

March 31, 1925.

1,531,681

F. AUTY

METHOD OF WINDING TOROIDAL COILS

Original Filed March 5, 1924 2 Sheets-Sheet 1

Fig. 1.

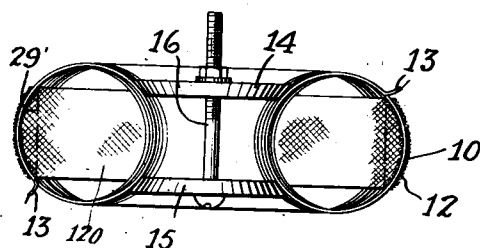


Fig. 2.

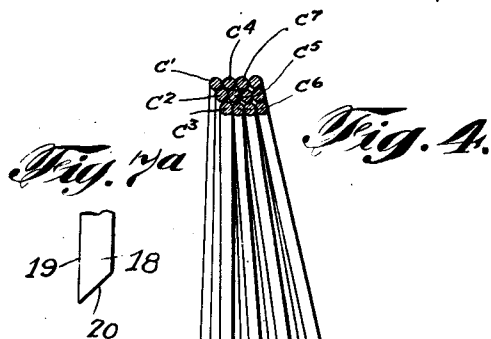
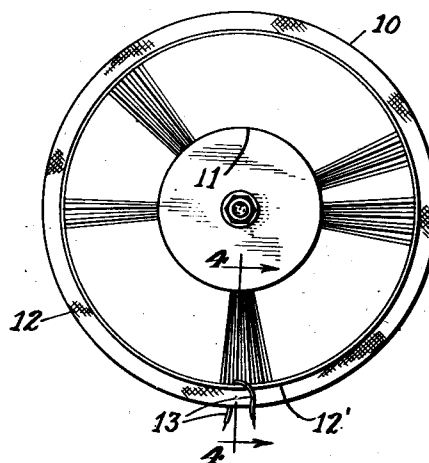


Fig. 4.

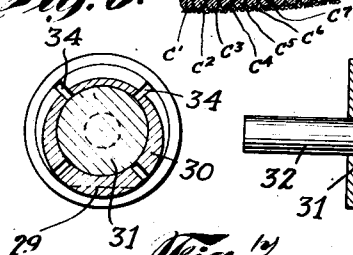


Fig. 5.

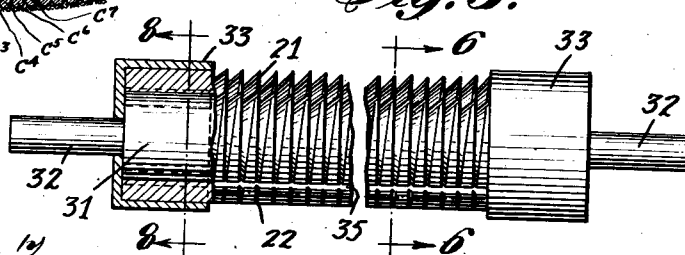


Fig. 6.

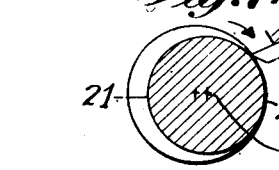


Fig. 7.

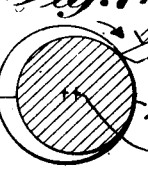
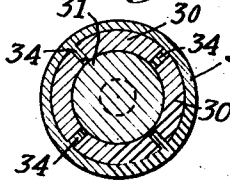


Fig. 8.



INVENTOR

Frank Auty

BY *Dean Fairbank,*
Owight Hensch,
his ATTORNEYS

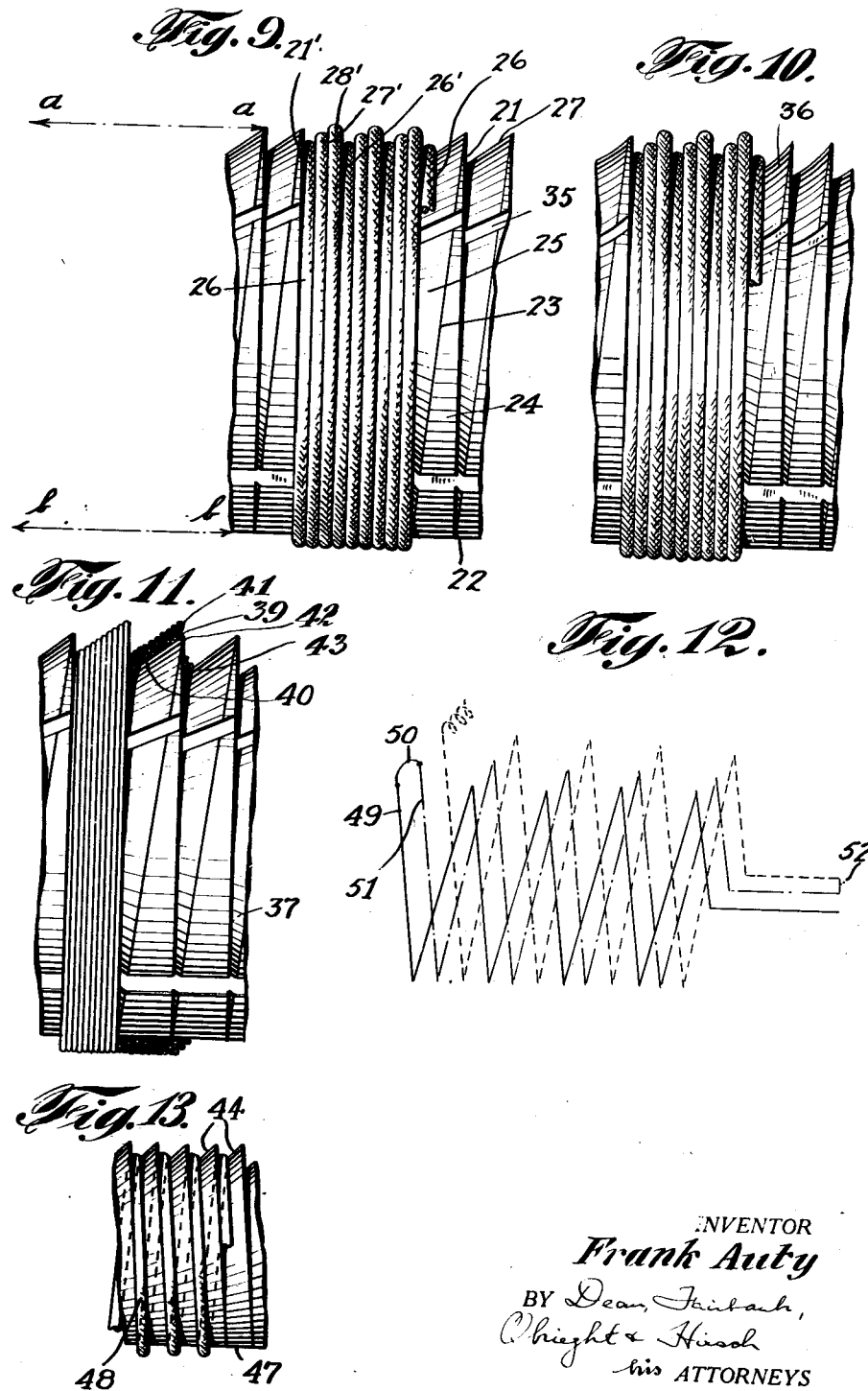
March 31, 1925.

F. AUTY

1,531,681

METHOD OF WINDING TOROIDAL COILS

Original Filed March 5, 1924 2 Sheets-Sheet 2



INVENTOR
Frank Auty
 BY Dean, Fairbank,
 Whight & Hirsch
 his ATTORNEYS

UNITED STATES PATENT OFFICE.

FRANK AUTY, OF NEW YORK, N. Y.

METHOD OF WINDING TOROIDAL COILS.

Application filed March 5, 1924, Serial No. 697,063. Renewed February 17, 1925.

To all whom it may concern:

Be it known that I, FRANK AUTY, a citizen of the United States, and resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Methods of Winding Toroidal Coils, of which the following is a specification.

My present invention is primarily concerned with the method of making toroidal coils, a more specific application being to coreless toroidal wire coils.

In their application for wireless receiving purposes, the theoretical and practical advantages of coreless or air-core toroidal coils have been freely recognized by those skilled in the art, but difficulty of economical production of such coils, satisfactory in mechanical construction and in operation, has prevented their general adoption.

It is accordingly among the objects of the invention to provide from wire of gage ordinarily used for variocouplers, variometers or transformers, a toroidal coil, satisfactory in its electrical characteristics, capable of sustaining itself in a firm and durable structure and capable of resisting rough handling though devoid of a core.

Another object is to provide a method of making a toroidal coil, which method can be executed expeditiously with simple apparatus to provide a toroidal coil, self-sustaining though devoid of a core, and which method in its execution will not engender undue frictional stresses or strains on the convolutions of the torus, tending to fray the insulating covering of the wire.

The invention embodies broadly the principle of winding the wire or equivalent member in convolutions along a straight axis, said convolutions being specially conformed or arranged preferably inherently to lap with respect to each other particularly at the inner periphery as the straight coil is curved to bring its ends together in forming the torus. In the preferred mode of executing the invention, the convolutions are formed in cyclically repeated groups arranged for a degree of lap which is a maximum at the inner periphery of the torus, and decreases progressively to full exposure of the entire run of convolutions without lap at the outer periphery of the

torus. Preferably the convolutions are so arranged as to lap at the inner periphery of the torus in a number of layers equal to the ratio of the outer to the inner periphery of the torus.

Inasmuch as the convolutions may have a tendency to spread or separate before curving into the torus, the consecutive convolutions are preferably secured against such separation by binding along at least one of the elements of the helix, preferably that which forms the outer periphery of the finished coil. The ends of the binding when joined will serve to maintain the toroidal coil in assembled relation.

In the preferred method of producing the toroidal coils, a collapsible mandrel is used upon which the lapping groups of convolutions are formed. The entire effective length of the preferred form of mandrel is provided with peripheral notches of appropriate shape, said notches of maximum depth and width along one element of the generally cylindrical mandrel, progressively decreasing to a minimum, preferably zero depth and width at the diametrically opposite element of the mandrel. The cross-section of the notch being preferably V-shaped with one side substantially radial of the mandrel and the other side inclined, it follows that in winding the wire thereon, the successive convolutions thereof will contact to cover the inclined side of the notch, whereupon the next convolution will drop into the base of the succeeding notch, until the effective length of coil has been formed. The mandrel being of collapsible type is readily removed from the coil. The coil thereupon is easily curved to draw its ends together, the convolutions of minimum diameter readily lapping into the contiguous convolutions of maximum diameter at the inner or concave periphery of the torus thus formed.

Other objects and features of the invention will be in part obvious and in part set forth hereinafter.

The coil as an article of manufacture is separately claimed in my divisional application, Serial No. 737,099, filed September 11, 1924; and the mandrel as an article of manufacture and also the method of making the same is separately claimed in my di-

visional application, Serial No. 728,072, filed July 25, 1924.

In the accompanying drawings in which are shown one or more of various possible embodiments of the several features of the invention,

Fig. 1 is a transverse sectional view through a toroidal coil shown mounted on an appropriate supporting fixture,

Fig. 2 is a plan view of the toroidal coil,

Fig. 3 is an end view thereof,

Fig. 4 is a view in cross-section on a greatly enlarged scale illustrating the lapping of the convolutions,

Fig. 5 is a fragmentary view of one form of mandrel for making the coil,

Fig. 6 is a sectional view taken along the line 6—6 of Fig. 5,

Fig. 7 is a diagrammatic view illustrating the method of making the mandrel,

Fig. 7^a is a fragmentary view of the tool used in cutting the mandrel.

Fig. 8 is a view in transverse cross-section taken along the line 8—8 of Fig. 6,

Fig. 9 is a fragmentary view on an enlarged scale illustrating the method of winding the wire upon the mandrel of Fig. 6,

Fig. 10 is a view similar to Fig. 9 of a modified form of the invention,

Fig. 11 is a view similar to Fig. 9 illustrating another manner of winding,

Fig. 12 is a diagrammatic view illustrating the mode of connecting the courses in the embodiment of Fig. 10, and

Fig. 13 is a view similar to Fig. 10 of a further modification.

Similar reference characters refer to similar parts in different views of the drawings.

Referring to the drawings, I have shown in Figs. 1, 2 and 3 in outline the general form of coreless toroidal coil with which my invention is primarily concerned, said coil being illustratively indicated with an outer periphery 10 substantially triple the inner periphery 11 thereof and held in assembled relation by a peripheral length of tape 12 connected about the outer periphery thereof, the terminals of the coil protruding as at 13. The coil as shown, would be mounted on a bracket including a pair of washers 14 and 15 near opposite sides thereof, substantially closing the inner periphery thereof and connected by a bolt 16 which tends to press said washers inward to securely grip the torus and which serves for mounting the coil in manner that will readily be understood.

The construction of the toroidal coil will be more easily comprehended from the method of producing the same which will be first set forth. The mandrel by which the torus is produced, includes a winding surface modified from the cylindrical form as will appear best from Figs. 5 to 9. The

mandrel construction will be most readily understood from the method by which it, in turn, is made. For this purpose, a tube of diameter equal to the inner diameter of the torus convolutions is mounted eccentrically, for instance, on centers 17 within a lathe (not shown). A tool 18 is employed having a cutting edge of buttress-thread type, that is, a V-shaped cutting edge with one side 19 substantially longitudinally of the tool shank and the other side 20 oblique as best shown in Fig. 7^a. The tool being held by an appropriate rest (not shown) so that its point substantially engages the mandrel at the element thereof nearest the eccentric mount, the mandrel is rotated, whereby, as will be easily understood, a peripheral groove or notch V-shaped in cross-section will be cut, of maximum depth as at 21 at the side nearest the eccentric mount, progressively decreasing to a minimum or zero depth at the side 22 diametrically opposite thereto. The operation set forth is repeated at intervals corresponding to the cutting width of the cutting tool, so that the entire effective length of the mandrel will be notched, as best shown in Figs. 5 and 9. It will be seen that as the depth of cut decreases, peripherally about the mandrel from the maximum at one side thereof, the width thereof decreases correspondingly. A plane oblique edge 23 is therefore formed at each peripheral notch. The portion 24 to the right of edge 23 remains cylindrical. The portion 25 to the left of oblique edge 23 is V-shaped in cross-section of maximum depth and width at the element *a—*a** corresponding to the side 21 and gradually decreasing both in depth and width progressively about the mandrel in both directions to zero at the diametrically opposite element *b—*b**, corresponding to side 22.

The mandrel described being mounted concentrically in a lathe or equivalent driving means, the wire or other element 26 to be wound thereon is applied at the base of one of the notches 21'. When the mandrel is now rotated, the wire will form substantially a helix. Consecutive convolutions thereof will be in lateral contact with each other along the straight element *b—*b** at one side of the mandrel while at the diametrically opposite side *a—*a**, the consecutive convolutions will climb up the incline 27' of the notch 21' until after the apex 28' of the notch is reached, the next convolution 26' will drop into the base of the succeeding notch for consecutive turns to build up along the corresponding notch incline. Thus, the conformations of the successive convolutions will vary to correspond with the mandrel, the convolutions 26' engaging the bases of the notches having a maximum eccentricity or degree of flattening extending substantially entirely within the origi-

nal cylinder from which the mandrel was cut, while the convolutions corresponding to the apex or outer edge 28' of the notches are substantially circular without eccentricity, since, as will be seen, they substantially follow along an uncut part of the mandrel surface.

The mandrel being of appropriate collapsible type, best shown in Figs. 5, 6 and 8 which will be described hereinafter, it is removed from within the wound coil after the adhesive tape 12 has been applied along the element $b-b$ of the latter. Thereupon the generally helical coil of wire can be easily curved to bring its opposite ends into engagement with each other, an appropriate generally conical fixture (not shown) being preferably used as a guide or template for this purpose, whereupon the ends are attached together by a short connecting piece 12' of adhesive tape with the wire terminals 13 projecting. Preferably a length 120 of tape similar to tape 12 is provided at the inside of the outer periphery of the torus, said latter tape being, of course, applied on the mandrel before the wire is wound, and extending along the substantially flat side of the mandrel to adherently attach itself to the aligned contiguous portions of the inner convolutions as the latter are formed.

The strip of tape or other binding means, whether applied internally or externally, either while the wire is being wound on the mandrel or after the wire has been wound, and before removing the same from the mandrel, serves to retain the helical coil in proper condition for handling. The binding means acts in a manner as a backbone, extending along the aligned contiguous portions of the loops and preventing endwise expansion of any of the convolutions which might otherwise take place upon removal from the mandrel by reason of the springiness of the wire.

It will be seen that the coil when removed from the mandrel and before it is curved into torus form, will present a segmented appearance, the convolutions being in contact with each other along element $b-b$ but arranged in groups at other elements thereof. By reason of this segmental or stepped conformation, as the coil is curved to form the torus, the successive segmented groups will readily lap or telescope with respect to each other, the convolutions of smaller diameter entering into the neighboring convolutions of larger diameter, the extent of entry or telescoping being, of course, a maximum at the inner periphery 11 of the torus formed by element $a-a$ of the helical coil and progressively decreasing by reason of the peculiar formation of the coils to zero at the outer periphery 10 formed by

element $b-b$, where the consecutive turns are in lateral engagement without lap.

If desired, the mandrel may be flattened as along line 29' at the side 22 where the notches are of minimum or zero depth. The wire when wound on the mandrel will have its convolutions correspondingly flattened, and the plane determined by said flattened portions will more readily curve into a cylinder 29' forming the outer periphery of the toroidal coil, than if the turns were cylindrical at the part of the helix that is to be curved into the outer periphery of the toroidal coil. Moreover, tape 12 applied to such flattened part also will develop no folds or wrinkles in curving into a cylindrical loop as the torus is formed.

In the specific toroidal coil illustratively shown, the inner periphery is one-third the outer periphery, so that only one-third as many turns can be exposed thereat, in lateral contact with each other than at the outer periphery. Accordingly, the successive convolutions are all exposed in lateral contact with each other to form the outer periphery of the torus, and only every third convolution will be exposed at the inner periphery, the intervening turns being lapped thereat in the interior of the torus. This is clearly shown in Fig. 4, where the consecutive turns c bear consecutive exponents, the diametrically opposite sides of the same turns C having the same exponents. Between the inner and the outer peripheries of the torus, by reason of the intermediate width and depth of the notches of the forming mandrel, the degree of telescoping or lapping between the successive contacting groups of convolutions will vary in accordance with the diameter of the torus thereat, so that the unit is self-sustaining and will not open or be distorted even under substantial pressure, the convolutions being in mutually trussing relationship.

It will, of course, be understood that the number of convolutions at each step or notch incline 27 should correspond approximately to the ratio of the outer to the inner periphery of the torus. By the use of a mandrel with corresponding width of notch relative to the diameter of the wire, a toroidal coil with any ratio of outer to inner diameter can be produced.

By my method, the convolutions are conformed to naturally or inherently enter into the telescoping relationship set forth, as the helix is curved to form the torus, so that no substantial strain is exerted on the wire and no friction or rubbing is engendered tending to fray the wire insulation. Accordingly, I avoid the use of heavily insulated wire, but the wire ordinarily used for inductance coils in amateur wireless receiving apparatus is suitable, and said relatively thin wire, by reason of the mutual

trussing relationship of its turns forms a rugged durable self-sustaining torus coil, when taped exteriorly only at its outer periphery, and even this is not necessary, when the internal binder strip is used.

Any other binding or attaching means may be employed which will permit curving the helix into a torus and yet anchor the lengths of wire of which the helix is formed at predetermined intervals, as, for instance, at every turn against separation longitudinally and peripherally of the helix.

To render the mandrel collapsible, any appropriate construction may be provided. In a preferred embodiment, the stepped cutting mandrel tube is slit longitudinally in a number preferably four segments 30, said segments embracing a solid cylindrical core 31, which may be of vulcanite and which has protruding metal center pieces 32. The segments are maintained assembled upon the core by end caps 33 preferably formed with integral spacing fins 34 to maintain the uniformity of the narrow gap 35 between the successive mandrel segments. It follows, therefore, that after the coil has been wound on the mandrel, the latter is collapsed by simply removing one of the end caps and drawing out the core whereupon the multiplicity of segments of the mandrel tube will collapse within the coil and can be removed without in any way distorting the wound product.

It is distinctly to be understood that although the method set forth for winding the generally helical coil on my mandrel is preferably applied to the production of my toroidal coil, and although the toroidal coil of my invention is preferably produced by the method set forth, the method may be applied to the formation of articles other than toroidal coils, and my coil is claimed per se regardless by what method it may be made.

While a preferred form of coil includes a series of convolutions which are contiguous at the outer circumference of the coil and overlapping at the inner circumference, it is within the scope of the invention from its broader aspects, to provide a coil in which the convolutions are contiguous at the inner circumference and spaced apart at the outer circumference. The binding strip or other binder or binders in any of the embodiments of my invention, may extend about any one or more peripheries of the toroidal coil, but preferably a binder extends about the limiting periphery of maximum rather than that of minimum length, that is, about the outermost periphery of the toroidal coil.

In Fig. 10 is shown a somewhat modified form generally similar to that described except that instead of forming the oblique side 27 of each notch straight in cross-section, the same is formed curved in cross-section as shown at 36. By this curvature in some

cases, the lapping or telescoping action in curving the helix into the torus may be somewhat facilitated.

In Fig. 11 is shown another embodiment employing a mandrel 37 identical either with that shown in Fig. 9 or with that shown in Fig. 10 for winding a torus with a multiplicity of layers of turns, illustratively of small gauge wire. It will be understood, of course, that by appropriate winding control mechanisms of known type, not material to the present invention, an inner layer 39 of convolutions would be laid on one incline 40 of the mandrel notch, the wire being thereupon fed back to the base of the same notch and a second layer 41 being formed, superposed over the first and, if desired, more layers, whereupon the succeeding convolutions would be dropped off the point or apex 42 of the mandrel notch into the base 43 of the succeeding notch. After the collapsible shaft has been removed, the completed coil would then be curved into a torus in the manner heretofore described.

By this arrangement, it will be seen that there is not the material difference in potential between successive layers which would result if one layer were wound complete and then connected in series with another layer wound thereover.

In Fig. 13 is shown a further embodiment which in certain special applications may be desirable, although in general, I prefer the embodiment shown in Fig. 5. The mandrel here instead of being formed with distinct peripheral notches is cut on a continuous thread, using, however, the identical buttress thread cutting tool 18 and mounting the mandrel in exactly the same manner as shown in Fig. 7 in the process of making the same. By this construction, the tool 18 being fed lengthwise of the mandrel, as in thread-cutting machines, a buttress thread 44 is formed of pitch equal to the maximum width of the individual notch cut, which notch cut decreases both in width and depth peripherally about the mandrel to a minimum or zero at the diametrically opposite element 47 substantially as in the embodiment of Fig. 5.

When a coil is wound on the mandrel just described, it will be seen that it will be fed forward by the pitch of the thread 44, as best shown in Fig. 13. One such wire 48 having been thus wound along the mandrel, a second or independent wire (not shown) would be placed against the first and would thereby be wound in lateral contact therewith, whereupon a third, and depending on the dimensions of the torus to be produced, further wires would be wound, each in contact with the previously applied wire until the incline of the thread notch is substantially entirely covered. As indicated in the diagram of Fig. 12, the left end 49, for in-

stance, of the first convolution would be connected by any appropriate coupling 50 to the left end 51 of the second convolution, the right end of which would be connected
 5 by a similar coupling 52 to the right end of the third convolution, etc., whereby the entire length of the wire helix would be series-connected. Thereafter the helical coil would be curved to form the torus in the
 10 manner already described.

While I have merely described in the foregoing a toroidal coil and the method of making the same, the principle of the invention could be readily applied to simple
 15 tuning coils, to variocouplers, or variometers including two semi-toroidal coils, and to transformers, especially to radio frequency transformers. In the latter application, the primary coil of lesser number of convolu-
 20 tions could be wound in ordinary fashion about the secondary after the latter had been made on the mandrel. In some of the applications noted, it may be desirable to form the individual turns of the toroidal coil generally elliptical rather than generally circular. For this purpose, the mandrel would be formed as a generally elliptical cylinder, with the notches heretofore described. Although the preferred application is to core-
 30 less or air-core coils, the invention is not limited to this application, but may be applied to coils with cores performing either a mechanical or a magnetic function or both.

35 The invention is not limited in its application to wireless apparatus but can be applied to other uses and many of the aspects thereof are more broadly applicable to winding and reeling, apart from electrical applica-
 40 tion.

It will thus be seen that there is herein described apparatus and a method in which the several features of this invention are embodied, and which apparatus and method
 45 in its action attains the various objects of the invention and is well suited to meet the requirements of practical use.

As many changes could be made in the above construction and many apparently
 50 widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings
 55 shall be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, what I claim as new and desire to secure by Letters-Patent of the United States is:

60 1. The method of producing a toroidal coil, which consists in winding a wire into a generally helical coil, with convolutions in side by side relation along one cylindrical element, and in groups or piles at the diam-
 65 metrically opposite cylindrical element, said

groups lapping to form the inner periphery of the torus.

2. The method of forming a toroidal coil, which consists in winding a continuous wire into a generally cylindrical helix having
 70 successive convolutions substantially in lateral contact with each other along one element of the cylinder, the convolutions at the diametrically opposite element in small identical groups, each having graduated
 75 radii.

3. The method of forming a toroidal coil, which consists in winding a continuous wire into a generally cylindrical helix having
 80 successive convolutions substantially in lateral contact with each other along one element of the cylinder, and flattened at said element, the convolutions at the diametrically opposite element in small identical groups, each having graduated radii, where-
 85 by in curving the helical coil into a torus, the groups of coils will lap at the inner periphery and the flattened sides of the coils will determine a cylinder as the outer
 90 periphery.

4. The method of producing a toroidal coil, which consists in winding a wire on a mandrel in convolutions of radius substan-
 95 tially uniform at one side and along the opposite sides in cyclically repeated groups of graduated radii or stepped formation, removing the mandrel from the coil and curving it into a toroidal form so that the stepped groups will telescope with respect
 100 to each other at the inner periphery of the torus.

5. The method of making a toroidal coil, which consists in winding a wire in a generally cylindrical spiral having the succe-
 105 ssive convolutions arranged in groups with radii varying in cyclic order along one element of the cylinder and then curving said spiral into a torus with the convolutions of smaller radius telescoping into contiguous convolutions of larger radius for regular
 110 arrangement of the convolutions at the central aperture of the torus.

6. In a method of producing a coil, the step which consists in winding a wire in a generally cylindrical spiral with successive
 115 convolutions lengthwise of the coil of uniform radius and substantially in lateral contact with each other along one element of the cylinder and with successive convolutions along the diametrically opposite element in sets of cyclically varying radius, whereby the spiral coil can be readily curved
 120 into a torus, the successive sets of coils lapping to form the inner diameter of the
 125 torus.

7. The method of forming toroidal coils, which consists in winding a wire into a generally cylindrical helix with convolu-
 130 tions flattened along one element of the cylinder in cyclic order, whereby in draw-

ing together the ends of the coils to form the torus, each flattened convolution will automatically lap within a flanking convolution.

8. In the method of forming a torus, the step of winding a wire in a generally helical form with successive convolutions lengthwise of the coil substantially in lateral contact with each other at one element thereof and with the convolutions at the diametrically opposite element thereof cyclically of reduced radius, whereby in curving the helix with said former cylindrical element at the outside, the successive convolutions will contact at the outer periphery of the torus and the convolutions of reduced radius will lap with respect to the flanking convolutions to expose at the inner torus periphery a lesser number of convolutions.

9. In the method of forming a torus coil, the step of winding a wire into a generally helical coil with successive convolutions lengthwise of the coil substantially in lateral contact with each other along one element of the cylinder and with the successive convolutions along the diametrically opposite element of cyclically varying radii with the number of convolutions of maximum radius at the latter cylinder element bearing a ratio to the total number of convolutions corresponding to the ratio of the inner periphery of the torus to the outer periphery thereof, whereby in drawing together the ends of the cylindrical helix to form the torus the convolutions of smaller diameter will lap into the contiguous convolutions of larger diameter at the inside of the torus, so that in the finished torus the successive coils of maximum diameter will engage each other to form the inner periphery of the torus.

10. The method of forming a torus coil, which consists in winding a wire with successive convolutions thereof lengthwise of the coil substantially in contact with each other along one element, said convolutions of cyclically varying radii for segmental conformation along the diametrically opposite element of the cylinder, the depth of the segment conformation decreasing progressively about the convolutions to zero at the diametrically opposite element.

11. The method of winding a torus coil, which consists in winding the wire on a specially formed collapsible mandrel having a zigzag contour along one element thereof decreasing in depth peripherally thereabout to a continuous or straight line along the diametrically opposite element, withdrawing the mandrel from the coil and then bending the coil to cause its ends to approach each other, whereby the segmental conformations of the coil due to the zigzag contour of the mandrel will interlap to accommodate the gradually decreasing pe-

riphery of the torus from the outer to the inner periphery thereof.

12. The method of forming a toroidal coil, which consists in winding a wire into a generally cylindrical form in segmental groups to determine a regular zigzag cross-section along one element of the helix cylinder, gradually decreasing in depth about the cylinder for merging to a straight line cross-section along the element diametrically opposite the maximum zigzag cross-section and curving the cylinder for approach of its ends, whereby the successive segmented groups of convolutions will lap with respect to each other to form the torus.

13. The method of forming a toroidal coil, which consists in winding a wire into a generally helical coil, having turns at uniform intervals substantially circular and intervening turns extending within the cylindrical locus of said first set of turns to lap thereinto in curving the helical into a toroidal coil.

14. The method of forming a toroidal coil, which consists in winding a wire in a generally helical conformation of pitch greater than the thickness of the wire, and winding one or more wires successively in lateral contact with the first wire, in turns of progressively greater diameters than those of said first wire, whereby the coils will have a stepped segmented conformation for facility in bending their ends toward each other to form the torus.

15. The combination set forth in claim 14, in which the successive wires are connected in series at their ends.

16. The method of producing a toroidal coil, which consists in winding a continuous wire into a generally cylindrical helix having successive convolutions substantially in lateral contact with each other along one element of the cylinder, and curving the helix to form a torus with the contiguous elements of the convolutions determining one of the limiting peripheries of the torus, said convolutions arranged in small substantially identical groups at the elements diametrically opposite said laterally contacting parts.

17. The method of forming a toroidal coil, which consists in bringing into contiguity substantially uniformly spaced parts of a length of wire, with the intervening substantially uniform lengths each extending in a substantially closed curve in a plane substantially at right angles to the locus of said parts, binding said parts against relative displacement both lengthwise of said locus and circumferentially of said curves, and curving the entity into a toroidal conformation with the said binder determining one of the limiting peripheries of the torus.

18. The method of forming a toroidal coil, which includes winding a wire into a

generally helical coil and binding said helical coil at predetermined intervals lengthwise of the wire from which the helical coil is formed, to maintain said bound points
5 against relative displacement both longitudinally and peripherally of the helical coil, while preserving the flexibility to permit curving the helical coil into a torus.

19. The method of forming a toroidal
10 coil, which consists in winding a wire into a generally helical coil, binding the beginnings and ends of the various convolutions of the coil to prevent relative displacement thereof both longitudinally and circumferentially of the coil, and curving the helical
15 coil into a torus with the binding means determining one of the limiting peripheries of the torus.

20. The method of forming a toroidal
20 coil, which includes winding a length of wire into a generally helical coil about a mandrel, binding the beginning and end of each convolution, to prevent relative displacement of the wire both longitudinally
25 and peripherally of the coil, while leaving exposed the length of each convolution between its bound ends, withdrawing the mandrel, and curving the coil thus formed into toroidal shape.

30 21. The method of winding a toroidal coil, which includes winding a wire into a plurality of contiguous convolutions about a mandrel and simultaneously binding the beginning and ends of the various convolutions
35 to prevent radial expansion to the convolutions and to insure contiguity of all of the convolutions along a common line when the coil is removed from the mandrel.

22. The method of forming a toroidal
40 coil, which includes winding a length of wire into approximately helical form about a mandrel, attaching a binding strip to one side of the helix in such a manner that when the helix is removed from the mandrel, the
45 strip will prevent radial expansion of any of the convolutions thereof and preserve along one side of the helix the relative spacing of the convolutions, curving said helix into toroidal form and securing the
50 ends thereof together.

23. The method of forming a toroidal
coil, which includes winding a length of wire in a series of convolutions about a
55 mandrel, binding all of the convolutions of said wire longitudinally of the mandrel and leaving exposed the major portions of the convolutions, withdrawing the mandrel, and

curving the coil thus formed into a toroidal shape.

24. The method of forming a toroidal
60 coil, which includes winding a length of wire about a mandrel into a series of contiguous convolutions to produce an approximately helical coil, binding the convolutions while the wire is on the mandrel in such a
65 manner as to prevent change in the diameter thereof, removing the helical coil from the mandrel and curving it into toroidal form.

25. The method of forming a toroidal
70 coil, which includes winding a length of wire in a series of contiguous loops about a mandrel, securing a binding strip to the wire on the mandrel in such a manner as to prevent variation in the diameter of the
75 loops or separation of the loops along one common line of contiguity, removing the coil from the mandrel, and curving the coil thus formed into toroidal shape.

26. The method of forming a toroidal
coil, which consists in winding a wire into
80 a generally helical coil having turns at uniform intervals of a definite shape and intervening turns extending within the generally cylindrical locus of said first set of turns, and binding the beginnings and ends of all
85 of the convolutions of said coil to prevent relative displacement thereof longitudinally or circumferentially of the coil, and curving the helix into a torus with the binding means at the outer periphery and the intervening turns lapping into the first-mentioned
90 turns.

27. The method set forth in claim 26, in which separation of the opposite ends of the constituent helical coil is prevented by the
95 step of connecting together the opposite ends of the binding.

28. The method of forming a toroidal
coil, which includes winding a wire into an approximate helix including a series of
100 sets of loops, the loops of each set being of progressively increasing sizes and all of the loops of all of the sets being contiguous to adjacent loops along a straight line at one side of the helix, applying a binder along
105 the common contiguous portions of the loops, curving the coil thus produced into toroidal shape and securing its ends together.

Signed at New York city in the county of
New York and State of New York this 4th
day of March A. D. 1924.

FRANK AUTY.