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[32] Priority Oct. 2, 1968
[33] Japan
[31] 43/85,346

[54] **ISOLATOR COMPRISING TUNED LUMPED ELEMENT CIRCULATOR**
10 Claims, 20 Drawing Figs.

[52] U.S. Cl. 333/24.2, 333/1.1
[51] Int. Cl. H01p 1/32
[50] Field of Search 333/1.1, 24.1, 24.2

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Paul L. Gensler
Attorney—Stevens, Davis, Miller & Mosher

ABSTRACT: The present invention relates to an isolator having a low forward direction loss over a very wide frequency range and a sufficiently high backward loss in a desired frequency range, and having a very compact configuration and a simple construction.

The isolator according to the present invention comprises a lumped element type circulator which is operative in the desired frequency range, a resonant circuit having its impedance characteristics to be at low impedance in said frequency range and to be at high impedance outside of said frequency range and being connected between outer conductor of the lumped element type circulator and a ground conductor, and an absorbing resistor connected between one of the terminals of the circulator and the outer conductor or the ground conductor.

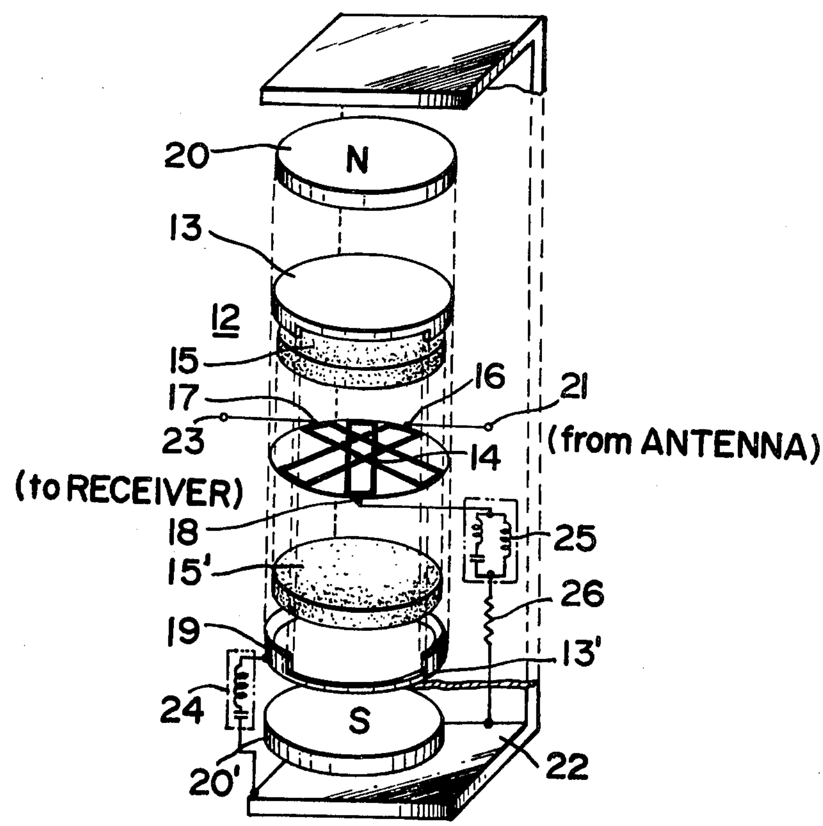


FIG_1
(Prior Art)

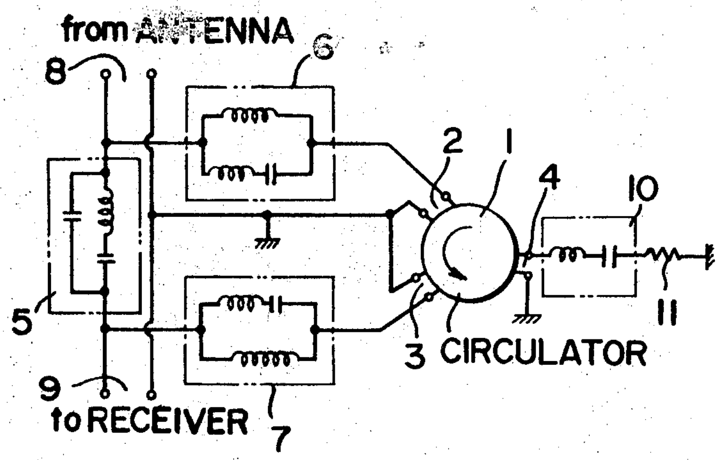
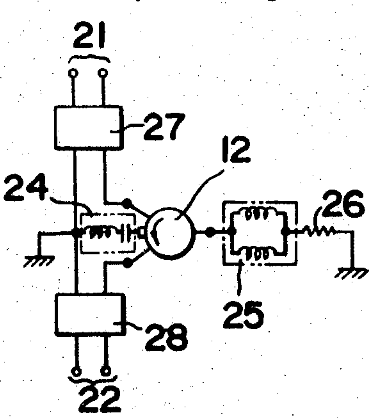


FIG_6



INVENTOR

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BY *Stevens, Davis, Miller & Mosher*
ATTORNEYS

FIG_2

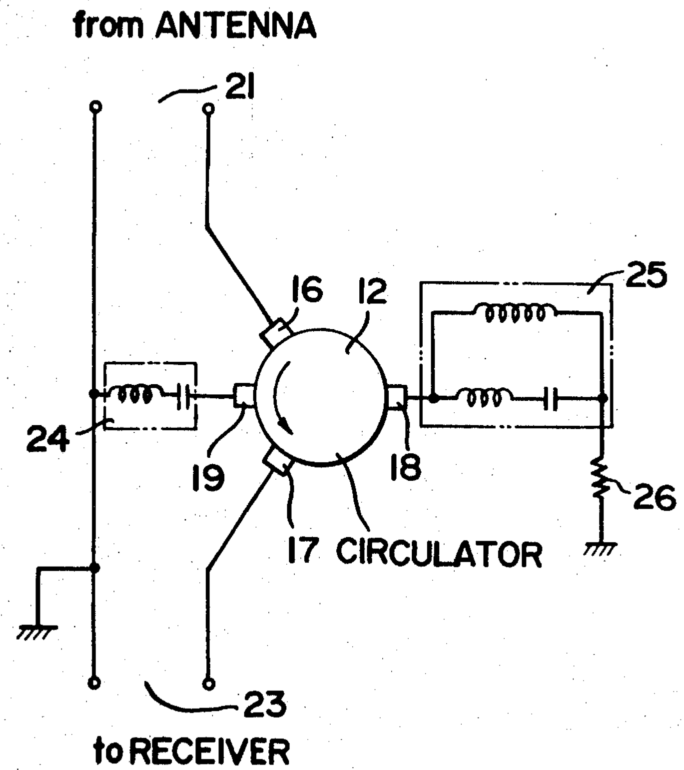
from ANTENNA
21
16
12
25
24
19
18
26
17 CIRCULATOR
23
to RECEIVER

FIG_3

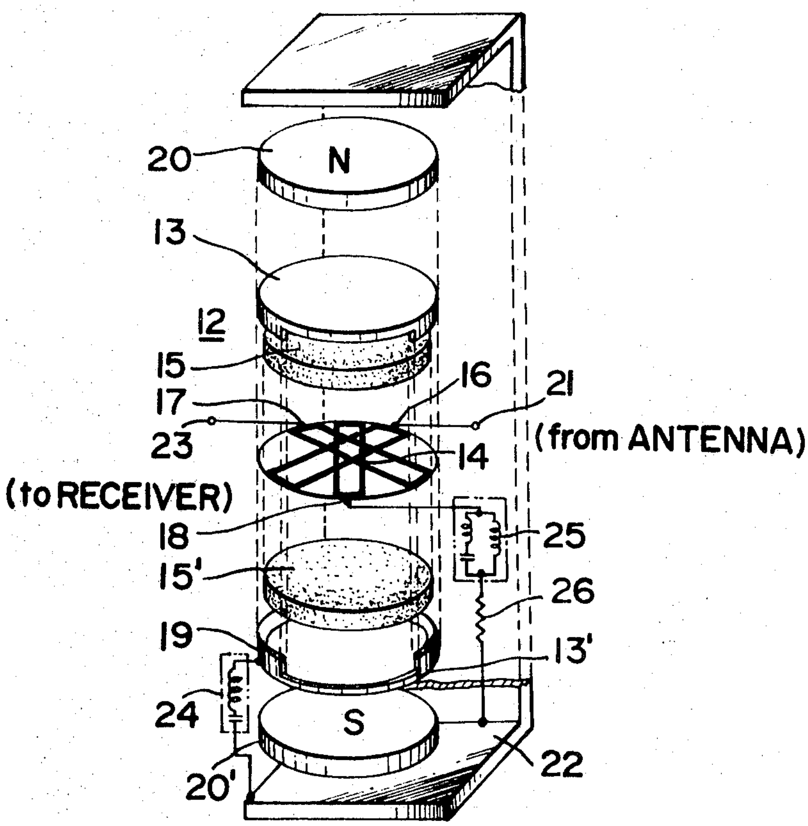
20
N
13
12
15
16
17
21
23
(from ANTENNA)
14
(to RECEIVER)
18
25
15'
26
19
13'
24
S
22
20'

FIG_4a

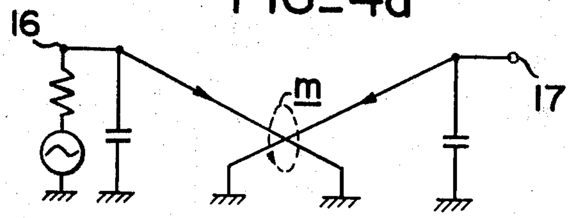

FIG_4b

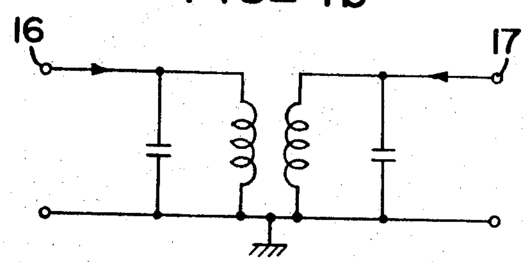

FIG_4c

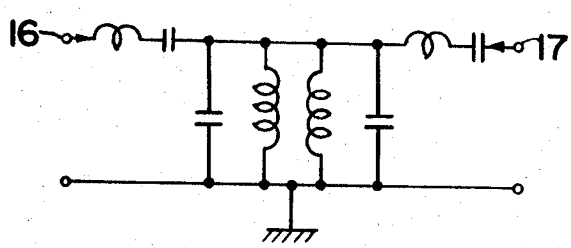

FIG_4d

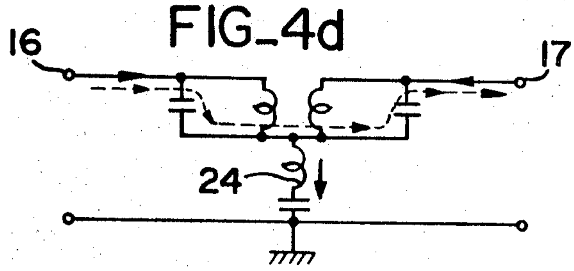

FIG_5

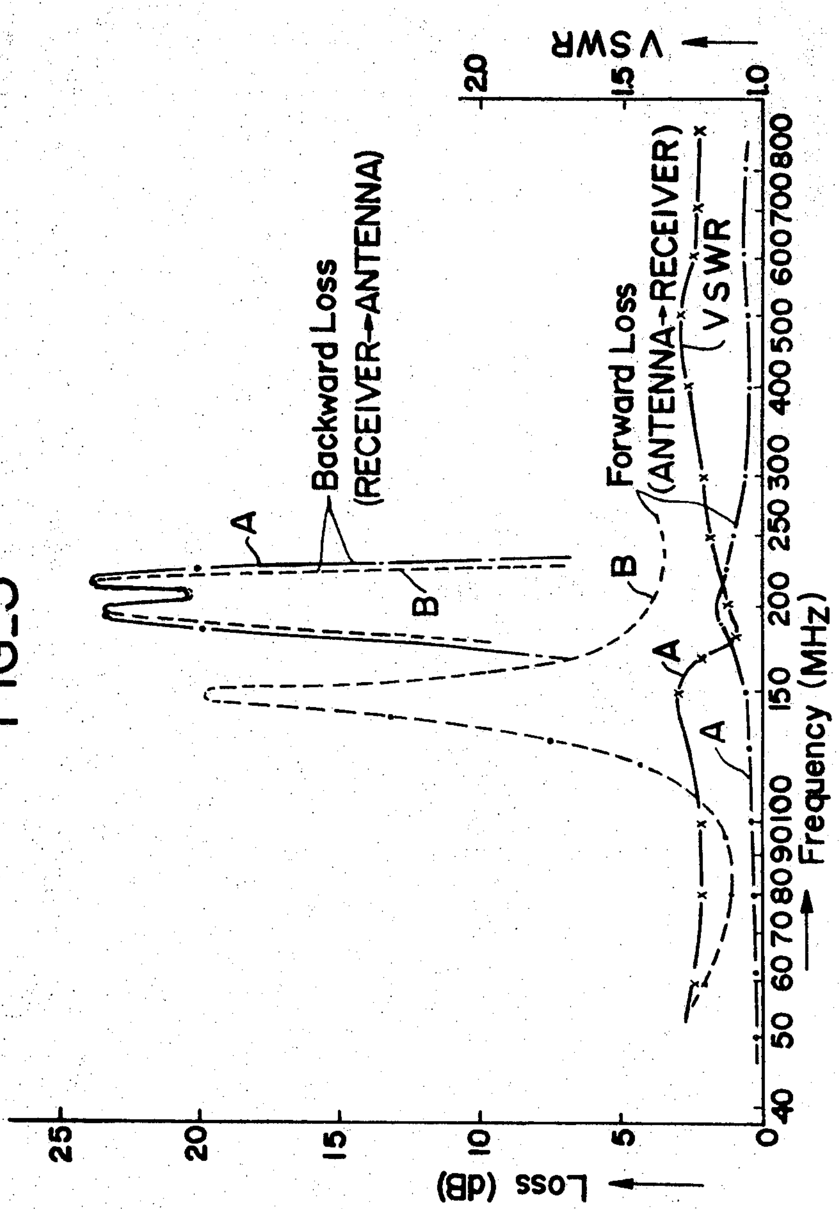
Backward Loss
(RECEIVER→ANTENNA)
Forward Loss
(ANTENNA→RECEIVER)
VSWR
A
B
Loss (dB)
0
5
10
15
20
25
V SWR
1.0
1.5
2.0
Frequency (MHz)
40
50
60
70
80
90
100
150
200
250
300
400
500
600
700
800

FIG_7a

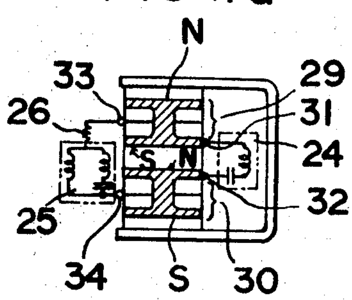

FIG_7b

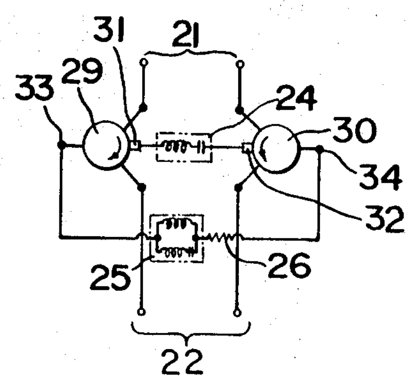

FIG_7c

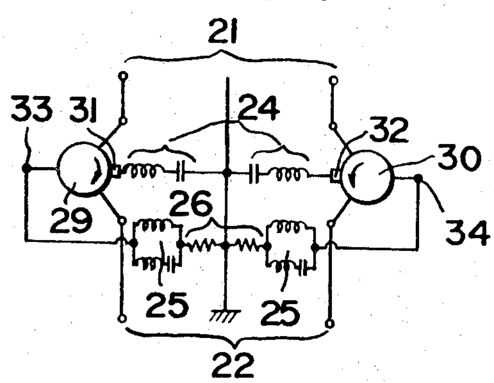

FIG_8

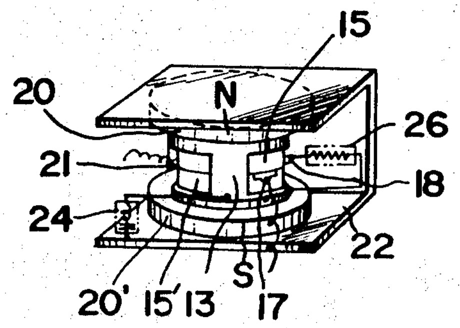
15
20
N
26
21
18
24
22
S
20'
15'
13
17

FIG_9

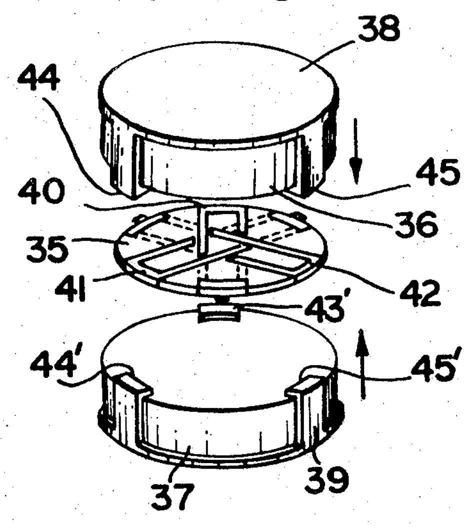
38
44
45
40
36
35
41
42
43'
44'
45'
37
39

FIG_10a

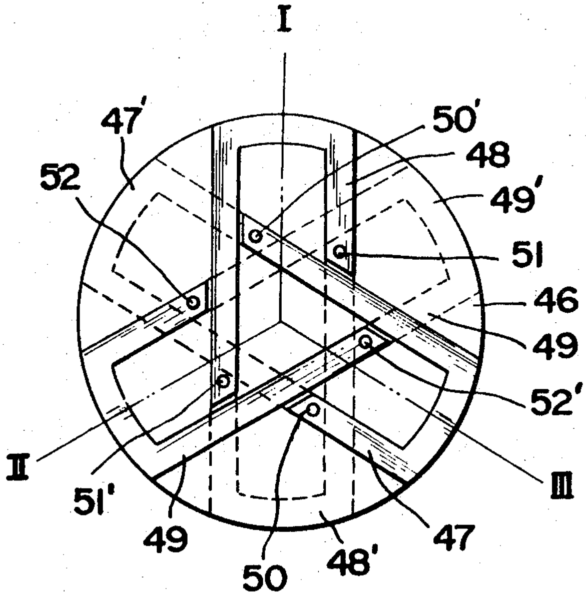

FIG_10b

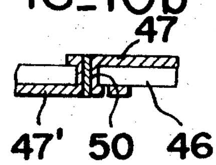

FIG_11a

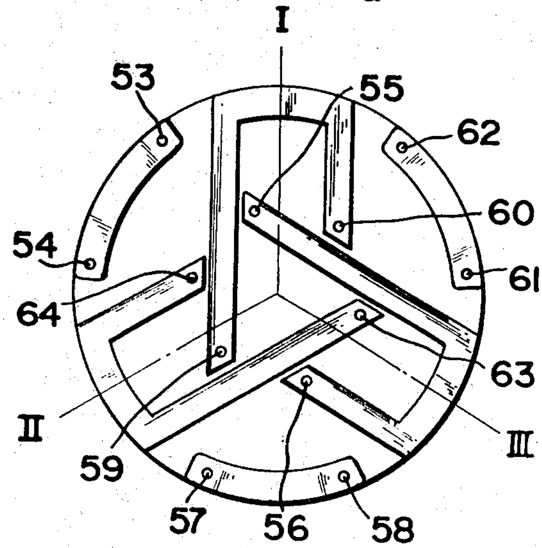

FIG_11b

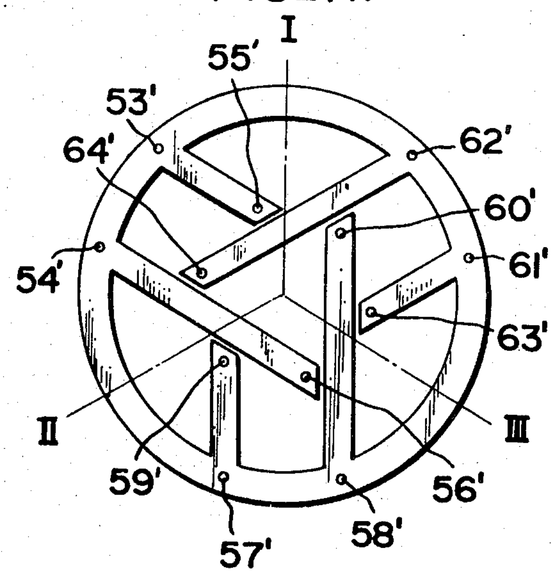

FIG_12

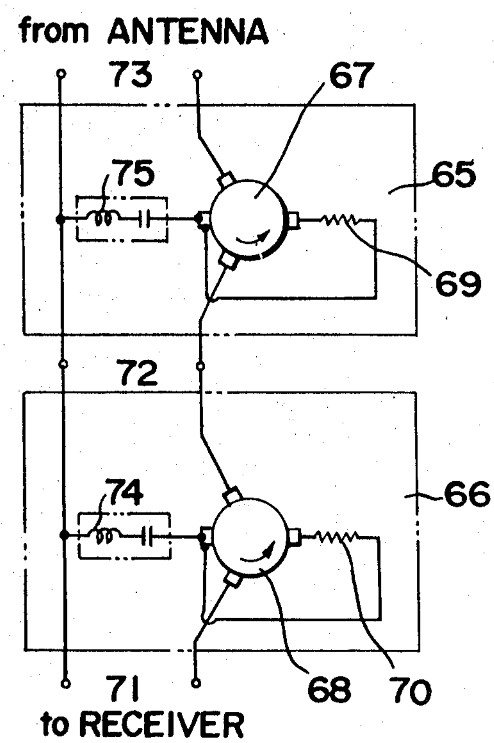

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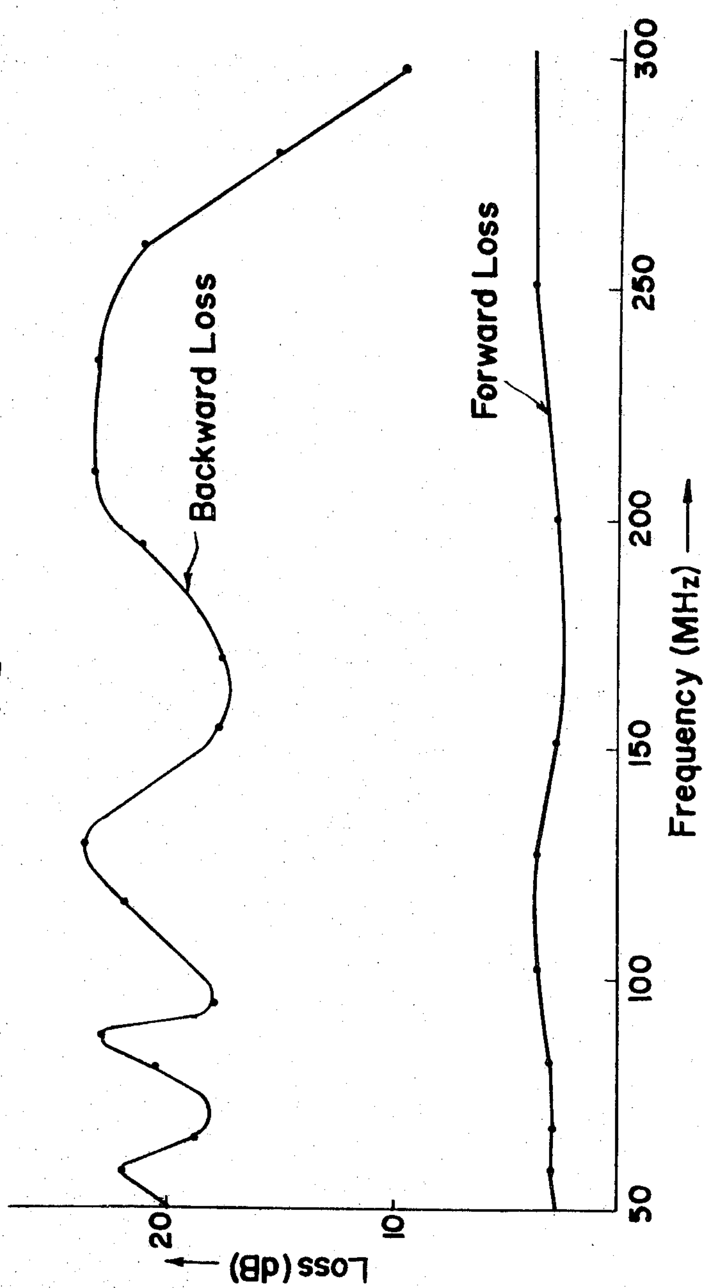
FIG_13



ISOLATOR COMPRISING TUNED LUMPED ELEMENT CIRCULATOR

BACKGROUND OF THE INVENTION

According to the recent remarkable increase in the number of television receivers interference for a television receiver caused by an emanation of local oscillation frequency originated from other television receivers in the adjacent area is becoming a big problem. This kind of interference causes a more significant problem especially for receivers in low field intensity areas, in big apartment buildings or in high buildings, wherein the receivers are coupled to each other through a common receiving antenna.

The principle of such phenomena of interference can be understood by the following explanation made with reference to Japanese television broadcasting channels as an example. In the higher VHF band, the channels are allocated from 171.25 MHz. to 219.25 MHz. with a separation of a 6 MHz. frequency band. These channels are termed usually as No. 4 –No. 12 channels. An ordinary television receiving set uses an intermediate frequency of 26.74 MHz. This results in an interference for the other working receivers receiving a higher frequency band which is spaced apart by four channel intervals. For instance a receiver receiving No. 4 channel will give a particular interference to the adjacent receiver receiving No. 8 channel by the local oscillation frequency and a receiver receiving No. 5 channel will give an interference to a receiver receiving No. 9 channel for the same reason. This can be explained as follows: For instance if a television receiving set is receiving No 4 channel, this set has a local oscillation frequency of 198 MHz., (171.25 MHz. + 26.75 MHz.) provided that the tuning is accurate. This 198 MHz. frequency lies between No. 8 channel (195.25 MHz.) and no. 9 channel (201.25 MHz.). Usually as the tuning of a receiving set deviates into the lower frequency side, the above local oscillation frequency is on the lower side of 198 MHz. and if this local oscillation frequency is received by an adjacent receiver which is receiving No. 8 channel of 195.25 MHz. a beat interference arises in the latter receiver. The beat frequencies fluctuate within a band of 3 –4 MHz. and give a particular interference into the color signal when the receiver is receiving a color television program. Exactly the same relationship happens tin each of combination of the channels No 5 and No. 9, No. 6 and No. 10, and No. 7 and No. 11. An interference from a receiver receiving No. 8 channel to a receiver receiving No. 12 channel is more pronounced. In this case if the local oscillation frequency of the receiver receiving No. 8 channel is exactly adjusted, the local oscillation frequency lies in the frequency band of No. 12 channel and causes a beat interference of about 2 MHz.

In order to suppress this kind of interference for a television receiver connected from a common feeder, a directional branching unit is used at the branch point from the main antenna feeder line to each of the receivers for coupling the receiver to the antenna. The directional branching unit usually consists of a directional coupler, or a combination of a circulator and filters in order to obtain a directional transmission characteristic for the wave. However the former directional coupler has a disadvantage that the obtainable directivity is limited up to about 10 –6 *db.* since the standing wave ration (SWR) of the antenna is normally about 2 –3, and the latter combination of a circulator and filters is not practically applicable, since it requires a circuit which is too complicated for separating the lower channel waves and the higher channel waves by means of a low-pass filter and a high-pass filter and for supplying only the high channel component to a circulator. Moreover, the latter embodiment has another disadvantage in that the insertion loss of the filters especially in the boundary frequency region of the higher and lower channels, i.e. the loss for a frequency range about 150 MHz. becomes too large in practice so that a practical device may hardly be obtained.

SUMMARY OF THE INVENTION

The present invention relates to an isolator having a very small forward direction loss over a very wide frequency range and sufficiently high backward loss in the desired frequency range which is to prevented from leaking into the other receivers.

The present invention has for its object a novel and practical isolator with a directivity in a desired frequency range and having a very low insertion loss in a frequency band outside of the above range.

A further object of the invention is an isolator comprising a lumped element circulator, having a directional coupling characteristic regardless of a standing wave ratio in the desired frequency range, and allowing to waves to pass in one direction and to absorbing and clamping the waves passing in the backward direction.

A still further object of the invention is an isolator having a wide operational frequency range by inserting a very simple two-terminal network between an outer conductor terminal common for each of the circulator terminals and a ground conductor. Another object of the present invention is to obtain a very compact size wide band isolator applicable as a branching unit for the common receiving feeder of color television broadcasting, suitable for use over a very wide frequency range from VHF band to UHF band and able to substantially absorb the local oscillation frequencies so that no spurious waves are received by the other receiving sets in the common antenna receiving system.

A still further object of the present invention is to obtain an isolator device having a very compact size which can be manufactured with a very low manufacturing cost by introducing printed circuits techniques suitable for the mass production of the inner meshed conductor portion of the lumped element circulator.

The device according to the present invention which fulfills the above-mentioned objects will be described hereinafter .

The isolator device according to the present invention comprises a circulator containing ferrite material under DC magnetic field, which has a different permeability for a positive and a negative rotational high-frequency magnetic field for the main constructive element.

The isolator according to the present invention comprises to circulator having at least three terminal ports, and a network which is tuned for center frequency of a frequency range desired to be nonreciprocal and is connected between the outer conductor and the ground conductor.

The isolator further comprises an absorbing resistor between at least one of the three terminal ports and the outer conductor of the circulator or the ground conductor; according to the need a two-terminal network is connected in series thereto which has an impedance to pass the operational frequency range of the circulator, assuming a large impedance value for the frequencies outside of the above range.

A signal received by the isolator device is applied to an input terminal of the circulator, which is located in the forward direction viewed from the terminal connected with the absorbing resistance, and the output signal is taken out of an output terminal of the circulator located in the forward direction viewed from said input terminal.

If such an isolator device is applied with the frequency outside of nonreciprocal operational range, the network connected between the outer conductor of the circulator and the ground conductor becomes an open impedance and furthermore the circulator is at low impedance at such a frequency band apart from the center frequency. Then the signal applied to the input terminal is passed through the device with a low attenuation.

Namely the circulator in the isolator device according to the present invention shows nonreciprocal characteristics or mere passing element characteristic according to the applied frequency. Therefore the operational frequency range of the isolator in the forward direction viewed from the input terminal is extremely enlarged without adding a particular compensating circuit.

The isolator device according to the present invention having above-mentioned functions can afford great advantages particularly in simplifying the circuit construction, minimizing the size of the equipment and improving the functional features.

Waves in the reciprocal frequency range of the circulator appearing at the output terminal of the isolator are fed to the absorbing resistor by the circulator and are consumed therein as a heat loss. Therefore the energy results in a backward directional loss and no leakage to the input terminal appears.

A directional branching unit having a more pronounced blocking effect for the spurious waves over a very wide frequency range can be obtained by connecting in cascade a plurality of isolator according to the present invention which have different center frequencies.

A mesh-type lumped element Y-circulator such as disclosed in U.S. Pat. No. 3,335,374 is conveniently used for the circulator of the isolator device according to the present invention. By this application the meshed inner conductors may be provided by printed circuit techniques which afford a particular advantage in mass production.

In the above case the lumped element type circulator of the isolator device is constructed by using a thin insulated film provided with meshed type printed wiring pattern on the both surfaces; the necessary portions of the printed conductor are jointed by through hole soldering and are loaded with ferromagnetic bodies. The circulator having such a construction can maintain the excellent symmetry required for a circulator and is suitable in mass production process so that not only an improvement of characteristics of the circulator itself is achieved but a decrease in manufacturing cost is also possible.

As the circulator is the most expensive element among the constructive elements of the isolator device according to the invention, the present invention is quite effective in decreasing the manufacturing cost of the device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram of a conventional type nonreciprocal spurious wave preventing circuit having same object as that of the present invention, wherein a circulator is combined with filters;

FIG. 2 is a basic circuit diagram of an isolator according to the present invention;

FIG. 3 is a perspective view showing an embodiment of construction of an isolator according to the present invention, in which the constructive elements are shown in detached form;

FIG. 4*a* is a circuit explaining a blocking operation of a circulator;

FIG. 4*b* is an equivalent circuit of the above circulator;

FIG. 4*c* is a circuit explaining the principle of widening the frequency range of the circulator;

FIG. 4*d* is an explanation diagram showing a principle for widening the operation range of the circulator according to the present invention;

FIG. 5 is a characteristic diagram showing isolators of the invention in comparison with a known type device;

FIG. 6 is a circuit diagram when the isolator device of the invention is used with balance to unbalance transformers;

FIG. 7*a* shows a construction of an example of balanced type isolator device of the invention, wherein two circulators are connected in push-pull;

FIG. 7*b* is a circuit diagram of the balanced type isolator device shown in FIG. 7*a;*

FIG. 7*c* is an explanation diagram explaining the operation of the isolator device shown in FIG. 7*a;*

FIG. 8 is a perspective view of the other embodiment of the isolator of the present invention, wherein an absorbing resistor is connected between a circulator terminal and the outer conductor;

FIG. 9 shows a construction of a printed wiring mesh-type circulator conveniently applicable to the isolator device of the present invention;

FIG. 10*a* is a diagram showing a printing pattern of the inner conductors of the circulator shown in FIG. 9;

FIG. 10*b* is a cross-sectional view of the thin film explaining through hole soldering;

FIG. 11*a* shows a modified printing pattern on the front side;

FIG. 11*b* is a corresponding pattern of the rear side of pattern shown in FIG. 11*a* which is viewed transparently from the front side;

FIG. 12 is a circuit diagram of a wide band isolator device, wherein two isolator units according to the present invention are connected in cascade; and

FIG. 13 is a characteristic diagram of an isolator device, wherein four units of inventive isolators are connected in cascade to effect a nonreciprocal operation over whole VHF band.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before explaining the device according to the present invention, a prior art nonreciprocal device using a circulator will be explained.

FIG. 1 is an embodiment of prior art nonreciprocal devices which prevent leakage of local oscillation from a television receiver to a common feeder.

In the conventional circuit as shown in FIG. 1, 1 is a Y-circulator of known type which operates to guide the wave in a direction as shown by the arrow. 2, 3 and 4 are the terminals of the circulator. 5 is a band-pass filter able to pass a frequency range of a lower channel group which is usually much less affected by a spurious wave caused by a leakage of local oscillation of other television receivers and to blocks a frequency range of the higher channel group which tends to be affected by the spurious signal. 6 and 7 show band-pass filters each having exactly complementary passing characteristics to that of the filter 5. Namely these filters 6 and 7 pass the frequency range of the higher channel group and block that of the lower channel group.

In the conventional circuit as shown in FIG. 1, the broadcast wave received by an antenna (not shown) is fed through a feeder and appears at the input terminal 8 of the device. The lower channel components in the received wave pass through the band-pass filter 5 since these components are in the pass range of the filter and are fed to a television receiver (not shown) via output terminal 9. The higher channel components of the received wave are blocked by the filter 5 since these components are in the blocking region of the band-pass filter 5 and pass through the band-pass filter 6 and appear at terminal 2 of the circulator 1. Said components are rotated in the direction of the arrow by the circulator function and derived from terminal 3. Then the components are fed through filter 7 and applied to the receiver via terminal 9.

On the other hand the leakage energy of the local oscillation with a frequency falling in a range of higher channel components, which is emanated from a television receiver and applied to the terminal 9, is blocked from passing the band-pass filter 5. This energy passes through the band-pass filter 7 and appears at the terminal 3 of the circulator. This energy is then transmitted in the rotational direction as indicated by the arrow by the circulator action and appears at the terminal 4. Then the energy is fed to an absorbing resistor 11 via a reasonant circuit 10 connected to the terminal 4 and is consumed in the absorbing resistor. Thus the leakage energy which might give an interference to other receiver connected in common to the feeder is prevented from appearing at the terminal 8 and the common feeder.

Although this conventional circuit shows good transmission characteristics, it has a disadvantage in that it requires a number of band-pass filters and that the higher channel components must pass two band-pass filters 6 and 7, Accordingly it causes a troublesome increase in the loss in the forward direction and increases the loss especially in the frequency range at the boundary of the filters 5 and 7 (6).

Also as the conventional circuit requires such a number of filters, the circuit construction becomes very complicated and the size of the device increases commercially. Thus the utility of the device is not too practical. More especially, if a plurality of these units must be connected in cascade in order to obtain a sufficiently large backward loss, the equipment is commercially impractical.

The present invention is intended to realize a novel isolator device which mitigates the aforementioned disadvantages of the conventional device.

FIG. 2 shows a basic circuit diagram of the isolator according to the present invention, which is applicable for the same use as the conventional nonreciprocal device as shown in FIG. 1 FIG. 3 is a perspective view showing each of the constructive elements of an isolator according to the present invention. In these figures corresponding parts are designated by the same reference numerals.

In FIGS. 2 and 3, 12 shows a circulator utilizing a tensor permeability of ferromagnetic bodies under application of a DC magnetic field. In the operation of the isolator, the circulator 12 may be any known type, but FIG. 3 shows a most practical embodiment which contains a circulator suitable to use in an isolator of the present invention.

As a typical construction of a circulator, the circulator 12 comprises ferrite plates 15 and 15′ inserted between each of outer conductors 13 and 13′ and an inner conductor 14.

16, 17 and 18 are terminals of the inner conductor 14 provided at the positions of rotational symmetry and used to supply or to take out signals between the inner conductor 14 and the outer conductors 13 and 13′.

19 is an outer conductor terminal. The signal applied to the circulator terminal 16 is rotated by the circulator as shown in the arrow and taken out of the terminal 17.

21 is a pair of input terminals of the isolator device according to the present invention which are to be connected to a feeder from an antenna. These terminals are so connected that the input signal is applied between the terminal 16 of the circulator 12 and the ground conductor. Ground plate 22 shown in FIG. 3 acts as the ground conductor. This ground conductor 22 has a U-shaped configuration and acts also as a magnetic path between magnetic poles N and S.

23 shows a pair of output terminals to be connected to antenna input terminals of a television receiver. One of the above terminals is connected to the terminal 17 of said circulator 12 and the other one of the terminals is connected to the ground plate 22, respectively.

The circulator 12 is rigidly mounted by the ground plate 22 but is insulated from the plate with respect to high frequency energy.

24 is a two-terminal network connected between the outer conductor terminal 19 of the circulator 12 and the ground plate 22 and is composed to resonate at a center frequency of the frequency range of the isolator operation.

25 is a two-terminal network connected in series with an absorbing resistor 26 and inserted between the last terminal 18 of the circulator 12 and the ground plate 22. This network is able to pass frequencies in the desired frequency range of the isolator operation and to be an open impedance for the frequencies outside of the above frequency range.

As a fundamental operation of the circulator, a case in which a signal having a frequency in the operational range of the circulator is applied from terminal 16 and appears at terminal 17 and does not appear terminal 18 will be considered.

As no voltage is induced at the circulator terminal 18 at the center frequency, the equivalent network can be considered as FIG. 4*a*, in which the terminal 18 is dispensed with. In this operation a current flowing from the terminal 16 induces a magnetic flux as shown by a dotted circle *m* which in turn induces a voltage at the terminal 17 having opposite polarity with that of the terminal 16. Accordingly, the current at the terminal 17 flows toward the center of the circuit in the same manner as the current from the terminal 16. This means that if +1 volt is applied to the terminal 16 of the circulator 12, −1 volt appears at the terminal 17. Accordingly, the equivalent circuit is expressed as an inductive coupling type parallel resonant circuit as shown in FIG. 4*b*

In order to widen the operation frequency range of the resonant circuits as shown in FIG. 4*b*, it may easily be understood that series resonant circuits may be inserted in each of the branch as shown in FIG. 4*c* so as to effect so-called "peaking". However, as mentioned before, both the currents passing through the terminals 16 and 17 are directed toward the center of the circuits; said series resonant circuits may be made as a common circuit 24 inserted in the manner as shown in FIG.4*d* to widen the operational frequency range.

Accordingly, in the isolator device of the present invention, a very simple series resonant circuit 24 may be inserted between the common outer conductors 13 and 13′ of the circulator 12 and the ground conductor as shown in FIG.4*d* for this purpose. By this simple circuit construction, the operational frequency range of the circulator 12 is materially widened and the frequency range of the isolator operation is widened accordingly.

Therefore, according to the present invention a substantial simplification of the circuit construction, if compared with a conventional wide band circulator in which series resonant circuits are connected in each of the terminals, is possible in obtaining the same effect.

As mentioned above the series resonant circuit 24 inserted between the common outer conductors 13 and 13′ of the circulator 12 and the ground conductor is substantially tuned with a center frequency of the frequency range desired to be operated in nonreciprocal manner such as, for instance, the frequency range of channels No. 4 –No. 12, the higher channels. Then, for the frequency range of the lower channels (FM-No. 3), said resonant circuit takes a high impedance and the lower channel signals pass through from the terminal 16 to the terminal 17 as shown by a dotted line in FIG. 4*d*.

Accordingly, the circuit of the present invention operates as a low attenuation transmitting line for lower channel signals and operates as an isolator for higher channel signals. This means that the isolator according to the invention operates in the same manner of the nonreciprocal device shown in FIG. 1 with a complicated circuit. Spurious signals in the operational frequency range of the circulator 12 appearing at the terminal 23 are fed through the terminal 17 of the circulator to the terminal 18 and the network 25 which passes the above frequency range and are led to the absorption resistor 26 and consumed as a heat energy, so that leakage to the common feeder is avoided.

The most remarkably feature of the isolator according to the present invention is that, as explained with respect to FIGS. 4*a* to 4*d*, all of the signals covering the desired receiving frequency range are supplied through the circulator and fed to the output terminal 23 irrespective of the frequency in the lower channels or in higher channels so that the band-pass filter which had been necessarily included in the conventional nonreciprocal device as shown in FIG. 1 for the separation of signals in lower channels and higher channels can be dispensed with; moreover for the required frequency band corresponding to the high channels (No. 4 –No. 12) it operates as a wide band isolator.

According to the present invention a plurality of the circuits as explained above may be connected in cascade, in which case an isolator device having very low forward direction attenuation and having a sufficiently high backward loss can be realized.

FIG. 5 shows frequency characteristics of transmission loss of a conventional device as shown in FIG. 1 in comparison with a device according to the present invention which will be explained in more detail by referring to FIG. 8. Both of the devices are designed for the operational frequency range of VHF television broadcasting channels, for instance, use in

Japan. In FIG. 5, full curve A corresponds to characteristics of the device according to the invention and dotted curve B corresponds to the conventional device. In the figure, forward loss shows attenuation characteristics for the transmission from an antenna to a receiver. As shown in the curves, the conventional device has a maximum attenuation point around 140 to 150 MHz. in the forward loss direction and by the influence of this attenuation has an increased insertion loss around the frequency range of No. 4 channel (171.25 MHZ). On the contrary, the device according to the present invention has much lower insertion loss, for instance, from DC range up to 1,000 MHz. Therefore, a great improvement of the invention may be realized by this comparison of the characteristic curves.

The backward loss shows characteristics for the transmission from receiver side to the common feeder of antenna in order to avoid a leakage of spurious signal in the desired frequency range.

FIG. 6 shows an application of the isolator device of the present invention, in which the receiving common feeder is a balanced type. In this case, two balance to unbalance transformers 27 and 28 may be inserted at the input side and output side of the device according to the invention.

FIGS. 7*a* to 7*c* show an embodiment of the invention in which the balance to unbalance transformers can be eliminated. FIG. 7*a* shows a practical construction of the embodiment, and FIG. 7*b* shows the electric circuit thereof. As shown in these figures two circulators 29 and 30 having the same operating characteristics in nonreciprocal manner in the desired frequency range are connected in push-pull. A two-terminal series resonant circuit 24 resonating at the center frequency of the operational frequency of the circulators 29 and 30 is connected between the outer conductor terminals 31 and 32 in order to widen the operational frequency range, and a series connection of an absorption resistor 26 and a network 25 which passes the signals in the nonreciprocal operational frequency range and blocks the signals in the outside of said range is connected between the terminals 33 and 34 of the two circulators 29 and 30.

In FIG. 7*a* , the input terminal 21 and the output terminal 22 shown in FIG. 7*b* are not shown in order to simplify the drawing, and hatched lines of FIG. 7*a* show the outer conductors each having terminals leads 31 and 32.

This isolator circuit may be expressed as an equivalent circuit shown in FIG. 7*c* As shown in this figure the circuit is constructed as a symmetrical circuit with the zero equipotential point for high frequency as the center of symmetry, and both circulators are operated in push-pull. As the detailed operation of this isolator is the same as that explained above no further explanation will be required for understanding it. This construction needs no balance to unbalance transformers, so that the transmission efficiency may be improved to an extent corresponding to the amount of the insertion loss.

FIG. 8 shows another embodiment of the invention in which the series circuit of the absorbing resistor 26 and the network 25 inserted between a circulator terminal and the ground conductor is replaced by only the absorbing resistor 26 which is connected between the circulator terminal and the outer conductor.

FIGS. 9 to 11 show an embodiment of a circulator suitable for use in the isolator device according to the present invention in order to improve the characteristics and the productivity.

It is already known to use a lumped element type circulator in order to miniaturize the size of a circulator.

A known lumped element type circulator has a construction in that the inner conductors led from each of the terminals are made to form a coil configuration wound around the ferrite plate or that the inner conductors led from each of the terminals are divided into a plurality of conductors and these conductors are intersected to form mesh pattern while insulating each other on the ferrite plate.

The above known construction has disadvantages in that it is not suitable for mass production since in the manufacturing process several manual steps are required. Thus decreasing the manufacturing cost is not easy and also a uniformity of the characteristics is difficult to obtain.

The above-mentioned disadvantages may be solved by the use of a lumped element type circulator in which the inner conductors are made by printing on a base of thin insulator film. The exampled of this construction will be explained.

FIG. 9 shows one embodiment of such construction of a circulator in the detached form. In FIG. 9, 35 is a printed base which is also shown in FIGS. 10*a* to 11*b*, the details of which will be explained later. Printed base 35 is sandwiched between ferrite plates in a sandwiched manner of that printed 36 and 37. 38 and 39 are the conductive films applied at the outside of the ferrite plates 36 and 37 by vaporization or other suitable methods. The ferrite plates are secured to sandwich the printed base 35, so that each end of meshed type intersecting conductors 40, 41 and 42 make contact with each of the extended ends 43 (not shown), 44, 45, 43', 44' and 45' of the outer conductors 38 and 39, each end of said conductors being joined by soldering.

FIG. 10*a* shows a pattern of the printed base 35 in which 46 is a thin insulated film and the top surface of the same three pieces of parallel conductors 47, 48 and 49 are printed as shown by full line in the drawing. One the rear side of the thin insulated film base 46 three pieces of parallel conductors 47', 48' and 49' are printed at a location as shown by the dotted lines. These conductors on the top side of the film and the rear side of the film are connected by a through hole soldering as shown in FIG. 10*b*. Terminals of the circulator are connected to the inner conductor which is placed at a location opposite to the position of extended portions of the outer conductor film.

By employing such pattern of inner conductors the function of the lumped element type circulator may be improved. Each piece of conductor connected to each terminal is insulated from each other and intersects to form a mesh or a lattice with high balancing accuracy.

FIGS. 11*a* and 11*b* show another embodiment of the pattern of the printed inner conductors.

As seen from these figures conductor pieces having the shape shown in FIGS. 11*a* and 11*b* on the front and rear sides of an insulating thin film are connected by through hole soldering between piece of conductors 53 and 53', 54 and 54', 55 and 55', 56 and 56', 57 and 57', 58 and 58', 59 and 59', 60 and 60', 61 and 61', 62 and 62', and 63 and 63' and 64 and 64'.

Also it is possible to enlarge the portion of conductor pieces at a location of the overlapping portion to equivalently inset a static capacity between the pieces.

In order to apply the isolator device of the invention to UHF broadcasting channels, which exists in close succession and in which a separation of the lower channels and the higher channels explained before with respect to VHF broadcasting channels is impossible, a plurality of isolator units according to the present invention may be connected in cascade.

FIG. 12 shows a circuit diagram of cascade connection of two isolator circuits. In this figure 65 and 66 are two isolator units according to the invention having circulators 67 and 68, respectively, wherein the operating frequency ranges of the two circulators are slightly deviated from each other. In this embodiment the spurious waves which may appear at the receiver terminal 71 may be absorbed by either of absorbing resistors 69 and 70 over the wide frequency range. Alternatively, the absorbing resistor is connected between the circulator terminal and the ground conductor as shown in figure 2.

FIG. 13 shows a transmission characteristic of a wide band isolator device, in which four isolator units are connected in cascade in order to function in nonreciprocal performance from VHF 50 MHz. to 300 MHz.

As may be clearly understood by the foregoing explanation the isolator device of the present invention may afford a great advantage not only to improve the facility of the circulator itself to decrease the insertion loss over a very wide frequency range extending at outside of the operational range but very simple and miniaturized construction compared with the conventional device may be obtained. Moreover, by employing printed circuit techniques for the inner conductors of the circulator the uniformity of the characteristic of the isolator is much improved. Therefore the manufacturing and the adjustment may easily be effected, so that the productivity is much improved and mass production of the devices may become very easy; also an advantage of a low manufacturing cost may eventually be obtained.

The present inventive isolator device may conveniently be applied to a branching unit for a common antenna television receiving system but the utility is not limited and it is suitable for all applications in the usual communications field for use as an isolator device.

What is claimed is:

1. An isolator comprising a circulator mounted on a ground conductor having an outer conductor, at least one inner conductor having a central coupling portion and a plurality of end portions each extending from corresponding terminals located at the periphery of the circulator and at least one ferrite element loaded at the central coupling portion, the outer conductor being insulated from the ground conductor with respect to high frequency energy, a two-terminal network being series resonant at center frequency of the operational frequency range of the circulator and connected between the outer conductor and the ground conductor, and an absorbing resistor connected between one of the circulator terminals and the ground conductor, wherein the other of said plurality of circulator terminals and the ground conductor comprise input and output terminals of the isolator.

2. An isolator as claimed in claim 1, further comprising a network which passes signals in the operational frequency range of the circulator with low attenuation and having a high impedance which is nearly equivalent to open impedance for signals having frequencies outside of the operational frequency range, which network is connected in series with the absorbing resistor.

3. An isolator as claimed in claim 1, wherein the circulator is constructed as a lumped element type circulator of which inner conductors are formed by printed circuits printed on an insulator base to form meshed configuration.

4. An isolator comprising a circulator mounted on a ground conductor having an outer conductor, at least one inner conductor having a central coupling portion and a plurality of end portions each extending from corresponding terminals located at the periphery of the circulator and at least one ferrite element loaded at the central coupling portion, the outer conductor being insulated from the ground conductor with respect to high frequency energy, a two-terminal network being series resonant at center frequency of the operational frequency range of the circulator and connected between the outer conductor and the ground conductor, and an absorbing resistor connected between one of said plurality of circulator terminals and the outer conductor , wherein the other of said plurality of circulator terminals and the ground conductor comprise input and output terminals of the isolator.

5. An isolator as claimed in claim 4, wherein the circulator is constructed as a lumped element type circulator of which inner conductors are formed by printed circuits printed on an insulator base to form meshed configuration.

6. A balanced type isolator device comprising two circulators, each having an outer conductor, at least one inner conductor having a central coupling portion and a plurality of end portions each extending from corresponding terminals located at the periphery of the circulator and at least one ferrite element loaded at the central coupling portion, a two-terminal network being series resonant at center frequency of operational frequency range of the circulators and connected between the outer conductors of the two circulators, and an absorbing resistor connected between one of the terminals of each circulator, wherein the other of said plurality of circulator terminals of each circulator comprises input and output terminals for the isolator device.

7. A balanced type isolator device as claimed in claim 6, further comprising a network which passes signals in the operational frequency range of the circulator with low attenuation and having a high impedance for signals having frequencies outside of the operational frequency range, which network is connected in series with said absorbing resistor.

8. A balanced type isolator device as claimed in claim 6, wherein each of the circulators is constructed as a lumped element type circulator of which inner conductors as formed by printed circuits printed on an insulator base to form meshed configuration.

9. A wide band isolator device comprising a plurality of isolator devices connected in cascade, each having a different operational frequency range and mounted on a common ground plate, wherein each of said isolator devices includes a circulator having an outer conductor insulated from a ground conductor with respect to high frequency energy, a two-terminal network being series resonant at a center frequency of operational frequency range of the relevant circulator and connected between the outer conductor of said relevant circulator and the ground conductor thereof, and an absorbing resistor connected between one of the circulator terminals and the outer conductor of said relevant circulator, wherein the other of the circulator terminals and the ground conductor comprise input and output terminals for the cascade connection in each of the isolator devices.

10. A wide band isolator device comprising a plurality of isolator devices connected in cascade, each having a different operational frequency range and mounted on a common ground plate, wherein each of said isolator devices includes a circulator having an outer conductor insulated from a ground conductor with respect to high frequency energy, a two-terminal network being series resonant at a center frequency of operational frequency range of the relevant circulator and connected between the outer conductor of said relevant circulator and the ground conductor thereof, and an absorbing resistor connected between one of the circulator terminals and the ground conductors of said relevant circulator, wherein the other of the circulator terminals and the ground conductor comprise input and output terminals for the cascade connection in each of the isolator devices.