United States Patent [19]

Takahashi et al.

[11] **3,763,447**

[45] **Oct. 2, 1973**

[54] **HIGH FREQUENCY HELICAL FILTER**

[75] Inventors: **Akira Takahashi**, Saitama-ken; **Senji Yokokawa**, Yamagata-ken, both of Japan

[73] Assignee: **Yagi Antenna Co., Ltd.**, Tokyo, Japan

[22] Filed: **Dec. 16, 1971**

[21] Appl. No.: **208,622**

[30] **Foreign Application Priority Data**

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Mar. 25, 1971 Japan 46/17082
Mar. 23, 1971 Japan 46/19664

[52] **U.S. Cl.** ..... **333/73 R**, 333/79, 333/73 C, 333/70 S

[51] **Int. Cl.** **H03h 7/10**, H03h 9/00

[58] **Field of Search** ..... 333/70 S, 73, 73 C, 333/79

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Primary Examiner—Eli Lieberman
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—D. Gordon Angus et al.

[57] **ABSTRACT**

A high frequency helical filter comprising a conductor case; an input coupling helix; an output coupling helix; and resonance means having a plurality of resonance helixes linearly arranged end to end between said input and output coupling helixes, each of said resonance helixes having an electrical length equal to $\lambda/4$ (λ represents the length of an electromagnetic wave being filtered), wherein the facing ends of the adjacent resonance helixes of said resonance means are separately connected or grounded to said conductor case or not grounded at all.

7 Claims, 15 Drawing Figures

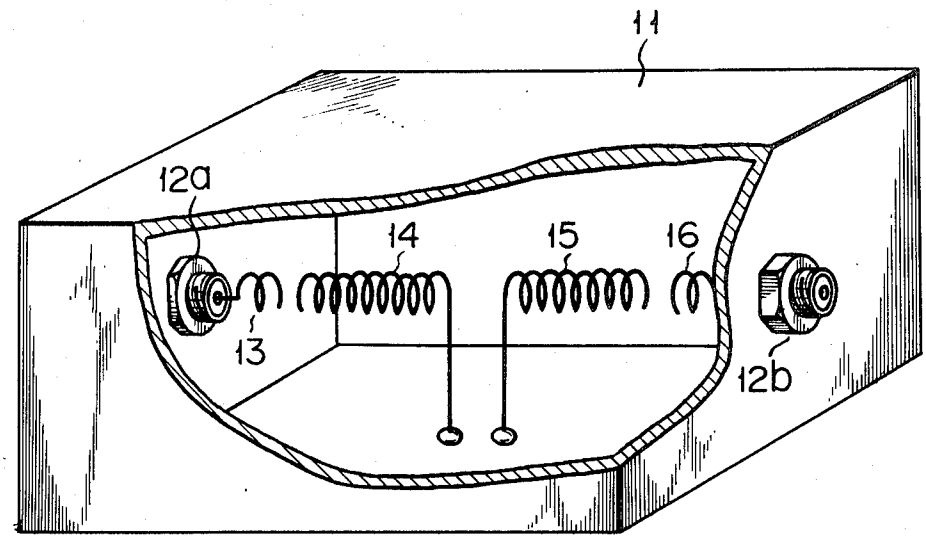


FIG. 1

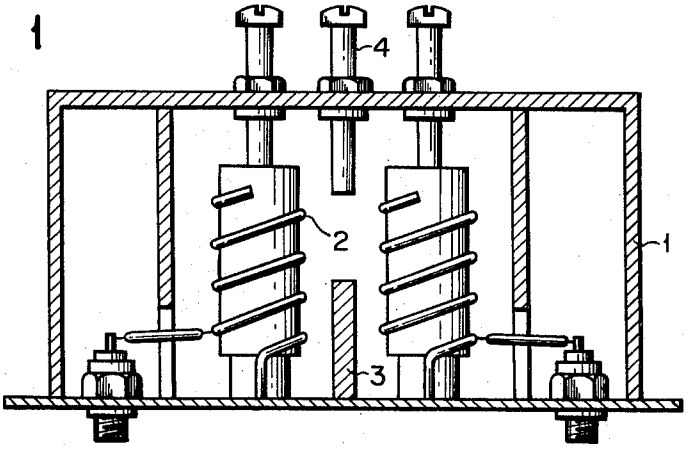


FIG. 2

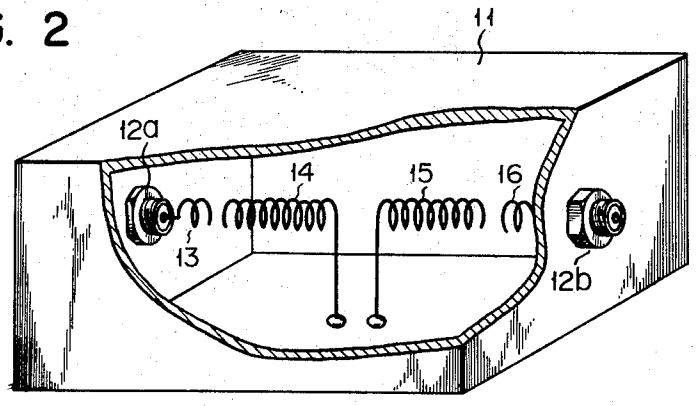


FIG. 3

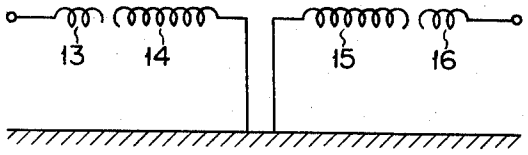


FIG. 4

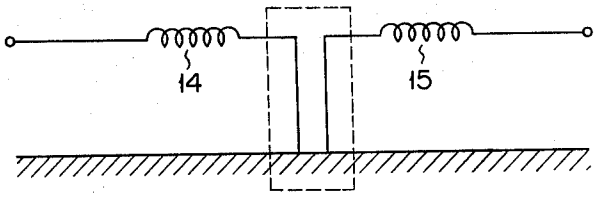


FIG. 5

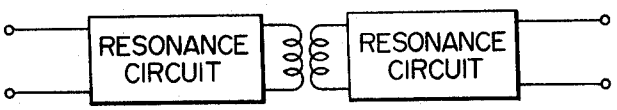


FIG. 6

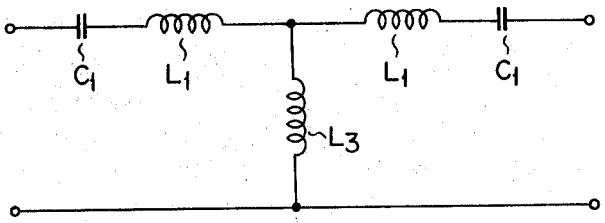


FIG. 7

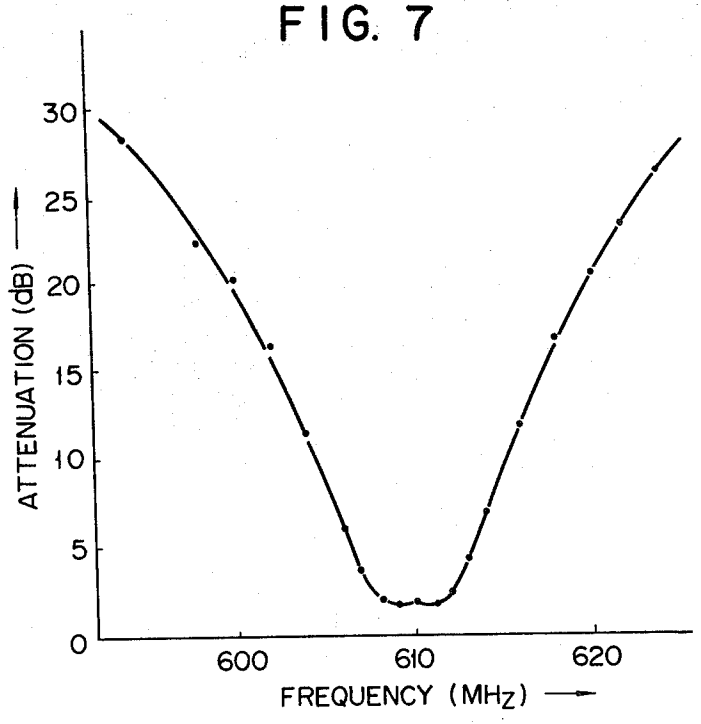


FIG. 8

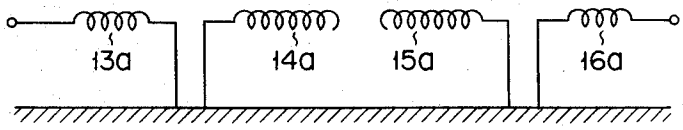


FIG. 9

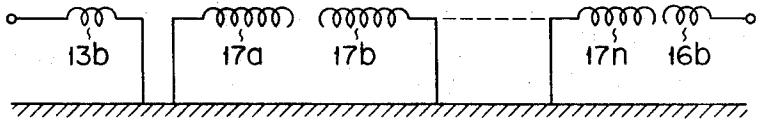


FIG. 10

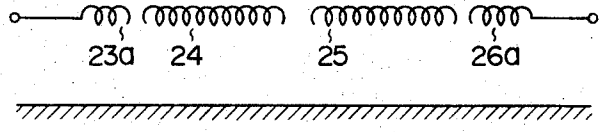


FIG. 11

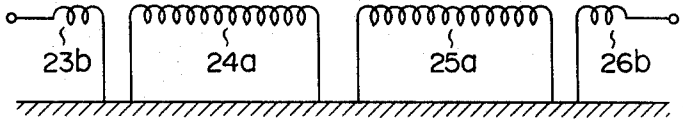
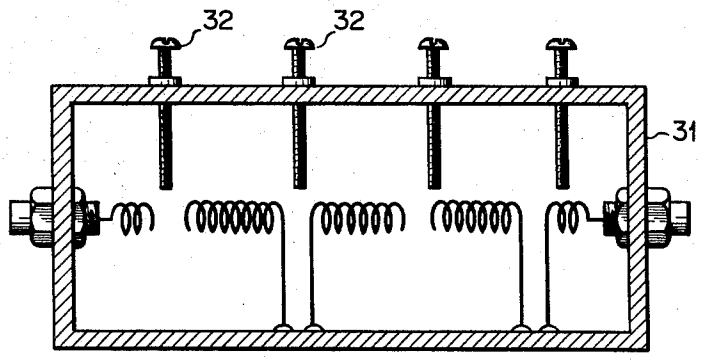


FIG. 12



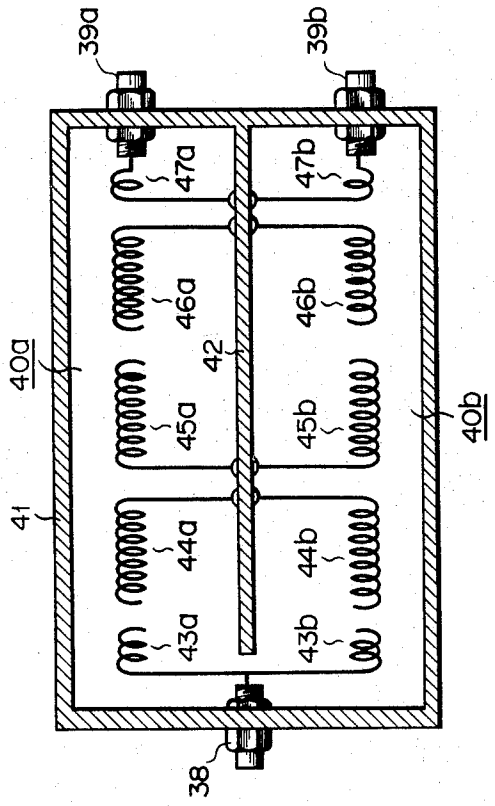


FIG. 14

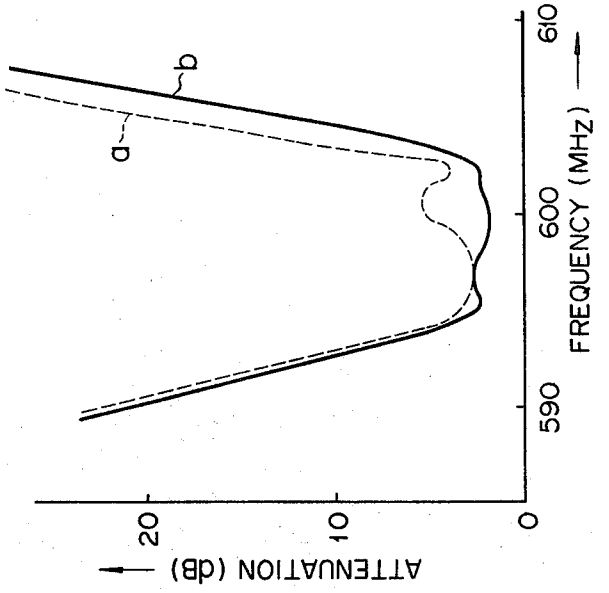


FIG. 13

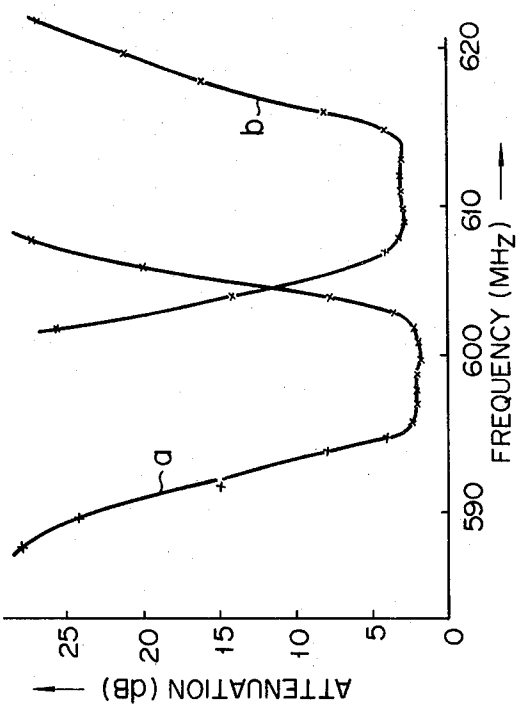


FIG. 15

HIGH FREQUENCY HELICAL FILTER

BACKGROUND OF THE INVENTION

This invention relates to a high frequency filter used, for example, with a VHF or UHF telecommunication apparatus. The prior art multistage helical filter includes, as illustrated in FIG. 1, a plurality of resonance helixes 2 laterally juxtaposed at a close interval in a conductive case 1. Though the resonance helixes 2 thus closely arranged are quite closely coupled, namely, are subject to very little energy loss, the filter as a whole presents an extremely gentle curve of attenuation, resulting in a considerably low degree of filtering. Between the adjacent resonance helixes, therefore, are disposed partitions 3 and coupling adjustments 4 to loosen and control their degree of coupling. However, provision of said partitions 3 and coupling adjustments 4 between the respective resonance helixes 2 results in a complicated process of manufacturing such type of helical filter and in consequence, high production cost and bulkiness.

SUMMARY OF THE INVENTION

It is accordingly the object of this invention to provide an inexpensive high frequency helical filter of simple, compact construction due to elimination of shields provided, as in the prior art, between the respective resonance helixes.

In this specification and in the claims the terms *M*, *N*, and *m* respectively denote the length of helix to be used, the overall length of a plurality of helixes and the position where each helix is connected to the conductive case.

According to an aspect of the invention, there is provided a high frequency helical electro-magnetic filter which comprises a conductive case; input coupling means; resonance means having a plurality of resonance helixes linearly arranged end to end in said conductor case, and each having an electrical length equal to $n\lambda/4$ (where n is a positive integer and λ represents the length of an electromagnetic wave being filtered), the first resonance helix of said resonance means being coupled to the input coupling means; and an output coupling means coupled to the last resonance helix of said resonance means.

The term "conductor" or "conductive" used herein means an electrical conductor or electrically conductive. The term "coupling" or "coupled" used herein means capacitive or inductive coupling.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of the prior art high frequency helical filter;

FIG. 2 is a perspective view, partly in section, of a high frequency helical filter according to an embodiment of this invention;

FIG. 3 presents a schematic arrangement of the helixes included in the high frequency helical filter of FIG. 2;

FIG. 4 shows an equivalent arrangement of FIG. 3 where there can be overlooked energy loss occurring between the helixes of the high frequency helical filter of FIG. 2;

FIG. 5 briefly illustrates the electromagnetic connection of two helixes in the arrangement of FIG. 4;

FIG. 6 indicates an equivalent concentrated constant circuit associated with the arrangement of FIG. 4;

FIG. 7 is an experimentally determined curve diagram showing the attenuation characteristics of the high frequency helical filter of FIG. 2;

FIGS. 8 to 11 shows the arrangements of high frequency helical filters according to other embodiments of the invenion;

FIG. 12 is a sectional view of a high frequency helical filter provided with screws for adjusting the capacitive and inductive coupling of helixes according to still another embodiment of the invention;

FIG. 13 compares the attenuation characteristics of the high frequency helical filter of FIG. 12 before and after there were used screws for adjusting the capacitive and inductive coupling of the helixes;

FIG. 14 is a sectional view of a high frequency helical filter according to a further embodiment of the invention; and

FIG. 15 is a curve diagram showing the attenuation characteristics of the high frequency helical filter of FIG. 14.

DETAILED DESCRIPTION OF THE INVENTION

The high frequency helical filter of this invention has a conductor case 11 having a rectangular prism form as illustrated in FIG. 2. On the opposite crosswise sides of said conductor case 11 are provided terminals 12*a* and 12*b*. On a line connecting said terminals 12*a* and 12*b* are linearly arranged end to end in tandem an input coupling helix 13, an assembly comprising a first resonance helix 14 and a second resonance helix 15, and output coupling helix 16. The first and second resonance helixes 14 and 15 each have an electrical length equal to $\lambda/4$ (λ represents the length of an electromagnetic wave being filtered) and each constitute a $\lambda/4$ resonantor. The assembly of resonance helixes 14 and 15 therefore have an electrical length of $\lambda/2$. The resonance helix should preferably be formed of, a material little subject to linear expansion such as amber so as to prevent its length from being thermally changed. The input and output coupling helixes 13 and 16 are connected at one end to said terminals 12*a* and 12*b* respectively. The facing ends of the first and second resonance helixes 14 and 15 are separately grounded at substantially the same point on the conductor case 11. It will be noted that the input coupling helix 13 and first resonance helix 14 are capacitively coupled, said first resonance helix 14 and second resonance helix 15 are inductively coupled, and said second resonance helix 15 and output coupling helix 16 are capacitively coupled. Unlike the prior art resonance helixes laterally juxtaposed at a close interval, the linearly arranged resonance helixes of this invention can be adjusted in capacitive and inductive coupling and resonance frequency simply by changing the pitch distance and physical interval of the respective resonance helixes.

FIG. 3 presents a schematic arrangement of the helixes included in the high frequency helical filter of the invention. As previously described, the helixes 13 and 16 are capacitively coupled with the helixes 14 and 15 respectively, and the helixes 14 and 15 are inductively coupled with each other. The degree of capacitive and inductive coupling between these helixes determines the attenuation characteristics of the high frequency helical filter. The close coupling reduces energy loss, presenting a gentle curve of attenuation, whereas their loose coupling prominently increases energy loss, showing a sharp curve of attenuation, even at the reso-

nance point of the first and second helixes **14** and **15**. Now let it be assumed that there exists an optimum coupling condition where the helical filter displays sharpest attenuation characteristics, in so far as there can be overlooked energy loss occurring between the respective helixes. Under this condition, the arrangement of the helixes shown in FIG. **3** may be equivalently represented as illustrated in FIG. **4**. Referring to this figure, the first and second resonance helixes **14** and **15** are inductively coupled with each other in a region defined by broken lines. This coupled section may be represented as a transformer in the concentrated constant circuit of FIG. **5**. With the first and second resonance helixes **14** and **15** assumed to have the same electrical properties, the helix arrangement of FIG. **4** may be equivalently illustrated as the concentrated constant circuit of FIG. **6**. When determined from the circuit of FIG. **6**, the fundamental four port matrix [F] may be expressed as

$$[F]=\begin{bmatrix} 1+Z_1Y_3 & Z_1(2+Z_1Y_3) \\ Y_3 & 1+Z_1Y_3 \end{bmatrix}$$

where:

$$Z_1 = j\omega L_1 + (1/j\omega C_1)\ Y_3 = 1/j\omega L_3$$

When determined from this matrix, the attenuation constant α may be represented as

$$\alpha=10\log_{10}\left[1+\frac{1}{4}\left\{\left(\omega L_1-\frac{1}{\omega C_1}\right)\left(2+\frac{\omega^2 L_1C_1-1}{\omega^2 L_3C_1}\right)+\frac{1}{\omega L_3}\right\}^2\right]$$

In case α is reduced to zero as measured from the above equation, the angular frequency ω_0 may be determined from the following equation:

$$\omega_0=\left[\frac{2(L_3+L_1)-C_1 \pm\sqrt{\{2(L_1+L_3)-C_1\}^2-4L_1(2L_3+L_1)}}{2L_1C_1(2L_3+L_1)}\right]^{1/2}$$

Accordingly, when capacitive and inductive coupling is adjusted as in a double tuned circuit, the attenuation pattern of the circuit of FIG. **3** will display a single or double peaks. As apparent from FIG. **7** showing the experimentally determined attenuation curve of the high frequency helical filter of FIG. **2**, this invention enables the filter to carry out very good filtation. According to FIG. **2**, those ends of the input and output helixes **13** and **16** which are not connected to the terminals **12***a* and **12***b* are raised above the bottom wall of the conductor case **11**, that is, are not grounded. However, even where those ends of both the input and output coupling helixes **13** and **16** which are not connected to the terminals **12***a* and **12***b* are grounded to the conductor case, as shown in FIG. **8**, or where such end of either of said helixes **13** and **16** is grounded, there can be obtained desired attenuation characteristics, that is, filtering capacity as indicated by the curve of FIG. **7**. Referring to FIG. **8**, the input coupling helix **13***a* and first resonance helix **14***a* are inductively coupled, the first and second helixes **14***a* and **15***a* are capacitively coupled, and the second resonance helix **15***a* and output coupling helix **16***a* are inductively coupled.

Where the helical filter is desired to present more prominent attenuation, that is, a sharper curve of attenuation, the object is attained by linearly arranging three or more resonance helixes **17***a* to **17***n* end to end between the input and output helixes **13***b* and **16***b*, as shown in FIG. **9**, using the fundamental circuit system of FIGS. **3** or **8**.

The foregoing description refers to the case where there was used a resonance helix having an electrical length of $\lambda/4$. However, the resonance helix may have an electrical length equal to an integral multiple of $\lambda/4$, that is, $n\ \lambda/4$ where n is a positive integer, and the assembly of a plurality of such resonance helixes can be $N\ \lambda/2$ or $(2N-1)\ \lambda/4$ where N is a positive integer. The resonance helix having such a long electrical length presents a larger increase in inductance L than in resistance R, offering the advantage of elevating the quality factor Q $(=\omega L/R)$.

FIGS. **10** and **11** indicate filter circuits each including two resonance helixes having an electrical length of $\lambda/2$. Referring to FIG. **10**, both ends of the resonance helixes **24** and **25** are open, and the input and output coupling helixes **23***a* and **26***a* are open at one end. Further, the input coupling helix **23***a* and resonance helix **24**, as well as the resonance helix **25** and output coupling helix **26***a*, are capacitively coupled. Referring to FIG. **11**, the input and output coupling helixes **23***b* and **26***b* are grounded at one end, and resonance helixes **24***a* and **25***a* are reach grounded at both ends. Further, the input helix **23***b* and resonance helix **24***a*, as well as the resonance helix **25***a* and output helix **26***b*, are coupled inductively. Helixes arranged as shown in FIGS. **10** and **11** display sharper attenuation curves than in FIG. **7**.

As is apparent from the foregoing description of this invention, a resonance helix disposed at a point corresponding to an electrical length of $(2m-1)\lambda/4$ as viewed from that end of the first resonance helix which is capacitively coupled with the input coupling helix is grounded at one end through the conductor case, whereas a resonance helix located at a point corresponding to an electrical length $(m-1)\lambda/2$ is raised at one end above the bottom wall of the conductor case, that is, not grounded. Where the first resonance helix is inductively coupled with the input coupling helix, a resonance helix positioned at a point corresponding to an electrical length of $(m-1)\lambda/2$ as viewed from the inductively coupled end of the first resonance helix is raised at one end above the bottom of the conductor case, whereas a resonance helix placed at a point corresponding to an electrical length of $(m-1)\lambda/2$ is grounded at one end to the conductor case.

Where the aformentioned type of filter is used within a relatively low range of frequency, it is considered necessary for a resonance helix to have a large electrical length. However, this decreases the mechanical stability of the helix and in consequence the performance of a filter as a whole. To avoid such drawback, the helix is customarily fixed in place by inserting thereinto an insulation rod causing very little energy loss which is fitted to the conductor case **11**. In this case, the insulation rod may be replaced by a magnetic material giving rise to very little energy loss, for example, ferrite in order to reduce the physical expansion of the helix without changing its electrical length. Unlike the conventional filter comprising laterally juxtaposed resonance helixes set apart by, for example, shield plates, the filter of this invention has resonance helixes linearly arranged end to end to permit the use of, for example,

a single common insulation rod to plural resonance helixes, thus offering great advantage.

Where it is desired minutely to control electromagnetic connection between the helixes, there are provided, as shown in FIG. **12**, adjustment screws **32** at those parts of a conductor case **31** which face the electromagnetic junctions of adjacent helixes. Proper operation of said adjustment screws **32** changes the degree of coupling between the helixes, obtaining desired attenuation characteristics. Referring to FIG. **13**, a broken line *a* shows a curve of attenuation presented by the helical filter of FIG. **12** when it was not provided with said adjustment screws **32**, and a solid line *b* denotes a curve of attenuation corrected from that indicated in the broken line *a*, using the adjustment screws **32**. Thus, use of the adjustment screws enables desired attenuation characteristics to be easily obtained.

FIG. **14** illustrates a filter assembly of channel separation type. This type of filter assembly has a conductor case **41** divided by a partition wall **42** into two mutually shielded cavities or unit helical filters **40***a* and **40***b*. The unit filters **40***a* and **40***b* respectively contain a group of an input coupling helix **43***a*, resonance helixes **44***a*, **45***a* and **46***a* and output coupling helix **47***a* and another group of an input coupling helix **43***b*, resonance helixes **44***b*, **45***b* and **46***b* and output coupling helix **47***b*, the elements of both groups being linearly arranged end to end as in the preceding embodiments. Now let it be assumed that the helical filter **40***a* is set for the passage of signals having a frequency f_1 and the helical filter **40***b* for that of signals having a frequency f_2. In this case, the helical filter **40***a* presents, as viewed from the input terminal **38**, a zero impedance for a frequency f_1 and an infinite impedance for a frequency f_2, while the helical filter **40***b* indicates, as viewed from said input terminal **38**, an infinite impedacne for a frequency f_1 and a zero impedance for a frequency f_2. When, therefore, the input terminal **38** is supplied with signals having frequences f_1 and f_2, then there are drawn out signals having frequences $f$and f_2 from the outpuut terminals **39***a* and **39***b* respectively. FIG. **15** illustrates the curves of attenuation of the above-mentioned channel separation type filter assembly. Where are group of signals has a frequency f_1 ranging from 596 to 602 MHz and another group has a frequency f_2 ranging from 608 to 614 MHz, they can be separated as much as more than 20dB. The signals f_1 and f_2 are subject to energy loss of about 1.5 dB while passing through said filters **40***a* and **40***b*. Conversely where the output terminals **39***a* and **39***b* are supplied with signals having a frequency f_1 and those having a frequency f_2 respectively, then there can be drawn out from the input terminal **38** two kinds of signals which are free from mutual interference.

This invention is not limited to the aforementioned embodiments, but may be applied in various modifications. Namely, the input and output coupling helixes used in the preceding embodiments may be replaced by, for example, coupling discs or loops. Though the foregoing description referred to band pass type helical filters, they may be used as band elimination type by connecting, for example, one end of the input coupling helix to a first transmission line and under this condition either omitting the output coupling helix or connecting one end of the output coupling helix to a second transmission line.

We claim:

1. A high frequency helical electro-magnetic wave filter comprising a conductive casing containing: an input coupling helix; an output coupling helix; a plurality of resonance helixes spaced from said casing and coaxially aligned in tandem and separated from each other end-to-end and each having an electrical length of $n\,\lambda/4$ and the electrical length of said plurality being $N\,\lambda/2$, the first of said resonance helixes in the tandem being physically and conductively separated from, but coupled with, said input helix and the last of said resonance helixes in the tandem being physically and conductively separated from, but coupled with, said output helix, each of said resonance helixes being conductively connected to the casing at one of its ends which is at the distance from the end of the first resonance helix which is coupled with said input helix, which has an electrical length of $(2m-1)\lambda/4$, wherein m, n and N are positive integers and λ represents the length of an electro-magnetic wave being filtered, said couplings to the input helix and to the output helix being capacitive couplings.

2. A high frequency helical electro-magnetic wave filter comprising a conductive casing containing: an input coupling helix; an output coupling helix; a plurality of resonance helixes spaced from said casing and coaxially aligned in tandem and separated from each other end-to-end and each having an electrical length of $n\,\lambda/4$ and the electrical length of said plurality being $N\,\lambda/2$, the first of said resonance helixes in the tandem being physically and conductively separated from, but coupled with, said input helix and the last of said resonance helixes in the tandem being physically and conductively separated from, but coupled with, said output helix, each of said resonance helixes being conductively connected to the casing at one of its ends which is at the distance from the end of the first resonance helix which is coupled with said input helix, which has an electrical length of $(m-1)\lambda/2$, wherein m, n and N are positive integers and λ represents the length of an electro-magnetic wave being filtered, said couplings to the input helix and to the output helix are inductive couplings.

3. A high frequency helical filter according to claim **2** in which there is an interspace between each helix and the next adjacent helix and which further includes means for adjusting coupling occurring in at least one of said interspaces.

4. A helical filter according to claim **1** in which there is an interspace between each helix and the next adjacent helix and which further includes means for adjusting coupling occurring in at least one of said interspaces.

5. A high frequency helical electro-magnetic wave filter comprising a conductive casing divided into a plurality of cavities electrically shielded from each other; a plurality of first coupling helixes the number of which is the same as the number of said cavities and each of which is connected at one end to a respective one of the cavities; a plurality of second coupling helixes; a plurality of resonance helix assemblies, the number of which is the same as the number of cavities, each assembly comprising a plurality of resonance helixes located in a respective one of the cavities and spaced from said casing and coaxially aligned in tandem and separated from each other end-to-end and each reso-

nance helix having an electrical length of n λ/4, the electrical length of each assembly being $(2N-1)\lambda/4$, the first resonance helix in the tandem of each assembly being capacitively coupled with the corresponding one of the first coupling helixes, each of said plurality of resonance helixes being conductively connected to said casing at one of its ends which is at the distance from the end of the first resonance helix which is capacitively coupled with the first coupling helix, which has an electrical length of $(2m-1)\lambda/4$, the last resonance helix in the tandem of each assembly being inductively coupled with the corresponding one of said second coupling helixes, wherein m, n and N are positive integers and λ represents the length of an electromagnetic wave being filtered.

6. A high frequency helical wave filter comprising a conductive casing having within it: a first coupling helix, a resonance helix assembly comprising a plurality of resonance helixes spaced from said casing and axially aligned with each other and separated end-to-end and each having an electrical length of n λ/4, the length of said assembly being $(2N-1)\lambda/4$; and a secondd coupling helix spaced from said assembly, the first helix of said resonance helix assembly being capacitively coupled with said first coupling helix, each of said plurality of resonance helixes being conductively connected at one of its ends to said casing, the point of said conductive connection of each resonance helix being spaced by an electrical length of $(2m-1)\lambda/4$ from that end of the first resonance helix which is capacitively coupled with said first coupling helix; the last resonance helix of the resonance helix assembly being inductively coupled with said second coupling helix, wherein m, and N are positive integers and λ represents the length of a electromagnetic wave being filtered.

7. A filter according to claim **6** in which there is an interspace between each of said helixes and the helix next adjacent and there is means for adjusting coupling occurring in at least one of said interspaces.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,763,447 Dated October 2, 1973

Inventor(s) AKIRA TAKAHASHI et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 29 "M, N and m" should be --n, N and m--

line 35 after "magnetic" insert --wave--

Col. 2, line 4 "shows" should be --show--

Col. 3, lines 31, 32 "$a = 10 \log_{10}[+\frac{1}{4}\{(wL_1 \frac{1}{wC_1})$ should be

--$a = 10 \log_{10}[1+\frac{1}{4}\{(wL_1 - \frac{1}{wC_1})$--

Col. 4, line 40 after "length" insert --of--

line 45 "$(m-1)\lambda/2$" should be --$(2m-1)\lambda/4$--

Col. 5, line 37 "impedacne" should be --impedance--

line 41 "f and f_2" should be --f_1 and f_2--

line 41 "outpuut" should be --output--

line 44 "are" should be --a--

Col. 8, line 2 "secondd" should be --second--

Signed and sealed this 27th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents