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(54) Radio frequency filter and a method for adjusting the frequency response thereof

(57) The present invention relates to radio frequency filters and a method for adjusting the frequency response of the filter, more particularly to filters having a resonator construction. In the construction in accordance with the invention, the surface currents appearing in the conducting material short circuiting the ends of the resonators, are influenced e.g. by forming patterns to said conducting material, and through that the high frequency characteristics of the short-circuiting connection are influenced, still maintaining a galvanic short circuit between the inner conductors of the resonator.

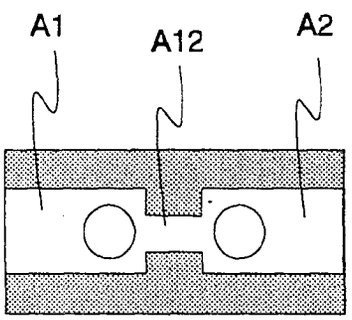

Fig. 3

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Description

The present invention relates to radio frequency filters and a method for adjusting the frequency response of the filter, more particularly to filters having a resonator construction.

Ceramic filters are very popular in radio techniques. One of their advantages is their simple construction. Due to their compact construction they are stable; the frequency characteristics of the ceramic filters are not significantly influenced by the vibration and the temperature variations of the device. Due to their simple construction, they are, in addition, suitable for serial production.

The known basic construction of a ceramic filter consists, as shown in figure 1, of a dielectric element with two holes, the inner surfaces of which are metal plated. The other surfaces of the element, except for the so called open upper surface, are totally metal plated, and the metal plating of the lower surface is connected with the metal plating of the holes. The metal plated holes, being short circuited at their lower ends, form a resonator construction supplied capacitively through the metal plated areas formed on the upper surface of the part. The frequency characteristics of the construction are primarily a function of the hole size, the distance between the holes and the capacity coupling determined by the patterning of the upper surface. If the resonator holes are short circuited only at their one ends, as described above, the construction forms a quarter-wave resonator. Also half-wave resonators can be implemented with the same kind of a construction, whereby the both ends of the resonator holes are short circuited. At the open end of the resonator construction, the electric field strength is at its maximum when the magnetic field is at its minimum, whereas at the short-circuited end of the hole, the electric field strength is at its minimum (nearly zero), and the magnetic field is at its maximum. Thus, also the surface currents appearing in the plating are at their maximum at the short-circuited end of the construction.

A number of variations have been developed of this basic construction, among other things, there can be only one resonator or more than two resonators as disclosed by the US patent publication no. 4,431,977 (Sokola et al.). There are also several other patented solutions of ceramic resonator filter constructions (e.g. US-5,239,279 Turunen, Näppä). All these are, however, characterized in that the short-circuited ends of the resonators are connected with a totally metal plated bottom. Figure 2 shows an equivalent circuit of this kind of a basic construction, where C1 and C2 are coupling capacities and K describes the electromagnetic coupling between the resonator holes TL1 and TL2.

Helical resonator constructions can be tuned e.g. by bending strips formed on the wall of the metal covering that forms the outer conductor of the resonator construction. With this kind of a tuning method there is the risk that the tuning of the resonator will later change when the strips are bent e.g. due to the vibration or when the resonator is handled.

According to a first aspect of the present invention there is provided a radio frequency filter comprising at least two resonators forming electrically conducting inner conductors, and an outer conductor of electrically conducting material, the inner conductors of the filter being at least at one end short circuited to the outer conductor, characterized in that at least to one short-circuited inner conductor end of the filter, means are formed for controlling electric currents between the inner conductors and the outer conductor.

A preferred embodiment of the invention may provide a small sized and more versatile resonator filter construction compared with prior art. An embodiment of the invention may also provide a construction, the characteristics of which can easily be changed, even in serial production. An embodiment of the invention may further provide a simple resonator construction adjustable after the production, for the tuning of which no movable parts are required.

Implementation of the invention may be achieved by changing the flow of the surface currents of the short-circuited end of the construction, e.g. by forming patterns on the area between the short-circuited ends of the resonators.

The inner conductors of the filter may be short circuited only at their one end in order to form a quarter-wave resonator construction.

As an alternative, the inner conductors may be short circuited at their both ends in order to form a half-wave resonator construction. In this arrangement, the control means of electric currents may be for each resonator respectively formed only to one of the two means short circuiting the ends of the resonator, or formed to both of the means short circuiting the ends of the resonator.

The input and output signal of the filter may be galvanically coupled with some of the control means of electric currents in order to arrange an inductive input/output to the filter.

The filter may have a basic construction of a ceramic filter. Accordingly, the control means of electric currents may be on the surface of a dielectric element forming the filter, or may be on a separate plate forming a galvanic contact between the resonator holes and a side surface of the dielectric element.

The resonators of the filter may be formed according to a stripline resonator construction, and/or a helical resonator construction, and/or a coaxial resonator construction.

The present invention is, in addition, related to a method for adjusting the frequency response of the filter.

According to a second aspect of the present invention there is provided a method for adjusting the frequency response of a radio frequency filter having a resonator construction, wherein said filter comprises at least two resonators forming electrically conducting inner

conductors and an outer conductor made of an electrically conducting material, the inner conductors of the filter being short circuited to the outer conductor at least at one end thereof, whereby strong electrical currents are generated to the parts short circuiting the inner conductors to the outer conductors, the method being wherein the frequency response is adjusted by changing the electric currents generated to said short-circuiting means of the resonator construction.

The operation of embodiments of the invention may be based on the realisation that a change caused to the surface current causes a change to the inductive characteristics of the construction and vice versa. Accordingly, through the patterning of the bottom plating of the filter construction, it is possible to affect the flow of the surface currents characteristic of different wave forms determining, among other things, the effective serial inductance against the ground coupled to the resonator. This serial inductance adjusts the resonance frequency of the resonator and the coupling between the resonators. Through the patterning of the plating it is also possible to affect the amount of the serial inductance between the inner conductors of the resonators, which primarily adjustes the coupling between the resonators.

It is clear for a man skilled in the art that the bottom or the lower surface of the filter construction, according to the customary practice, refers to that surface of a frame element having a form of a substantially rectangular prism, which corresponds to the short-circuited end of a quarter-wave resonator, and the upper surface refers to the surface that corresponds to the open end of a quarter-wave resonator, and that the invention is not limited to a certain position of use or viewing direction of the filter.

In the following, embodiments of the present invention will be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a basic construction of a ceramic resonator of prior art;

Figure 2 shows an electric equivalent circuit of this kind of a basic construction;

Figure 3 shows an example of a basic construction in accordance with the present invention;

Figure 4 shows an electric equivalent circuit of this kind of a basic construction;

Figure 5 shows the frequency response of this kind of a construction and the change of the frequency response when changing one part of the patterning;

Figure 6 shows the frequency response of this kind of a construction and the change of the frequency response when changing an other part of the patterning;

Figure 7 shows a variation of the basic construction in accordance with the present invention, with no direct coupling between the lower ends of the resonators;

Figure 8 shows a variation of the basic construction in accordance with the present invention, where the input and output couplings of the filter are implemented as inductive couplings instead of capacity couplings;

Figure 9 shows an electric equivalent circuit of a construction of figure 8; and

Figure 10 shows as examples some other possible variations of the construction in accordance with the present invention.

In the figures, the corresponding elements are identified by the same reference numbers and symbols.

In accordance with the invention, an area that is only partly plated with electrically conducting material will be formed to the short-circuited end of the filter. By means of the patterning formed by said plating, the surface currents of the filter are influenced and, through that, the couplings between the resonators and the characteristic frequencies of the resonators are influenced. In addition to the plating itself, also electrically conducting material attached to the construction by other means than plating can be used.

Figure 3 shows one method in accordance with the present invention, for forming patterns on the lower surface of the filter construction. The inner conductors of the resonators have galvanic couplings through the strip areas A1 and A2 to the ground potential of the end surfaces of the filter construction. In addition, the strip area A12 couples the areas A1 and A2 with each other.

The construction can be illustrated through the equivalent circuit of figure 4. Coils L1 and L2 illustrate the effective inductance between the central conductor of the resonator and the ground potential of the construction, caused by the strip portions A1 and A2. Coil L12 illustrates the inductance of the strip portion A12 between the inner conductors.

In accordance with the invention, the lower surface is firstly either totally or partly plated with an electrically conducting plating. In order to achieve the desired characteristics, the plating is then removed or added according to need. For example, in order to affect the coupling between the resonators, it is possible to remove material from the strip area A12 of the pattern in accordance with figure 3, whereby the inductance between the resonators will be increased. If the characteristic frequencies of the resonator wish to be increased, conducting material can be added to the strip areas A1 and A2 of the pattern formed according to figure 3, whereby the effective serial inductance against the ground coupled to the resonator will decrease.

Figure 5 shows the influence of narrowing the strip area A12, in other words, of increasing the inductance of the coil L12 described by the equivalent circuit, on the frequency response (insertion loss) of the filter. The solid curve describes the response of the starting situation of the filter illustrated in figure 3, and the broken line curve describes the situation after the area A12 has

been narrowed. The narrowing decreases the inductive total coupling, the capacity coupling staying almost constant. As the figure shows, the narrowing of the area A12 has a clear influence on the coupling between the resonators.

Figure 6 illustrates the influence of the widening of the strip areas A1 and A2, in other words, of decreasing the inductance of coils L1 and L2 shown in the equivalent circuit, on the frequency response of the filter. The solid curve describes the response of the starting situation of the filter shown in figure 3, and the broken line curve describes the situation after widening the areas A1 and A2. The widening of said areas decreases the inductive total coupling between the resonators. As it can be seen from the figure, the widening of the portions A1 and A2 moves the resonator frequencies upwards.

In accordance with the invention, the strip areas causing the desired electric characteristics, can be made by removing certain plating areas from the surface that has first been totally plated. Another alternative is to make a ready patterned plating having already the characteristics with influence on the surface currents. If additional adjustment is desired, the plating can be removed from certain points or added to desired points of the plating of the lower surface.

Figure 7 shows a variation of the bottom patterning in accordance with the present invention. The inner conductors of the resonators are coupled through strip areas with the end surfaces of the filter construction. On the area A5 between the conductors there is no conducting material, and thus the inductance between the resonators of the equivalent circuit (L12 in figure 4) is missing.

In the example constructions described above, the input and output couplings to the resonators are implemented as capacitive couplings. One advantage of a construction in accordance with the invention is that the input and output couplings can be easily implemented also inductively by connecting the input and output signals directly with a galvanic contact to strip areas of the bottom. Figure 8 shows one embodiment, where the strip areas A1 and A2 that couple the inner conductors of the resonators with galvanic couplings to the ground potential of the filter construction, are equipped with open extensions A3 and A4, where the filter ports IN and OUT can be directly coupled with galvanic couplings. The equivalent circuit of the construction is shown in figure 9, where coils L3 and L4 describe the effective serial inductances of strip areas A3 and A4.

Figure 10 shows examples of other preferred bottom patternings of the resonator construction. In the left example there is no direct contact between the resonators, but the lower ends of the resonators are electrically connected with the side surface of the filter construction. The centre example is like the one shown in figure 3, but the second resonator of the example has, in addition to the contact with the end surface of the filter construction, also another contact with the side surface of the filter construction. In the right example there is shown a patterning with a non-conducting area parallel with one side surface of the filter construction, the resonators being electrically connected only with three side surfaces of the filter construction.

The dielectric filter in accordance with the present invention can consist of one dielectric element, whereby the patterning in accordance with the invention is totally on the surface of the element. The dielectric filter in accordance with the present invention can also be a combination of a dielectric element and a plate patterned with conducting material, whereby the patternings of the element and the plate are electrically connected with each other and the patterning in accordance with the invention can either partly or totally be also on the surface of the plate.

Although reference has been made above to a dielectric filter construction, the invention is also applicable to filters implemented with other resonator constructions, like stripline, helical or coaxial resonator constructions, in other words, with constructions, at least one end of which is short circuited, whereby surface currents are generated to the short-circuited end to be influenced in accordance with the present invention.

By means of the present invention, more versatile filter constructions compared with prior art can be implemented. The invention is applicable to serial production and facilitates the serial production of the resonator filters, because it is possible by means of the invention to produce a basic model that can be adjusted afterwards for various purposes. Additionally, the invention allows a stable tuning: no separate tuning means that could move due to vibration, impacts etc. are used for the tuning.

Claims

1. A radio frequency filter comprising at least two resonators forming electrically conducting inner conductors, and an outer conductor of electrically conducting material, the inner conductors of the filter being at least at one end short circuited to the outer conductor, characterized in that at least to one short-circuited inner conductor end of the filter, means are formed for controlling electric currents between the inner conductors and the outer conductor.

2. A filter according to claim 1, wherein the control means of the electric currents of the short-circuited end are formed by forming patterns to the conducting material forming the short circuit of the inner conductors.

3. A filter according to claim 2, wherein said control means form a strip area (A12) that forms an inductance between the inner conductors of the filter.

4. A filter according to claim 2, wherein said control means form an electrically non-conducting area (A5) on the area between the inner conductors of the filter.

5. A filter according to claim 2, wherein said control means are in contact with the conducting plating of two or three side surfaces forming the outer conductor of the resonator construction.

6. A filter according to claim 2, wherein said control means form an electrically non-conducting area parallel with one of the side surfaces forming the outer conductor of the resonator construction.

7. A filter according to claim 1, wherein the control means of the electric currents of the short-circuited end are formed by shaping the conductive material that forms the short circuit of the inner conductors.

8. A method for adjusting the frequency response of a radio frequency filter having a resonator construction, wherein said filter comprises at least two resonators forming electrically conducting inner conductors and an outer conductor made of an electrically conducting material, the inner conductors of the filter being short circuited to the outer conductor at least at one end thereof, whereby strong electrical currents are generated to the parts short circuiting the inner conductors to the outer conductors, the method being wherein the frequency response is adjusted by changing the electric currents generated to said short-circuiting means of the resonator construction.

9. A method according to claim 8, wherein the surface of the resonator construction, on which the short-circuiting electric contact is formed, is totally covered with a conducting material, and the electric currents of the construction are changed by removing selectively said conducting material.

10. A method according to claim 8, wherein the surface of the resonator construction, on which the short-circuiting electric contact is formed, is partly covered with a conducting material, and the electric currents of the construction are changed by removing selectively the conducting material.

11. A method according to claim 8, wherein the surface of the resonator construction, on which the short-circuiting electric contact is formed, is partly covered with a conducting material, and the electric currents of the construction are changed by adding selectively the conducting material.

12. A method according to claim 10 or 11, wherein a desired pattern is formed on said surface by said partly covering of the surface, and said pattern is fine adjusted by removing said conducting material.

13. A method according to claim 10 or 11, wherein a desired pattern is formed on said surface by said partly covering of the surface, and said pattern is fine adjusted by adding the conducting material.

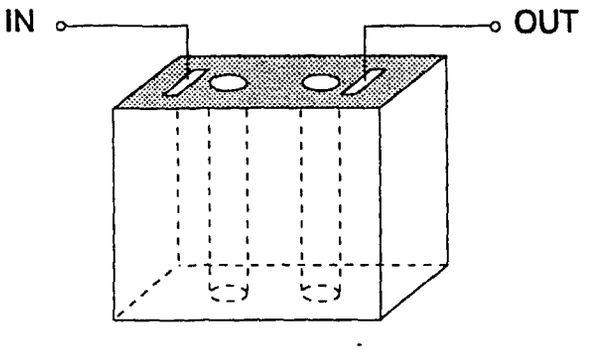


Fig. 1

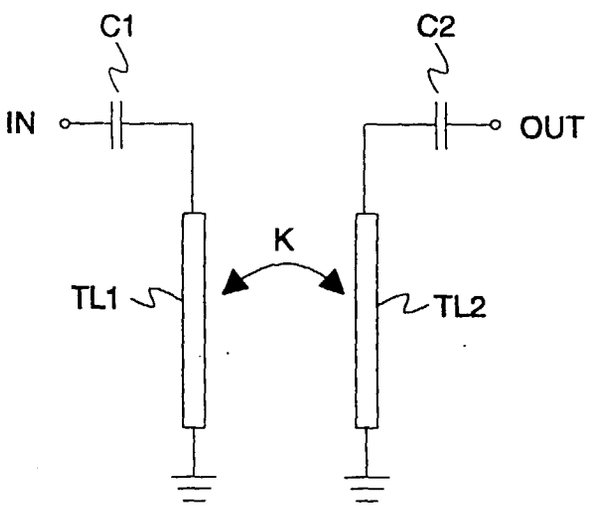


Fig. 2

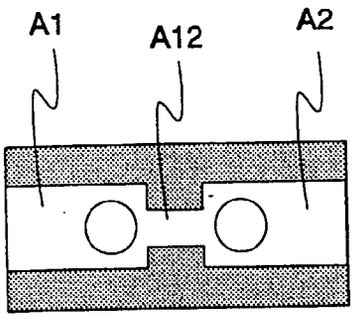


Fig. 3

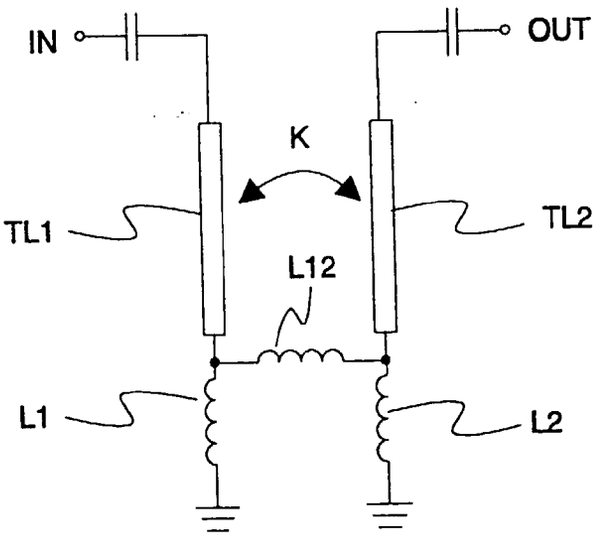
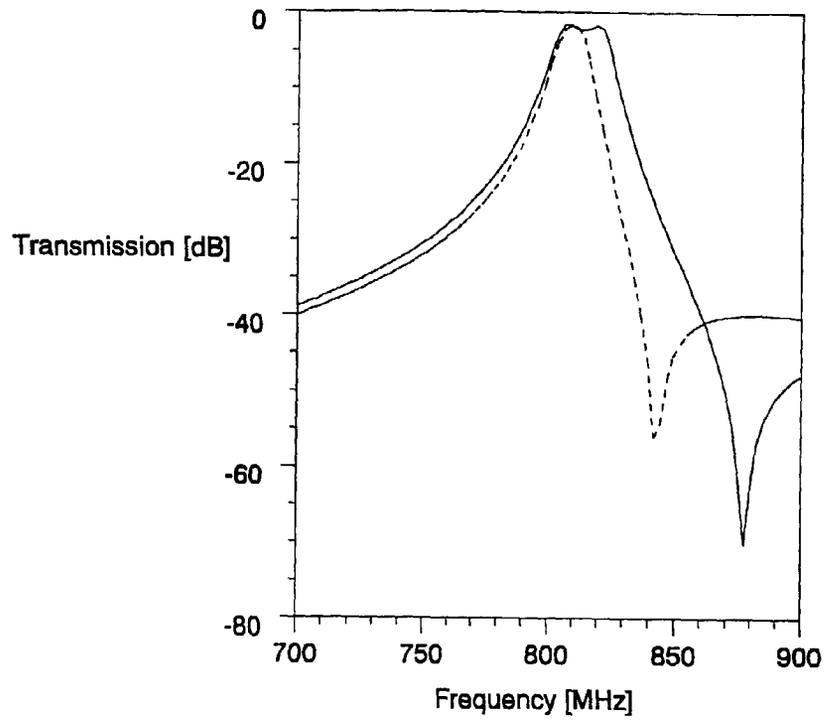


Fig. 4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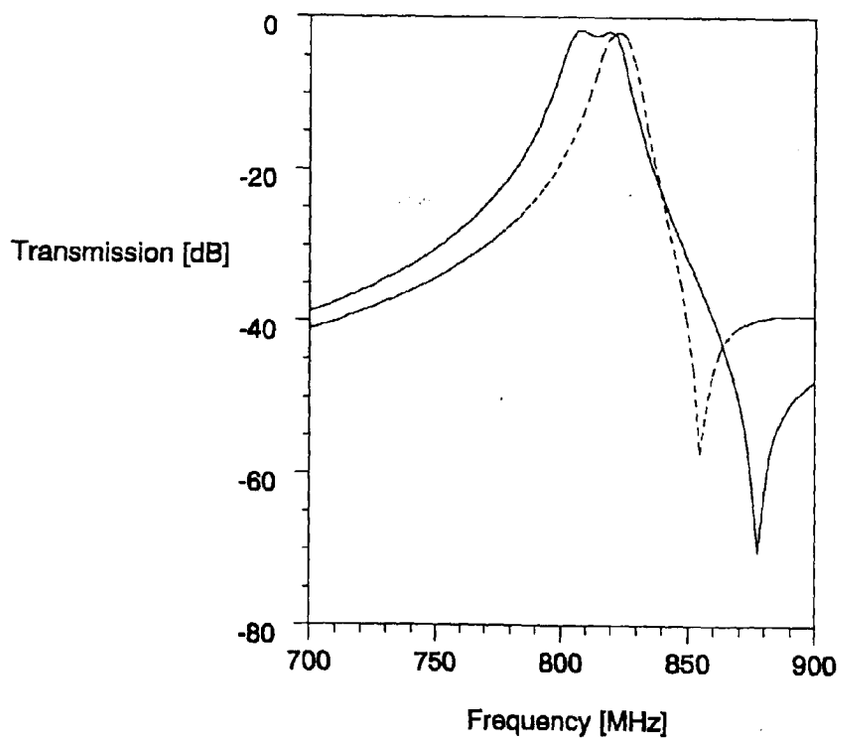
-20
-40
-60
-80
Transmission [dB]
700
750
800
850
900
Frequency [MHz]

Fig. 5


0
-20
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Transmission [dB]
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Frequency [MHz]

Fig. 6

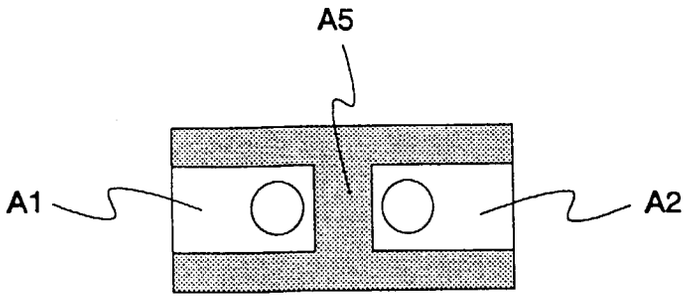

Fig. 7

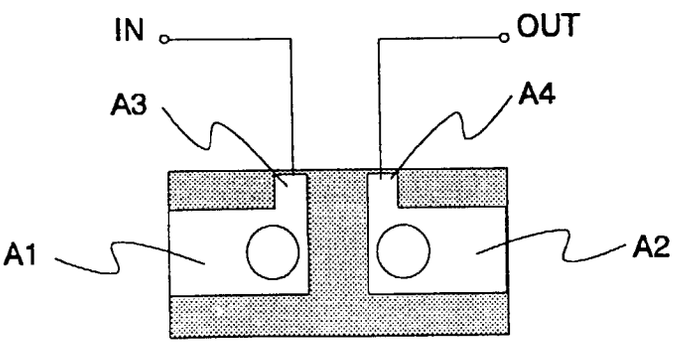

Fig. 8

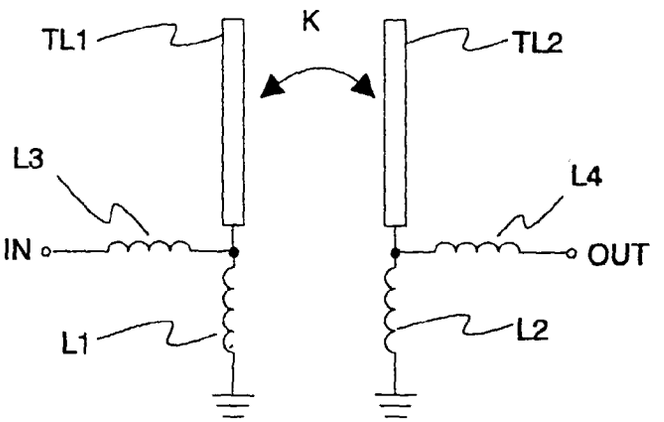

Fig. 9

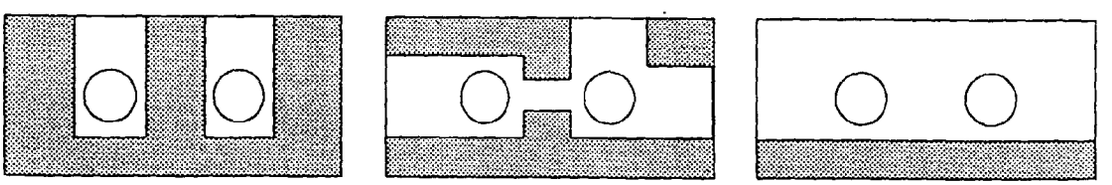

Fig. 10