for receiving the adjustable tuning member.

8. The coil structure of claim 7 wherein said second portion of said coil includes a plurality of helical windings each of a diameter which is less than said first diameter.

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