Nov. 16, 1943. A. O. DODGE 2,334,178

VARIABLE INDUCTANCE DEVICE

Filed Oct. 29, 1941

Fig.1.

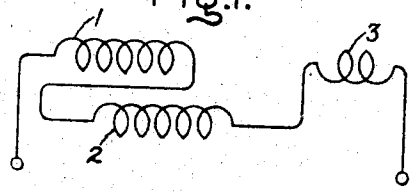


Fig.2.

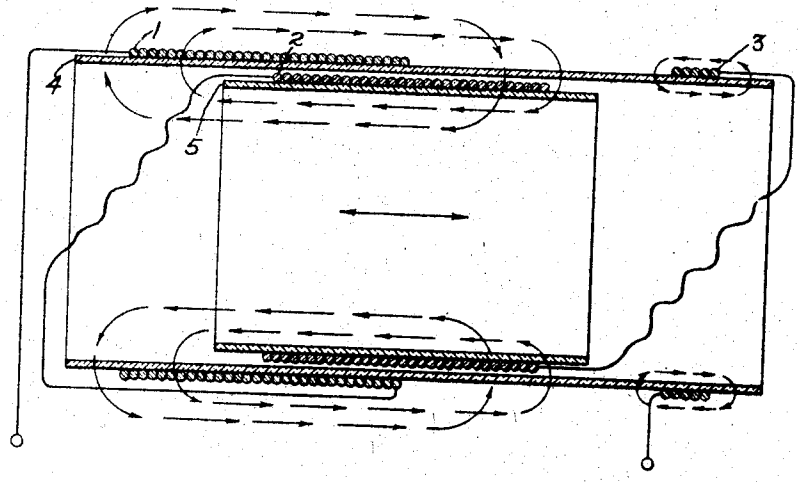
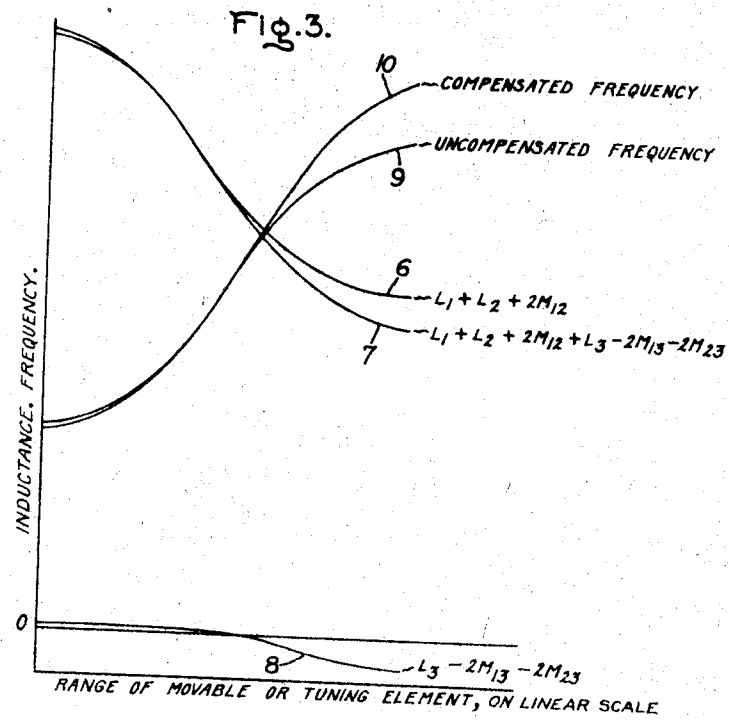


Fig.3.



Inventor:
Albert O. Dodge,
by Harry E. Dunham
His Attorney.

Patented Nov. 16, 1943

2,334,178

UNITED STATES PATENT OFFICE

2,334,178

VARIABLE INDUCTANCE DEVICE

Albert O. Dodge, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application October 29, 1941, Serial No. 417,026

6 Claims. (Cl. 171—242)

My invention relates to variable inductance devices and particularly to such devices employed as variable controlling means for tuning radio or like circuits over bands of frequencies.

The general object of the invention is to provide compensating means for variable inductance devices such that linear or substantially linear variation of the frequency of a tuned circuit is provided over a considerably extended portion of the range of linear variation of a controlling element or elements of the device. This compensation can be extended until linear or substantially linear variation of the inductance of the device results.

It is a particular object to compensate variable inductance tuning devices in such manner that the frequencies of a given band over which a controlled circuit is tuned are distributed more evenly over the range of linear motion of the controlling element or elements of the device, this distribution being preferably substantially linear over an extended frequency range, or in some cases varying from linearity only within predetermined small limits over this extended range.

It is well known that in certain cases it is desirable to employ a variable inductance instead of a variable capacity in tuning a frequency determining circuit. In accordance with one usual variable inductance tuning method heretofore suggested the circuit tuning is accomplished by the variation of the mutual inductance between two solenoidal windings, obtained by varying the relative position of the windings with respect to each other. It is known, however, that in this method the shape of the characteristic curve of inductance variation with linear relative motion of the windings is such that only a small portion of the curve approximates a linear frequency variation, while only a slightly more extended portion of the curve is such as to permit maintaining the frequency variation per unit linear motion within required small percentages.

In accordance with the present invention the above-noted disadvantage is overcome by the provision of a variable inductance device including a combination of windings, certain of which are of opposite inductive sense, so located and proportioned as to compensate for the region or regions of excess change in slope of the characteristic curve.

The novel features which are considered to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing wherein Fig. 1 is a diagrammatic representation of a combination of solenoidal windings comprised in a variable inductance device embodying my invention, Fig. 2 is a sectional view of the variable inductance device illustrated diagrammatically in Fig. 1, and Fig. 3 shows characteristic curves of inductance and frequency illustrating the invention.

In the variable inductance arrangement illustrated diagrammatically in Fig. 1, three windings 1, 2 and 3 are provided connected preferably in series. Two of the windings, as 1 and 2, are mounted closely adjacent to each other and movable with respect to each other for varying their mutual inductance, substantially as in the above-mentioned usual variable inductance tuning method heretofore suggested, and the third winding, 3, is fixed in position relative to one of the other windings, for example to winding 1.

In the sectional view, Fig. 2 of the inductance device, the three windings are shown as coaxially disposed, the windings 1 and 3 being spaced apart and mounted upon a common form or support, as insulating cylinder 4, at opposite ends thereof, and the winding 2 being mounted upon a similar insulating form or support, as cylinder 5. Windings 1 and 2 are arranged concentrically and are preferably respectively of such diameter that one winding, as 2, mounted upon its insulating cylinder 5, is disposed within and closely adjacent to the other winding.

The pair of spaced windings 1 and 3, mounted upon their common support 4, and the winding 2 mounted upon its support 5, are thus movable axially relative to each other from a first position, for example a position wherein windings 1 and 2 are closely adjacent to each other throughout their length or a major portion thereof, to a second position wherein none of winding 1 or only a limited portion thereof is closely adjacent to any portion of winding 2. In the first position the winding 2 is at its maximum distance from winding 3 and in the second position the distance between windings 2 and 3 becomes a minimum.

Windings 1 and 2 are so connected and wound that their magnetic fields are in the same direction, as indicated in dotted lines in Fig. 2. Winding 3, however, is so connected and wound that its magnetic field is in the opposite direc-

tion from that of the fields of windings 1 and 2.

The total inductance of the winding arrangement illustrated in Figs. 1 and 2 is

$$L_t = L_1 + L_2 + L_3 + 2M_{12} - 2M_{23} - 2M_{23}$$

In this formula L_t represents the total inductance; L_1 the self inductance of winding 1; L_2 the self inductance of winding 2; L_3 the self inductance of winding 3; M_{12} the mutual inductance of windings 1 and 2; M_{13} the mutual inductance of windings 1 and 3; and M_{23} the mutual inductance of windings 2 and 3.

The inductance provided by the concentrically disposed windings 1 and 2 when considered alone is represented by the terms $L_1+L_2+2M_{12}$ wherein M_{12} varies in value when the windings 1 and 2 are moved axially relative to each other. The compensating inductance provided by the third winding, 3, is represented by the terms $L_3-2M_{13}-2M_{23}$ wherein M_{23} varies in value when the windings 2 and 3 are moved axially relative to each other in the process of tuning by moving the pair of windings 1, 3 and the winding 2 relative to each other.

Referring more particularly to Fig. 3, curves 6 and 7 represent variation in inductance with linear change in position of the movable or tuning elements, curve 8 represents the varying compensating inductance provided by the third winding 3, and curves 9 and 10 represent variation in frequency, corresponding to the inductance variation, in a circuit (not shown) tuned by the variable inductance device in accordance with my invention. Curve 6 is the characteristic of the inductance variation represented by

$$L_1+L_2+2M_{12}$$

alone, when M_{12} is varied, by moving winding 2 for example between positions of maximum and minimum inductance. Curve 9 is the corresponding characteristic of the frequency variation represented by $L_1+L_2+2M_{12}$ alone.

As shown in the curves 6 and 9 of inductance and frequency which are characteristics of the variation provided by the relative axial movement of the two concentric windings 1 and 2 alone, those portions which are substantially linear are quite short, and the more extended portions wherein the slope varies within permissible limits are also relatively short. To extend the linear portions of curve 9, or the portions over which the slope varies within permissible limits, the third winding 3 is so spaced from winding 1 and so dimensioned and wound that the term

$$L_3-2M_{13}-2M_{23}$$

represents an inductance varying in a manner to compensate the undue changes in slope in curve 9 over a considerable portion of the total inductance and frequency range. As indicated by curve 8 the compensating inductance is preferably positive in the portion of the tuning range toward the maximum inductance end thereof and becomes negative toward the minimum inductance end, the resultant frequency curve 10 being thereby substantially linear over a considerably extended portion of its length as compared with the frequency curve 9. If this compensating inductance is increased beyond the requirements for linearity of controlled frequency, the resultant inductance curve 7 will become substantially linear over a considerably extended portion of its length as compared to curve 6.

In a typical variable inductance device in accordance with the present invention the windings, arranged as in Fig. 2, were as follows: winding 1—98 turns single layer, mean diameter 4½ inches, length $4^{29}/_{64}$ inches; winding 2—88 turns single layer, mean diameter 4 inches, length 4 inches; winding 3—11 turns single layer, mean diameter 4½ inches, length one-half inch. The spacing between the centers of windings 1 and 3 was 6⅝ inches.

In operation of the above-described typical variable inductance device in tuning a radio circuit over a suitable band of frequencies the frequency characteristics of the device were substantially as illustrated in curve 10 of Fig. 3, the linear portions, or those portions varying from linearity only by a permissibly small percentage, being so extended as compared with the similar portions in curve 9 that commercially practical straight line or linear tuning of a circuit was readily accomplished without the necessity of adding mechanical or other compensating means to the tuning control.

My invention has been described herein in a particular embodiment for purposes of illustration. It is to be understood, however, that the invention is susceptible of various changes and modifications and that by the appended claims I intend to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over a band of frequencies, said device including two windings providing magnetic fields of the same polarity and movable in relation to each other to produce substantially linear variation in the frequency of the controlled circuit over a predetermined portion of the range of said movement, and a third winding in fixed relation with one of said first-named windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said three windings cooperating to produce substantially linear variation of said frequency over a greater portion of said range.

2. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over bands of frequencies, said device including two concentric windings providing magnetic fields of the same polarity and movable axially in relation to each other to produce a linear variation in the frequency of the controlled circuit over a predetermined portion of the range of said movement, and a third winding spaced axially from and in fixed relation with one of said two windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said three windings cooperating to produce linear variation of said frequency over a greater portion of said range.

3. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over bands of frequencies, said device including two windings providing magnetic fields of the same polarity and movable in relation to

each other to produce substantially linear variation in the frequency of the controlled circuit over a predetermined portion of the range of said movement, and a third winding in fixed relation with one of said first-named windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said third winding being so spaced from said one of said first-named windings and the field provided by said third winding being of such value relative to that of the field produced by the other of said first-named windings that said substantially linear variation of said frequency is extended over a greater portion of said range.

4. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over bands of frequencies, said device including two windings providing magnetic fields of the same polarity and movale in relation to each other to produce substantially linear inductance variation of said device over a predetermined portion of the range of said movement, and a third winding in fixed relation with one of said first-named windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said three windings cooperating to produce substantially linear variation of said inductance over a greater portion of said range.

5. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over bands of frequencies, said device including two concentric windings providing magnetic fields of the same polarity and movable axially in relation to each other to produce a substantially linear inductance variation of said device over a predetermined portion of the range of said movement, and a third winding spaced axially from and in fixed relation with one of said two windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said three windings cooperating to produce linear variation of said inductance over a greater portion of said range.

6. A variable inductance device for use as a variable controlling means for tuning radio and like circuits over bands of frequencies, said device including two windings providing magnetic fields of the same polarity and movable in relation to each other to produce substantially linear inductance variation of said device over a predetermined portion of the range of said movement, and a third winding in fixed relation with one of said first named windings and providing a magnetic field of opposite polarity to that of said first-named fields, the total inductance of said device being the sum of the self-inductances of said windings plus the mutual inductance of said two windings and minus the mutual inductances of said third winding taken respectively with each of said two windings, said third winding being so spaced from said one of said first-named windings and the field provided by said third winding being of such value relative to that of the field produced by the other of said first-named windings that said substantially linear variation of said inductance is extended over a greater portion of said range.

ALBERT O. DODGE.

CERTIFICATE OF CORRECTION.

Patent No. 2,334,178. November 16, 1943.

ALBERT O. DODGE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 5, for that portion of the formula reading "$2M_{23}$-$2M_{23}$" read --$2M_{13}$-$2M_{23}$--; line 20, for "L_2" read --L_3--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 1st day of February, A. D. 1944.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 2,334,178. November 16, 1943.

ALBERT O. DODGE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 5, for that portion of the formula reading "$2M_{23}$-$2M_{23}$" read --$2M_{13}$-$2M_{23}$--; line 20, for "L_2" read --L_3--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 1st day of February, A. D. 1944.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.