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J. L. REINARTZ

2,471,777

METHOD OF MAKING ULTRA HIGH FREQUENCY INDUCTORS

Original Filed March 27, 1946

2 Sheets-Sheet 1

Fig. 1

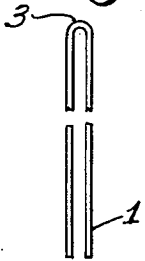


Fig. 2

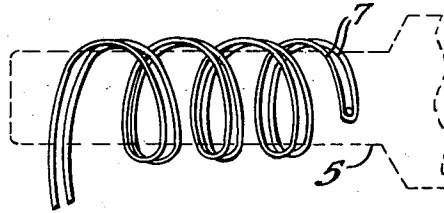


Fig. 3

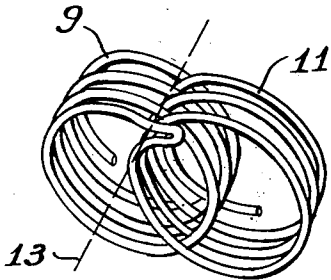


Fig. 4

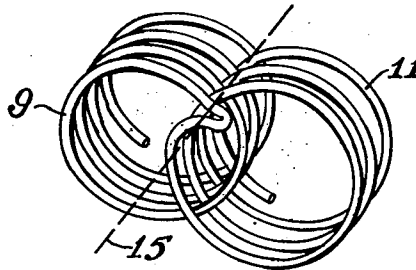
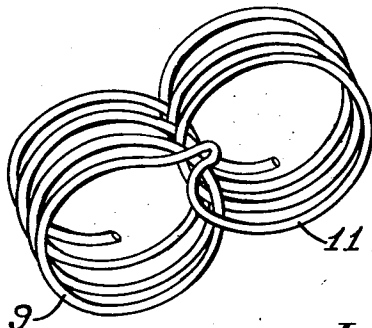


Fig. 5



INVENTOR.
John L. Reinartz

BY

C. Huska

ATTORNEY

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Fig. 6

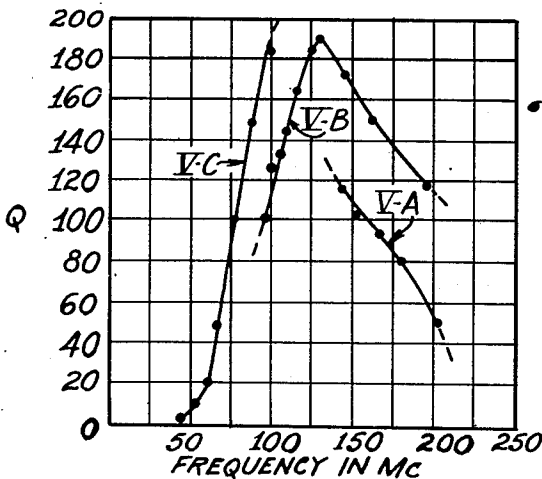
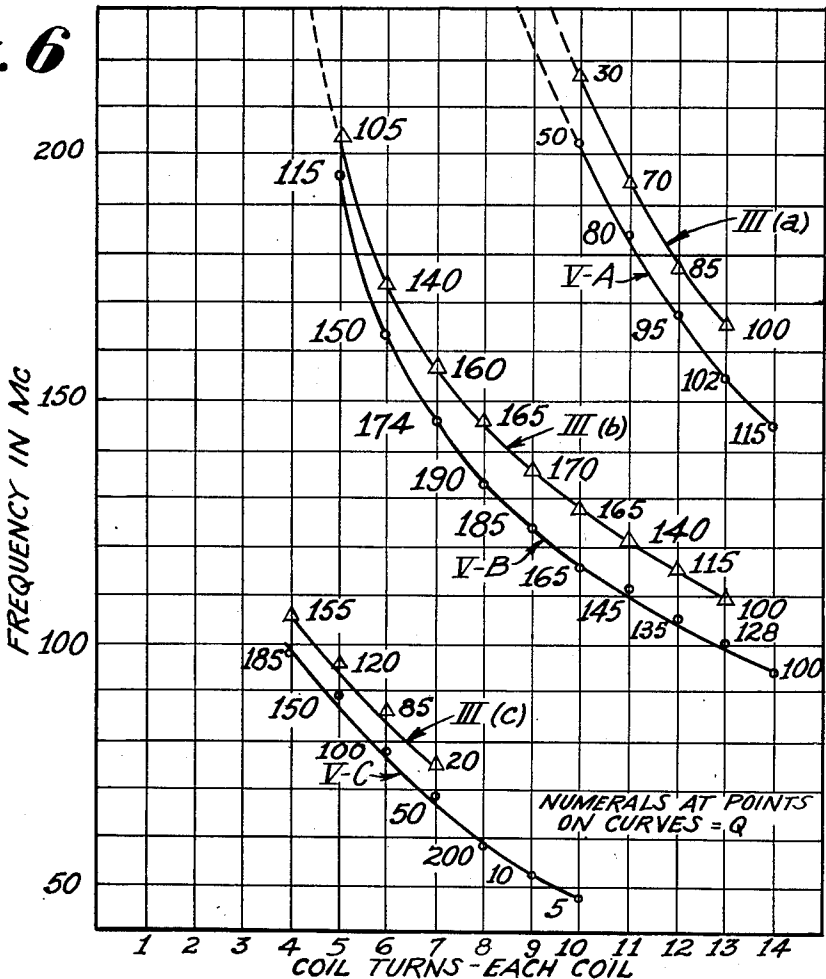


Fig. 7

INVENTOR.
John L. Reinartz
BY *CD Aushka*
ATTORNEY

UNITED STATES PATENT OFFICE

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METHOD OF MAKING ULTRA HIGH
FREQUENCY INDUCTORSJohn L. Reinartz, Lancaster, Pa., assignor to
Radio Corporation of America, a corporation of
DelawareOriginal application March 27, 1946, Serial No.
657,420. Divided and this application March
27, 1947, Serial No. 737,659

3 Claims. (Cl. 29—155.57)

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This application is a division of my copending application Serial No. 657,420, filed March 27, 1946, entitled "Ultra-high frequency inductor and method of making same" and assigned to the assignee as the instant application.

This invention relates generally to ultra-high frequency inductors, and more particularly to the method of winding said inductors to provide units having relatively large physical size and a relatively large ratio of reactance to resistance.

Most ultra-high frequency inductors of helical type comprise a relatively few turns of small diameter conductor, wherein extremely small variations in turn diameter, cross-section, and turn spacing provide relatively wide variations in total inductance. Various methods have been devised for reducing the mutual inductance of such windings in order to lengthen the winding axis and provide a greater number of turns for a predetermined inductance value. However, most mutual inductance cancellation methods employed heretofore have required the use of complex winding forms which are not well adapted to screw machine mass production methods.

The instant invention comprises a novel ultra-high frequency inductor and the method of making such inductors wherein a single length of relatively large diameter wire is formed into a U-shaped loop. The U-shaped loop comprising parallel conductor portions is wound upon a conventional mandrel into a cylindrical coil of the type employed heretofore for non-inductive resistors. After the double conductor winding is wound, alternate turns are separated to a desired degree to provide two interleaved serially connected windings having opposing magnetic fields. The degree of inductance cancellation is determined by the separation of the axes of the interleaved coil portions.

When the coils are first formed and entirely interleaved so that their axes coincide, the resultant inductance has a very low value. As the axes of the oppositely-wound interleaved coil portions are separated, the total inductance, and Q (ratio of reactance to resistance) increase, thereby providing an extremely flexible and uncritical method of adjusting an ultra-high frequency inductor to predetermined inductance and Q characteristics. Also after the final coil conformation has been determined, the open ends of the coils may be cut off in order further to adjust the inductance value. Since a relatively large physical size may be employed for a winding having a predetermined inductance and Q value, the conductor cross-sectional dimensions may be substan-

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tially increased to provide a self-supporting, air-spaced winding which is suitable for ultra-high frequency transmitter circuits having high current values. The conductor forming the coil may be insulated or not, depending upon the spacing between adjacent coil turns. An extremely convenient type of conductor is that employing a double layer of enamel insulation.

Among the objects of the invention are to provide an improved method of constructing an ultra-high frequency inductor. Another object is to provide an ultra-high frequency inductor having a large physical size with respect to total inductance. A further object is to provide an ultra-high frequency inductor having adjustable means for securing inductance cancellation. A still further object is to provide an ultra-high frequency inductor comprising a single conductor shaped to provide a pair of interleaved winding portions having opposing magnetic fields. Another object is to provide an ultra-high frequency inductor in which the inductance and Q values may be adjusted over relatively wide ranges. An additional object is to provide an ultra-high frequency inductor which may be initially adjusted to provide predetermined inductance and Q values. A still further object of the invention is to provide an improved means for winding an ultra-high frequency inductance to provide a desired degree of inductance cancellation. A still further object is to provide an ultra-high frequency inductor comprising two interleaved windings having opposing magnetic fields wherein the inductor convolutions of one winding intersect the central or eccentric axis of the other of said windings.

The invention will be further described by reference to the accompanying drawings of which Figure 1 illustrates the first stage of constructing the novel inductor, Figure 2 illustrates the second stage of the said construction; Figures 3, 4 and 5 illustrate optional third stages of said construction, Figure 6 is a family of graphs illustrating the operating characteristics of the novel inductance in terms of frequency vs. coil turns, and Figure 7 is a family of graphs illustrating the Q values of said inductors in terms of the resonant frequency thereof. Similar reference characters are applied to similar elements throughout the drawings.

The invention will be described, by way of example, in terms of the procedure of forming and adjusting a typical ultra-high frequency inductor utilizing a single length l of No. 12 double enamel insulated copper wire wound upon a $\frac{7}{8}$ " mandrel. The length of copper wire is bent to form a "hair-

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pin" loop 3 as shown in Figure 1 and then is wound upon the mandrel 5 to form a double conductor non-inductive winding 7 as shown in Figure 2. The coil then is opened up to form two interleaved coils 9, 11 as shown in Figures 3, 4 and 5. Figure 3 shows an interleaved coil structure wherein the convolutions of one of the coils 11 pass through the central axis 13 of the other of the coils 9, the coils being serially connected.

Figure 4 shows further separation of the coil axes wherein the coil convolutions of one of the coils 11 intersect an eccentric axis 15 of the other of the coils. Figure 5 shows further separation of the coil axes.

Before the double wound coil turns are separated axially, the inductance of the winding has a minimum value. As the interleaved coil axes are separated, the inductance of the series coils increase, and the Q (ratio of reactance to resistance) also increases. The extent of linkage of the serially connected coil sections affects the Q of the coil, since the resistance thereof remains substantially constant while the effective inductance increases as the coil axes are separated.

Even order harmonic excitation of the windings is possible, and may be efficiently utilized up to at least the eighth harmonic.

The family of graphs of Figure 6 illustrates the tuning range of the serially-connected windings shown in Figs. 3 and 5 as the number of turns on a 1" diameter coil are reduced from 14 to 4. Graphs III—(a), III—(b), and III—(c) indicate the characteristics of the winding of Fig. 3. Graphs V—A, V—B and V—C indicate similarly the characteristics of the winding of Fig. 5.

The graphs of Figure 7 show the variation in Q (ratio of reactance to resistance) of the coil of Fig. 5 in relation to the resonant frequency thereof shown in the corresponding graphs V—A, V—B, and V—C of Figure 6.

The coil structure is particularly adaptable to inductors for ultra-high frequency transmitters wherein relatively high coil currents are utilized. The No. 12 enamel insulated copper wire has ample rigidity to provide self support for the winding turns, thereby minimizing dielectric losses in the inductor. Further, since the winding may be formed upon a conventional mandrel,

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the structure is ideally suited to mass production. The coil axis separation may be readily accomplished by means of a simple expanding jig, not shown. From the graphs of Figures 6 and 7, the particular requirements for total inductance and Q may be readily selected to meet specific operating requirements.

Thus the invention described comprises an improved ultra-high frequency inductor in the form of a self supporting double coil winding wherein alternate turns are separated axially to provide the desired degree of mutual inductance cancellation and to permit efficient design with respect to total inductance and Q.

I claim as my invention:

1. The method of utilizing a single conductor for making an ultra-high-frequency inductor comprising the steps of bending said conductor at a point midway between its ends to form a U-shaped loop having substantially parallel-disposed sides, winding said loop to form a substantially non-inductive uniform diameter cylindrical coil, and separating alternate turns of said coil to form two intersecting coils having parallel axes.
2. The method according to claim 1 wherein the convolutions of one of said coils are separated with respect to the convolutions of the other of said coils to intersect the axis of the other of said coils.
3. The method according to claim 1 wherein the convolutions of one of said coils are separated with respect to the convolutions of the other of said coils to intersect an axis intermediate the axis and the convolutions of the other of said coils.

JOHN L. REINARTZ.

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