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(54) **Improved distributed capacitance resonant tag**

(57) In a distributed capacitance resonant tag the current in the turns is not constant. The invention im-

proves the sensitivity of these tags by adjusting the track width to the current through this track, so that the losses become smaller.

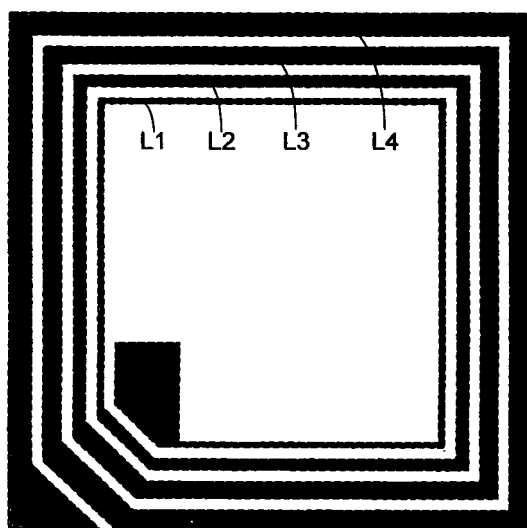


FIGURE 4

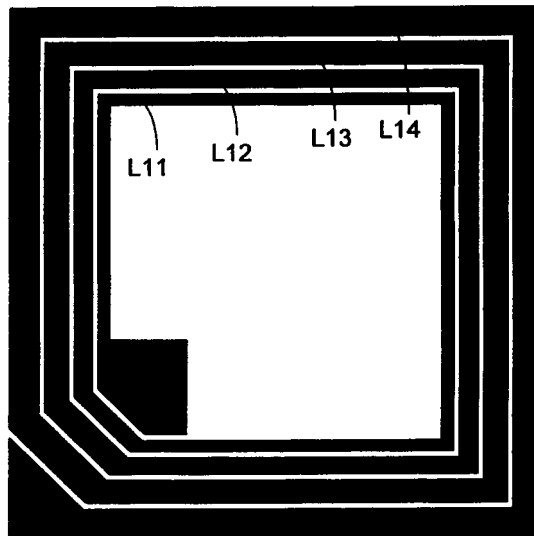


FIGURE 5

Description

[0001] This invention relates to an improved design of a resonant tag for an electronic antishoplifting system. More particularly, the invention relates to a resonant detection tag, in particular a shoplifting detection tag, which is provided with a dielectric which is situated substantially in a plane; a first spiraling electroconductive track on a first side of the dielectric, which first track comprises a plurality of turns; and a second spiraling electroconductive track on a second side of the dielectric, which second track comprises a plurality of turns, and which second side is situated opposite the first side; wherein the first track and the second track spiral in opposite directions, each form an induction and are aligned relative to each other such that at least a part of the first track coincides with at least a part of the second track, so that a distributed capacitance is formed as a result of the mutually aligned tracks.

[0002] Electronic antishoplifting systems have long been known and are widely in use to produce a signal if protected articles leave the shop. United States Patent US 3,500,373 to A.J. Minasy from 1966 already describes such an Electronic Article Surveillance (EAS) system with a resonating tag. A still older description is to be found in the French patent to Picard. For an improved detection system, applicant has been granted a patent having number EP0608961B1. The resonant tags that are used in shoplifting detection systems exist in many designs. In the trend towards increasingly smaller and cheaper designs, the so-called sticker tags have become popular. These tags consist of a number of layers of thin foil, in which both the coil and the resonant capacitor are realized. An adhesive layer on the tags makes them easy to fit and gives them their name. These sticker tags are manufactured very cheaply in large numbers and are used as disposable tags, that is, upon payment by the customer the operation of the tag is switched off, the tag is deactivated, but remains attached to the product to be protected.

[0003] One method of producing sticker tags was disclosed as early as 1975 by Lichtblau in US 3,913,219 "Planar circuit fabrication process". A sticker tag with provisions to make deactivation more reliable is described by Checkpoint in US 6,091,607.

[0004] In the above-mentioned tags, the resonant capacitance is concentrated. A different design of the resonant tags makes use of the distributed capacitance that is present between the upper and lower conductor. Such a tag is described by Vandebult (Polyonics) in US 4,583,099. In US 4,818,312, Monarch Marking Systems has described a different design of a distributed capacitance resonant tag. Also in US 4,598,276 to Tait (3M) the capacitance is provided in a manner distributed between the windings. An example of a widely used tag is described in EP 1 107 205 to Checkpoint. In the European patent EP 0 665 705 Miyake describes a distributed capacitance tag and a production process to make these

tags.

[0005] In resonant tags with concentrated capacitance, everywhere in the turns of the coil the same current flows and it is obvious to make the cross section of the turn equally large throughout. In the state of the art for distributed capacitance tags, the cross section of the conductors is also constant. An advantage of this distributed capacitance solution is that no extra surface of the tags is used for the capacitor. Because two conductive layers are used for the coil, there is a small disadvantage - the flexibility is less - but a major advantage is that as a consequence of the current distribution over the windings on either side the ohmic losses are smaller. For use in the antishoplifting systems, it is important that the tags be small, so that they can be fitted simply and without being conspicuous. Also, a small detection tag contains less material, and hence has less environmental impact, and in particular is cheaper to produce. A major disadvantage of small tags is that the detection distance is limited. This limits the width of the passage in which a tag can be detected, and also the chance of detection diminishes. Hence, there is a great need for a small detection tag having improved sensitivity.

[0006] The object of the invention is to make an improved design of a distributed capacitance resonant tag by making more efficient use of the portion of the tag surface that is available for the conductors.

[0007] The sensitivity of a resonant tag is determined by a number of characteristics. Firstly the voltage that is induced in the windings by the interrogation field, secondly the current that proceeds to flow in the windings, in which connection the resonant rise of the current by a factor Q is important, and thirdly the dipole moment that is generated in the tag by this current.

[0008] A tag according to the invention optimizes the product of these partly conflicting effects. The tag according to the invention may be characterized in that the magnitude of a surface of a cross section of at any rate at least a first part of the first track is greater than the magnitude of a surface of a cross section of at any rate at least a second part of the first track, wherein, in use, the current through the first part of the first track is greater than the current through the second part of the first track.

[0009] The invention will now be further elucidated with reference to the drawing:

Figure 1 shows prior art of a distributed capacitance resonant tag.

Figure 2 shows a simplified equivalent circuit of a distributed capacitance resonant tag.

Figure 3 visualizes the current distribution in a distributed capacitance resonant tag.

Figure 4 shows the upper spiral of a resonant tag according to Fig. 6.

Figure 5 shows the lower spiral of a resonant tag according to Fig. 6.

Figure 6 shows a possible embodiment of a distributed capacitance resonant tag according to the in-

vention.

In Fig. 1 a distributed capacitance resonant tag 1 according to prior art reference US 4,598,276 is shown. The tag 1 is provided with a dielectric 2 which is situated substantially in a flat plane. The label is provided with a first, in this example upper, spiraling electroconductive track 4 which is situated on a first side 6 of the dielectric. Further, the tag is provided with a second, in this example lower, spiraling electroconductive track 8 on a second side 10 of the dielectric, which second side 10 is situated opposite the first side 6. The first track and the second track have been wound in opposite directions and hence spiral in opposite directions. Each track forms an induction. Furthermore, the tracks 4, 8 have been aligned relative to each other, such that at least a part of the first track coincides with at least a part of a second track, so that a distributed capacitance is formed as a result of the mutually aligned tracks 4, 8. In this tag, the innermost ends of the upper and lower winding are electrically interconnected by means of a conductor 12. The above-mentioned parts of the tracks that coincide thus form segments of the spirals that are situated directly above each other and which are magnetically coupled. These segments at the same time form the plates of a capacitor.

[0010] The whole system can be represented by an electric equivalent circuit. A simplified electronic circuit model of such a tag is shown in Fig. 2, where L1 and L11 represent the magnetically coupled coil segments situated above each other. Ditto for L2 and L12, and so forth. The distributed capacitance that occurs between the segments L1 and L11 is represented by the concentrated C1, and similarly for the further segments. This numbering corresponds to the references in Figs. 4 and 5. In the circuit model, the number of sections is limited. A better approximation of the distributed effects requires many more sections, but for an analysis of the operation of a distributed capacitance resonant tag this model has good utility. All coils are weakly coupled with a coil, not shown, which represents the interrogation antenna. Further, all coils are weakly coupled with another coil, which represents the receiving antenna. Analysis has shown that the current in the windings is not constant. Due to the distributed capacitance, current crosses over between the lower and upper conductor. Close to the open end of the winding the current is lowest; towards the interconnection between the lower and upper conductor the current in the conductors becomes increasingly greater. In Fig. 3 this is visualized. Eventually, the maximum current occurs at the contact of lower and upper conductor. The invention makes use of this effect. To minimize the total ohmic losses, the cross section of the conductors is not constant but the cross section is adjusted to the current through this conductor. In a practical design, the height of the conductor is determined by the thickness of the

metal foil and hence equal for all windings, and the width of the conductor has been adjusted to the prevailing current.

[0011] Given an interconnection between the lower and upper spiral on the inner side, most current then flows in the innermost turn. The largest current then runs in the innermost loop, the loop with the smallest surface. A greater dipole moment can be obtained by providing the connection between lower and upper conductor on the outer side. The largest current then runs in the outermost loop. The greater surface of this loop consequently gives a greater dipole moment. The preferred embodiment of the invention therefore has the interconnection on the outer side.

[0012] In a distributed capacitance tag, a single turn along the outer contour is optimal. This holds for tags with a dimension of for instance 4 cm x 4 cm or 5 cm x 5 cm. With smaller tags (3 cm x 3 cm), built up with manageable thicknesses of the foil for the dielectric and with the minimum track widths that are needed for achieving sufficient capacitor surface and an ohmic resistance that is low enough for a sufficiently high Q factor, it is not possible to achieve a resonant frequency of 8 MHz with a single turn. The self-inductance of a single turn is too low for that. For that reason, several turns are needed: in practice between 3 and 7 turns.

[0013] Of a tag, only a portion of the total surface is available for the conductors; this is because the surface of a turn determines how well this turn couples with the external interrogation field. Wide tracks make the comprised surface smaller. Similarly, the magnetic dipole moment generated by the tag is directly proportional to the surface that is comprised by the conductor in which the current flows. Hence, in first approximation, the surface of the turns reappears quadratically in the sensitivity. In practical designs this means that the turns cannot be made too wide, because they must at the same time comprise a large surface. In addition to the losses in the conduction, a distributed capacitance tag also involves non-negligible dielectric losses. The effect of reducing the conduction losses by extreme track widths is thereby limited.

[0014] The most important components of a preferred embodiment of a tag according to the invention are shown in Figure 6. A suitable dielectric layer is provided between these spirals. The preferred position for contact for connecting the two spirals is indicated on the outer side of the tag by A. The maximum voltage in a tag in a deactivation field will then occur at the open end of the spirals, this is indicated in Figure 6 by the letter B. Accordingly, this is the place of choice for providing a weakening in the dielectric for the purpose of deactivation, or for connecting an RFID chip. In the tag according to the invention, the track width has been adjusted stepwise per turn to the prevailing current. This prevents the geometric problems of a continuously proceeding adjustment of the track width.

[0015] The invention is not limited to the track width

shown in the preferred embodiment varying stepwise per turn. Connecting an RFID chip between the spiral coils described is understood to be part of the invention.

[0016] In Fig. 6, parts corresponding to Fig. 1 are provided with the same reference numeral. It is noted that the dielectric 2 is shown schematically transparent. The plane in which the dielectric 2 extends is a flat plane in this example. The resonant tag 1 of Fig. 6 is provided, in addition to the dielectric 2, with a first spiraling electroconductive track 4 which is situated on a first side 6 of the dielectric. A second spiraling electroconductive track 8 is situated on a second side of the dielectric, which second side is situated opposite the first side 6. The first track and the second track have been wound in opposite directions. It holds, therefore, that the first track and the second track spiral in opposite directions. Each track forms an induction. Furthermore, tracks 4, 8, just as in Fig. 1, have been aligned relative to each other, such that at least a part of the first track coincides with at least a part of the second track, whereby, as a result, a distributed capacitance is formed as a result of the mutually aligned tracks. In this example, the first track is provided with an outermost turn 14 and an innermost turn 16 as well as intermediate turns 18 and 20. Similarly, the second track 8 is provided with an outermost turn 14 and an innermost turn 16 as well as intermediate turns 18 and 20. The outermost turn 14 of the first track in this example is situated opposite the outermost turn 14 of the second track, and thus forms a capacitance. The same holds for the innermost turns 16 of the first and second track, the intermediate turns 18 of the first and second track and the intermediate turns 20 of the first and second track.

[0017] In this example, it further holds that the first track 4 is electroconductively connected with the second track 8 at a position A which is situated at the outermost turns 14 of the first and second track. Furthermore, it holds that, viewed in a direction 22 along the first track from an outermost turn to an innermost turn, the magnitude of the surface of a cross section of the first track decreases. Because in this example the thickness of the first track, viewed in a direction perpendicular to the plane of the dielectric, is constant, it holds that, viewed in the direction 22 along the first track from an outermost turn to an innermost turn, the magnitude of the width of the first track decreases. In particular, it holds, as a consequence, that a width of a first turn (14, 18, 20) that is situated outside a second turn (18, 20, 16) of the first track is greater than the width of the second turn of the first track. For the widths b_1 , b_2 , b_3 and b_4 indicated in Fig. 6, it holds, accordingly, that b_1 is greater than b_2 , b_2 is greater than b_3 , and b_3 is greater than b_4 .

[0018] Correspondingly, it may be stated that the magnitude of a surface of a cross section of at least a first part of the first track is greater than the magnitude of a surface of a cross section of at any rate at least a second part of the first track, while, in use, the current through the first part of the first track is greater than the current through the second part of the first track. The first part of

the first track can for instance be formed by, in this example, the outermost turn 14, while the second part of the first track is formed by the turn 18 situated within the turn 14. Also, in that case, the second part can be designated as the turn 20 or as the turn 16. It holds that the second part of the first track (e.g. the turn 18), viewed in the direction 22 along the first track from an outermost turn to an innermost turn, is situated beyond the first part of the first track (here for instance the outermost turn 14). As stated, the greatest current occurs through the tracks at the position A. In a direction 22 of the first track, the current will gradually diminish in that it partly crosses from the first track to the second track. Because in those parts of the first track where the current is relatively great the width of the track is also relatively great, the ohmic losses are reduced, that is, reduced with respect to the situation where all tracks were to have the same width as that of the innermost turn 16. If on the other hand all tracks were to have the same width as the outermost turn 14, the ohmic losses, it is true, will likewise be reduced, but the surface that is enclosed by the outermost turn would be enlarged, so that the tag obtains an undesirably larger size.

[0019] All that has been discussed above for the first track likewise holds *mutatis mutandis* for the second track and this will therefore not be explained in more detail here. Suffice it to note that in general it also holds for the second track that the magnitude of a surface of a cross section of at any rate at least a first part of the second track is greater than the magnitude of a surface of a cross section of at any rate at least a second part of the second track, while, in use, the current through the first part of the second track is greater than the current through the second part of the second track. This condition is again, as with the first track, satisfied in different ways. The first part of the second track can for instance be the outermost turn 14 again, while the second part of the second track is for instance the turn 18 or 20 situated within turn 14, or the innermost turn 16 of the second track. Also, the first part of the second track can for instance be the turn 18 or 20 and the second part of the second track for instance the innermost turn 16. All other properties mentioned for the first track hold *mutatis mutandis* for the second track.

[0020] Preferably, it holds furthermore that between the free end 40 of the innermost turn 16 of the first track 4 and the free end 40 of the innermost turn 16 of the second track 8, an RFID chip 42 is arranged. It is furthermore possible that the dielectric situated between the free ends 40 of the innermost turns of the first and second tracks is provided with a weakening for deactivating the tag. This deactivation can then be done by introducing the tag into an electromagnetic interrogation field with a relatively large power.

[0021] According to an alternative embodiment (not shown), the first and second track are conductively connected with each other at a position B of the innermost turns. In that case, the greatest current occurs through

the first and second track at the position B. In that case, for instance the innermost turn 16 will be the widest turn, the turn 20 can for instance be less wide than the turn 16, the turn 18 can for instance be less wide than the turn 20 and the turn 14 can for instance be less wide than the turn 18. Then this holds for both the turns of the first track and the turns of the second track. It holds then that, viewed in a direction along the first track from an innermost turn to an outermost turn, the magnitude of the surface of a cross section of the first track decreases. This holds *mutatis mutandis* for the magnitude of the surface of a cross section of the second track. It also holds then that a width of a first turn of the first track that is situated within a second turn of the first track is greater than the width of the second turn of the first track. It also holds that the second part of the first track, viewed in a direction along the first track from an innermost turn to an outermost turn, is situated beyond the first part of the first track. It also holds then that, viewed in a direction along the second track from an innermost turn to an outermost turn, the magnitude of the surface of a cross section of the second track decreases. All other above-mentioned features of the first track then also hold *mutatis mutandis* for the second track. Here too, it holds that between the free ends of the outermost turn of the first and second tracks e.g. an RFID chip may be provided. It is also possible that the dielectric is weakened between these free ends for deactivating the tag. Such variants are each and all understood to fall within the framework of the invention.

Claims

1. A shoplifting detection tag that is built up from two metal tracks spiraling in opposite directions on opposite sides of a dielectric, with distributed capacitance between the two layers and more than one turn of the spiral coils, which jointly form a resonant circuit, **characterized in that** the ratio of the surfaces of the cross sections of at least two turns has been adjusted to the different current intensities in those turns.
2. A shoplifting detection tag according to claim 1, **characterized in that** in the turn having the largest cross section the largest current flows.
3. A shoplifting detection tag according to claim 1 or 2, **characterized in that** in the outermost turn the largest current flows.
4. A tag according to any one of the preceding claims, **characterized in that** the contact between the two spirals is in the outermost turn.
5. A tag according to any one of the preceding claims, **characterized in that** an RFID chip is connected

with the two spiral coils.

6. A resonant detection tag, in particular a shoplifting detection tag, which is provided with:
 - a dielectric which is situated substantially in a plane;
 - a first spiraling electroconductive track on a first side of the dielectric, which first track comprises a plurality of turns; and
 - a second spiraling electroconductive track on a second side of the dielectric, which second track comprises a plurality of turns, and which second side is situated opposite the first side; wherein the first track and the second track spiral in opposite directions, each form an induction and are aligned relative to each other, such that at least a part of the first track coincides with at least a part of the second track, so that a distributed capacitance is formed as a result of the mutually aligned tracks, **characterized in that** the magnitude of a surface of a cross section of at any rate at least a first part of the first track is greater than the magnitude of a surface of a cross section of at any rate at least a second part of the first track, wherein, in use, the current through the first part of the first track is greater than the current through the second part of the first track.
7. A tag according to claim 6, **characterized in that** the magnitude of a width of the first part of the first track in a direction parallel to said plane is greater than the magnitude of a width of the second part of the first track in a direction parallel to said plane.
8. A tag according to claim 6 or 7, **characterized in that** the magnitude of a surface of a cross section of at any rate at least a first part of the second track is greater than the magnitude of a surface of a cross section of at any rate at least a second part of the second track, wherein, in use, the current through the first part of the second track is greater than the current through the second part of the second track.
9. A tag according to claim 8, **characterized in that** the magnitude of a width of the first part of the second track in a direction parallel to said plane is greater than the magnitude of a width of the second part of the second track in a direction parallel to said plane.
10. A tag according to any one of claims 6-9, **characterized in that** the first track is electroconductively connected with the second track at a position which is situated at outermost turns of the first and second track, respectively.
11. A tag according to claim 10, **characterized in that**,

viewed in a direction along the first track from an outermost turn to an innermost turn, the magnitude of the surface of a cross section of the first track at least substantially decreases.

12. A tag according to claim 10 or 11, **characterized in that** a width of a first turn of the first track that is situated outside a second turn of the first track is greater than the width of the second turn of the first track.
13. A tag according to claim 10, 11 or 12, **characterized in that** the second part of the first track, viewed in a direction along the first track from an outermost turn to an innermost turn, is situated beyond the first part of the first track.
14. A tag according to claim 8, and according to any one of claims 10-13, **characterized in that**, viewed in a direction along the second track from an outermost turn to an innermost turn, the magnitude of the surface of a cross section of the second track at least substantially decreases.
15. A tag according to claim 8 and according to any one of claims 10-14, **characterized in that** a width of a first turn of the second track that is situated outside a second turn of the second track is greater than the width of the second turn of the second track.
16. A tag according to claim 8 and according to any one of claims 10-15, **characterized in that** the second part of the second track, viewed in a direction along the second track from an outermost turn to an innermost turn, is situated beyond the first part of the second track.
17. A tag according to any one of the preceding claims 10-16, **characterized in that** between the free ends of the innermost turns of the first and second track, an RFID chip is arranged.
18. A tag according to any one of the preceding claims 10-17, **characterized in that** the free ends of the innermost turns of the first and second track are situated opposite each other on opposite sides of the dielectric, while the dielectric, between these ends, is provided with a weakening for deactivating the tag.
19. A tag according to any one of claims 6-9, **characterized in that** the first track is electroconductively connected with the second track at a position which is situated at innermost turns of the first and second track, respectively.
20. A tag according to claim 19, **characterized in that**, viewed in a direction along the first track from an innermost turn to an outermost turn, the magnitude

of the surface of a cross section of the first track at least substantially decreases.

21. A label according to claim 19 or 20, **characterized in that** a width of a first turn of the first track which is situated within a second turn of the first track is greater than the width of the second turn of the first track.
22. A tag according to claim 19, 20 or 21, **characterized in that** the second part of the first track, viewed in a direction along the first track from an innermost turn to an outermost turn, is situated beyond the first part of the first track.
23. A tag according to claim 8 and according to any one of claims 19-22, **characterized in that**, viewed in a direction along the second track from an innermost turn to an outermost turn, the magnitude of the surface of a cross section of the second track at least substantially decreases.
24. A label according to claim 8 and according to any one of claims 19-23, **characterized in that** a width of a first turn of the second track which is situated within a second turn of the second track is greater than the width of the second turn of the second track.
25. A tag according to claim 7 and according to any one of claims 19-24, **characterized in that** the second part of the second track, viewed in a direction along the second track from an innermost turn to an outermost turn, is situated beyond the first part of the second track.
26. A tag according to any one of the preceding claims 19-25, **characterized in that** between the free ends of the outermost turns of the first and second track an RFID chip is arranged.
27. A tag according to any one of the preceding claims 19-26, **characterized in that** the free ends of the outermost turns of the first and second track are situated opposite each other, on opposite sides of the dielectric, while the dielectric, between these ends, is provided with a weakening for deactivating the tag.
28. A tag according to any one of the preceding claims 6-27, **characterized in that** the first part of the first track comprises a turn of the first track, and/or that the second part of the first track comprises a turn of the first track, and/or that the first part of the second track comprises a turn of the second track, and/or that the second part of the second track comprises a turn of the second track.

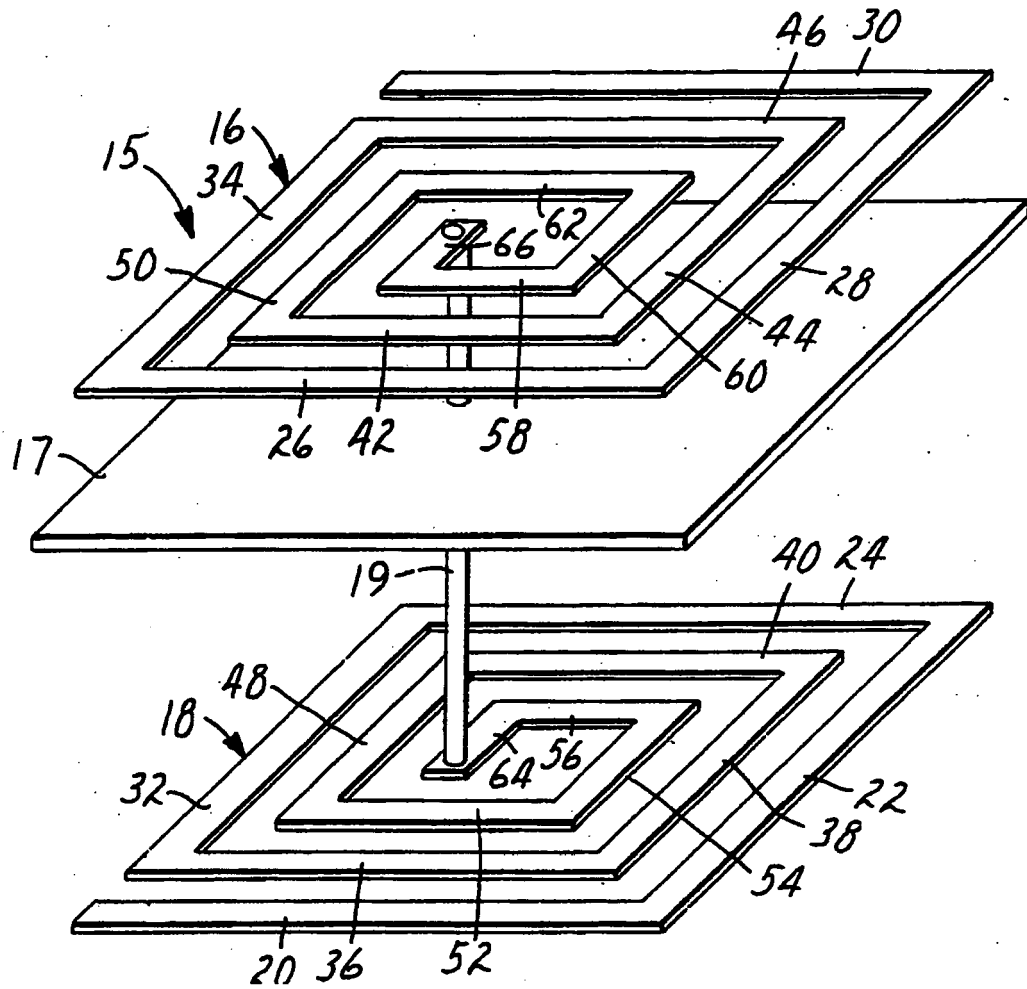


FIGURE 1

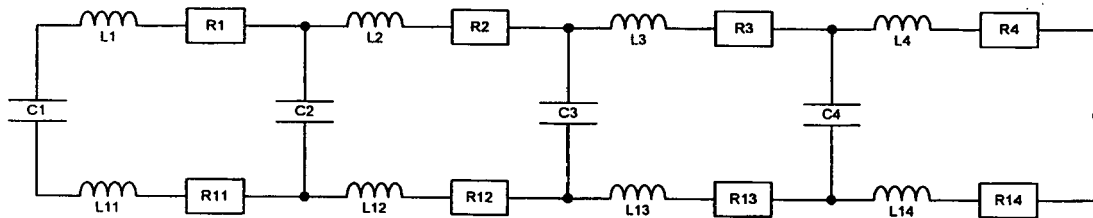


FIGURE 2

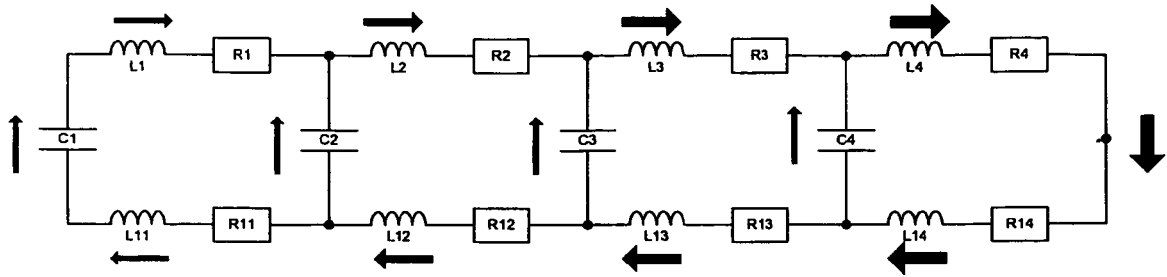


FIGURE 3

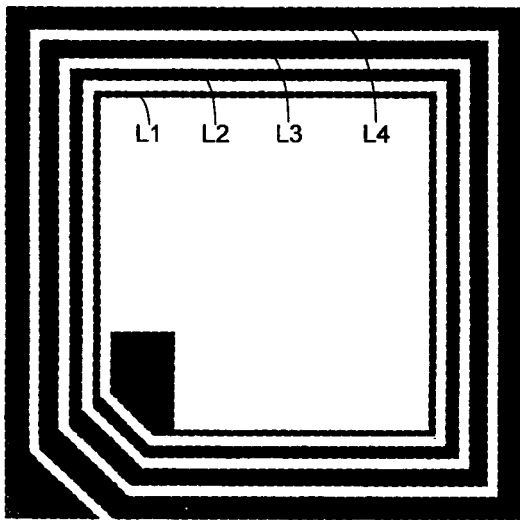


FIGURE 4

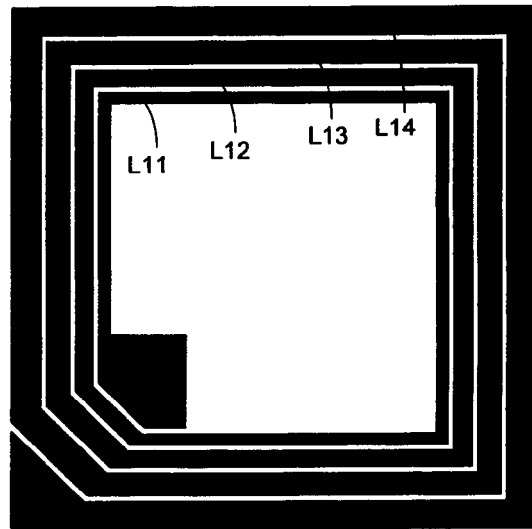


FIGURE 5

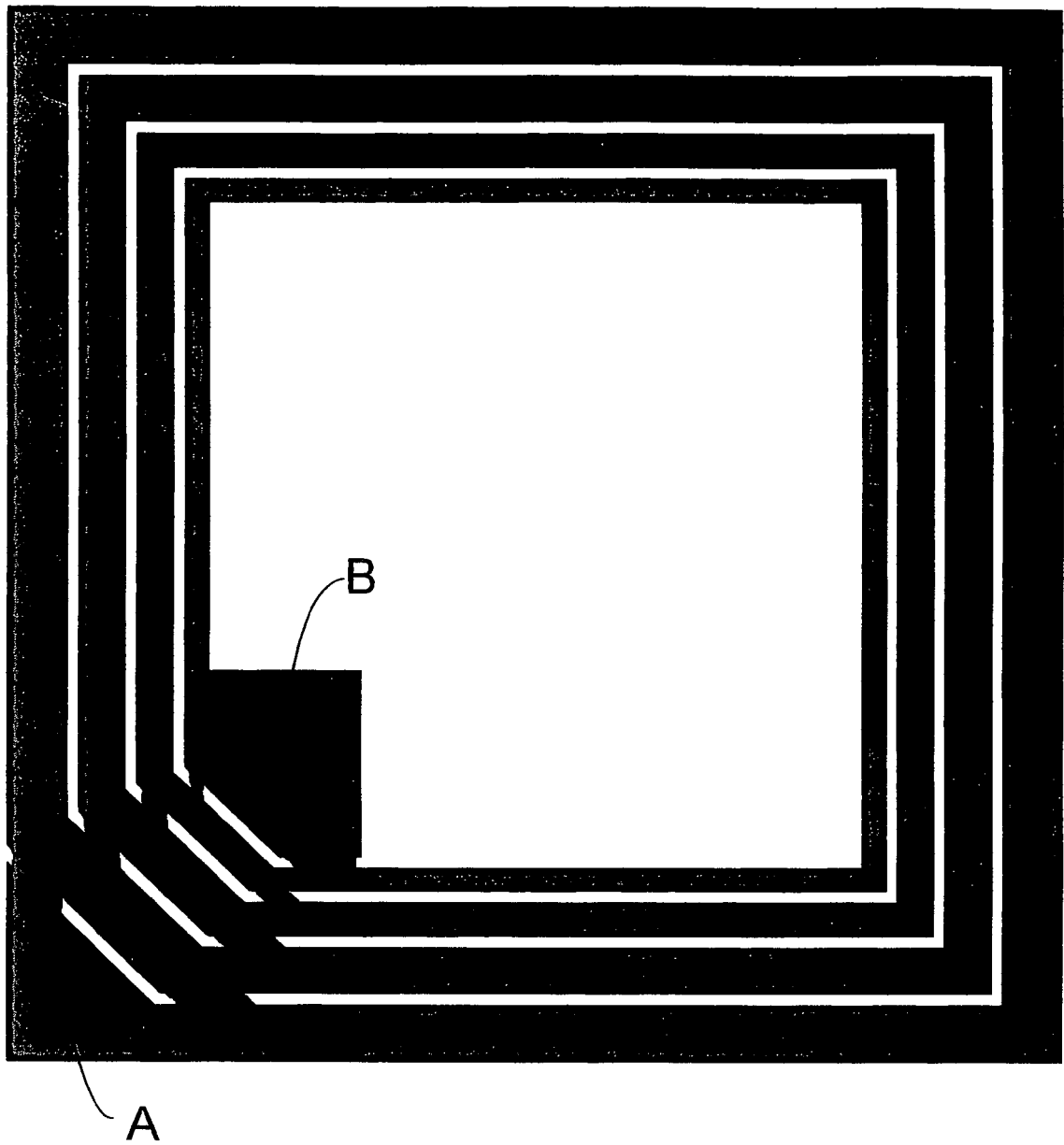


FIGURE 6

REFERENCES CITED IN THE DESCRIPTION

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