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(71) Applicant: Hitachi Metals, Ltd.
1-2, Marunouchi, 2-chome Chiyoda-ku
Tokyo(JP)

(72) Inventor: Takeda, Shigeru
787-16, Ohaza-Jurokken
Kumagaya-Shi Saitama-Ken(JP)

(72) Inventor: Kawashima, Masaharu
450, Ohaza-Niborishinden
Kumagaya-Shi Saitama-Ken(JP)

(74) Representative: von Füner, Alexander, Dr. et al,
Patentanwälte Schiff, von Füner Strehl, Schübel-Hopf,
Ebbinghaus, Finck Mariahilfplatz 2 u. 3
D-8000 München 90(DE)

(54) Microwave ferrite component.

(57) A microwave ferrite component comprises one or two ferrite cores (18) enclosed by a shield plate (20), at least one central conductor (19) extending through the shield plate (20) and the ferrite core (18). This arrangement is disposed approximately at the center of, and in close contact with, an element (16) of soft magnetic material or an earth plate (17) mounted on the soft magnetic material (16). A permanent magnet (21) optionally provided with magnetic field and flux-regulating pieces on either side is disposed above or upon the shield plate (20) enclosing the ferrite core (18) and central conductor (19). A DC magnetic field is applied to the ferrite core (18). This microwave ferrite component may be used for a 30° circulator-isolator operating at 800 MHz under high electric power.

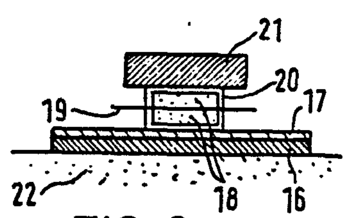

FIG. 6

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Microwave Ferrite Component

The present invention relates to a microwave ferrite component employable in VHF, UHF and microwave bands.

Microwave ferrite components, for example a circulator-isolator which forms an important part of a microwave apparatus, are used widely in the microwave technical field for the purposes of producing transistors for handling large electric power, of matching between different circuit stages, of eliminating undesirable radiation, etc.

In general, microwave ferrite components have become popular by the application of DC magnetic field. Furthermore, the performance of microwave ferrite components is largely developed with the manner of applying said DC magnetic field. For example, in regard to a microwave ferrite component as one of the most important parts of a microwave apparatus, i.e. a circulator-isolator, it is not too much to say that the insertion loss, the band width, the electrical power reistance, the dimensions of all components, etc. may be determined by the application of DC magnetic field.

However, since other microwave components have recently miniaturized very much, the volume of microwave ferrite components compared to the total volume of microwave apparatus has become rather remarkable. For example, there are certain apparatus in which the volume share of the microwave ferrite component exceeds 50 %. On the other hand, the cost of microwave ferrite components has reached a considerable proportion relative to the total cost of microwave apparatus. That is why miniaturization and cost reduction of microwave ferrite components are being more and more demanded.

The structure of a conventional microwave component is, for example, such a shown in Fig. 1, wherein two permanent magnets 3a and 3b are mounted at upper and lower portions in a housing 1 to play both roles of constituting a magnetic circuit and an electric field, while in the central space a ferrite core 6 and a central conductor 7 are enclosed by a shield plate 5 and mounted on an earth table 4. The upper permanent magnet 3b can be moved by an adjustment screw 2 so that the magnet field applied to the ferrite core 5 may be finely controlled. However, this sort of structure has some drawbacks, for example, that the magnetic field is uneven and unsatisfactory because of large insertion loss, that an adjustment screw for fine control of magnetic field is necessary and that the heat radiation can be only smoothly effected. As long as relying on such a structure of microwave ferrite component, we cannot enhance its miniaturization, cost reduction or high efficiency.

From this standpoint, a convenient structure of magnetic circuit was considered in which, as shown in Fig. 2, a permanent magnet 9 is mounted near the center of a metal plate 8, and then a central conductor 13 and at least one ferrite core 12 enclosed by a shield plate 11 are disposed on said permanent magnet 9. This microwave ferrite component structure was excellent in view of miniaturization, cost reduction and improvement of electric power resistance, as compared to the conventional structure shown in Fig. 1. After then, however, it was found that this structure had a drawback that it was difficult to find out the desirable conditions for simultaneously obtaining satisfactory band width and preventing insertion loss because the distribution of magnetic field was inferior in the zone around the ferrite core. In other words, as shown in Fig. 3 the intensity of magnetic field decreases rapidly along the central axis of the permanent magnet 9 in the direction away from the surface of the permanent magnet.

In Fig. 3 where a ferrite material of 12.5ϕ x 20t in dimensions is employed for the permanent magnet, such a large magnet field variation as about 64×10^3 A/m is found for a thickness of about 3.0 mm of the ferrite core. Accordingly this ferrite core structure may permit the thickness of the ferrite core 12 to be reduced extremely or the diameter of the permanent magnet 9 to be enlarged in order to improve the distribution of the magnetic field. However, the thinning of the ferrite core involves a loss of electric power resistance, while the enlargement of the diameter of the permanent magnet prevents miniaturization. Since the ununiformity of magnet field distribution deteriorates a microwave ferrite component in its band width and its insertion loss, this drawback must be remedied by some means.

The object of the present invention is to propose a small-sized, high-efficient and low-cost microwave ferrite component which can enhance the conventional technical limit and can withstand high electric power.

In order to achieve the mentioned object, a circulator-isolator of the present invention is characterized in that an earth plate is placed in close contact on a soft magnet material, and a shield plate containing both at least one ferrite core and at least one central conductor is placed in close contact on the center of said earth plate.

Hereafter the present invention is elucidated in detail referring to the attached drawings. In the drawing:-

Fig. 1 (referred to above) is a schematic cross-sectional view of a conventional microwave ferrite component,

Fig. 2 (referred to above) is a schematic cross-sectional view of an earlier technique proposed by the present applicants,

Fig. 3 (referred to above) is a diagram for the intensity of magnetic field measured with the structure of Fig. 2,

Fig. 4 is a construction diagram for the principle of the present invention,

Fig. 5 is a measurement diagram for the intensity of magnetic field for the present invention,

Fig. 6 is a cross-sectional view for the basic construction of the present invention,

Fig. 7 is a cross-sectional view for a realization example to improve the temperature characteristic in the present invention,

Figs. 8 to 19 are aspects or cross-sectional views for certain realization examples to improve the construction method or characteristics of the microwave ferrite component of the present invention,

Fig. 20 is a diagram of electric characteristics of microwave ferrite component of the present invention realized with a rare earth-alloyed magnet having an $_{I}Hc$ value of about 640×10^3 A/m,

Figs. 21 and 22 are schematic cross-sectional views of an example applied to realize a strip line joint type circulator, and

Figs. 23 to 28 are schematic cross-sectional views of certain realization examples of the magnet field-regulation according to the present invention.

The magnetic circuit shown in Fig. 4 is so constructed that a permanent magnet 15 is disposed above a soft magnetic material 14. This soft magnetic material 14 is prepared from an iron plate 1.0 mm thick and the permanent magnet 15 is prepared of a rare earth-alloyed magnet of $12.5\phi \times 2.0t$. The iron plate is spaced about 3.5 mm from the rare earth-alloyed magnet.

The microwave ferrite component of the present invention is prepared with such a form that a ferrite core is inserted in the gap between said iron plate 14 and said rare -earth alloyed magnet 15. Fig. 5 shows the measurement results of the axial distribution of the magnetic field in the center of said gap. Comparing with Fig. 3 for the earlier proposal, it is evident that the variation of magnetic field strength is about 8 to 16 x 10^3 A/m which is considerably less, and so the uniformity of magnetic field is much improved.

Fig. 6 is a cross-sectional view representing a first example of the present invention. An earth plate 17 is placed in close contact on a soft magnetic material 16 (iron plate of 30 mm x 30 mm x 2 mm) and fastened solidly or with an eyelet. Alternatively a shield plate 20 containing two ferrite cores 18 of round disc type and three reticulate central conductors 19 is attached by solder to the approximate center of the upper part of said earth plate 17. In addition, a permanent magnet 21 (rare-earth alloyed magnet of 18ϕ × 25t) is tightly attached by adhesive, etc. to the upper part of said ferrite core 18 through the shield plate 20.

The mentioned structure was employed to prepare a circulator-isolator of broad band concentration constant count type for 30° and a band of 800 MHz. It is evident by comparing the mentioned structure (Fig. 6) of the present invention with the structure of conventional technique (Fig. 1) that not only a permanent magnet is saved but also a case 1 of complicate shape and a screw 2 for adjusting the magnetic field are replaced by a soft magnetic plate 16. It is obvious that this means a simplification in structure.

In order to combine the temperature characteristic of the ferrite core 18 with the temperature characteristic of the permanent magnet 21 for the present invention and to improve the temperature characteristic of entire microwave ferrite component, a magnetic regulating material 23 is effectively placed on the permanent magnet 21 (Fig. 7).

In the present example of realization, a magnetic regulating material 23 having a Curie point of 50°C is so designed that the small temperature coefficient of the rare-earth alloyed magnet, i.e. 0.05%/°C, may be enhanced to nearly the temperature coefficient of the ferrite core, i.e. 0.3%/°C, as close as possible. The application of this system could realize a circulator-isolator of broad band concentration constant count type for an 800 MHz band which can work stably within a broad temperature range from -30 to +80°C.

When the microwave ferrite component of the present invention which is constructed as mentioned above is exposed to high electric power, the heat generated from the ferrite core 18 flows through the soft magnetic material 16 by the shortest way into a radiator plate 22 such as an aluminum table so that the temperature difference between the ferrite core 18 and other parts becomes small, and so the behaviour under high electric power is much stabilized. In the case of employing a metal magnet such as a rare earth-alloyed magnet having a small thermal resistance as the permanent magnet 9 similarly to the present realization example, the magnet itself has a heat-radiating effect so that the thermal resisting effect is more remarkable.

It is noted that the coils, condensers and the like for regulation which are necessary to the performance of circulator are omitted in Fig. 6. When the present realization example was applied to a circulator for a band of 800 MHz and 30°, the circulator was not only miniaturized by reducing the thickness to less than about 0.5 mm, but also the material cost was reduced to about 2/3. This fact proves the excellent effect of the present invention.

Figs. 8 to 11 show other realization examples for the present invention. In the realization example shown in Fig. 6, since the permanent magnet 21 is fixed only with adhesive, there is a danger that the magnet may come off and drop after a long time because of vibration, heat or other factors. In the present realization example, in order to remedy this drawback, a part of the field plate is employed to fix the permanent magnet.

As shown in Figs. 8 and 9, elbows 24a, 24b and 24c protrude upwards from the periphery of a shield plate 24 to grip around the permanent magnet 21. In this case, adhesive material is employed to fasten the permanent magnet. Fig. 9 is a cross-sectional view of the example shown in Fig. 8.

In order further to ensure this grip, a metal plate 25 can be added to fasten the permanent magnet 21 by soldering, etc. as shown in Fig. 10. If desired, a magnetic field-regulating material 26 may be inserted under this metal plate 25 to improve the temperature characteristic. If a magnetic regulating material is employed to prepare said metal plate 25, a single plate of magnetic regulating material can meet with both said functions.

In order to enhance reliability, said metal plate 25 may be provided with three through holes 25a, 25b and 25c as shown in Fig. 11, through which said L-shaped elbows 24a, 24b and 24c are passed and then bent to fasten themselves, thus realizing a very reliable microwave ferrite component.

Other examples of realization for the present invention are shown in Figs. 12 and 13. The structure as shown in Fig. 6 has a disadvantage that the shield plate 20 containing both ferrite cores 18 and the central conductor 19, after having been finished, must be fastened onto the earth plate 17 by soldering, etc. This manner of preparation requires not only many processes but also two shield plates, while the permanent magnet 21 is too distant from the soft magnetic material 16 to have a desirable structure for the characteristic of the microwave component.

The present invention, therefore, may take the structure of Fig. 12 to overcome said difficulties. In Fig. 12, the part of shield plate 27 in contact with earth plate 28 is omitted, and the shield plate is combined with the earth plate 28.

Fig. 13 shows the process for combining the shield plate 27 with the earth plate 28. The earth plate 28 is mounted with L -fixtures 29 for gripping the ferrite core 18 with its central conductor 19. The shield plate 27 prepared of a single plate covers the ferrite core 18 from above and is soldered to the vertical fingers of the L-fixtures 29. This sort of structure works with a single shield plate 27 instead of the two shield plates 20 required in the structure of Fig. 6. It has the further advantage of shortening the process steps of construction. On the other hand, because the space between the permanent magnet 21 and the soft magnetic material 16 can be reduced by the thickness of shield plate 20, both the distribution of magnetic shield and the characteristic of circulator-isolator are improved.

Fig. 14 is a schematic assembly view of an isolator for 30°, 800 MHz according to the present invention.

In Fig. 14, numerals 30a and 30b denote terminals of strip line, 31 a condenser, 32 a coil, 33 a printed wiring plate, 34a and 34b earth terminals incorporated with an earth plate 36, 37 a dummy of a flat plate type for high electric power, 38 and 39 fixtures incorporated with the earth plate 36, 40 an insulating material and 41 a hole for mounting the isolator.

Figs. 15 and 16 are aspects of a realization example of a soft magnetic material for use in said isolator. In this structure, the part 16 of soft magnetic material corresponding to the terminals of strip line in the schematic view of the isolator for 30° 800 MHz band as shown in Fig. 14 is provided with notches 42 (Fig. 15) or portions 43 of reduced thickness clearance (Fig. 16) to interrupt the short circuit of the strip line terminals

30a and 30b with the soft magnetic material 16. Also holses 44 for mounting the isolator are provided.

Furthermore, in the example of realization of Fig. 14, as more clearly shown in Figs. 17 and 18, the earth plate 36 is mounted with the fixtures 38 and 39, the fixture 38 being bent to thrust the dummy 37 against the soft magnetic material 16 through the insulator 40. The fixture 39 is employed to ground one terminal of the dummy of flat plate type and to fasten the same simultaneously.

In the isolator constructed as above mentioned according to the present invention, the dummy load 37 is disposed on the soft magnetic material 16. The dummy load 37 employed in the present realization example is a resistor of flat plate type for high electric power and pasted on one side of an aluminum magnetic plate with a resistor membrane.

In order to mount the dummy load, the surface opposite the membrane surface is bonded to the metal plate 16 with a heat sinker, etc. so as to enhance the thermal conductivity. Since this structure permits the heat generated from the dummy load 37 by the absorption of reverse electric power to flow directly to the soft magnetic material 16 and then to the heat radiation plate 22, considerable electric power can be absorbed. An isolator with the soft magnetic material 16 employed in the experiment of the present realization example and dimensioned at 30° for 800 MHz band, could work steadily for a long time even when having absorbed a reflection electric power of about 30 W. Now that the conventional dummy load of 30 W class was placed outside and separately from the circulator, it is evident that an isolator of the present invention containing a dummy for high electric power may greatly reduce the volume share of entire microwave apparatus.

In addition, it is evident from Fig. 14 that another difficulty of the present invention is the exposure of the coil 32 and the condenser 31 for regulation.

This exposure occasionally may cause the operator to touch the coil 32 by mistake to deform it thus changing its electric characteristics. In addition, the coil 32 is exposed occasionally to interact with circuits other than the circulator-isolator.

In order to solve this problem, it was additionally tried to mount such a casing as denoted with numeral 143 in Fig. 19. This casing may be prepared from metal, non-metal, ferromagnetic material or nonmagnetic material, but was prepared from copper in the present realization example to achieve both objects of protection in handling and of electric interruption.

The above-mentioned structure of microwave ferrite component has one more difficulty. This difficulty is that the structure has no mechanism for fine adjustment of the magnetic field as shown in the conventional structure of Fig. 1 and should be replaced by some other means.

One method of fine regulation of the magnetic field according to the present invention is to demagnetize the permanent magnet 21 by another electromagnet, etc. A permanent magnet 21 for use to this purpose is required as follows: The magnet must be easy magnetizable (first requirement) or must be stably maintained in magnetized condition against heat or other external disturbances (second requirement). A magnet of minimum coercive force ${}_{I}Hc$ is desirable for the first requirement, while a magnet of maximum coercive force is desirable for the second requirement. For example, a certain sort of rare earth-alloyed magnet having a particular stability has a coercive force of more than 2.4×10^6 A/m, though some sorts of electromagnets are hardly demagnetizable. According to the structure of Fig. 6 for the present invention, the upper limit of coercive force ${}_{I}Hc$ should be determined from the fact that it must be a permanent magnet for a coercive force less than the magnetic field obtained with a broadly usable electromagnet. Though the intensity of magnetic field for a broadly usable electromagnet depends on its dimensions, this intensity has a limit of 2×10^6 A/m for such dimensions that an ordinary microwave ferrite component manufacturer can possess. An apparatus which can generate a magnetic field stronger than this limit will be extremely complicate in its usage and also extraordinarily expensive in its installation cost.

The coercive force of a magnetizable and demagnetizable permanent magnet of this sort may be as follows: The permeance for the magnetic circuit of Fig. 6 will be approximately unity, though it depends on the thickness of the permanent magnet. In the case of employing a permanent magnet of rare earth-alloyed type of the alnico type having a large value of saturation magnetic flux intensity, the intensity of demagnetizing field is at a level of 0.4×10^6 A/m. In the case of employing a permanent magnet of a coercive force larger than this value, the demagnetization will be very difficult to control and the productivity will be reduced very much.

From these reasons, it is evident that the upper limit of the coervice force of a permanent magnet according to the present invention should be 1.6×10^6 A/m.

On the other hand, the stability of a permanent magnet or the stability of microwave ferrite component is very important for the lower limit. Especially, since the structure of Fig. 6 according to the present invention is an open magnet circuit and is employed under condition of lower permeance, it must work under different conditions. In the present realization example, magnets of the ferrite group of lower coercive force were investigated to obtain the following value of the lower limit for $_{I}Hc$. For our investigation, a ferrite magnet of such dimensions that the permeance may be at a level of 4.0 was employed. Since the intensity of saturation magnetic flux of the ferrite magnet is approximately 0.32×10^6 A/m, the intensity of demagnetizing field in the magnetic circuit of Fig. 6 is approximately 80 x 10^3 A/m. Accordingly, the magnetized condition at ambient temperature can be stabilized with an $_I$Hc value at least 80 x 10^3 A/m, but this value of $_I$Hc is insufficient for the stability in the presence of external disturbance such as the temperature variation or the access of other ferromagnetic material. This is because the intensity of saturation magnetic flux of the ferrite magnet or the intensity of the demagnetizing field increases at a rate of 0.2%/$^{\circ}$C as the temperature falls, and the coercive force decreases at a rate of 0.4%/$^{\circ}$C. Since the value of $_I$Hc at ambient temperature should be at least 160 x 10^3 A/m, this value may be the lower limit for the present invention.

In another realization example, a rare earth-alloyed magnet of about 0.64 x 10^6 A/m in $_I$Hc value was employed. The present microwave ferrite component, however, is free from instability against external disturbance or from irreversible changes by heat or by access of another ferromagnetic material, thus presenting an excellent performance. This proves that the effect of the present invention is remarkable.

Fig. 20 indicates the electric characteristics of a circulator of the concentration constant value type for the 800 MHz band having the structure of the present invention in the case of employing a rare earth-alloyed magnet of about 0.64 x 10^6 A/m in $_I$Hc value. It was revealed that VSWR was less than 1.2, the isolation loss more than 20 dB and the insertion loss less than 0.6 dB in a broad range from 800 - 900 MHz, these characteristics being sufficient for high performance of the circulator.

While the circulator of the concentration constant value type for 30° as above-mentioned was subjected to electric power of 40 W, the temperature rise in every part of the circulator was measured with an infrared thermometer. The temperature rise of the conventional ferrite core amounted to as much as 10 to 20°C higher than that of the environment. The temperature rise in the circulator of the structure according to the present invention was only 0 to 10°C, i.e. substantially the same as that of the environment.

It is evident that the arrangement of a ferrite core between a soft magnetic material and a permanent magnet, and the employment of permanent magnet whose coercive force resides within a range from 0.16 to 1.6 x 10^6 A/m, these requirements according to the construction of the present invention, are necessary or applicable not only to a circulator of the concentration constant value type of the described realization example but also to a circulator of the distribution constant value type. Fig. 21 shows the system of the present invention applied to the strip line circulator of the joint type, while Fig. 22 shows the system of the present invention applied to the circulator of the waveguide type, wherein numeral 18 denotes a ferrite core, 36 an earth conductor, 19 a central conductor, 144 a waveguide, 21 a permanent magnet and 16 a soft magnet material.

Fig. 23 shows another realization example for fine adjustment of the magnetic field according to the present invention. A ferrite core 18 provided with a central conductor 19 is enveloped with a shield plate 20, and a permanent magnet 21 is mounted on a soft magnetic material 45 arranged above said core 18. Said soft magnetic material 45 is bonded to the permanent magnet 21 with adhesive, etc. Since this structure permits the soft magnetic material to absorb the magnetic flux, the magnetic field is so uniformly distributed that the electric symmetry is excellent to provide a microwave ferrite component substantially free from insertion loss. The regulation of the magnet field in the present invention is easily achieved by the control of dimensions such as diameter and thickness of the soft magnetic material.

The permeance of the employed magnet is increased by bonding the soft magnetic material to the permanent magnet. It is advantageous that even a material having the tendency of low temperature demagnetization such as a ferrite magnet can work steadily.

When a through hole is disposed around the center of the employed soft magnetic material, the working effect of the present invention is enhanced, because the distribution of magnetic field is regulated to become more uniform.

Fig. 24 is a schematic cross-sectional view elucidating another realization example of the present invention. In the drawing, numeral 19 denotes a central conductor, 18 a ferrite core shielded outside electrically with a shield material 20 and held by the central conductor 19, said ferrite core 18 being mounted to the substantial center of a soft magnetic material 16 by a suitable means, for example, solder or adhesive and, if desired, through an earth plate 17. A permanent magnet 21 is mounted to the other side of the ferrite core 18 through a magnetic flux-regulating material 46, and a magnetic field-regulating soft magnetic material 47 is disposed on the surface of the magnet 21 opposite the plane facing the soft magnetic material 16.

In the microwave ferrite component of the present realization example constructed as above mentioned, the DC magnetic field applied to the ferrite core 18 by the magnet 21 is extensively homogenized in the presence of the magnetic field regulating material 47 and also works to compensate the temperature variation of the magnetic flux generated from the magnet 21. Especially the latter effect is enchanced in the presence of the magnetic field regulating soft magnetic material 47.

On the other hand, the permeance of the magnetic circuit is enlarged in the presence of the magnetic field regulating material 46 and the soft magnetic material 47, while the temperature characteristic, particularly the characteristic at lower temperature, is improved. Furthermore, in the present realization example, since the magnetic field is finely regulated by controlling the thickness of the soft magnetic material 47, the position of permanent magnet is never changed by vibration or other different effects of the conventional technique, and the stability of the magnetic field after completion of the regulation is excellent.

Fig. 25 is a schematic cross-sectional view elucidating another realization example of the present invention. In Fig. 25, numeral 19 denotes a central conductor, 18 a ferrite core shielded outside electrically with a shield material 20 and held by the central conductor 19, said ferrite core 18 being mounted to the substantial center of a soft magnetic material 16 by a suitable means, for example, solder or adhesive and, if desired, through an earth plate 17. A permanent magnet 21 is mounted to the other side of ferrite core 18 through a magnetic flux-regulating nonmagnetic material 48. In the present realization example, since the fine regulation of magnetic field is effected by controlling the thickness of non-magnetic material 48, the position of permanent magnet is never shifted even under the influence of vibration, etc., contrary to the conventional technique, and thus an excellent stability of the magnetic field is obtained after completion of the regulating process.

Fig. 26 is a schematic cross-sectional view elucidating another realization example of the present invention. In Fig. 25, a soft magnetic disc 49 is attached onto the magnet 21 with adhesive, etc., and the mounting point of said iron disc 49 is so shifted that the intensity of the magnetic shield may be controlled. Iron discs of different dimensions were employed, though other soft magnetic pieces may be employed.

The soft magnetic piece is not required to be a disc but may have different shapes. In this manner, the diameter and thickness of iron disc 49 were changed in so many ways that the intensity of magnetic field applied to the ferrite core 18 could be changed. At lower temperatures, a permanent magnet is generally demagnetized, though a soft magnetic material piece can be attached to a permanent magnet according to the present invention so that the magnet may have a high permeance and becomes difficult to demagnetize.

Fig. 27 is a schematic cross-sectional view elucidating a further realization example of the present invention. In Fig. 27, numeral 18 denotes a ferrite core holding a central conductor 19 and being shielded outside with a shielding material 20. This ferrite core 18 is fastened to the approximate center of a soft magnetic material 16 by a suitable means such as solder or adhesive, etc. and, if desired, through an earth plate 17. A permanent magnet 21 is mounted on the other side of ferrite core 18 through a soft magnetic material 50, and a magnetic field-regulating soft magnetic material 51 is disposed on the surface of the magnet 21 opposite the plane facing the soft magnetic material 16.

In a microwave ferrite component of the present invention constructed as above mentioned, the DC magnetic field applied to the ferrite core 18 by the magnet 21 is extensively homogenized in the presence of the magnetic field-regulating materials 47, 51, so that a microwave ferrite component excellent in electric symmetry may be obtained. Furthermore in the present invention, the permeance of the magnetic circuit is enhanced by the presence of the soft magnetic materials 50, 51, and the temperature characteristic, particularly the lower temperature characteristic, is improved. Also in the present invention, since the magnetic field is finely regulated by controlling the thickness of soft magnetic material 51 and the dimensions such as diameter, etc., the position of the permanent magnet is never shifted even under the influence of vibration, etc. contrary to the conventional technique. Thus an excellent stability of the magnetic field is obtained after completion of the regulating process.

Fig. 28 is a schematic cross-sectional view elucidating a realization example of the present invention. In Fig. 28, numeral 18 denotes a ferrite core holding a central conductor 19 and being shielded outside with a shielding material 20. This ferrite core 18 is fastened to the approximate center of a soft magnetic material 16 by a suitable means such as solder or adhesive, etc. and, if desired, through an earth plate 17. A permanent magnet 21 is mounted on the other side of the ferrite core 20 through a soft magnetic material 52, and a magnetic field regulating soft magnetic material 53 is disposed on the surface of the magnet 21 opposite the plane facing the soft magnetic material 16. Furthermore a magnetic field-regulating material 54 is wound annully about said permanent magnet 21.

In a microwave ferrite component of the present invention constructed as above mentioned, the DC magnetic field applied to the ferrite core 18 by the magnet 21 is extensively homogenized in the presence of the magnetic field-regulating materials 52, 53, so that a microwave ferrite component excellent in electric symmetry may be obtained. Also in the present invention, the presence of the soft magnetic materials 52, 53 and the magnetic field-regulating material 54 permits this material 54 to work in parallel with the magnetic circuit and enhance the permeance of the magnetic circuit, thus improving the temperature characteristic, particularly the lower temperature characteristic. Also in the present invention, since the magnetic field is finely regulated by controlling the thickness of the soft magnetic material 53, the position of the permanent magnet is never shifted even under the influence of vibration etc. contrary to the conventional technique. Thus an excellent stability of the magnetic field is assured after completion of the regulating process.

In the microwave ferrite components of the present invention as shown in Figs. 23 to 28, the actual regulation of the magnetic field assures excellent workability when several magnetic materials of different shapes and techniques are prepared and an optimal magnetic material is selected among them. Moreover, with the construction of magnetic circuit and system of magnetic field-regulation according to the present invention, certain conventional parts such as a casing of complicate shape can be saved so that the apparatus may be miniaturized. For example, a 30° circulator could be miniaturized to about half size comparing with the conventional circulator.

As described hereinbefore, the microwave ferrite component of the present invention is not only miniaturized and prepared at reduced cost but also excellent in electric symmetry and thermal stability. According to such minaturization, the apparatus may be installed in automobiles, airplanes and artificial satellites, and may develop new application fields. Its industrial effects will be extensive.

Patent Claims:

1. A microwave ferrite component characterized in that a shield plate (20) enclosing at least one ferrite core (18) and at least one central conductor (19) is placed on the approximate center of a soft magnetic material (16) or an earth plate (17) mounted thereon in close contact therewith, and a permanent magnet (21) or a magnet assembly with at least one side fastened with a permanent magnet is disposed above said shield plate (20), and in that said component is so constructed and adapted as to apply a DC magnetic field to said ferrite core (18). (Fig. 6)

2. A microwave ferrite component as set forth in claim 1, characterized in that said permanent magnet (21), said ferrite core (18), said central conductor (19) and said shield plate (2o) are covered with a casing (143) from above. (Fig. 19)

3. A microwave ferrite component as set forth in claim 1 or 2, characterized in that a part of said shield plate (27) is combined with an earth plate (28). (Figs. 12, 13)

4. A microwave ferrite component as set forth in any of claims 1 to 3, characterized in that said permanent magnet (21) is fixed with fixtures (24a, 24b, 24c) protruded from said shield plate (24). (Figs. 8 - 11)

5. A microwave ferrite component as set forth in any of claims 1 to 4, characterized in that said soft magnetic material (16) is provided with notches (42) or portions (43) of reduced thickness to prevent short circuit between said soft magnetic material (16) and terminals (30, 34). (Figs. 14 to 16)

6. A microwave ferrite component as set forth in any of claims 1 to 5, characterized in that a flat resistor is employed as a dummy load (37). (Figs. 14, 18, 19)

7. A microwave ferrite component as set forth in claim 6, characterized in that said earth plate (36) is employed to fix said flat resistor (37). (Figs. 14, 17 to 19)

8. A microwave ferrite component as set forth in claim 7, characterized in that the plane of dummy membrane (37) is in close contact with said soft magnetic material (16) or earth plate (36). (Figs. 17 to 19)

9. A microwave ferrite component as set forth in any of claims 1 to 8, characterized in that said permanent magnet (21) has a range of coercive force $_{I}Hc$ from 0.16 to 1.6×10^6 A/m.

10. A microwave ferrite component as set forth in any of claims 1 to 9, characterized in that a soft magnetic material (47) effective as said magnetic material is disposed on the side of said permanent magnet (21) opposite the ferrite core (18).(Fig. 24)

11. A microwave ferrite component as set forth in any of claims 1 to 9, characterized in that a magnetic field-regulating material (47; 41; 53) effective as said magnetic material is disposed on the side of the permanent magnet (21) opposite the ferrite core (18). (Figs. 24, 27, 28)

12. A microwave ferrite component as set forth in any of claims 1 to 9, characterized in that a nonmagnetic material (48) in place of said magnetic material is disposed between said permanent magnet (21) and ferrite core (18). (Fig. 25)

13. A microwave ferrite component as set forth in claim 1, characterized in that a soft magnetic material (45) for said magnetic material is disposed on the side of the permanent magnet (21(facing the ferrite core (18). (Fig. 23)

14. A microwave ferrite component as set forth in any of claims 1 to 9, characterized in that a magnetic field-regulating material (45; 46) effective as said magnetic material is disposed on the side of the permanent magnet (21) facing the ferrite core (18). Figs. 23, 24)

15. A microwave ferrite component as set forth in any of claims 1 to 9, characterized in that soft magnetic materials (52, 53) for said magnetic material are disposed on both sides of said permanent magnet (21). (Fig. 28)

16. A microwave ferrite component as set forth in claim 10, 13 or 15, characterized in that a magnetic field-regulating material (54) of ring form is disposed round said permanent magnet (21). (Fig. 28)

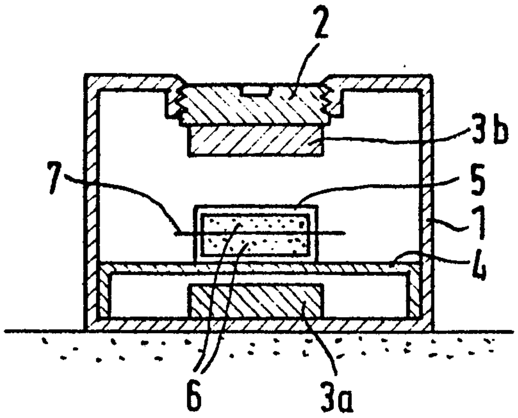

FIG. 1

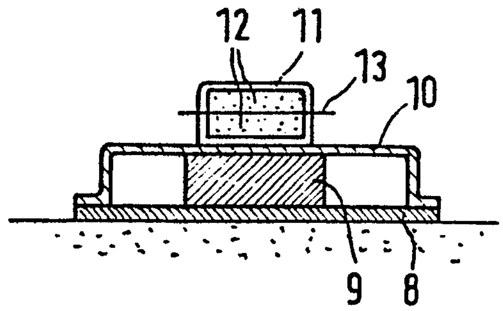

FIG. 2

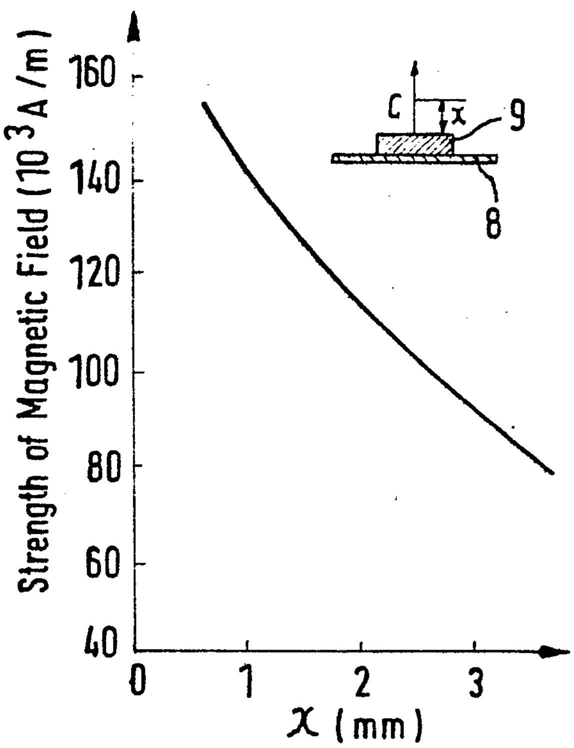

FIG. 3

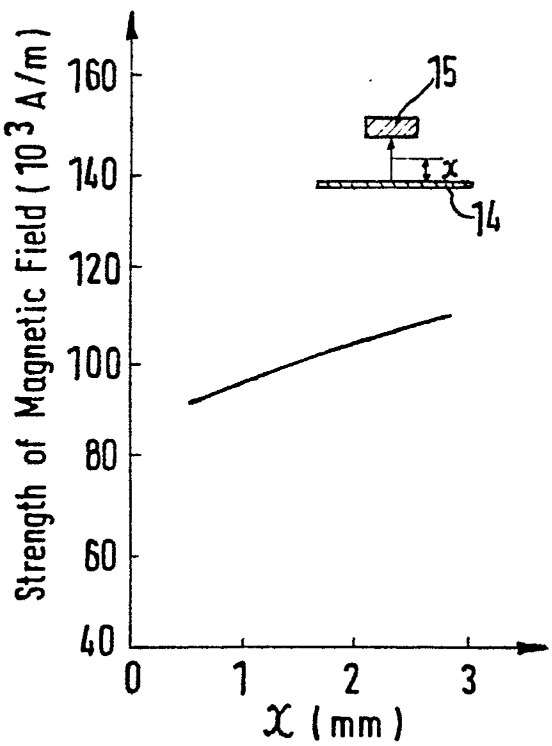

FIG. 5

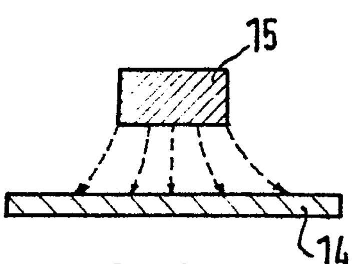

FIG. 4

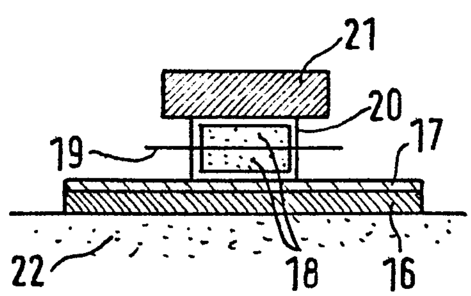

FIG. 6

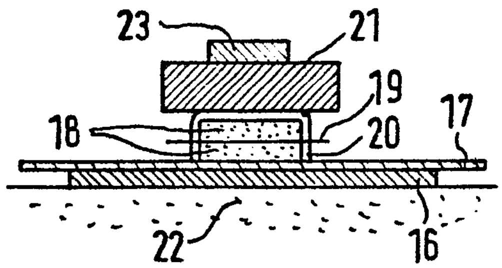

FIG. 7

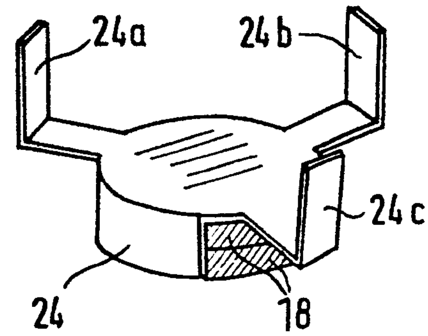

FIG. 8

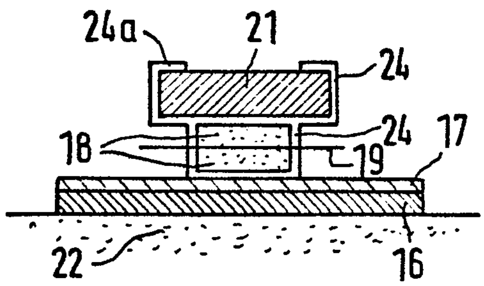

FIG. 9

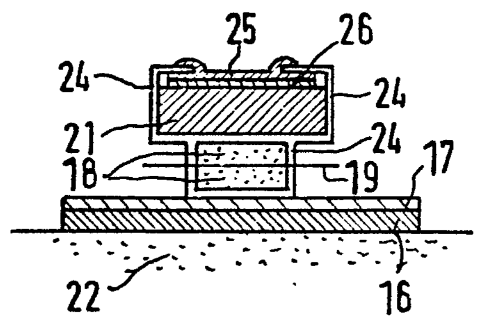

FIG. 10

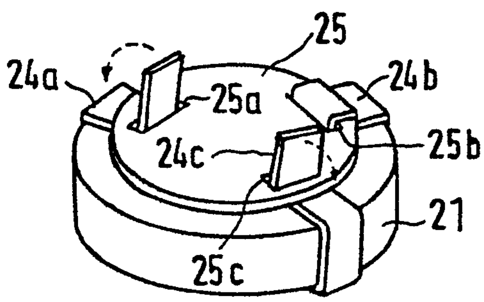

FIG. 11

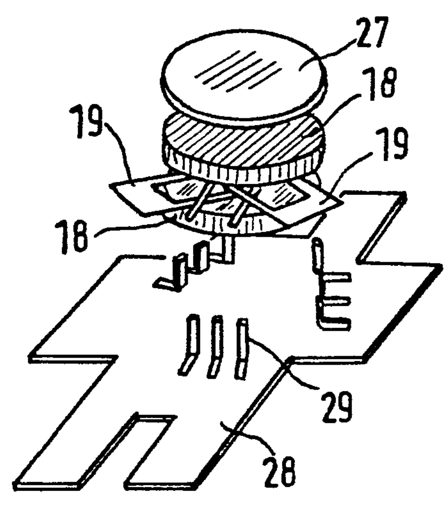

FIG. 13

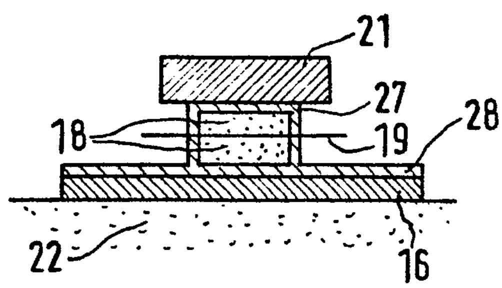

FIG. 12

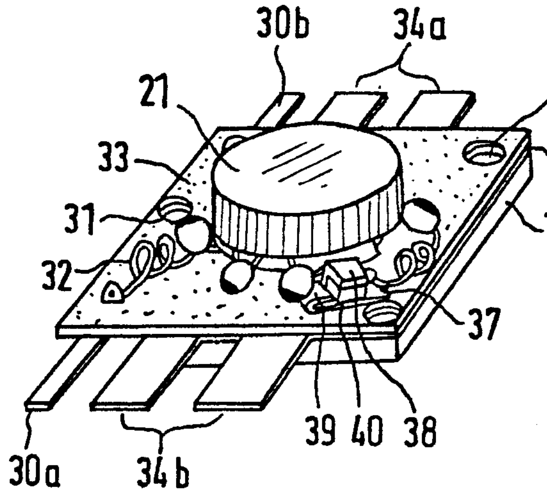

FIG. 14

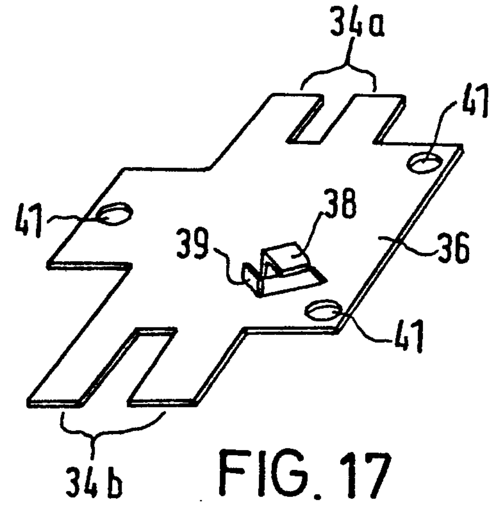

FIG. 17

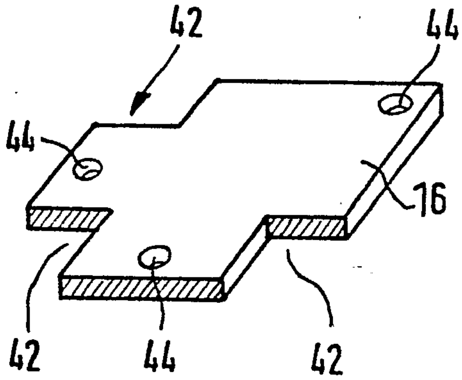

FIG. 15

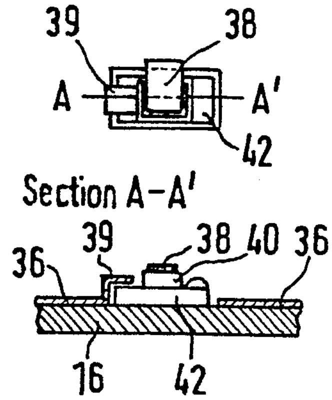

FIG. 18

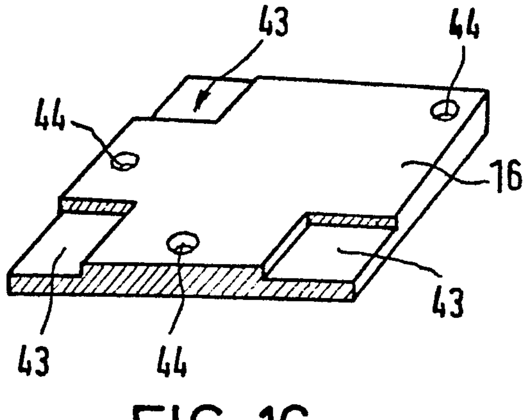

FIG. 16

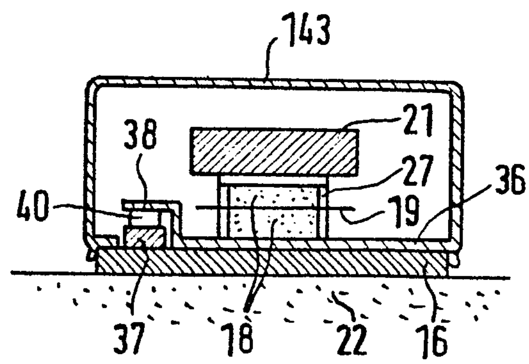

FIG. 19

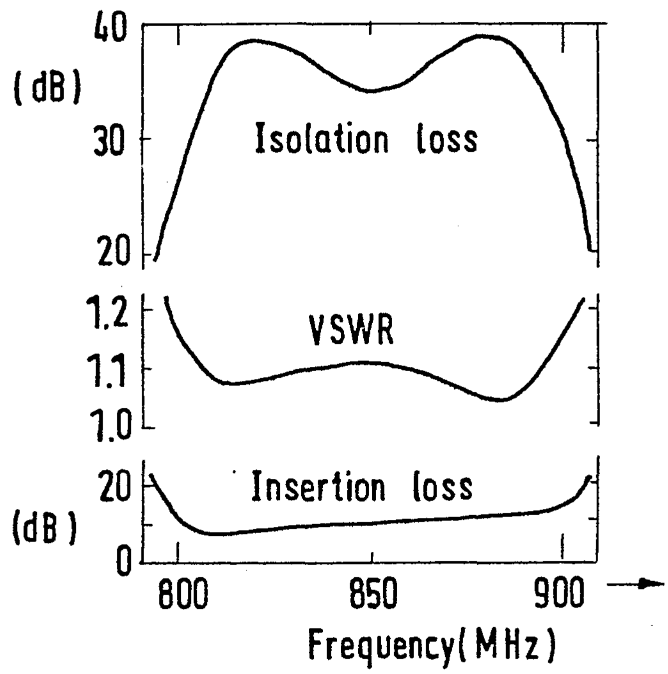

FIG. 20

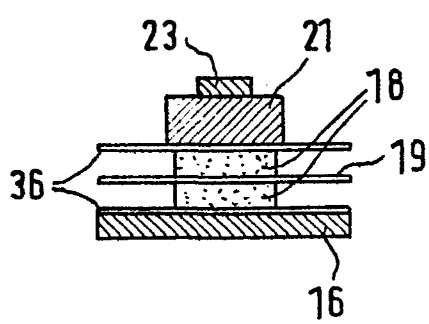

FIG. 21

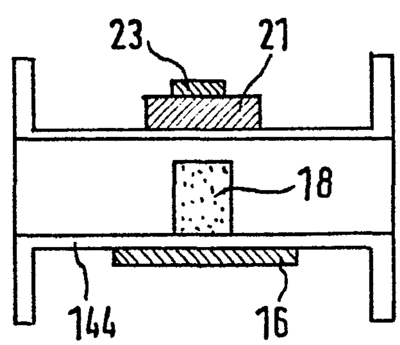

FIG. 22

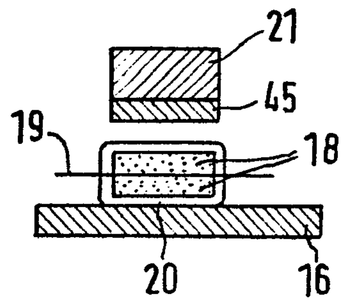

FIG. 23

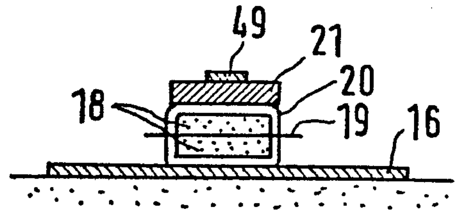

FIG. 26

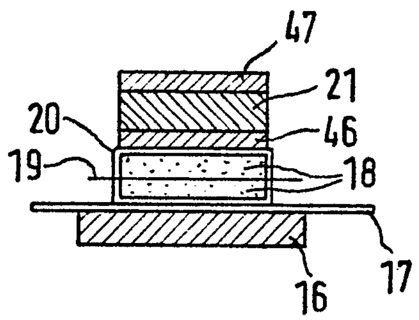

FIG. 24

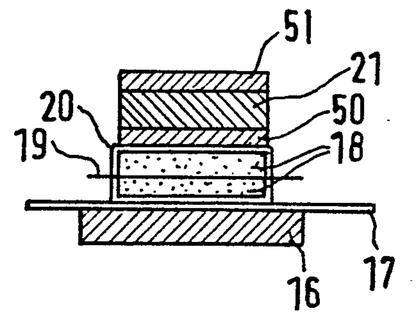

FIG. 27

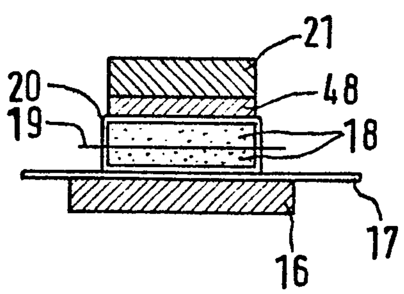

FIG. 25

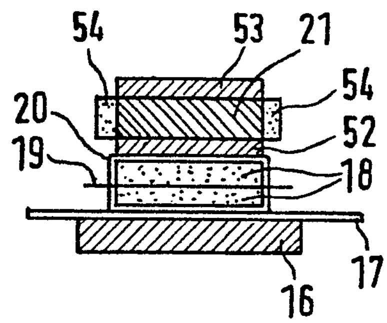

FIG. 28

0005801

Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 79 10 1597

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	US - A - 3 621 476 (NAOHIKO KANBAYASHI) * the whole document * --	1-3,5
A	FR - A - 1 518 671 (MOTOROLA) * page 2, right-hand column, line 23, to page 3, right-hand column, line 12; the figures * --	1-3, 5-8, 10, 13, 15
A	US - A - 3 739 302 (J.W. Mc ANUS) * abstract; figures 1,3 and 4 * --	1-3, 5-8, 10, 13, 15
	DE - B - 1 282 754 (SIEMENS) * column 5, lines 15 to 68; figure 3 * --	10, 13-15
	DE - A - 2 226 509 (PHILIPS) * page 7, ligne 6 to page 8, line 9; the figure * --	10, 13-15
	FR - A - 2 204 986 (SIEMENS) * page 3, line 32 to page 4, line 38; figure 1 * --	10, 13, 15, 16
	DE - B - 1 280 354 (TELEFUNKEN) * column 3, lines 1 to 9; figure 2 * --	10, 16
A	THE MICROWAVE JOURNAL, volume 2, no. 2, February 1959, HORIZON HOUSE, DEDHAM (US) G. WHEELER et al.: "Temperature Compensation of Ferrite Isolators", pages 31 to 32 * the whole document * --	11, 14, 16
A	NACHRICHTENTECHNISCHE ZEITSCHRIFT NTZ, vol. 22, no. 3, March 1969	11, 14, 16 ./.

CLASSIFICATION OF THE APPLICATION (Int. Cl.²)

H 01 P 1/32

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

H 01 P 1/32

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	17-07-1979	LAUGEL

European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 79 10 1597

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.²)
	BERLIN (DE) B. WIESER: "Resonanzrichtungsleitung mit konzentrierten Bauelementen für 230 MHz" pages 160 to 161 * the whole document * --		
A	FR - A - 2 152 461 (RADIALL) * page 7, lines 2 to 11; the figures * ----	12	
			TECHNICAL FIELDS SEARCHED (Int. Cl.²)