July 27, 1943. W. A. SCHAPER 2,325,279

SIGNAL COLLECTING SYSTEM

Filed March 8, 1941

Fig. 1.

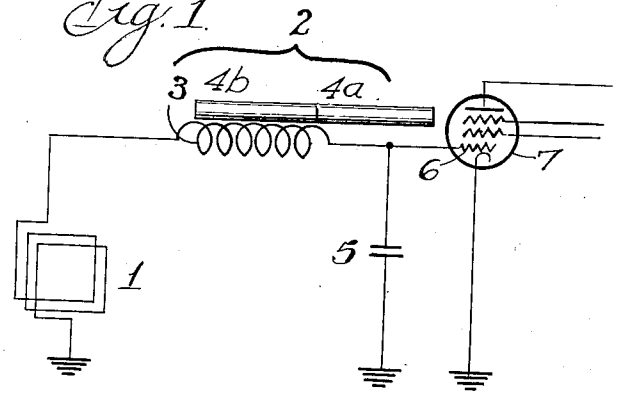
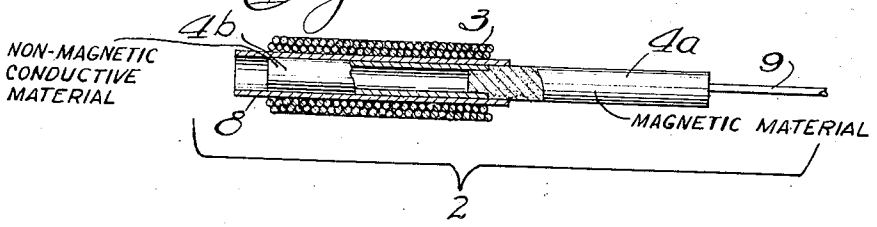


Fig. 2.



INVENTOR.
WILLIAM A. SCHAPER.

BY Kurt Kuehn

Patented July 27, 1943 2,325,279

UNITED STATES PATENT OFFICE

2,325,279

SIGNAL COLLECTING SYSTEM

William A. Schaper, Cicero, Ill., assignor to Johnson Laboratories, Inc., Chicago, Ill., a corporation of Illinois

Application March 8, 1941, Serial No. 382,370

7 Claims. (Cl. 250—40)

This invention relates to signal collecting systems for radio receivers and particularly to signal collecting systems of the type that employ an exposed inductive element commonly called a "loop."

A loop consists generally of a number of turns of wire mounted upon a framework of insulating material and its two ends are usually connected with a condenser to form a resonant circuit which is commonly called the "loop circuit." If a loop circuit is tuned to resonance with a desired signal the intercepted voltage is materially increased. Loop circuits therefore include usually a variable condenser or a variable inductance in order that they may be tuned over a desired range of frequencies.

The present invention relates to inductively tuned loop antenna systems employing variable inductors of the movable core type.

Tuning by the relative movement of a coil and a magnetic core is now generally known. Over other tuning devices the movable core inductor offers the advantage of compactness and durability and it allows the performance of the circuit which it tunes to be predetermined within wide limits. The range of inductance variation obtainable with a movable core inductor is determined by the effective permeability of its core. The permeability of cores intended for high frequency operation, however, is limited by the fact that the magnetic material from which they are made must be finely subdivided and the resultant particles carefully insulated to impede the formation of eddy currents in the core, and this severely reduces the permeability initially possessed by the magnetic materials from which the cores are made. The effective permeabilities which the art has been able to realize in high frequency cores without excessive eddy current losses are of the order of 10 to 15; they are more than adequate to tune high frequency circuits over wide ranges of frequencies such as the broadcast range.

However, when a loop circuit is tuned by a movable core variometer the loop which forms part of the total inductance of the system but which is removed from the effect of the tuning core materially reduces the range of inductance variation obtainable within the circuit; and the larger the loop and the greater the number of its turns the more pronounced will be this range-reducing effect until the permeabilities now available are no longer adequate to tune the loop system over a sufficiently wide range of frequencies, such as for instance the broadcast band. Therefore, to prevent the loop from reducing the tuning range obtained below an essential minimum it is necessary to restrict its inductance, that is, to keep the number of its turns at a minimum and to make it small in size. However, the signal energy intercepted by a loop is directly proportional to the number and size of its turns. Additionally, it inherently decreases with decreasing frequency; therefore the loop must be of adequate size and have an adequate number of turns if satisfactory reception and satisfactory performance of the receiver is to be had over the total tuning range.

It is an object of the present invention to provide a movable-core-tuned signal collecting system of the type employing an exposed inductive element and which covers an adequate range of frequencies.

Additionally it is an object of the present invention to provide a movable-core-tuned signal collecting system employing a loop and combining adequate tuning range with adequate signal interception over the whole of said range.

It is another object of the present invention to provide a loop system of the type tuned by movable core inductors and covering a wide range of frequencies while maintaining the signal voltage supplied to the grid of the first tube independent of frequency.

Additionally it is an object of the present invention to provide a loop system of the type tuned by movable core inductors which, while providing for adequate signal interception, is capable of being tuned over a wide range of frequencies with the signal voltage supplied to the grid of the first tube being independent of frequency.

The present invention furnishes a signal collecting system for radio receivers and the like and of the type employing an exposed inductive element, which includes an unexposed inductive element comprising a winding and a core structure, said core structure having a conductive portion and an insulated magnetic portion and being movable relatively to said winding from a position wherein said conductive portion is within said winding, to a position wherein said magnetic portion is within said winding, thus providing a large inductance change within said winding so that the exposed inductive element may have an inductance as great as that of said winding in air and even greater, and yet a range coverage as wide as the broadcast range be retained. Additionally, in accordance with the invention said core portions may be given such

loss characteristics by proper choice of the material from which they are made and by properly proportioning their dimensions relative to one another and relative to the winding that as they vary the inductance of said winding to change the resonant frequency of the system they simultaneously vary the resistance of said winding in such a manner that the ratio

$$\frac{\omega L}{R}$$

of the system varies substantially inversely as the frequency. In this manner the gain of the signal collecting circuit increases in the same proportion as the signal energy intercepted by the exposed inductive element decreases, with the result that the voltage supplied to the grid of the first tube remains independent of frequency over the total frequency range covered and is proportional only to the strength of the signal received.

In the accompanying drawing a preferred embodiment of the present invention is explained by way of example.

Fig. 1 shows the wiring diagram of a signal collecting system embodying the present invention, and

Fig. 2 shows an enlarged sectional view of the movable core inductor employed in the system of Fig. 1.

The signal collecting system of Fig. 1 comprises a loop 1, a movable core inductor 2 and condenser 5 connected to form a series resonant circuit, one end of said loop and one electrode of said condenser being connected to ground. Movable core inductor 2 consists of a winding 3 and a core structure 4, movable relatively to said winding to vary its inductance and to thus tune the circuit over a range of frequencies. The incoming signal is intercepted by loop 1, is amplified in series resonant circuit 1, 2 and 5, and the resonant potential developed across condenser 5 is applied to grid 6 of vacuum tube 7, the junction between inductor 2 and condenser 5 being connected directly to said grid.

With reference to Fig. 2 inductor 2 comprises a winding 3 wound upon coil form 8 of insulating material and having a length several times its diameter. Within coil form 8 there is movably arranged core structure 4 including two portions 4*a* and 4*b* both of which correspond in length roughly to the length of winding 3. An operating handle 9 of non-magnetic material is provided at one end of the core structure. Portion 4*a* is made of comminuted magnetic material such as iron or iron alloy the individual particles of which have been insulated from one another and have been compounded under pressure into a core body of predetermined shape and permeability. Cores of this type are well-known in the art and are, for instance, disclosed in United States Patent 1,982,689 to Polydoroff. Core portion 4*b* is made of a conductive material such as copper, aluminum or brass and has preferably the shape of a tube as shown. It may also be made by compressing uninsulated metal powders into a body of desired shape in a manner similar to that in which magnetic high frequency cores are made. The two core portions are united into a single core structure in any suitable manner, for instance by the metal tube of core portion 4*b* being molded onto one end of core portion 4*a* as shown.

When core structure 4 is in the position illustrated in the drawing, that is, when its conductive portion 4*b* is completely within winding 3, the inductance of inductor 2 is at its minimum because the presence of the conductive body in the field of said winding reduces its apparent inductance. As conductive portion 4*b* is removed from winding 3 and as magnetic portion 4*a* moves into said winding the inductance reducing effect of core portion 4*b* is gradually eliminated while the magnetic material contained in core portion 4*a* increases the inductance of the winding. Finally when core portion 4*a* is completely within winding 3 the device is at the position of maximum inductance. Thus, the movable core inductor described provides a materially wider range of inductance variation than can be realized by the use of a magnetic core portion alone. For instance, if the effective permeability of the magnetic core portion relative to the particular winding shown is 11, and if the conductive core portion is constructed to reduce the inductance of winding 3 to one third of its value in air, the inductance of the device changes from L/3 to 11L; that is, the device provides an inductance change of a ratio of 33.

Reverting now to Fig. 1 the inductance of loop 1 restricts the inductance variation produced by movable core inductor 2 in circuit 1, 2 and 5 in the same manner as any other series connected coil of fixed inductance value. Thus, if variable inductor 2 were of the ordinary type providing an inductance variation of say 11, and if the signal collecting system were expected to operate over a range of frequencies such as the broadcast range, which requires a total inductance change of approximately 9, it would only be possible to cover this range if the loop inductance were not larger than approximately one fifth of the total inductance of the circuit at the high frequency end of the tuning range. A loop of such a low inductance, however, would not provide an adequate amount of signal interception to secure satisfactory performance of the receiver over the total tuning range. Therefore in the construction of movable-core-tuned loop circuits the art was faced with the alternative to either sacrifice range coverage in order to secure greater interception, or to sacrifice interception in order to cover a desired range of frequencies.

In accordance with the present invention I am able to construct the loop of my signal collecting system as of a sufficiently large inductance to intercept an adequate amount of signal energy even at the low frequency end of the range, and yet retain coverage of a wide range of frequencies such as the broadcast range. Bearing in mind the inductance value that loop 1 is to have for adequate interception, I so proportion core portions 4*a* and 4*b* relative to one another and relative to winding 3 that movement of core structure 4 with respect to winding 3 will produce such an inductance change as will vary the total inductance of circuit 1, 2 and 5 to the required degree, in spite of the range-reducing-effect of the loop inductance. For instance, by constructing my variable inductor 2 to provide a ratio of inductance variation of, say, 33 my loop may have 3 times as much inductance as my variable inductor 2 at the high end of the frequency range, thus providing for an adequate amount of signal voltage to be intercepted, and yet the system may readily be tuned over a range as wide as the broadcast range.

Additionally, in accordance with my invention I may so construct my antenna system that whatever signal voltage I am able to supply to the grid of the first tube at the high frequency end may be maintained substantially independ-

ent of frequency over the total range of operation, in spite of the inherent characteristic of loops to receive signals of a lower frequency with lesser power than signals of a higher frequency.

In order to compensate for this inherent non-uniformity of loops I construct variable inductor **2** in such a manner that the gain of my signal collecting system will vary inversely as the frequency. In signal collecting systems, the gain is a function of the Q or

$$\frac{\omega L}{R}$$

of the circuit, and by proper choice of the permeability of core portion **4***a* and of its loss characteristics, and by proper choice of the wall thickness of tube **4***b* and the dimensions of both core portions relative to one another and relative to winding **3** and the frequency range to be covered, I may construct these core portions to produce such a change of the circuit resistance relative to the change in circuit inductance and circuit frequency that the expression

$$\frac{\omega L}{R}$$

varies inversely as the frequency. For this purpose I may construct the conductive core portion from a blend of metallic powders of different conductivity and I may vary the character of the blend lengthwise in the core so as to give it predeterminedly varying loss characteristics. Also I may employ a blend of magnetic and non-magnetic metal powders for parts of my core structure.

In a practical embodiment of the present invention constructed in accordance with Fig. 1 the signal collecting system was tunable over a range of frequencies from 1560 to 540 kc. Loop **1** had 13 turns of wire No. 20/44 S. S. E. 7½-inches high and 7½-inches wide, the length of the winding space being 2½-inches. The calculated inductance of this loop was 65 μH. Winding **3** was of the type known as progressive universal winding and was wound with wire No. 7/44 S. S. E. over a length of 1⅜-inches on a coil form having an outer diameter of .221-inch. Its inductance in air was 52.3 μH. Portion **4***a* of core structure **4** was $1\frac{7}{8}$-inches long and had an outer diameter of .2-inch. It was made of a finely divided tin-iron alloy consisting of 94% of iron and 6% of tin, the individual particles of which had been insulated and bound together under compression with the aid of a binder, the amount of inert material in the finished core being 3%. Its effective permeability relative to winding **3** was 11.1 when completely within said winding. Core portion **4***b* was made of copper and had an outer diameter of 0.2-inch and an inner diameter of 0.165-inch. Its length was 1⅜-inches. When completely within winding **3** it decreased the inductance of said winding from 52.3 μH to 20 μH. Condenser **5** had a capacitance of 123 μμF which tuned circuit **1**, **2** and **5** to a frequency of 1560 kc. with copper tube **4***b* completely within winding **3**. The total resistance of the circuit at this frequency was 23.8 ohms. Hence the Q or

$$\frac{\omega L}{R}$$

of the circuit was 35 at the upper end of the frequency range. With the core moved so that core portion **4***a* was completely within winding **3**, the inductance of inductor **2** had risen to 640 μH. The circuit then resonated at a frequency of 540 kc. At this frequency the total resistance of the circuit was 26.4 ohms and the effective Q of the total circuit therefore was 91.2 at the low end of the frequency range. Thus, as the circuit was tuned from 1560 kc. to 540 kc. its Q value

$$\left(\frac{\omega L}{R}\right)$$

had increased from 35 to 91.2. Therefore while the energy intercepted by the loop had dropped to

$$\frac{1}{2.89}$$

of its original value the gain of the circuit had increased by a factor of 2.61 with the result that the voltage applied to the grid of the first tube had remained substantially constant.

The following practical data were obtained from the embodiment of the invention described above.

Frequency	Grid gain ratio
1,560	.65
1,000	.65
540	.625

By grid gain ratio I means the ratio of the output voltage of the system measured in micro-volts to the field strength measured in micro-volts per meter that existed at the point of interception and which had been adjusted to a substantially constant value throughout the range.

The above data show that the voltage supplied to the grid of the first tube had remained substantially constant over the frequency range covered in spite of the inherent characteristic of the loop to receive signals of a lower frequency with lesser power than signals of a higher frequency.

Still greater frequency independence of the voltage supplied by the loop circuit to the grid of the first tube may be obtained, for instance, by core portion **4***b* being constructed as of variable wall thickness or of variable shape. Also core portion **4***a* may be constructed to have variable loss characteristics with the end entering the winding **3** first being preferably constructed to have relatively higher losses per unit volume than other parts thereof (measured at the same frequency). Likewise core member **4***b* may be constructed from a number of metals of different electrical conductivity. Moreover, the two core members may be constructed to partly overlap one another at their junction in a manner similar to that indicated in Fig. 2.

While I have explained my invention with the aid of a particular embodiment thereof, it will be understood that I do not limit myself thereto. Thus, the present invention may be used in signal collecting systems other than the one specifically illustrated and over ranges other than the broadcast range.

Having thus described my invention what I claim is:

1. An improved resonant circuit and tuning means of the class including an unexposed inductive winding, a fixed tuning capacitor, and a core structure movable relatively to said unexposed inductive element to change the inductance of the resonant circuit to tune it throughout a band of frequencies, said core structure including

two portions in end to end relationship, a first of said core portions being magnetic and varying the inductance of said unexposed inductive winding from substantially the amount due to unity permeability of an air magnetic path to a substantially larger and maximum inductance value due to the greater effective permeability of said magnetic portion, and the other of said core portions being non-magnetic and of electrically conductive material acting to reduce the inductance of said unexposed inductive winding below its inductance resulting from unit permeability of its magnetic path depending upon the position of said other core portion relatively to said unexposed inductive winding, which improved resonant circuit includes in series with said unexposed inductive winding an exposed inductive element having an air path inductance at least as great as the air path inductance of the unexposed inductive winding, said improved tuning means including a two part core construction of the class above described in which the magnetic core part comprises comminuted ferromagnetic particles closely associated in solid form and having a high effective permeability when fully inserted into said unexposed inductive winding and capable unaided of tuning said resonant circuit over at least two-thirds of said frequency band from the low frequency end thereof, and the non-magnetic and electrically conductive core part comprises a tube of metal of good electrical conductivity and having a thin wall limiting the maximum inductance-reducing effect thereof in such manner that said non-magnetic core part will unaided tune said resonant circuit over not more than one third of said frequency band from the high frequency end thereof.

2. An improved resonant circuit and tuning means of the class including an unexposed inductive winding, a fixed tuning capacitor, and a core structure movable relatively to said unexposed inductive element to change the inductance of the resonant circuit to tune it throughout a band of frequencies, said core structure including two portions in end to end relationship, a first of said core portions being magnetic and varying the inductance of said unexposed inductive winding from substantially the amount due to unity permeability of an air magnetic path to a substantially larger and maximum inductance value due to the greater effective permeability of said magnetic portion, and the other of said core portions being non-magnetic and of electrically conductive material acting to reduce the inductance of said unexposed inductive winding below its inductance resulting from unit permeability of its magnetic path depending upon the position of said other core portion relatively to said unexposed inductive winding, which improved resonant circuit includes in series with said unexposed inductive winding an exposed inductive element having an air path inductance at least as great as the air path inductance of the unexposed inductive winding, said improved tuning means including a two part core construction of the class above described in which the magnetic core part comprises comminuted ferromagnetic particles closely associated in solid form and having a high effective permeability when fully inserted into said unexposed inductive winding and capable unaided of tuning said resonant circuit over at least two-thirds of said frequency band from the low frequency end thereof, and the non-magnetic and electrically conductive core part comprises a tube of metal of good electrical conductivity and having a thin wall limiting the maximum inductance-reducing effect thereof in such manner that said non-magnetic core part will unaided tune said resonant circuit over not more than one third of said frequency band from the high frequency end thereof, said core construction having such dimensions and such distribution of effective permeability and effective resistance relatively to the form, size and inductance of said unexposed inductive winding as to vary the ratio

$$\frac{\omega L}{R}$$

of the resonant circuit substantially inversely as the tuned frequency throughout the tuning band.

3. An improved resonant circuit and tuning means of the class including an unexposed inductive winding, a fixed tuning capacitor, and a core structure movable relatively to said unexposed inductive element to change the inductance of the resonant circuit to tune it throughout a band of frequencies, said core structure including two portions in end to end relationship, a first of said core portions being magnetic and varying the inductance of said unexposed inductive winding from substantially the amount due to unity permeability of an air magnetic path to a substantially larger and maximum inductance value due to the greater effective permeability of said magnetic portion, and the other of said core portions being non-magnetic and of electrically conductive material acting to reduce the inductance of said unexposed inductive winding below its inductance resulting from unit permeability of its magnetic path depending upon the position of said other core portion relatively to said unexposed inductive winding, which improved resonant circuit includes in series with said unexposed inductive winding an exposed inductive element having an air path inductance at least as great as the air path inductance of the unexposed inductive winding, said improved tuning means including a two part core construction of the class above described in which the magnetic core part comprises comminuted ferromagnetic particles closely associated in solid form and having a high effective permeability when fully inserted into said unexposed inductive winding and capable unaided of tuning said resonant circuit over at least two-thirds of said frequency band from the low frequency end thereof, and the non-magnetic and electrically conductive core part comprises a tube of metal of good electrical conductivity and having a thin wall limiting the maximum inductance-reducing effect thereof in such manner that said non-magnetic core part will unaided tune said resonant circuit over not more than one third of said frequency band from the high frequency end thereof, the effective permeability of said magnetic core part when fully inserted in said unexposed element being at least of the order of ten, and the thickness of wall of said non-magnetic core part being of the order of one sixty-fourth of an inch.

4. An improved resonant collector circuit and tuning means of the class including a permeability tuning coil, a fixed tuning capacitor connected with said coil, and a core structure movable into and from said coil to tune said resonant circuit throughout a band of frequencies, said core structure including a magnetic portion and a non-magnetic and electrically conductive portion connected in end to end relation, which improved resonant collector circuit includes the

combination of a loop collector, a permeability tuning coil connected in series with said loop collector, said coil having an axial length at least three times its internal diameter and said loop collector having an air path inductance at least as great as the air path inductance of said coil, a fixed capacitor having its terminals connected around the series related loop collector and coil, and a tuning means comprising a cylindrical core portion of powdered ferromagnetic material in solid form and a non-magnetic and electrically conductive tubular core portion axially aligned with and connected end to end with said cylindrical core portion, the external diameter of said tubular core portion being substantially the same as the diameter of said cylindrical core portion, said cylindrical core portion having a high effective permeability when fully inserted in said coil by which said cylindrical core portion unaided will tune said resonant circuit throughout at least two-thirds of said frequency band from the low frequency end thereof, said tubular core portion having a thin wall effecting the tuning of said resonant circuit throughout not more than one-third of said frequency band from the high frequency end thereof, said two core portions being each substantially as long as the length of said coil.

5. An improved resonant collector circuit and tuning means of the class including a permeability tuning coil, a fixed tuning capacitor connected with said coil, and a core structure movable into and from said coil to tune said resonant circuit throughout a band of frequencies, said core structure including a magnetic portion and a non-magnetic and electrically conductive portion connected in end to end relation, which improved resonant collector circuit includes the combination of a loop collector, a permeability tuning coil connected in series with said loop collector, said coil having an axial length at least three times its internal diameter and said loop collector having an air path inductance at least as great as the air path inductance of said coil, a fixed capacitor having its terminals connected around the series related loop collector and coil, and a tuning means comprising a cylindrical core portion of powdered ferromagnetic material in solid form and a non-magnetic and electrically conductive tubular core portion axially aligned with and connected end to end with said cylindrical core portion, the external diameter of said tubular core portion being substantially the same as the diameter of said cylindrical core portion, said cylindrical core portion having a high effective permeability when fully inserted in said coil by which said cylindrical core portion unaided will tune said resonant circuit throughout at least two-thirds of said frequency band from the low frequency end thereof, said tubular core portion having a thin wall effecting the tuning of said resonant circuit throughout not more than one-third of said frequency band from the high frequency end thereof, said two core portions being each substantially as long as the length of said coil, said cylindrical core portion having an effective permeability when fully inserted into said coil of at least the order of ten and said tubular core portion having a wall thickness of the order of one sixty-fourth of an inch.

6. An improved resonant collector circuit and tuning means of the class including a permeability tuning coil, a fixed tuning capacitor connected with said coil, and a core structure movable into and from said coil to tune said resonant circuit throughout a band of frequencies, said core structure including a magnetic portion and a non-magnetic and electrically conductive portion connected in end to end relation, which improved resonant collector circuit includes the combination of a loop collector, a permeability tuning coil connected in series with said loop collector, said coil having an axial length at least three times its internal diameter and said loop collector having an air path inductance at least as great as the air path inductance of said coil, a fixed capacitor having its terminals connected around the series related loop collector and coil, and a tuning means comprising a cylindrical core portion of powdered ferromagnetic material in solid form and a non-magnetic and electrically conductive tubular core portion axially aligned with and connected end to end with said cylindrical core portion, the external diameter of said tubular core portion being substantially the same as the diameter of said cylindrical core portion, said cylindrical core portion having a high effective permeability when fully inserted in said coil by which said cylindrical core portion unaided will tune said resonant circuit throughout at least two-thirds of said frequency band from the low frequency end thereof, said tubular core portion having a thin wall effecting the tuning of said resonant circuit throughout not more than one-third of said frequency band from the high frequency end thereof, said two core portions being each substantially as long as the length of said coil, said core portions having such dimensions, proportions and compositions relatively to the form, size and inductance of said coil as to vary the ratio

$$\frac{\omega L}{R}$$

of the resonant circuit substantially inversely as the tuned frequency throughout the tuning band.

7. A signal collecting system for radio receivers and the like including an exposed inductive element, an unexposed inductive element, and a capacitance connected to form a resonant circuit, said unexposed inductive element comprising a winding and a core structure having first and second portions arranged end to end for successive movement into and from said winding, said first core portion comprising a ferromagnetic body of comminuted magnetic material in cylindrical form and said second core portion comprising a thin walled non-magnetic tube of good electrical conductivity, the materials of said core portions and their proportions relatively to each other and to the inductance of said winding being such as to vary the ratio

$$\frac{\omega L}{R}$$

of said resonant circuit inversely as the tuned frequency of said resonant circuit.

WILLIAM A. SCHAPER.