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Description

This invention relates to ceramic filters comprising two or more transmission line resonators of the coaxial type.

It is known that a ceramic resonator comprises a basic structure, in which a hole is made in a ceramic block of a material with a high dielectric constant, e.g. titanate, the block having side surfaces, a top surface and a bottom surface, and the hole extending from the top surface to the bottom surface. The surfaces of the block are coated, except for the top surface, with an electrically conducting material. Circuit patterns are applied to the top surface, the circuits capacitively coupling a signal to the resonator and outputting the signal. The structure forms a transmission line resonator whose resonant frequency is determined by the length of the hole, i.e. by the thickness of the block. Usually the length of the hole is dimensioned so that a transmission line resonator of a quarter-wave length is obtained.

When several holes are made in the block it is possible to realize a band-pass filter with several nodes, but the number of zeros is limited to one, because it is difficult to isolate from the other resonators a resonator corresponding to a zero.

Band-stop filters using ceramic technology became commercially available only recently. It is characteristic to all these known band-stop filters, that the filter is composed of separate resonators and a desired number of these coated separate resonator blocks are arranged in a row, whereby a band-stop filter is obtained with a desired bandwidth and center frequency. In a sense each resonator block forms a draining circuit, and these draining circuits are then coupled in a series through inductive or reactive circuits, connecting the upper ends of the resonators using e.g. a separate transmission line length. It is necessary to use separate resonators coated on the outside, because otherwise the mutual inductive and capacitive leaks between the resonators are difficult to control, i.e. in order to obtain sufficient isolation between the resonators. The isolation between the separate resonators is formed with the same coating, which forms an effective partition between the blocks.

Duplex filters are commonly used in radio transceivers which have a common antenna. Such filters comprise two individual band-pass filters, one being connected in the receiving branch and having a center frequency and a bandwidth corresponding to the receiving band, the other filter being connected in the transmission branch and having a center frequency and a bandwidth corresponding to the transmission band. Often the other ends of the filters are connected through a transmission line to the common antenna line. While the duplex filter often is located in a common housing with interfaces for the transmitter, the receiver and the antenna, in practice however it will be formed by two individual band-pass filters, because a very high isolation between the filters must be obtained so that their mutual electromagnetic leaks do not interfere with the operation.

These filters are made so that first the transmission branch band-pass filter and the receiving branch band-pass filter are made separately, each thus having interfaces for the antenna and for the receiver/transmitter. The ceramic bodies of both filters are coated with a conductive layer on the side surfaces and on the bottom surface. The finished filters are soldered onto a common support, that may be a board, a frame, or the like. At the same time the ceramic bodies are mutually fixed by soldering at the end faces. Soldering is possible, because the outer surfaces of the ceramic bodies are coated. The antenna interfaces are joined into one interface, and so a duplex filter is obtained, virtually comprising a single block.

A disadvantage of all these filters assembled of separate blocks is that a filter made of many blocks requires a high production capacity, because every block is separately sintered and coated, and the blocks are electrically individually connected to each other, usually by soldering the connecting wires by hand. Further the separate blocks must be fastened to some mounting support in a mechanically reliable way. The electrical and mechanical connection of the blocks is a cumbersome and slow operation. In other words, the production capacity must be doubled compared to a situation where it would be possible to make the whole filter in a single ceramic block.

US patent 4,823,098, Motorola, describes a monolithic ceramic filter with band-stop characteristics. The filter comprises seven resonators located in the same ceramic block, of which three operate as a band-stop filter and the other as a band-pass filter. The resonators in the band-stop section are interconnected via quarter-wave transmission lines. The transmission lines invert the impedance of the resonators, so that the resonators generate zeros in the filter. It is stated in the publication, that by sawing it is possible to separate said three filters from the block and to coat the new side wall obtained in the cutting with conducting material, whereby the obtained filter operates as an independent band-stop filter with several zeros. It is not mentioned in the publication what influence the inductive coupling between the resonators, effected through the ceramics, has on the filter characteristic, but it seems probable that mutual coupling between the resonators makes it difficult to control the characteristics.

European patent application 90110834.0 of the present, applicants LK-Products Oy, describe band-pass filters realized in a single ceramic block, where the basis of the inventive idea is that one side surface of the filter is substantially uncoated and that strip conductor patterns are applied on this side surface in order to have the connections to the transmission line resonators. When the circuit patterns are made on the side surface of the body, the filter input and output and the connections between the resonators can be made in a desired way, either purely capacitive or inductive, or as a combination of these. It is also possible to connect block components and inductance wires to the circuit patterns of this side surface, which act on the resonators and on their mutual coupling. This side surface is finally covered with a conductive cover, whereby the ceramic block is entirely enclosed by conductive material.

According to the present invention there is provided a filter comprising a body of dielectric material having at least two holes extending from a top to a bottom surface of the body; a conductive layer covering the major portion of the body and the interiors of the holes, except for one of the side faces of the body which is substantially uncoated so as to form at least two transmission line resonators; and an electrically conductive electrode pattern provided on the uncoated side of the body for providing electrical signal coupling to and from the resonators characterized in that at least one conductive region is provided on the uncoated side, the region extending between the top and bottom surfaces of the body between two of the at least two resonators and whereby the two resonators separated by said region are substantially electrically and magnetically isolated from each other. This provides many advantages. It is not necessary to assemble the band-stop filter from separately coated resonator blocks, but a single ceramic body may be used. This saves both processing steps and material.

A mechanically strong filter is also obtained.

The invention will now be described, by way of example only, with reference to the accompanying drawings of which:

Figure 1 shows a band-stop filter according to a first embodiment of the invention comprising three resonators,

Figure 2 shows in a simplified view the filter of Figure 1, where the conducting areas have been modified, and

Figure 3 shows the attenuation curve of the resonator in Figure 1.

Figure 4 which shows a duplex filter according to a second embodiment of the invention.

The invention is based on the development of the resonator circuits described in the above mentioned European patent application.

Unexpectedly it was found that by making, in a suitable way, a conducting area i.e., a coating on the surface of the uncoated side between the resonator circuits of a ceramic filter block, the electric and magnetic coupling between the resonators can be adjusted close to zero. When this conducting area is made in the form of a strip extending from the ceramic block bottom surface, where it is in contact with the conducting coating of the block, up to the upper surface of the side, an almost perfect electric and magnetic isolation is obtained between the resonators. The conducting areas according to the invention provide in a sense an electric "partition" between the resonators.

A band-stop filter 1 according to a first embodiment the invention comprises three transmission line resonators A, B and C. A bar-like block of ceramic material is provided with holes 2_1, 2_2 and 2_3 extending from the top surface 3 to the bottom surface of the block. The holes, the bottom surface, the ends, and one side of the block are coated with conducting material, e.g. with a silver-copper compound. The top surface 3 can also be coated, except for a narrow annular area around the upper edge of the holes 2_1, 2_2 and 2_3. A circuit pattern 5 is applied with the aid of a mask on the uncoated side 4 of the block, the pattern including a strip around the edge of the uncoated side 4. Contact points 9, 10 and 11 are also applied using the mask to the side 4 of each resonator. Conducting areas 14 and 15, located between the resonators, are made with the same mask, the areas extending from the block bottom edge, where they join the strip extending along the bottom edge of the side 4, to the top edge of the block, where they join the strip extending along the top edge of the side 4. The circuit pattern formed with the mask is shown by hatching. The end surface of the block, being one of the coated surfaces, is also shown by hatching. To the circuit pattern are connected the required components and wires for the coupling of signals to the filter, for interconnection of the resonators, and for outputting the signal from the filter. The high frequency signal is input with wire IN to the connection point 9 at the middle of resonator A. A block capacitor 6 is connected between this point 9 and the conducting strip at the bottom edge of the side 4. The signal is coupled from resonator A via the connecting wire 12 to the connection point 10 of second resonator B, which is also connected to the strip at the bottom edge of the uncoated side 4 of the side through a block capacitor 7. The connecting wire 12 represents a defined inductance. In a corresponding way the resonator B is connected to the resonator C with a wire 13 representing an inductance, and the connection point 11 is connected to the strip at the bottom edge of the uncoated side 4 through a block capacitor 8. The signal is then outputted from the point 11 and out from the filter 1 along the conductor OUT. In order to have the circuit operating as a band-stop filter there must be no coupling through the dielectric material between resonators A, B and C, only through the connecting wires 12 and 13. This is possible only in that the conducting areas 14 and 15 are located between the resonators in the way shown in the Figure. As discussed above, it has been found these conducting areas 14,15 can cause the inductive and capacitive coupling between the resonators to be almost completely canceled, whereby there is formed an almost ideal electric "partition" between the resonators. This enables the circuit to operate as a band-stop filter having a defined stop-band. The bandwidth and the center frequency are determined by the circuit pattern made with the mask, and by the concentrated inductances and capacitances, so that it is possible to obtain a desired band-stop filter by varying these.

When the circuit pattern has been applied and the components fastened, the side of the block is covered with a metallic protecting cover, so that a small gap is left between the cover and the side surface.

For some purposes it may be necessary to decrease the isolation between the resonators. It is possible to make an "opening" in the partition, by which opening a coupling can be provided between the resonators, and this can be made by shortening or narrowing the conducting area, or both. Depending on whether the shortening is made at the open end or at the short circuited end of the resonator, this will have an effect on either the capacitive or on the inductive coupling. When the conducting area is narrowed in the direction of the resonator it is possible to influence the strength of the coupling between the resonators. Coupling can be effected in this way as illustrated Figure 2. In this Figure the same reference numerals are used as in Figure 1, but for simplicity the individual coupling means are omitted. The coupling between the resonators can be increased in that the conducting area between the resonators is shortened, as in the area 14 between the resonators A and B, or the conducting area is narrowed, as is made in the area 15 between the resonators B and C. It is also possible to use a combination of these.

Figure 3 shows the actual measured attenuation curve for a band-stop filter manufactured according to the invention in a single ceramic block. The realized filter is particularly intended to attenuate the frequency band 890 - 915 MHz, which is the transmission bandwidth of the European digital mobile phone system known as GSM, the filter being suited e.g. for use in the receiving branch in connection with the antenna filter. The curve I, being an attenuation curve, shows that the attenuation is high, more than 40 dB between the markers 1 and 2 constituting said frequency band, and thereafter the attenuation rapidly approaches zero. This is advantageous in that the transmitter frequency will not reach the receiver. The curve II shows the matching of the filter.

A duplex filter 100 according to a second embodiment the invention is based on a single monolithic ceramic block 103 with parallel holes R1, R2, R3, R4 and T1, T2, T3 extending from the top surface 102 to the bottom surface. All surfaces of the block, except the top surface 102 and the side 105 shown in Figure 4, are entirely coated with an electrically conductive material 104. The internal walls of the holes R1-R4;T1-T3 are also coated, these coatings joining the coating on the bottom. Thus in a known way seven transmission line resonators are formed. The interface to the resonators is accomplished by providing circuit patterns on the uncoated side 105 using a mask, the circuit patterns being formed by conductive areas having a defined shape. These circuit patterns form for example the conductive areas illustrated in the Figure 4 by hatching, the areas having conductive strips 107 at the top of uncoated side 105 and conductive strips 106 at the bottom of uncoated side 105. The pattern includes contact points, 111,113,115,117 where connections are made for the signal wire ANT to the antenna, for the conductor Rx to the receiver and for the conductor Tx to the transmitter. When needed, block components can also be used; for example the antenna contact point 113 may be connected not only to the transmission line, but also through the block capacitor 108 to the conductive strip 106 at the bottom edge of side 105. These circuit patterns are only intended to illustrate the use of circuit patterns on the uncoated side 105 of the ceramic block. Their number, size, and characteristics, and the possible discrete components, will vary according to the characteristics which are desired for the filter.

As with the band-stop filter, the duplex filter is manufactured using a mask in accordance with the method described in more detail in the above mentioned European Patent Application, as is the coupling between the resonators and thus it is not necessary to describe in further detail the provision of the patterns with the aid of a mask.

A conductive strip 109 extends from the conductive strip 106 at the lower edge of the side 105 to the conductive strip 107 at the upper edge of the side 105, and which is located exactly between the resonators R4 and T1. As described above, this strip 109 causes the capacitive and the inductive coupling to cancel each other out, in other words the coupling between the resonators will be almost zero. In a sense an "electric partition" is formed between the resonators. Due to this two separate filters are formed in the same monolithic ceramic block: the filter D comprising the resonators R1, R2, R3, R4, and the filter E, comprising the resonators T1, T2, T3. Filter D is the band-pass filter of the receiver branch, and filter E is the band-pass filter of the transmitter branch. While these filters are on the same ceramic block, they do not interfere with each others operation, because the electric partition provides an almost complete isolation between them. The only connection between them is the jumper connection 110 between points 113 and 115 that connects the transmitter branch filter to the antenna interface. As with the first embodiment, finally the side 105 containing the circuit patterns and the interfaces, is covered with a conductive cover, whereby the ceramic block is substantially entirely enclosed by a conductive layer.

Earlier it was mentioned that the conductive area providing the electrical partition is a continuous strip extending from the lower surface of the side to the upper surface, the width of which has an influence of the separation provided by the electric partition, and thus it is possible to obtain a desired value of coupling between the resonators by varying its width. However, this is not the only alternative. The conductive strip could have an interruption, a non-conductive area of a defined length as described in connection with the first embodiment. This interruption is preferably closer to the lower edge of the side 105, where the inductive coupling is at its highest. The interruption enables the realization of the strip 109 as a strip line directly on the wall surface. This interruption also has an effect on the coupling between adjacent resonators R4 and T1 of the filters D and E. Thus within the scope of the claims it is possible to adjust the coupling by varying the form of the conductive area and its discontinuities.

In view of the foregoing description, it will be evident to a person skilled in the art that modifications may be made within the scope of the claims.

Claims

1. A filter (1,100) comprising
a body of dielectric material having at least two holes (2,R,T) extending from a top surface (3,102) to a bottom surface of the body;
a conductive layer (104) covering the major portion of the body and the interiors of the holes, except for one of the side faces (4,105) of the body which is substantially uncoated, so as to form at least two transmission line resonators; and
an electrically conductive electrode pattern provided on the uncoated side of the body for providing electrical signal coupling to and from the resonators
characterized in that at least one conductive region (14,15,109) is provided on the uncoated side, the region extending between the top and bottom surfaces of the body between two of the at least two resonators such that the two resonators separated by said region are substantially electrically and magnetically isolated from each other.

2. A filter according to claim 1, wherein the uncoated side is provided with conductive strips (5,106,107) at its edges adjacent the top and bottom surfaces the conductive region being connected at each of its ends to said strips.

3. A filter according to claim 1 or claim 2, wherein the conductive region has a discontinuity therein to provide some magnetic and electric coupling between the two resonators.

4. A filter according to claim 1 or claim 2, wherein the conducting region has a width such that some magnetic and electric coupling between the two resonators is provided.

5. A filter according to claim 1 or claim 2, wherein the conducting region has a dimension and shape such that the magnetic and the electric coupling between the resonators is substantially zero.

6. A filter according to any preceding claim including a metallic outer cover.

7. A filter according to any preceding claim wherein the filter is a band-stop filter (1) comprising at least two resonators (A,B,C) in which a conducting region is provided between each hole.

8. A filter according to claim 7 wherein inductive coupling is provided between each resonator by coupling means (12,13) bridging said conducting regions.

9. A filter according to claim 7 or claim 8 wherein capacative coupling (6,7,8) is provided between each resonator and the lower conducting strip.

10. A filter according to any of claims 1 to 6 wherein the filter is a duplex filter (100) comprising at least one resonator (R) forming a first branch (D) of the duplex filter and at least one resonator (T) forming a second branch (E) of the duplex filter, said conductive region being provided between said first and second branches to provide substantial electric and magnetic isolation therebetween.

Patentansprüche

1. Filter (1, 100), enthaltend:
   - einen Körper aus dielektrischem Material mit wenigstens zwei Löchern (2, R, T), die sich von einer oberen Fläche (3, 102) bis zu einer Bodenfläche des Körpers erstrecken;
   - eine leitende Schicht (104), die im wesentlichen den Körper und das Innere der Löcher bedeckt mit Ausnahme einer der Seitenflächen (4, 105) des Körpers, die im wesentlichen unbedeckt ist. um auf diese Weise wenigstens zwei Übertragungsleitungsresonatoren zu erhalten; und
   - ein elektrisch leitendes Elektrodenmuster

auf der unbedeckten Seite des Körpers, um elektrische Signale in die Resonatoren ein- oder aus diesen auskoppeln zu können,

dadurch gekennzeichnet, daß auf der unbedeckten Seite wenigstens ein leitender Bereich (14, 15, 109) vorhanden ist, der sich zwischen der oberen Fläche und der Bodenfläche des Körpers sowie zwischen zwei der wenigstens zwei Resonatoren erstreckt, derart, daß die beiden durch diesen Bereich getrennten Resonatoren in hohem Maße elektrisch und magnetisch gegeneinander isoliert sind.

2. Filter nach Anspruch 1, **dadurch gekennzeichnet**, daß die unbedeckte Seite an ihren der oberen Fläche und der Bodenfläche benachbarten Rändern mit leitenden Streifen (5, 106, 107) versehen und der leitende Bereich mit jedem seiner Enden mit diesen Streifen verbunden ist.

3. Filter nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, daß der leitende Bereich eine Diskontinuität aufweist, um eine gewisse magnetische und elektrische Kopplung zwischen den beiden Resonatoren zu erhalten.

4. Filter nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, daß der leitende Bereich eine solche Breite aufweist, daß eine gewisse magnetische und elektrische Kopplung zwischen den beiden Resonatoren erhalten wird.

5. Filter nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, daß der leitende Bereich eine solche Abmessung und Form aufweist, daß die magnetische und die elektrische Kopplung zwischen den Resonatoren im wesentlichen Null ist.

6. Filter nach einem der vorhergehenden Ansprüche mit einer metallischen äußeren Abdeckung.

7. Filter nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß es als Bandsperrfilter (1) mit wenigstens zwei Resonatoren (A, B, C) ausgebildet ist, wobei ein leitender Bereich zwischen jedem Loch vorhanden ist.

8. Filter nach Anspruch 7, **dadurch gekennzeichnet**, daß eine induktive Kopplung zwischen jedem Resonator durch Kopplungsmittel (12, 13) erhalten wird, die die leitenden Bereiche überbrücken.

9. Filter nach Anspruch 7 oder 8, **dadurch gekennzeichnet**, daß eine kapazitive Kopplung (6, 7, 8) zwischen jedem Resonator und dem unteren leitenden Streifen vorhanden ist.

10. Filter nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet**, daß das Filter ein Duplexfilter (100) mit wenigstens einem Resonator (R), der einen ersten Zweig (D) des Duplexfilters bildet, und wenigstens einem Resonator (T), der einen zweiten Zweig (E) des Duplexfilters bildet, ist, wobei der leitende Bereich zwischen dem ersten und dem zweiten Zweig vorhanden ist, um beide Zweige in hohem Maße elektrisch und magnetisch gegeneinander zu isolieren.

Revendications

1. Filtre (1, 100) comprenant

un corps de matériau diélectrique ayant au moins deux trous (2, R, T) s'étendant d'une surface supérieure (3, 102) jusqu'à une surface inférieure du corps ;

une couche conductrice (104) recouvrant la partie principale du corps et les intérieurs de trous, sauf pour une des faces latérales (4, 105) du corps qui est pratiquement non revêtu, de façon à former au moins deux résonateurs de ligne de transmission ; et

un motif d'électrode électriquement conducteur placé sur le côté non revêtu du corps pour assurer le couplage du signal électrique vers les résonateurs et depuis les résonateurs.

caractérisé en ce qu'au moins une région conductrice (14, 15, 109) est prévue sur le côté non revêtu, la région se trouvant entre les surfaces supérieure et inférieure du corps entre deux des au moins deux résonateurs de sorte que les deux résonateurs séparés par lesdites régions sont isolés pratiquement électriquement et magnétiquement l'un de l'autre.

2. Filtre selon la revendication 1, dans lequel le côté non revêtu est muni de bandes conductrices (5, 106, 107) à ses bords adjacents aux surfaces supérieure et inférieure, les régions conductrices étant connectées à chacune de ses extrémités aux dites bandes.

3. Filtre selon la revendication 1 ou la revendication 2, dans lequel la région conductrice présente une discontinuité dans celle-ci afin de procurer un certain couplage magnétique et électrique entre les deux résonateurs.

4. Filtre selon la revendication 1 ou la revendication 2, dans lequel la région conductrice présente une certaine largeur de sorte qu'un certain couplage magnétique et électrique entre les deux résonateurs est assuré.

5. Filtre selon la revendication 1 ou la revendication

2, dans lequel la région conductrice présente une certaine dimension et forme de sorte que le couplage magnétique et électrique entre les résonateurs est pratiquement nul.

6. Filtre selon l'une quelconque des revendications précédentes, incluant un couvercle extérieur métallique.

7. Filtre selon l'une quelconque des revendications précédentes, dans lequel le filtre est un filtre coupe-bande (1) comprenant au moins deux résonateurs (A, B, C) dans lequel la région conductrice est prévue entre chaque trous.

8. Filtre selon la revendication 7, dans lequel le couplage inductif est assuré entre chaque résonateur par des moyens de couplage (12, 13) pontant lesdites régions conductrices.

9. Filtre selon la revendication 7 ou la revendication 8, dans lequel le couplage capacitif (6, 7, 8) est assuré entre chaque résonateur et la bande de conduction inférieure.

10. Filtre selon l'une quelconque des revendications 1 à 6, dans lequel le filtre est un filtre duplex (100) comprenant au moins un résonateur (R) formant une première branche (D) du filtre duplex et au moins un résonateur (T) formant une seconde branche (E) du filtre duplex, ladite région conductrice étant placée entre lesdites première et seconde branches afin d'assurer un isolement presque total électrique et magnétique entre cellesci.

Fig.1.

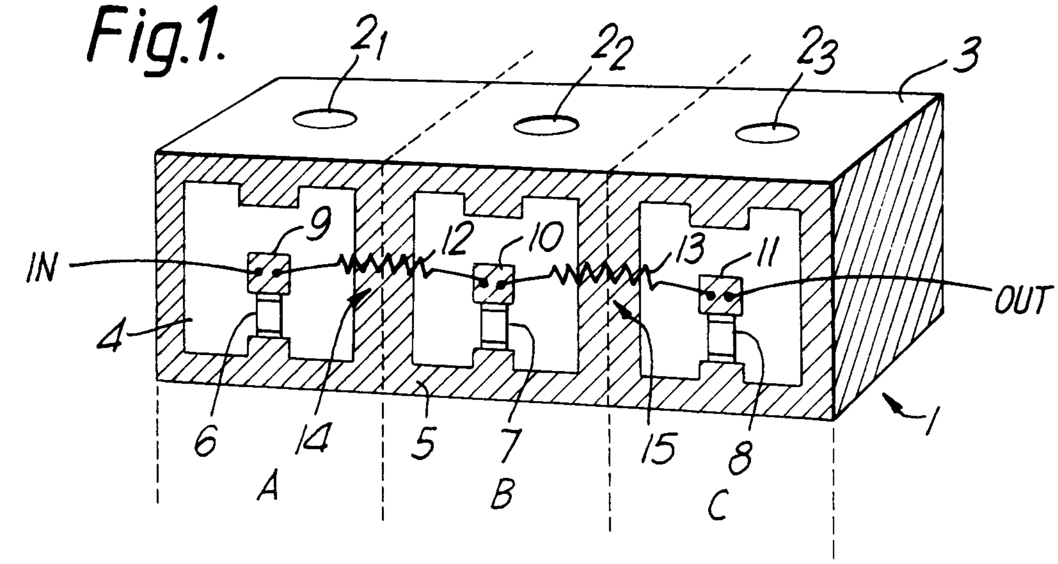


Fig.2.

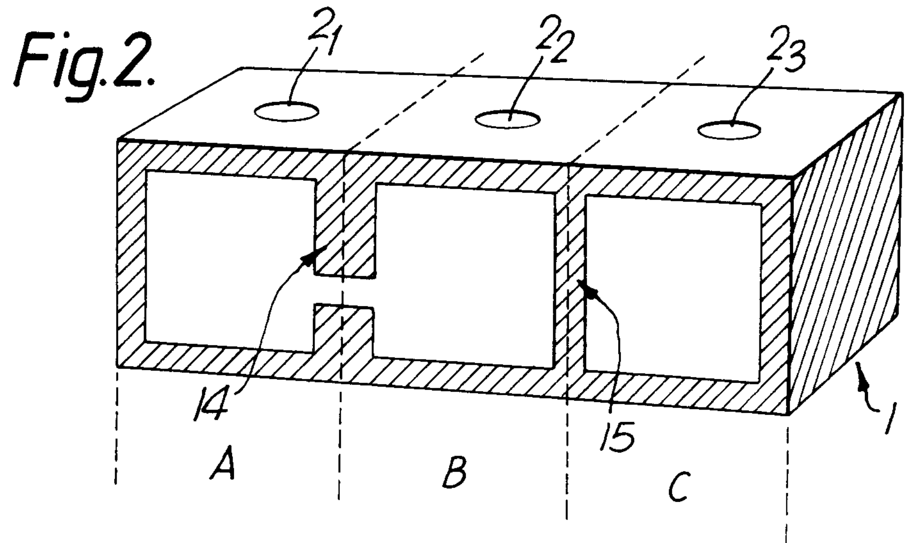
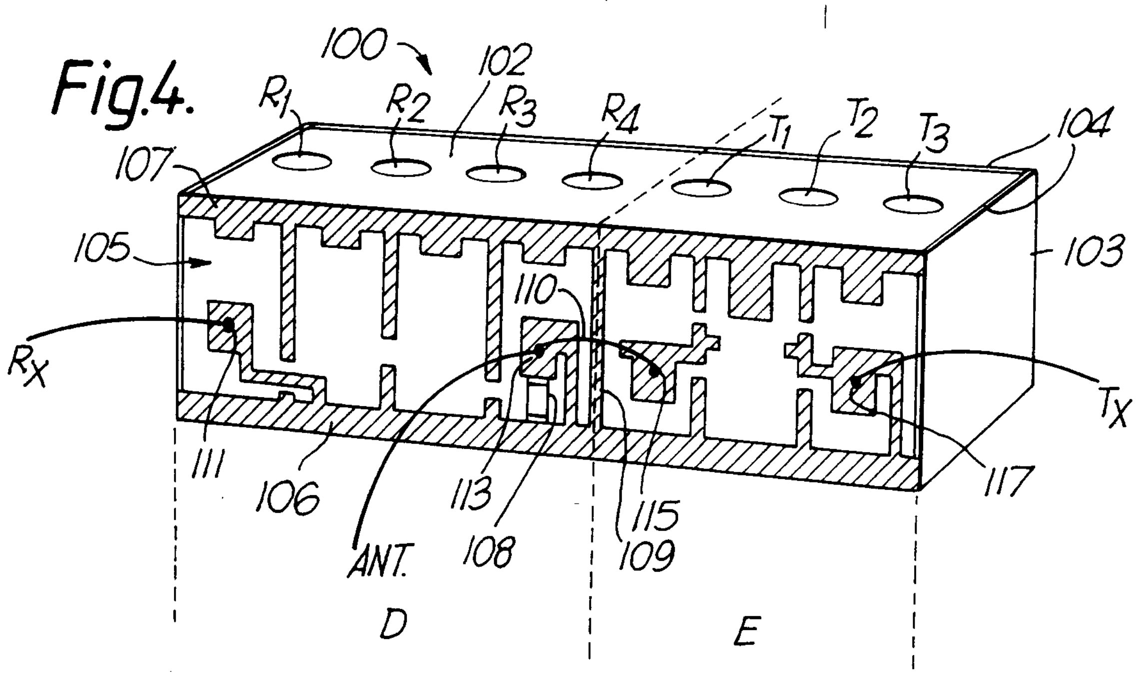
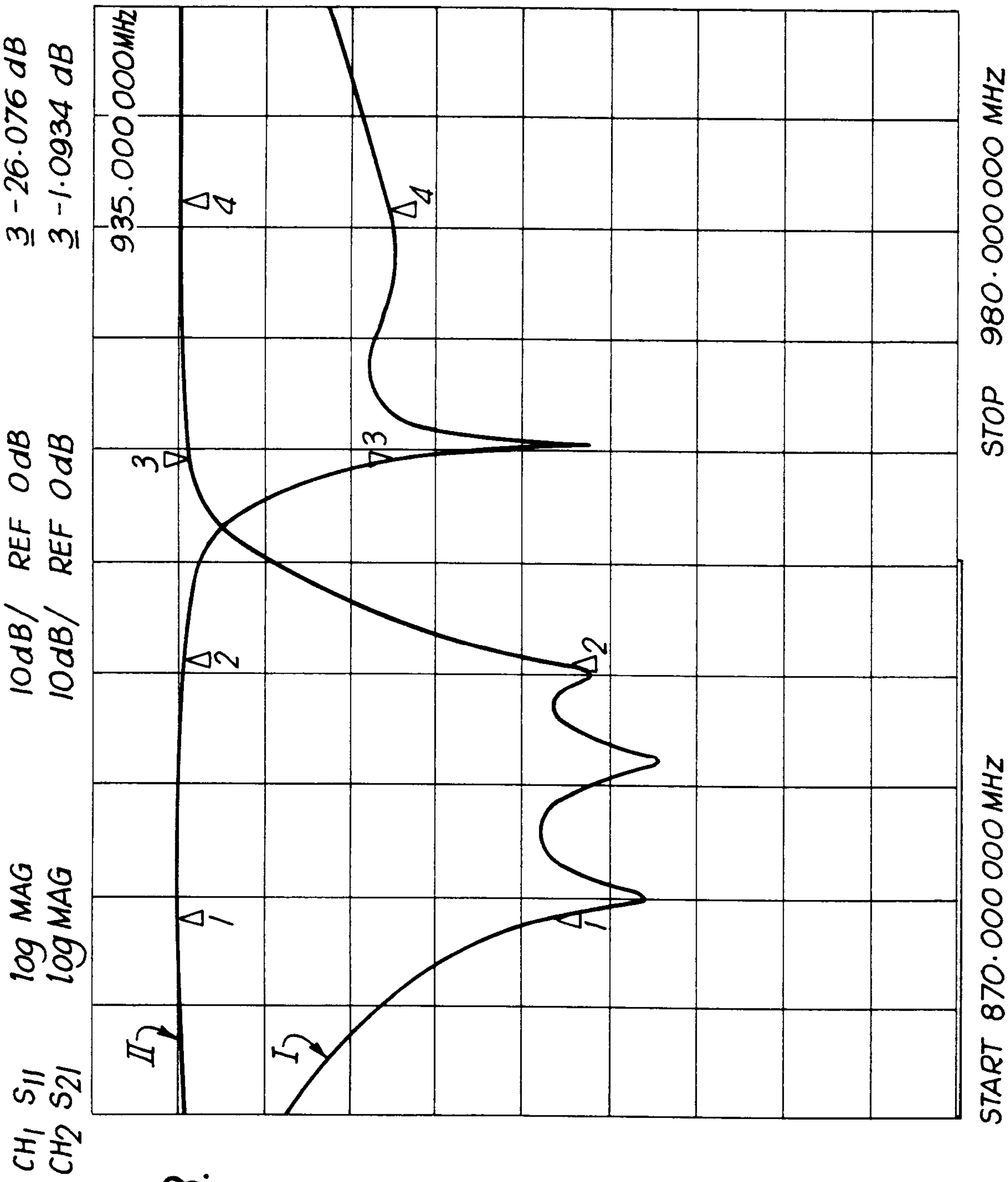


Fig.4.

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CH2 S21 log MAG 10dB/ REF 0dB 3 -1.0934 dB
935.000 000MHz
START 870.000 000 MHz
STOP 980.000 000 MHz
I
II
1
2
3
4

Fig.3.