Oct. 1, 1963 S. R. McCUTCHEON ETAL 3,105,945

SIGNAL ENERGY TAKE OFF DEVICE

Filed Nov. 7, 1960

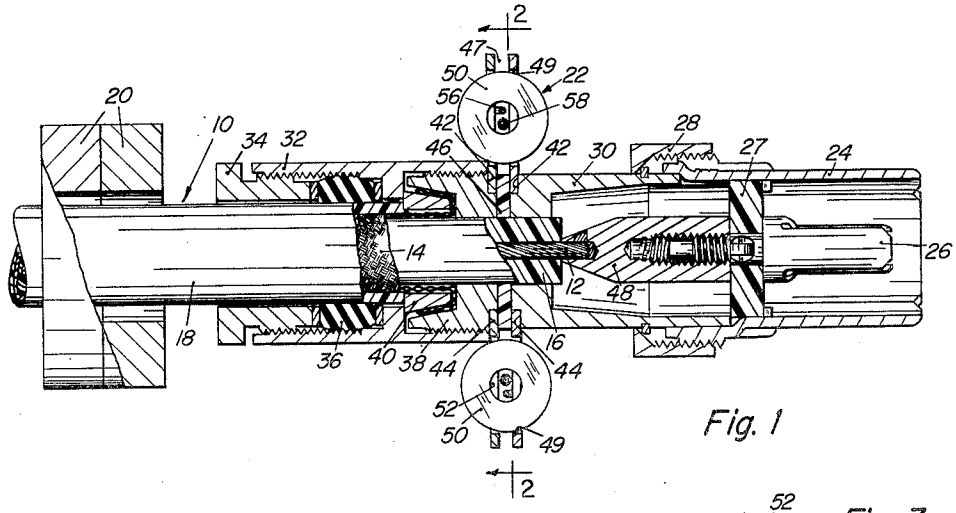


Fig. 1

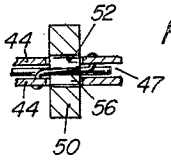


Fig. 3

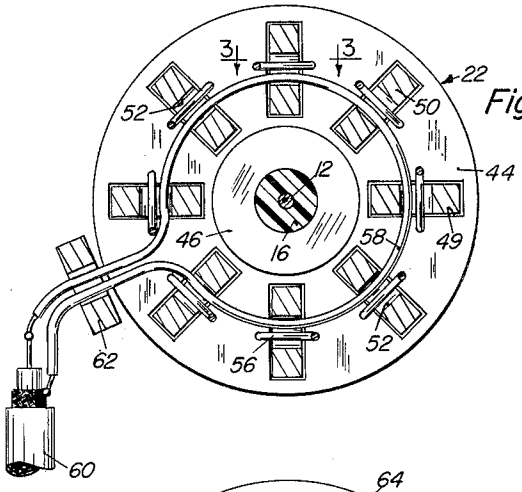


Fig. 2

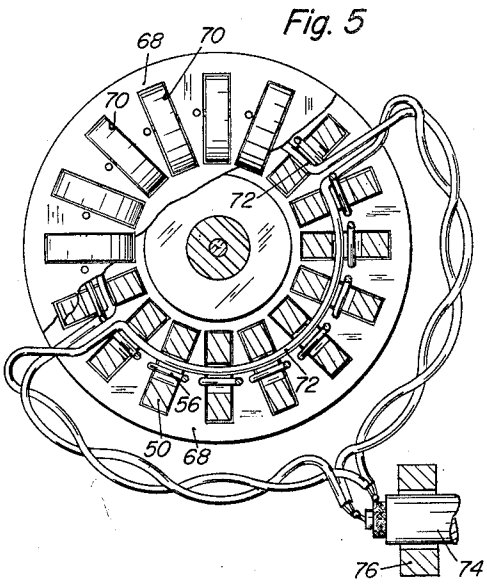


Fig. 5

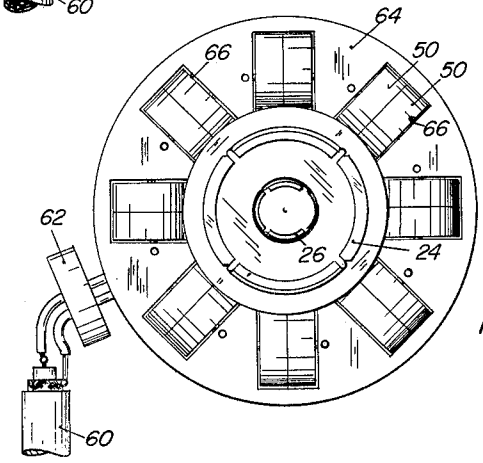


Fig. 4

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3,105,945

Patented Oct. 1, 1963

3,105,945

SIGNAL ENERGY TAKE OFF DEVICE

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Filed Nov. 7, 1960, Ser. No. 67,680
9 Claims. (Cl. 333—9)

This invention relates to a signal energy take off device and more particularly to a device which will extract a usable small amount of signal energy from a feed through transmission line along which the signal is traveling without materially degrading the quality of the signal in the transmission line or producing an appreciable amount of discontinuity in the transmission line so as to cause deleterious reflections therein and in a manner which delivers such signal energy through an output transmission line to provide an output signal voltage having substantially the same wave form as that of the signal voltage passing along the feed through transmission line.

In many cases it is desirable to extract a portion of the signal energy traveling along a transmission line. Such signal energy may, for example, be employed in cathode ray oscilloscope circuits to actuate a trigger circuit which in turn initiates the actuation of a sweep circuit, the remaining signal energy continuing to travel along such transmission line and being employed to produce a vertical deflection in the oscilloscope after a time delay. In prior devices resistive isolation involving resistance in series with the output cable has been employed to keep the reflections in the feed through transmission line small thus resulting in extremely poor efficiency of signal energy delivery to the output line because of losses in such resistance.

In accordance with the present invention, an extremely efficient signal energy take off device is provided. A very small reflection is produced in the feed through line and substantially all of the signal energy which is extracted from the signal propagated along such line is delivered to the output line. In such device, a gap which is short relative to the spacing of the conductors of the feed through line is provided in one of such conductors and a plurality of small transformers, each employing an annular core of magnetic material and single turn primary and secondary winding, have their primary windings connected in parallel across such gap. The transformers may be divided into one or more similar groups and a single conductor extends through all of the cores of each group to provide single turn secondary windings for the transformers of each group which are connected in series. Such conductor is connected to an output transmission line and the arrangement and connection of the transformers is such to provide a low impedance across the gap referred to and an impedance across the output transmission line substantially equal to the characteristic impedance of such output line. The resulting device will extract a usable small amount of signal energy from the feed through transmission line over a wide range of frequencies including extremely high frequencies with very little effect on the signal traveling along the feed through line.

The signal energy take off device of the present invention is particularly adapted for employment with transmission lines of the coaxial type. A gap may be provided in the outer tubular conductor of such line which is short relative to the diameter of such conductor and a plurality of small transformers of the type discussed above may be circumferentially spaced around such gap. By employing annular members of conducting material, such as metal, having their inner peripheries engaging the ends

of the outer conductor of the input or feed through line on opposite sides of the gap and mounting small annular magnetic cores in slots in such conducting members, a compact structure having high mechanical strength and excellent electrical properties can be provided.

It is therefore an object of the present invention to provide an improved signal energy take off device for extracting a portion of the signal energy traveling along a transmission line in which device a plurality of small transformers are employed.

Another object of the present invention is to provide a signal energy take off device for extracting a portion of the signal energy traveling along a transmission line in which device a plurality of small transformers each having a magnetic core and single turn primary and secondary windings are employed and in which the primary windings of such transformers are connected in parallel across a gap in one conductor of the transmission line and in which device the transformers are divided into one or more similar groups and the secondary windings of each such group are connected in series.

A further object of the invention is to provide an improved signal energy take off device capable of operating with extremely high frequency signals for extracting a small portion of the signal energy traveling along a transmission line in which device a plurality of small transformers are employed and substantially no distortion of the signal traveling along such transmission line is produced, and very little reflection of signal energy is produced in such line.

Other objects and advantages of the invention will appear in the following description of preferred embodiments thereof shown in the attached drawing of which:

FIG. 1 is a longitudinal section taken axially through a device in accordance with the present invention with portions of the device shown in elevation with parts broken away;

FIG. 2 is a transverse cross section of the device of FIG. 1, taken on the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary sectional view of the device of FIGS. 1 and 2, taken on the line 3—3 of FIG. 2;

FIG. 4 is an end elevation of a modified device similar to the device of FIGS. 1 to 3; and

FIG. 5 is an end elevation with parts broken away in a further modified device, similar to the devices of FIGS. 1 to 4.

Referring more particularly to the drawing, the device illustrated in FIGS. 1 to 3 includes a coaxial cable 10 having an inner flexible conductor 12 and an outer tubular flexible conductor 14. A flexible tubular member 16 of insulating material is positioned between the inner and outer flexible conductors 12 and 14 and the cable also has an outer insulating sheath 18 surrounding the outer conductor 14. The coaxial cable 10 preferably passes through one or more cores of magnetic material 20 for the purpose discussed below.

A transformer structure 22 is shown surrounding the end of the coaxial cable from which the insulating sheath 18 and outer flexible conductor 14 has been stripped. Except for such transformer structure 22, the remainder of the device is made up largely of standard or slightly modified coaxial cable connector elements which are employed to hold the transformer structure in position and provide a continuation of the inner and outer conductors of the cable 10 with a gap in the outer conductor. Thus the outer connector element 24 and inner connector element 26, shown at the right of FIG. 1 as being insulated from each other by an insulating member 27, may be parts of a commercial coaxial cable connector and the same is true of the nut 28 holding the connector elements 24 and 26 in assembled position

with a metal sleeve 30 surrounding the end of the insulating member 16 of the coaxial cable 10. The internally and externally threaded sleeves 32 and 34 on the other side of the transformer structure 22 may also be coaxial cable connector parts and the same is true of the sleeve 36 of rubber or other similar flexible material which serves to clamp the end of the coaxial cable 10 in position relative to the sleeves 34 and 36, respectively. An externally threaded sleeve 38 in conjunction with a split conical sleeve 40 provides an effective electrical connection to the flexible outer conductor 14 of the coaxial cable 10.

The sleeves 30 and 38 each have a shoulder 42 which provides annular recesses on their adjacent ends. An annular member 44 of sheet metal is supported by each sleeve 30 and 38. Thus each annular member 44 has its inner periphery received in an annular recess in one of the sleeves 30 or 38 and the two annular members 44 are held in axially spaced position by a washer 46 of insulating material positioned between the two sleeves 30 and 38 and engaging the inner portions of such annular members. It will be apparent that the sleeve 38 forms a continuation of the outer flexible conductor 14 of the coaxial cable 10 and that the sleeve 30 forms a continuation of the outer conductor of any coaxial cable to be connected to the device shown in FIG. 1 by a suitable cable connector fitting the cable connector including the outer connector member 24 and the inner connector member 26. The outer conductor of the resultant feed through coaxial cable therefor has a gap therein provided by the washer 46 of insulating material between the two sleeves 38 and 30 and the annular members 44. Such washer 46 is of smaller diameter than the annular members 44 so as to provide a space 47 between the annular members 44.

The inner connector element 26 in conjunction with another inner conducting element 48 secured to the inner conductor 12 of the cable 10 and to the element 26 forms a continuation of the inner conductor 12 of the coaxial cable 10 so that the inner conductor extends continuously through the device of FIG. 1. It will be understood that the various elements of the connector element including the outer connector element 24 and the inner elements 26 and 48 as well as the sleeve 30 are of a form which preserves the characteristic impedance of the cable 10 throughout the device of FIG. 1, except for any discontinuity which may be imparted by the gap provided by the washer 46 in the outer conductor of the resulting feed through coaxial cable.

The annular members 44 forming part of the transformer structure 22, as shown most clearly in FIG. 2, each have a plurality of radially extending rectangular slots 49 uniformly circumferentially spaced around the coaxial cable. The slots 49 in the two members 44 are in alignment axially of the coaxial cable and are shaped to each receive and fit a small annular core 50 of suitable magnetic material. The cores 50 have their apertures 52 positioned in alignment with the space 47 between the two annular members 44 of conducting material. As shown most clearly in FIG. 3, a short wire 56 extends from one of the annular members 44 to the other annular member 44 through the apertures 52 in each core 50, such wire being positioned within the space 47. Each wire 56 constitutes a single turn transformer primary winding across the gap in the outer conductor of the feed through coaxial cable and all of such primary windings are connected in parallel across such gap. As shown most clearly in FIG. 2, a single wire 58 extends through the apertures 52 in all of the cores 50 and has its ends positioned adjacent each other and connected to the conductors of an output coaxial cable 60. The wire 58 constitutes a single turn secondary winding for each of the transformers provided by the cores 50 and primary windings 56, and such secondary windings are all connected in series to the two conductors of the output coaxial cable 60. Another core 62 of magnetic material is positioned to surround the output circuit made up of the two ends of the wire 58 for the reasons discussed below.

The modification shown in FIG. 4 is similar to the modification shown in FIGS. 1 to 3 except that modified annular members 64 of metal or other conducting material are employed having circumferentially spaced slots 66 extending radially therein. The slots 66 in the annular members 64 are of sufficient size to enable two annular cores 50 to be positioned therein if found necessary for effective transformer action. Each transformer thus has two cores 50 instead of one core 50 in order to provide more magnetic material in the cores of each transformer to therefore extend the low frequency response. Otherwise the device of FIG. 4 may be entirely similar to the device of FIGS. 1 to 3.

In the modified device of FIG. 5, annular members 68 of conducting material are employed, each having a plurality of radially extending circumferentially spaced slots 70, the number of such slots being greater in number than the number of slots 49 or 66 of the devices of FIGS. 1 to 4. As in the devices of FIGS. 1 to 4, each of the cores 50 has a single turn primary winding consisting of a wire 56 extending between the two annular members 68. The cores 50 of FIG. 5 are, however, divided into two similar groups each of which has a separate secondary winding consisting of a conductor 72 extending through the apertures in the cores 50 of one group. The two secondary windings 72 have their ends connected in parallel to the conductors of an output coaxial cable 74 which passes through a core 76 of magnetic material.

The magnetic cores 20 of FIG. 1 through which the coaxial cable 10 passes, provide an effective transformer or choke having a bifilar winding made up of the inner and outer conductors of the coaxial cable 10. Such cores are of magnetic material having low eddy current and hysteresis losses so as to be usable at high frequency and of relatively high permeability. Suitable cores are available commercially and are usually referred to as Ferrite cores. The cores 50 are also of the same type of material. The cores 20 electrically isolate the end of the outer conductor of the feed through coaxial cable structure which is positioned on the left of the gap in FIG. 1 provided by the insulating washer 46 from any ground connection which the outer conductor 14 of the coaxial cable 10 may have at the left of the cores 20 in FIG. 1. A voltage appears across such gap when signal energy travels along the feed through coaxial cable even though the outer conductor of the cable connected to the right end of the device in FIG. 1 is also grounded. Since the individual transformers having the cores 50 have a one-to-one ratio, a substantially similar voltage is simultaneously produced in the common secondary winding 58 by each transformer and such voltages add to produce a resultant higher voltage across the conductors of the adjacent end of the coaxial cable 60. The impedance looking into the gap in the outer conductor of the feed through coaxial cable arrangement of FIG. 1 is preferably made as small as possible while at the same time the impedance looking into the voltage take off device from the output transmission line, such as the coaxial cable 60 of FIG. 2, should be at least approximately the same as the characteristic impedance of such cable. Since the small transformers employing the cores 50 all have their primary windings connected in parallel across such gap and their secondaries connected in series, the impedance across such gap is quite small, due to the step down action of the transformers on the load impedance. The transformer windings are arranged to form a transmission line of appropriate characteristic impedance to match the load transmission line.

As a specific example, the feed through cable 10 of

a device employing eight cores, such as shown in FIGS. 1 to 4, may have a characteristic impedance of 125 ohms while the output cable 60 may have a characteristic impedance of 50 ohms so that the impedance connected across the gap in the feed through cable is approximately 0.78 ohm. Also in the device of FIG. 5 the feed through cable may have a characteristic impedance of 125 ohms and the output cable may have a characteristic impedance of 50 ohms to again provide an impedance connected across the gap in the cable of approximately 0.78 ohm. In either case the impedance connected across the gap in the feed through transmission line is small relative to the characteristic impedance of the line. In the examples the voltage across the gap is approximately 0.625% of that traveling along the feed through line so that the voltage delivered to the output cable is approximately 5% of the signal voltage traveling along the feed through cable. Such output voltage is obtained at a loss of only about 0.625% of the signal energy traveling along the feed through cable with no more than about 0.313% voltage reflection in the feed through cable so that approximately 99.7% of the signal voltage continues along the feed through line.

A time factor resulting from the velocity of propagation of the signal in the secondary winding of the small coupling transformers enters into the operation of the devices illustrated. If it is assumed that the signal voltage induced in the secondary winding starts from a point directly opposite the output leads of the secondary winding 58 in FIG. 2, and is propagated in both directions along such secondary to the output coaxial cable 60, such signal passes the successive small transformers along such secondary winding at progressively later times. All of such transformers, however, simultaneously produce the same increment of signal voltage in such secondary winding. Because of the time element referred to, such increments add slightly out of phase. The least effect is produced when the output circuit is passed one or more times through a magnetic core 62 so as to isolate the transformer secondary winding 58 from ground even when the outer conductor of the output transmission line 60 is grounded. Such time factor places a limit on the frequency or rise time response of the device shown but, nevertheless, devices of the type described above are capable of operating satisfactorily at several thousand megacycles and with pulses having very short rise time.

It will be apparent that the details of the specific devices shown may be varied including the number of small transformers and their secondary winding connections, and that the invention can be applied to transmission lines of different types than the coaxial cables shown having different value of characteristic impedances than those specifically disclosed.

We claim:

1. A signal energy take off device comprising a feed through transmission line having a pair of spaced conductors, one of said conductors having a gap therein which is short relative to the spacing between said conductors, an output transmission line, a plurality of transformers each having an annular core of magnetic material and arranged in at least one group of transformers, said cores being circumferentially spaced around said one conductor adjacent said gap, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output transmission line to provide single turn secondary windings for the transformers of each said group all connected in series with said output transmission line.

2. A signal energy take off device comprising a feed through transmission line having a pair of spaced conductors, one of said conductors having a gap therein which is short relative to the spacing of said conductors of said transmission line, an output transmission line, a plurality of transformers each having an annular core of magnetic material and arranged in at least one group of transformers, said cores being corcumferentially spaced around said one conductor adjacent said gap, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output transmission line to provide single turn secondary windings for the transformers of each said group all connected in series with said output transmission line, the parallel connection of said primary windings providing an impedance across said gap which is small relative to the characteristic impedance of said feed through transmission line and the series connection of said secondary windings at least approximately matching the characteristic impedance of said output transmission line.

3. A signal energy take off device comprising a feed through transmission line having a pair of spaced conductors, one of said conductors having a gap therein which is short relative to the spacing between said conductors, an output transmission line, a plurality of similar groups of transformers each including a plurality of transformers each having an annular core of magnetic material, said cores being circumferentially spaced around said one conductor adjacent said gap, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output transmission line to provide single turn secondary windings for the transformers of each said group all connected in series with said output transmission line and with the series connected secondary windings of said groups connected in parallel to said output transmission line.

4. A signal energy take off device comprising a feed through transmission line having a pair of spaced conductors, one of said conductors having a gap therein which is short relative to the spacing of the conductors of said transmission line, an output transmission line, a plurality of similar groups of transformers each including a plurality of transformers each having an annular core of magnetic material, said cores being circumferentially spaced around said one conductor adjacent said gap, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output transmission line to provide single turn secondary windings for the transformers of each said group all connected in series with said output transmission line and with the series connected secondary windings of said groups connected in parallel to said output transmission line, the parallel connection of said primary windings providing an impedance across said gap which is small relative to the characteristic impedance of said transmission line and the series-parallel connection of said secondary windings at least approximately matching the characteristic impedance of said output transmission line.

5. A signal energy take off device comprising a feed through coaxial cable having inner and outer conductors, said outer conductor having an annular gap therein which is short relative to the diameter of said outer conductor

of said cable, an output coaxial cable, a plurality of transformers each having an annular core of magnetic material and arranged in at least one group of transformers, said cores being circumferentially spaced around said feed through cable adjacent said gap, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output coaxial cable to provide single turn secondary windings for the transformers of each said group all connected in series with said output coaxial cable.

6. A signal energy take off device comprising a feed through coaxial cable having inner and outer conductors, said outer conductor having an annular gap therein which is short relative to the diameter of the outer conductor of said cable, an output coaxial cable, a plurality of transformers each having an annular core of magnetic material and arranged in at least one group of transformers, said cores being circumferentially spaced around said feed through cable adjacent said gap and having their central axes tangent to a circle concentric with said feed through cable, a conductor extending from one side of said gap to the other through each of said cores to provide a single turn primary winding for each of said transformers which primary windings are all connected in parallel across said gap, and a single conductor extending in series through all of said cores of the transformers of each said group and having its ends connected to said output coaxial cable to provide single turn secondary windings for the transformers of each said group all connected in series with said output coaxial cable.

7. A signal energy take off device comprising a feed through coaxial cable having inner and outer conductors, said outer conductor having an annular gap therein which is short relative to the diameter of said outer conductor and which provides an end of said outer conductor on each side of said gap, a pair of axially aligned annular conducting members surrounding said cable, one of said annular members being positioned on each side of said gap and having its inner periphery engaging one of said ends of said outer conductor, said members having a space therebetween and having radially extending slots circumferentially spaced around said members with corresponding slots in said members aligned axially of said cable to provide axially aligned pairs of slots, at least one annular core of magnetic material positioned in each of said pairs of slots with its axes extending circumferentially of said members, a separate conductor in said space extending through each of said cores from one of said members to the other, an output coaxial cable providing part of an output circuit, a conductor in said space extending in series through a plurality of said cores and having its ends connected to said output cable, said ends of the last mentioned conductor also providing a part of said output circuit, an annular member of magnetic material surrounding said feed through cable on at least one side of said gap and an annular member of magnetic material surrounding the conductors of said output circuit.

8. A signal energy take off device comprising a feed through coaxial cable having inner and outer conductors, said outer conductor having an annular gap therein which is short relative to the diameter of said outer conductor and which provides an end of said outer conductor on each side of said gap, a pair of annular conducting members surrounding said cable, one of said members being positioned on each side of said gap and having its inner periphery engaging one of said ends of said outer conductor, said members having a space therebetween and having radially extending slots circumferentially spaced around said members with corresponding slots in said members aligned axially of said cable to provide axially aligned pairs of slots, at least one annular core of magnetic material positioned in each of said pairs of slots with its axes extending circumferentially of said members, a separate conductor in said space extending through each of said cores from one of said members to the other, an output coaxial cable providing part of an output circuit, a conductor in said space extending in series through all of said cores and having its ends connected to said output cable, said ends of the last mentioned conductor also providing a part of said output circuit, an annular member of magnetic material surrounding said feed through cable on at least one side of said gap and an annular member of magnetic material surrounding the conductors of said output circuit.

9. A signal energy take off device comprising a feed through coaxial cable having inner and outer conductors, said outer conductor having an annular gap therein which is short relative to the diameter of said outer conductor and which provides an end of said outer conductor on each side of said gap, a pair of annular conducting members surrounding said cable, one of said members being positioned on each side of said gap and having its inner periphery engaging one of said ends of said outer conductor, said members having a space therebetween and having radially extending slots circumferentially spaced around said members with corresponding slots in said members aligned axially of said cable to provide axially aligned pairs of slots, at least one annular core of magnetic material positioned in each of said pairs of slots with its axes extending circumferentially of said members, a separate conductor in said space extending through each of said cores from one of said members to the other, an output coaxial cable providing the conductors of part of an output circuit, said cores being arranged in a plurality of groups each having the same number of cores, a separate conductor in said space extending in series through all of said cores of each group and having its ends connected in parallel to said output cable, said ends of the last mentioned conductors also providing a part of said output circuit, an annular member of magnetic material surrounding said feed through cable on at least one side of said gap and an annular member of magnetic material surrounding the said conductors of said output circuit.

References Cited in the file of this patent

UNITED STATES PATENTS

775,800 Schmidt ---------- Mar. 29, 1904