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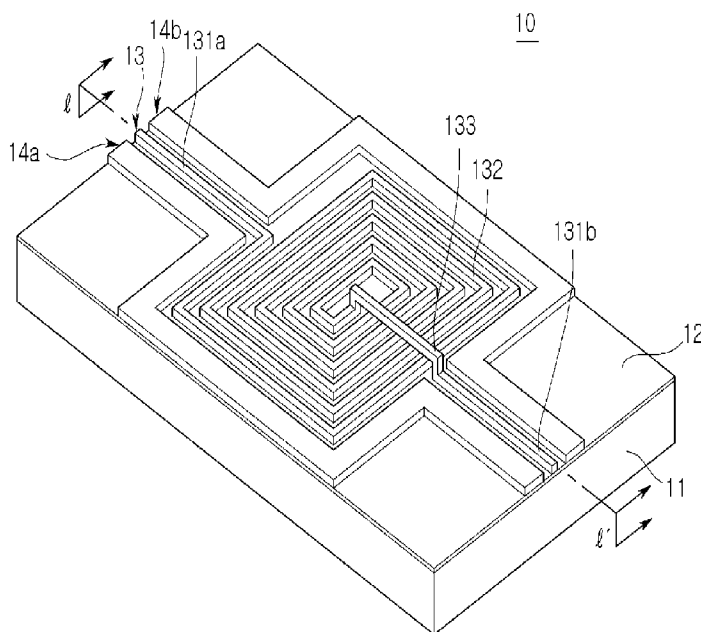
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(54) Title: ELECTROMAGNETIC NOISE FILTER



(57) Abstract: The invention relates to an electromagnetic noise filter capable of regulating LC resonance frequency and applicable to coplanar transmission lines with excellent skirt characteristics. The electromagnetic noise filter includes a semiconductor substrate, and a dielectric film formed on an upper surface of the semiconductor substrate. The electromagnetic noise filter also includes a coplanar signal line formed on the dielectric film with conductive material, the coplanar signal line having a spiral pattern turned at least one time. The electromagnetic noise filter further includes first and second coplanar grounding lines formed on the dielectric film with conductive material, forming opposed peripheries of the coplanar signal line.

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Description

ELECTROMAGNETIC NOISE FILTER

Technical Field

- [1] Field of the Invention The present invention relates to an electromagnetic noise filter, and more particularly, to an electromagnetic noise filter capable of adjusting LC resonance frequency and applicable to coplanar transmission lines having excellent skirt characteristics.

[2]

Background Art

- [3] In general, to cope with needs for prompt exchange of information due to diversification and specialization in today's society, markets have been rapidly expanded for various wireless mobile communication systems enabling telephonic communication any time, any place. A Radio Frequency (RF) semiconductor device, which is an essential part of the wireless mobile communication, refers generically to the semiconductor devices manufactured by a semiconductor process, among the radio frequency devices used in an RF system capable of processing signals of an RF band exceeding the typical GHz level at high speed. In the past, passive elements or single components were used to realize a device or circuit for RF communication, which however have been increasingly substituted with devices adopting the semiconductor technology, due to its unreliable performance in RF applications. In addition, there has been a rapid advancement in Monolithic Microwave IC (MMIC) as an information communication component, which has excellent RF characteristics, exhibits less variation in characteristics according to the size of the signals, and can integrate a number of devices at an RF end, and thus noted of its increasing importance.
- [4] Suggested as a solution for preventing RF noise radiation inevitable in the non-linear semiconductor device mounted to a main board for wireless mobile communication, a personal computer, and the like, the present invention is aimed to minimize electromagnetic wave interference effects by providing a magnetic noise filter integrally with the non-linear semiconductor device.
- [5] In general, the MMIC components require a solution for suppressing RF noise radiation inevitable in the non-linear semiconductor device mounted to the main board of the wireless mobile communication and portable personal computer. Conventionally, an electric wave absorber in the form of a sheet or a thin configuration has been adopted.
- [6] Such an electric wave absorber is a sheet or a device with a thickness of several mm, made of a composite material containing organic high polymer matrix and

magnetic or dielectric powder compacts mixed therein. Such an electric wave absorber is manufactured separately from the non-linear semiconductor chips, which are the source of noise generation, and is mounted near IC chips.

- [7] However, the conventional methods of reducing noise using the electric wave absorber increases the volume and complexity of the circuit, hindering miniaturization, and is not effective in eliminating noise in actual RF applications.

[8]

Disclosure of Invention

Technical Problem

- [9] The present invention has been made to solve the foregoing problems of the prior art and therefore an object of certain embodiments of the present invention is to provide an electromagnetic noise filter which is integrally formed with a non-linear semiconductor device, which is a source of noise generation, thereby minimizing the volume and complexity of a circuit and having excellent noise elimination efficiency.

[10]

Technical Solution

- [11] The present invention has been made to solve the foregoing problems of the prior art and therefore an object of certain embodiments of the present invention is to provide an electromagnetic noise filter which is integrally formed with a non-linear semiconductor device, which is a source of noise generation, thereby minimizing the volume and complexity of a circuit and having excellent noise elimination efficiency.

- [12] According to an aspect of the invention for realizing the object, there is provided an electromagnetic noise filter. The noise filter includes a semiconductor substrate; a dielectric film formed on an upper surface of the semiconductor substrate; a coplanar signal line formed on the dielectric film with conductive material, the coplanar signal line having a spiral pattern turned at least one time; and first and second coplanar grounding lines formed on the dielectric film with conductive material, forming opposed peripheries of the coplanar signal line.

- [13] Preferably, the dielectric film is made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 . The semiconductor substrate may comprise a silicon substrate or a GaAs substrate well known in the art. Especially when adopting a silicon substrate, the dielectric film may be made of SiO_2 .

- [14] Preferably, the coplanar signal line may be made of at least one selected from a group consisting of Cu, Ag, Au, Fe, permalloy, Fe-Ni-based alloy and Fe-Ni-Co-based alloy. In the same fashion, the coplanar grounding lines can also be made of the same material as the coplanar signal line.

- [15] According to the preferred embodiment of the present invention, the electromagnetic noise filter may further include a second dielectric film formed on the spiral pattern of the coplanar signal line. It is preferable that the second dielectric film is made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 , likewise with the dielectric film. Also, for the sake of the convenience in the process, it is preferable that the dielectric film and the second dielectric film are made of the same dielectric material.
- [16] In a more specific embodiment, the coplanar signal line may include first and second signal input/output lines having a linear form; an inductor line with one end connected to the first signal input/output line, the inductor line having a spiral pattern turned at least one time; and an air bridge for electrically connecting the other end of the inductor line and the second signal input/output line. In this embodiment, the electromagnetic noise filter may further include a second dielectric film formed on an upper part of the inductor line and having a through hole which the air bridge passes through, wherein at least a part of the air bridge is formed within the through hole and on an upper surface of the second dielectric film.
- [17] According to another embodiment of the present invention, the electromagnetic noise filter may further include a magnetic film formed on an upper surface of the second dielectric film. The magnetic film may be formed on an entire surface or at least a part of the dielectric film. In the embodiment including the air bridge formed on the second dielectric film, the magnetic film may be formed in various configurations on at least a part of an area on an upper surface of the second dielectric film excluding the part where the air bridge is formed.
- [18] In this embodiment, it is preferable that the magnetic film is made of one selected from a group consisting of a CoFe-based nano-granular soft magnetic film, a Co-based nano-granular soft magnetic film, a Fe-based nano-granular soft magnetic film, a permalloy-based nano-granular soft magnetic film, a Co-Nb-Zr alloy soft magnetic film and a Fe-based alloy soft magnetic film.

[19]

Advantageous Effects

- [20] According to the present invention set forth above, the inductor line is formed in a spiral pattern in the coplanar transmission lines and the number of turns of the inductor line is adjusted, thereby suitably regulating the signal stop band of the electromagnetic noise filter.
- [21] In addition, according to the present invention, the magnetic film is additionally formed on the inductor line to significantly improve the skirt characteristics of the electromagnetic noise filter. Also, even after the number of turns of the inductor line is

set, the area of the magnetic film can be adjusted to regulate the signal stop band of the electromagnetic noise filter in a wide range of the frequency band.

- [22] Further, when the electromagnetic noise filter of the present invention is produced as a single chip with a non-linear semiconductor device, the circuit of the main board can be minimized in its volume and complexity, enabling miniaturization and low power of portable wireless communication terminals and wireless LAN and personal computers and decreasing electromagnetic wave interference (EMI) including crosstalk to improve the RF performance of the semiconductor devices sensitive to noise.

[23]

Brief Description of the Drawings

- [24] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

- [25] FIGS. 1 and 2 are perspective view and side sectional view illustrating an electromagnetic noise filter according to a first embodiment of the present invention;

- [26] FIGS. 3 to 5 are a perspective view, an exploded perspective view and a side sectional view illustrating an electromagnetic noise filter according to a second embodiment of the present invention;

- [27] FIGS. 6 to 8 are a perspective view, an exploded perspective view and a side sectional view illustrating an electromagnetic noise filter according to a third embodiment of the present invention;

- [28] FIG. 9 is a graph showing attenuation characteristics of electromagnetic noise according to the number of winding in the electromagnetic noise filter according to the present invention;

- [29] FIG. 10 to 12 are graphs showing attenuation characteristics compared between the electromagnetic noise filters including magnetic films according to the present invention and those without such magnetic films;

- [30] FIG. 13 and 14 are plan views illustrating the magnetic film applied to the electromagnetic noise filter according to the present invention; and

- [31] FIG. 15 is a graph showing attenuation characteristics compared among the electromagnetic noise filter without the magnetic film, the one with the magnetic film shown in FIG. 13 and another one with the magnetic film shown in FIG. 14.

[32]

Mode for the Invention

- [33] Preferred embodiments of the present invention will now be described in detail with reference to the accompanying drawings. The invention may however be embodied in many different forms and should not be construed as limited to the embodiments set

forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. The terms are defined herein in consideration of the function in the context of the present invention, and may be defined differently depending on the intention and practice by a person with skill in the art. Therefore, the definitions of the terms should not be construed as limiting the technical features of the present invention.

- [34] FIGS. 1 and 2 are a perspective view and a side sectional view illustrating an electromagnetic noise filter according to a first embodiment of the present invention.
- [35] With reference to FIGS. 1 and 2, the electromagnetic noise filter 10 according to the first embodiment of the present invention includes a semiconductor substrate 11, a dielectric film 12 formed on an upper surface of the semiconductor substrate 11 and coplanar transmission lines 13, 14a and 14b formed on the dielectric film 12. The coplanar transmission lines 13, 14a and 14b are composed of a coplanar signal line 13 and first and second coplanar grounding lines 14a and 14b formed about the coplanar signal line 13 at opposed sides, forming outer peripheries of the coplanar signal line 13.
- [36] The semiconductor substrate 11 may be one that is used typically in the manufacture of an integrated circuit device, but is not limited thereto, and thus may be a Si substrate or a GaAs substrate. The area of the semiconductor substrate 11 where the electromagnetic noise filter 10 is formed can be understood as a partial region of the semiconductor substrate where an RF integrated circuit including an irreversible device is formed.
- [37] The dielectric film 12 is an insulation material for forming the coplanar signal line 13 and the first and second coplanar grounding lines 14a and 14b, and is provided as a dielectric material constituting a distributed element capacitor in the present invention. The dielectric film 12 may be made of at least one selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 . In the case of using a Si substrate as the semiconductor substrate 11, SiO_2 which can be formed through a process of oxidizing the silicon substrate, can be adopted for the dielectric film 12.
- [38] The coplanar transmission lines adopted in the present invention has good signal transmission characteristics in RF applications, exhibits minimal change of characteristics according to the size of the signals, and is more easily manufactured than other types of lines, thus advantageously adopted for an RF semiconductor device.
- [39] The coplanar signal line 13 and coplanar grounding lines 14a and 14b can be made of at least one metallic material selected from a group consisting of Cu, Ag, Au, Fe, permalloy, Fe-Ni-based alloy and Fe-Ni-Co-based alloy, on the dielectric film 22. In such coplanar transmission lines, the coplanar signal line 13 and the coplanar

grounding lines 14a and 14b have widths, thicknesses and intervals therebetween that are designated by Muller and Hilberg Equations, which is used to design the widths and thicknesses of and intervals between the coplanar transmission lines 13, 14a and 14b to satisfy desired characteristic impedance.

[40] In particular, the coplanar signal line 13 has a spiral pattern having at least one turn. More specifically, the coplanar signal line 13 includes first and second input/output lines 131a and 131b having a linear form; an inductor line 132 having one end connected to the first signal input/output line 131a and having a spiral pattern having at least one turn; and an air bridge 133 electrically connecting the other end of the inductor line 132 with the second signal input/output line 131b. In the present invention, the spiral pattern of inductor line 132 is formed in the coplanar signal line 13, so that the inductance generated by the spiral pattern can be obtained in addition to the inductance generated by the length of the coplanar signal line alone. Further, the number of turns of the spiral pattern of the inductor line 132 can be adjusted to determine the resonance frequency desired.

[41] The coplanar grounding lines 14a and 14b can be formed in parallel with the linear first and second signal input/output lines 131a and 131b at opposed sides, forming opposed peripheries of the inductor line 132.

[42] In addition, the air bridge 133 is formed across and above in a predetermined interval from the inductor line 132 to connect one end of the inductor line 132 with the second signal input/output line 131b.

[43] In FIGS. 1 and 2 illustrating the first embodiment, the spiral pattern is turned in a rectangular shape but it will be apparent to the person in the art that the shape of the spiral pattern may be modified variously to a circle, a polygon, etc. In addition, the first and second signal input/output lines 131a and 131b are opposed to each other linearly, which is also modifiable variously as apparent to the person in the art.

[44] As described above, the electromagnetic noise filter 10 according to the first embodiment of the present invention utilizes the principle of LC resonance, providing an effective shielding effect of electromagnetic noise with a small volume. That is, the electromagnetic noise filter 10 according to the first embodiment of the present invention can act as a low pass filter due to the resonance effect by the inductance generated from the spiral pattern (the inductor line 132) of the coplanar signal line 13 and the capacitance generated at the dielectric film 12 in combination with the coplanar transmission lines 13, 14a and 14b. In addition, the electromagnetic noise filter 10 according to the first embodiment of the invention can adjust the inductance value of the coplanar signal line 13 by adjusting the number of turns of the spiral pattern, thereby suitably regulating the LC resonance frequency and attenuation band of electromagnetic noise if necessary.

- [45] FIGS. 3 to 5 are a perspective view, an exploded perspective view and a side sectional view illustrating an electromagnetic noise filter according to a second embodiment of the present invention.
- [46] Referring to FIGS. 3 to 5, the electromagnetic noise filter 20 according to the second embodiment of the present invention further includes a second dielectric film 25 formed additionally on an upper part of the spiral pattern, i.e., the inductor line 232 of the electromagnetic noise filter according to the aforescribed first embodiment. The semiconductor substrate 21, the dielectric film 22, the coplanar transmission lines 23, 24a and 24b, the first and second signal input/output lines 231a and 231b constituting the coplanar signal line 23 and the inductor line 232 in the second embodiment are substantially identical to those described in the first embodiment, and thus a detailed explanation on these components will be substituted by the description in the first embodiment.
- [47] In the electromagnetic noise filter 20 according to the second embodiment of the present invention, the second dielectric film 25 may be made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 , similar to the dielectric film 22. In order to facilitate the fabrication process, it is preferable that the second dielectric film 25 is made of the same material as the dielectric film 22.
- [48] The second dielectric film 25 may have a through hole h which the air bridge 233 passes through and the air bridge 233 is configured to contact an inner surface of the through hole h and an upper surface of the second dielectric film 25. Having a part in contact with an upper surface of the second dielectric film 25, the air bridge 233 can be prevented from being deformed or damaged by physical impacts, etc. and from being short-circuited with the line formed underneath. Further, the second dielectric film 25 may have an additional effect of preventing a short circuit between a magnetic film described in a third embodiment to be described later and the coplanar transmission lines formed underneath.
- [49] The second dielectric film 25 may provide additional distributed element capacitance. That is, according to the second embodiment of the present invention, the second dielectric film 25 is formed above the coplanar transmission lines 23, 24a and 24b and the dielectric film 22 is formed underneath the coplanar transmission lines 23, 24a and 24b, respectively, and thus two kinds of capacitance may be at work, similar to a typical Multi-Layer Ceramic Capacitor (MLCC), thereby further increasing the capacitor effects.
- [50] In FIGS. 3 to 5, the second dielectric film 25 is illustrated to be formed above the spiral pattern (the inductor line 232), but it can also be formed in other locations in other embodiments. Therefore, it should be understood that the second dielectric film

25 is formed in areas including a region above the spiral pattern.

[51] FIGS. 6 to 8 are a perspective view, an exploded perspective view and a side sectional view illustrating an electromagnetic noise filter according to a third embodiment of the present invention.

[52] Referring to FIGS. 6 to 8, the electromagnetic noise filter 30 according to the third embodiment of the present invention further includes a magnetic film 36 additionally formed on the second dielectric film 35 of the electromagnetic noise filter 30 according to the second embodiment of the present invention. In the third embodiment of the present invention, the semiconductor substrate 31, the dielectric film 31, the coplanar transmission lines 33, 34a and 34b, the first and second signal input/output lines 331a and 331b and the inductor line 332 are substantially identical to those described in the first and second embodiments, and thus a detailed explanation on these components is omitted.

[53] The magnetic film 36 may comprise one selected from a group consisting of a CoFe-based nano-granular soft magnetic film, a Co-based nano-granular soft magnetic film, a Fe-based nano-granular soft magnetic film, a permalloy nano-granular soft magnetic film, a Co-Nb-Zr alloy soft magnetic film and a Fe-based alloy soft magnetic film.

[54] In order to prevent a short circuit with the air bridge 333 exposed over an upper part of the second dielectric film 35, the magnetic film 36 is not formed directly in contact with the air bridge 333. In order for this, the magnetic film 36 is illustrated in FIGS. 6 to 8 as a rectangular structure with a slot s formed. However, the magnetic film 36 is not limited to the structure illustrated in the drawings, and may be modified to various shapes including a circular and polygonal shape as long as it does not directly contact the air bridge 333.

[55] The magnetic film 36 adopted in the third embodiment of the present invention serves to additionally increase the inductance value of the electromagnetic noise filter 30. Further, the magnetic film 36 is provided to minimize ferromagnetic resonance absorption loss and improve eddy current loss. This allows the electromagnetic noise filter 30 according to the third embodiment to obtain higher inductance value than in the aforescribed embodiments, and to exhibit improved skirt characteristics distinguishing between a signal pass band and a signal stop band.

[56] Now, the attenuation effects of the electromagnetic noise filter will be explained through specific Examples with reference to the aforescribed embodiments.

[57]

[58] **Example 1**

[59] In this Example, the electromagnetic noise filter according to the aforescribed second embodiment of the present invention was fabricated through the following

procedures. The Example will be explained with reference to FIGS. 3 to 4 and FIG. 9.

[60] First, a dielectric film made of SiO_2 is formed in a thickness of $1\ \mu\text{m}$ on a silicon substrate 21 having a thickness of $500\ \mu\text{m}$. Then, to form coplanar transmission lines, a buffer layer made of Ti and a seed layer made of Cu for electric plating are deposited in thicknesses of 10 nm and 50 nm, respectively, on the dielectric film 22 via sputtering. With Ti and Cu deposited on the dielectric film 22, a photoresist film is coated on the dielectric film 22 via spin coating, and then a mold having a spiral pattern corresponding to an inductor line 232 and the rest of the patterns corresponding to a coplanar signal line 23 and coplanar grounding lines 24a and 24b is fabricated via a photo-lithography process. Next, Cu is deposited in a thickness of $3\ \mu\text{m}$ via electric plating in the mold with the patterns as just described. Then the mold is removed to complete the electromagnetic noise filter as shown in FIG. 1. In the electromagnetic noise filter, the coplanar signal line 23 was formed in a width of $10\ \mu\text{m}$, and each of the coplanar grounding lines 24a and 24b were formed in a width of $35\ \mu\text{m}$. In addition, the coplanar signal line 23 and each of the coplanar grounding lines 24a and 24b were formed to have an interval of $20\ \mu\text{m}$, and the inductor line 232 of the coplanar signal line 23 was formed to have a width of $10\ \mu\text{m}$ and an interval of $10\ \mu\text{m}$ between adjacent turns thereof.

[61] In this Example, in order to probe the relationship between the number of turns and the noise attenuation characteristics, the electromagnetic noise filters were fabricated with each of the inductor lines 232 fabricated in the dimensions and by the method described above, except for the number of turns varying at 5, 10 and 13 turns. A second dielectric film 25 having a thickness of $4\ \mu\text{m}$ from an upper surface of the dielectric film 22 was formed via E-beam evaporation on each of the inductor line 232. Thereby, the electromagnetic noise filters according to the second embodiment were completed as illustrated in FIGS. 3 to 4. Since the coplanar transmission lines 23, 24a and 24b have a thickness of $3\ \mu\text{m}$, the second dielectric film 25 was formed $1\ \mu\text{m}$ higher than the uppermost part of the coplanar transmission lines 23, 24a and 24b.

[62] FIG. 9 shows the results obtained from measuring the signal attenuation characteristics of the electromagnetic noise filters fabricated according to this Example in the band of 0.1 to 20GHz, with a network analyzer. Reference numeral '41' refers to the attenuation characteristics at 5 turns of the inductor line 232, reference numeral '42' refers to the attenuation characteristics at 10 turns of the inductor line 232, and reference numeral '43' refers to the attenuation characteristics at 13 turns of the inductor line 232.

[63] As shown in FIG. 9, when the inductor line 232 has 5 turns, 41, LC resonance occurs at 11.2 GHz, with signal attenuation of -18.7 dB. When the inductor line 232 has 10 turns, 42, LC resonance occurs at 5.8 GHz, with signal attenuation of -18.2 dB.

When the inductor line 232 has 13 turns, 43, LC resonance occurs at 3.8 GHz, with signal attenuation of -19.2 dB. Given that -3 dB is the minimum index for a signal to pass, the electromagnetic noise filter with 5 turns of the inductor line 232 exhibited the attenuation of the electromagnetic noise beginning at 2.9 GHz and at maximum at 11.2 GHz. In addition, in the case of the electromagnetic noise filters with 10 and 13 turns of the inductor lines 232, the electromagnetic noise begins to attenuate at 1.0 GHz and 0.55 GHz, respectively, and attenuates at maximum at 5.8 GHz and 3.8 GHz, respectively.

- [64] As the results indicate, with the increasing number of turns of the inductor line 232, the total inductance of the coplanar transmission lines increases and thus the LC resonance frequency decreases. That is, the electromagnetic noise filter of the present invention adjusts the number of turns of the spiral pattern of the inductor line 232 to obtain LC resonance at a desired frequency band, thereby determining a signal band desired. For example, in the case of the electromagnetic noise filters with 5 and 10 turns of the inductor lines, the RF electromagnetic noise attenuation is expected in the typical mobile communication frequency band (1 to 5 GHz), and in the case of the electromagnetic noise filter with 13 turns of the inductor line, the electromagnetic noise attenuation is expected in the wireless LAN frequency band (5 to 10 GHz).

[65] **Example 2**

- [66] In this Example, a magnetic film is formed on the second dielectric film of the electromagnetic noise filter fabricated in Example 1, related to the aforescribed third embodiment. In this Example, the attenuation characteristics are compared between the case with the magnetic film and the case without the magnetic film. This Example is explained with reference to FIGS. 6 to 8 and FIG. 10 to 12.

- [67] An Fe soft magnetic film 36 is deposited in a thickness of 2 μ m via RF sputtering on the second dielectric film 35 of SiO₂ of each of the electromagnetic noise filters fabricated in the Example 1. Then, in order to prevent a short-circuit between the air bridge 333 exposed above an upper surface of the second dielectric film 35 and the Fe soft magnetic film 36, a portion S of the Fe soft magnetic film 36 in contact with the air bridge 333 was removed via wet etching (Buffered Oxide Etch solution HF:H₂O = 1:6).

- [68] FIGS. 10 to 12 are the results obtained from measuring the signal attenuation characteristics of the electromagnetic noise filters having the inductor lines 332 having 5 turns, 10 turns and 13 turns, respectively, with a network analyzer.

- [69] As shown in FIG. 10, the electromagnetic noise filter 51b without the magnetic film 36, and with 5 turns of the inductor line 332, exhibited gradual skirt characteristics, and thus the signal pass band and the signal stop band were not clearly distinguished. Given that -3 dB is the minimum index value for a signal to pass, the stop band started

at 2.9 GHz and the maximum signal attenuation occurred at 11.2 GHz where LC resonance took place. On the contrary, with the Fe soft magnetic film 36 deposited, 51a, the stop band started at 1.8 GHz(based on -3 dB) and the maximum signal attenuation index value occurred at 2.9 GHz where the LC resonance took place, indicating very steep skirt characteristics. That is, in the case without the magnetic film 36, 51b, the band width from the frequency where the signal stop band starts to the LC resonance occurrence frequency was 8.3GHz, indicating very gradual skirt characteristics. But, with the magnetic film 36 deposited, 51a, the band width from the frequency where the signal stop band starts to the LC resonance occurrence frequency was 1.1 GHz, which indicates very steep skirt characteristics.

[70] Similarly, as shown in FIG. 11, in the case of the electromagnetic noise filter 52b without the magnetic film, and with 10 turns of the inductor line 332, 52b, the band width from the frequency (1.0 GHz) where the signal stop band starts to the LC resonance occurrence frequency (5.8 GHz) is 4.8 GHz, indicating very gradual skirt characteristics. On the contrary, with the Fe soft magnetic film 36 formed on the inductor line 332, 52a, the band width from the frequency (0.8 GHz) where the signal stop band starts to the LC resonance occurrence frequency (1.3 GHz) is 0.5 GHz, indicating very steep skirt characteristics.

[71] Moreover, as shown in FIG. 12, in the case of the electromagnetic noise filter 53b without the magnetic film 36 and with 13 turns of the inductor line 332, the band width from the frequency (0.55 GHz) where the signal stop band starts to the LC resonance occurrence frequency (3.8 GHz) was 3.25 GHz, indicating gradual skirt characteristics. On the contrary, with the Fe soft magnetic film 36 deposited on the inductor line 332, 52a, the band width from the frequency (0.46 GHz) where the signal stop band starts to the LC resonance occurrence frequency (0.8 GHz) was 0.34 GHz, indicating very steep skirt characteristics.

[72] As the measurement results in this Example indicate, when the magnetic film is deposited on the inductor line, the increase in the inductance due to the magnetic permeability of the magnetic film results in shifting the LC resonance frequency of the coplanar transmission lines to a low frequency band and in decreasing the bandwidth from the frequency where the signal stop band starts to the LC resonance occurrence frequency, significantly improving the skirt characteristics.

[73] **Example 3**

[74] In this Example, the signal attenuation characteristics were observed according to the area of the magnetic film of each of the electromagnetic noise filters fabricated in Example 2. This Example will be explained with reference to FIGS. 6 to 8 and FIGS. 13 to 15.

[75] Two of the electromagnetic noise filters with 5 turns of the inductor line 332 were

fabricated according to the method described in Example 1. Then, the magnetic films 36a and 36b as shown in FIGS. 13 and 14, respectively, were formed on the respective second dielectric films 35 of the electromagnetic noise filters. The magnetic films were fabricated with the material and through the process as described in Example 2. The second dielectric films 35 were fabricated in an upper surface area of $420\ \mu\text{m} \times 400\ \mu\text{m}$, and the magnetic films 36a and 36b were fabricated in a shape similar to 'U' formed along a periphery of the second dielectric film. The magnetic film 36a shown in FIG. 13 was formed in a strip having a width of $30\ \mu\text{m}$ along the periphery of upper surface of the second dielectric film 35, and the magnetic film 36b shown in FIG. 14 was formed in a strip having a width of $100\ \mu\text{m}$ along the periphery of the upper surface of the second dielectric film 35.

[76] FIG. 15 shows the results obtained from measuring the signal attenuation characteristics of the electromagnetic noise filters with the magnetic films shown in FIGS. 13 and 14, respectively, with a network analyzer. Reference numeral '71a' in FIG. 15 refers to the noise attenuation characteristics of the electromagnetic noise filter without the magnetic film formed on the inductor line 332 having 5 turns, reference numeral '71b' refers to the noise attenuation characteristics of the electromagnetic noise filter with the magnetic film 36a shown in FIG. 13 formed on the inductor line 332 having 5 turns, and reference numeral '71c' refers to the noise attenuation characteristics of the electromagnetic noise filter with the magnetic film 36a shown in FIG. 13 formed on the inductor line 332 having 5 turns.

[77] As shown in FIG. 15, in the case of the electromagnetic noise filter without the magnetic film, indicated by reference numeral 71a, LC resonance occurred at 11.2 GHz. In the case of the electromagnetic noise filter with the magnetic film 36a shown in FIG. 13, indicated by reference numeral 71b, LC resonance occurred at 8.4 GHz, and in the case of the electromagnetic noise filter with the magnetic film 36b shown in FIG. 14, indicated by reference numeral 71c, LC resonance occurred at 2.9 GHz.

[78] Through this Example, it is confirmed that the inductance of the coplanar transmission lines increases with the greater area of the magnetic film 36, and thereby the LC resonance frequency is shifted to the lower frequency band. This is also effective in the case where the second dielectric film 35 is formed on the inductor line 332 already set in the number of turns. The signal stop band of the electromagnetic noise filter can be regulated in a wide range of the frequency band by suitably adjusting the area of the magnetic film 36.

[79]

[80] While the present invention has been shown and described in connection with the preferred embodiments, it will be apparent to those skilled in the art that modifications and variations can be made without departing from the spirit and scope of the invention

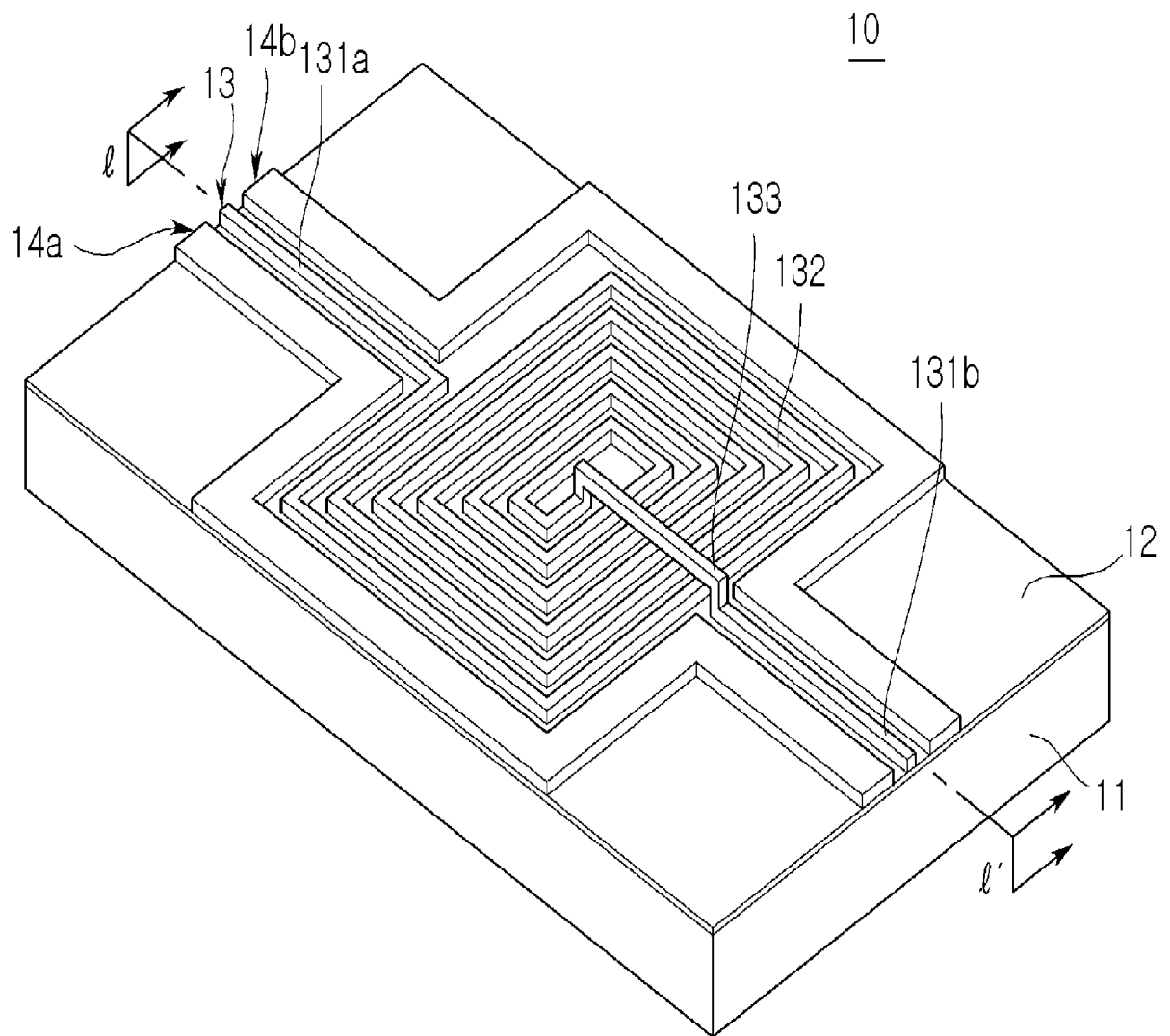
as defined by the appended claims.

Claims

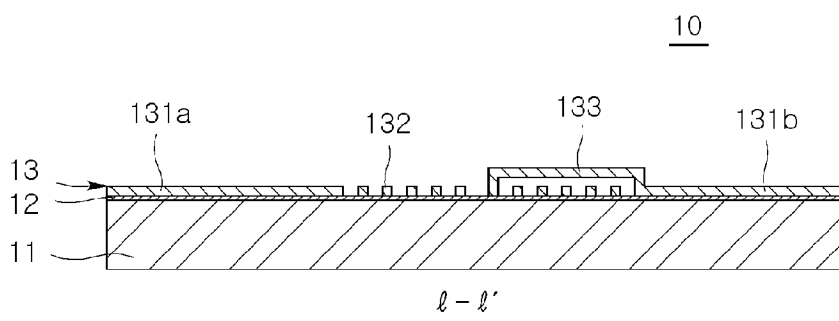
- [1] An electromagnetic noise filter comprising:
a semiconductor substrate;
a dielectric film formed on an upper surface of the semiconductor substrate;
a coplanar signal line formed on the dielectric film with conductive material, the coplanar signal line having a spiral pattern turned at least one time; and
first and second coplanar grounding lines formed on the dielectric film with conductive material, forming opposed peripheries of the coplanar signal line.
- [2] The electromagnetic noise filter according to claim 1, wherein the dielectric film is made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 .
- [3] The electromagnetic noise filter according to claim 1, wherein the semiconductor substrate comprises a silicon substrate or a GaAs substrate.
- [4] The electromagnetic noise filter according to claim 3, wherein the dielectric film is made of SiO_2 .
- [5] The electromagnetic noise filter according to claim 1, wherein the coplanar signal line is made of at least one selected from a group consisting of Cu, Ag, Au, Fe, permalloy, Fe-Ni-based alloy and Fe-Ni-Co-based alloy.
- [6] The electromagnetic noise filter according to claim 1, wherein the coplanar grounding line is made of at least one selected from a group consisting of Cu, Ag, Au, Fe, permalloy, Fe-Ni-based alloy and Fe-Ni-Co-based alloy.
- [7] The electromagnetic noise filter according to claim 1, further comprising a second dielectric film formed on the spiral pattern of the coplanar signal line.
- [8] The electromagnetic noise filter according to claim 7, wherein the second dielectric film is made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 .
- [9] The electromagnetic noise filter according to claim 8, wherein the dielectric film and the second dielectric film are made of the same dielectric material.
- [10] The electromagnetic noise filter according to claim 7, further comprising a magnetic film formed at least a part of an upper surface of the second dielectric film.
- [11] The electromagnetic noise filter according to claim 10, wherein the magnetic film comprises one selected from a group consisting of a CoFe-based nano-granular soft magnetic film, a Co-based nano-granular soft magnetic film, a Fe-based nano-granular soft magnetic film, a permalloy-based nano-granular soft magnetic film, a Co-Nb-Zr alloy soft magnetic film and a Fe-based alloy soft magnetic film.

- [12] The electromagnetic noise filter according to claim 1, wherein the coplanar signal line comprises:
first and second signal input/output lines having a linear form;
an inductor line with one end connected to the first signal input/output line, the inductor line having a spiral pattern turned at least one time; and
an air bridge for electrically connecting the other end of the inductor line and the second signal input/output line.
- [13] The electromagnetic noise filter according to claim 12, further comprising a second dielectric film formed on an upper part of the inductor line and having a through hole which the air bridge passes through,
wherein at least a part of the air bridge is formed within the through hole and on an upper surface of the second dielectric film.
- [14] The electromagnetic noise filter according to claim 13, wherein the second dielectric film is made of at least one dielectric material selected from a group consisting of SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , BaTiO_3 and SrTiO_3 .
- [15] The electromagnetic noise filter according to claim 14, wherein the dielectric film and the second dielectric film are made of the same dielectric material.
- [16] The electromagnetic noise filter according to claim 13, further comprising a magnetic film formed on at least a part of an upper surface of the second dielectric film.
- [17] The electromagnetic noise filter according to claim 16, wherein the magnetic film is formed on at least a part of an area on an upper surface of the second dielectric film excluding the part where the air bridge is formed.
- [18] The electromagnetic noise filter according to claim 16, wherein the magnetic film is made of one selected from a group consisting of a CoFe-based nano-granular soft magnetic film, a Co-based nano-granular soft magnetic film, a Fe-based nano-granular soft magnetic film, a permalloy-based nano-granular soft magnetic film, a Co-Nb-Zr alloy soft magnetic film and a Fe-based alloy soft magnetic film.

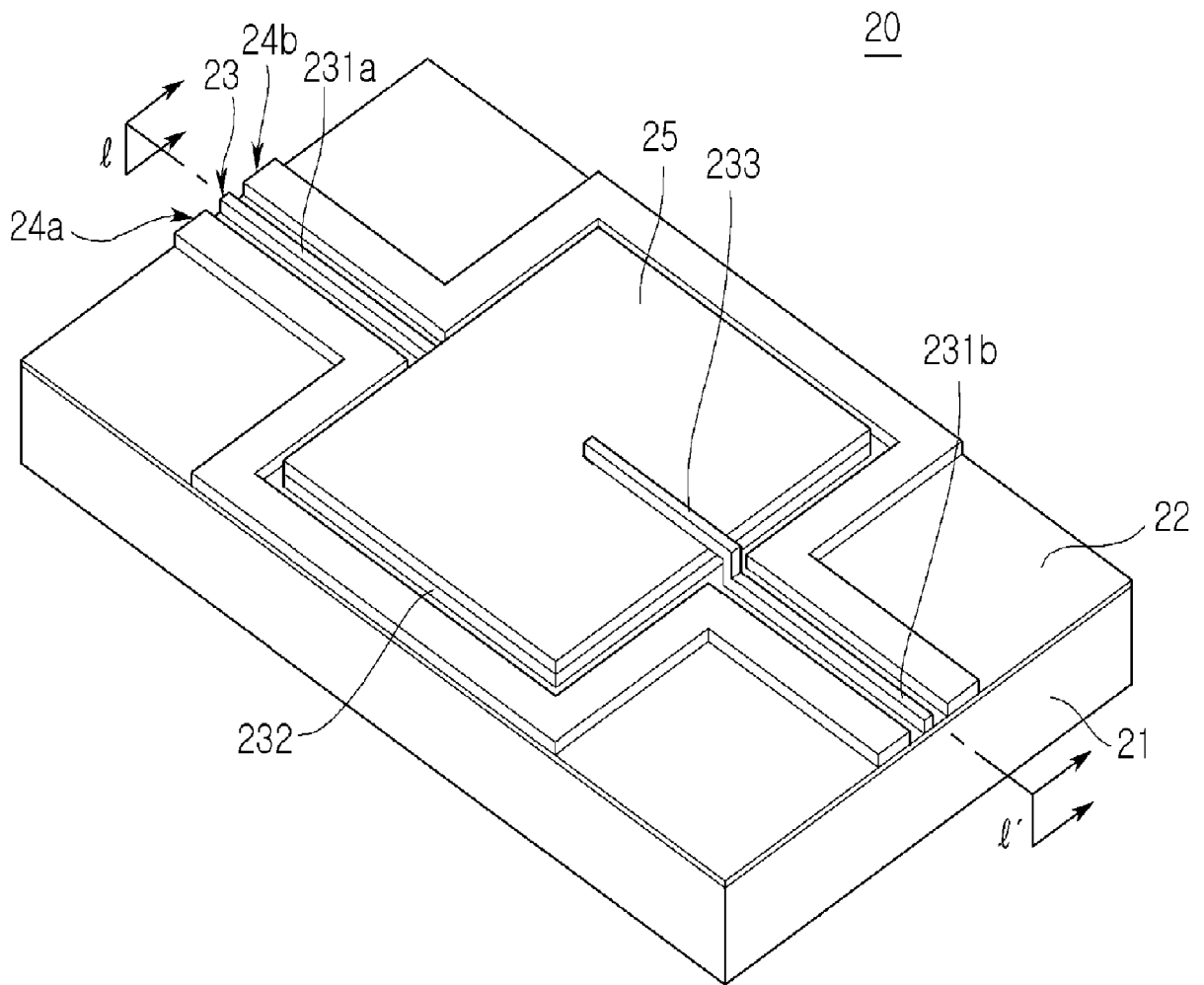
[Fig. 1]



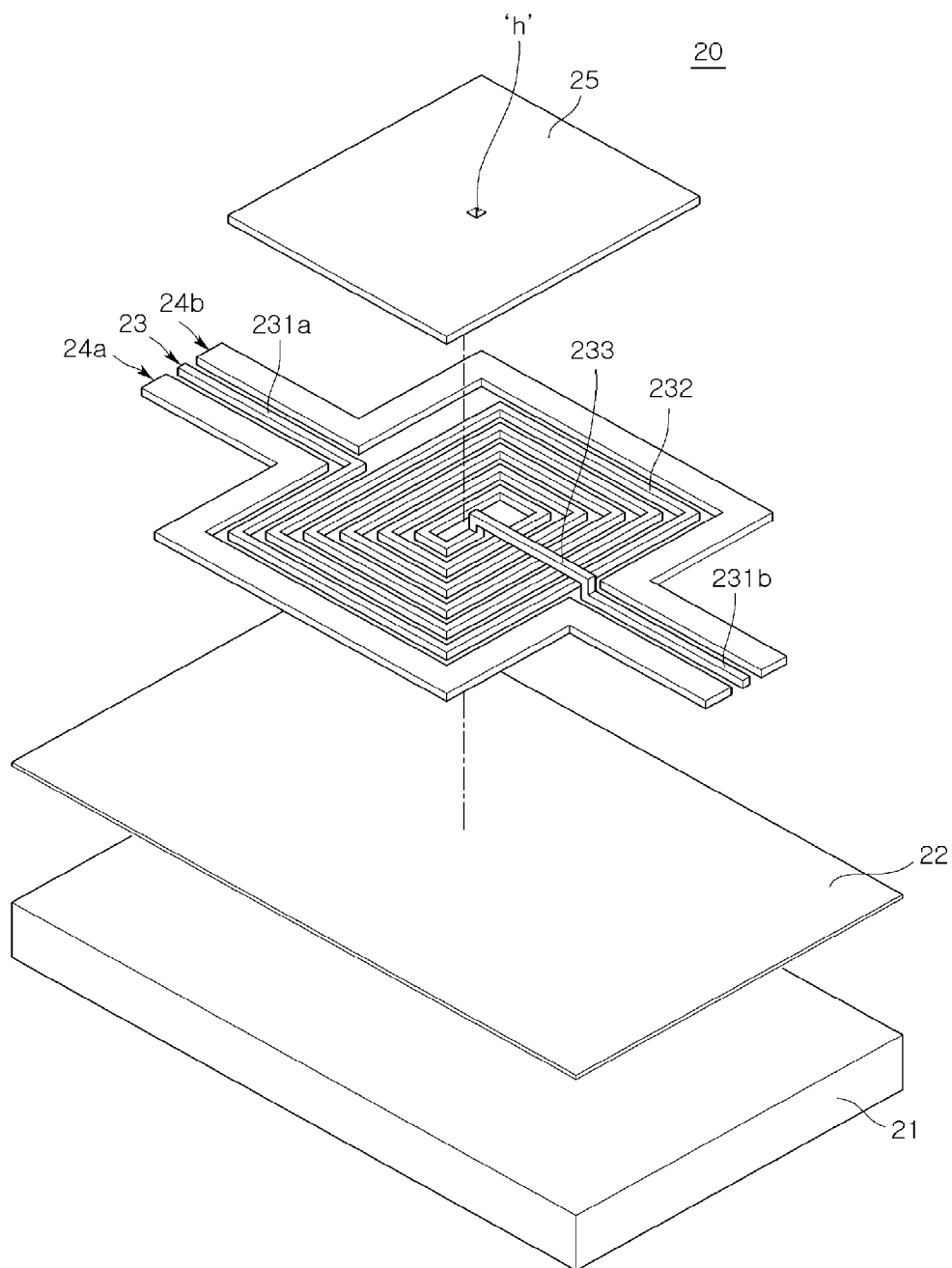
[Fig. 2]



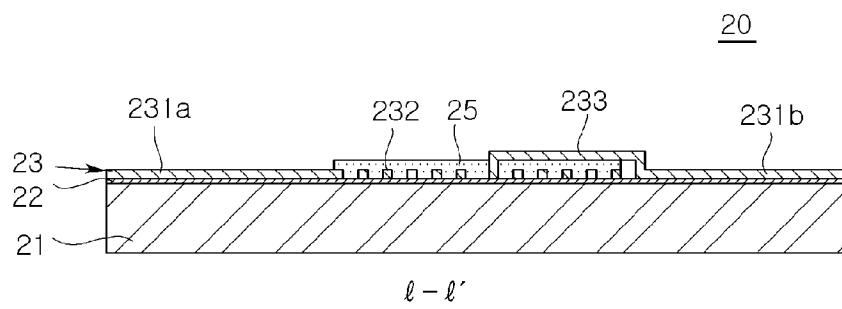
[Fig. 3]



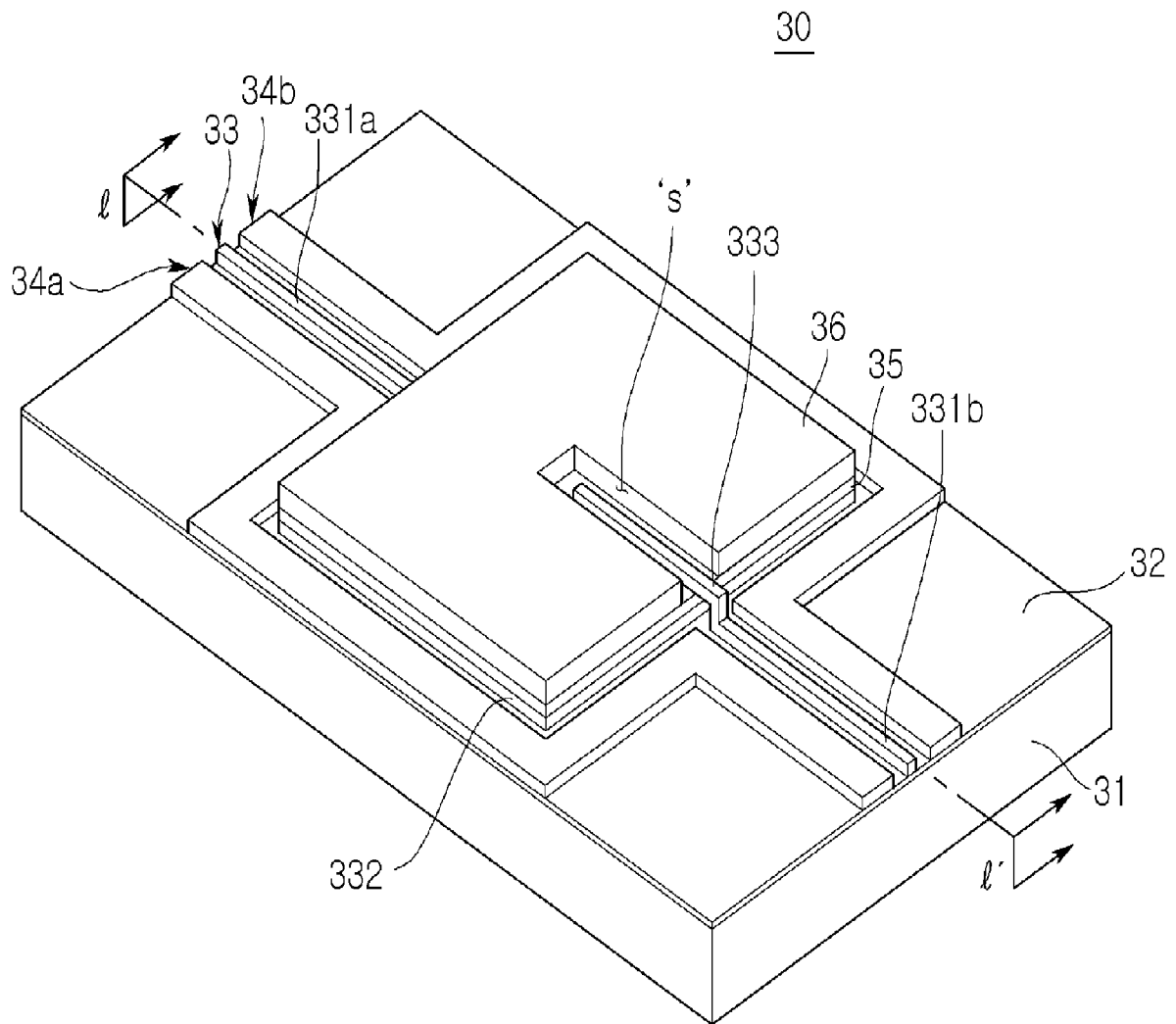
[Fig. 4]



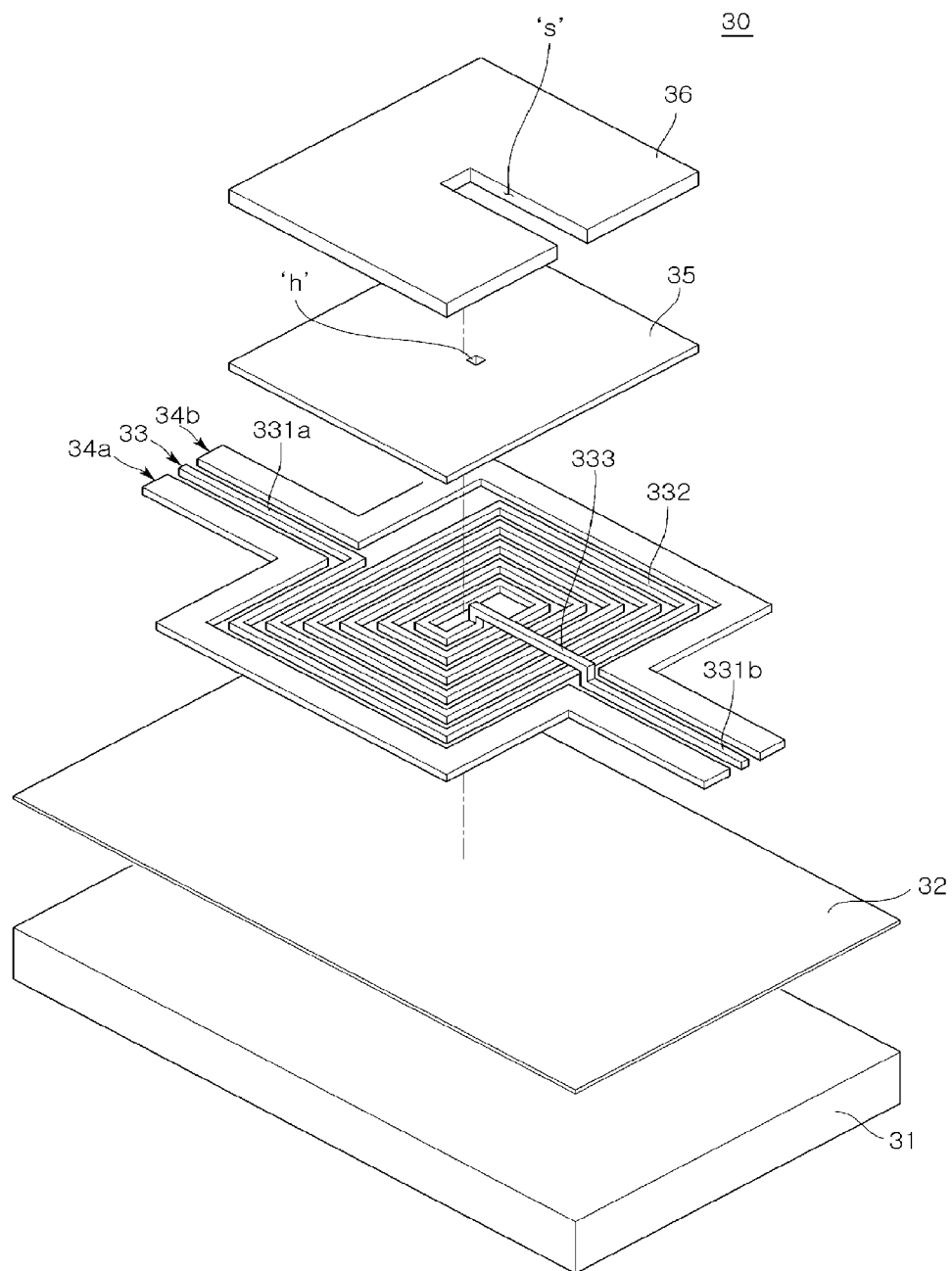
[Fig. 5]



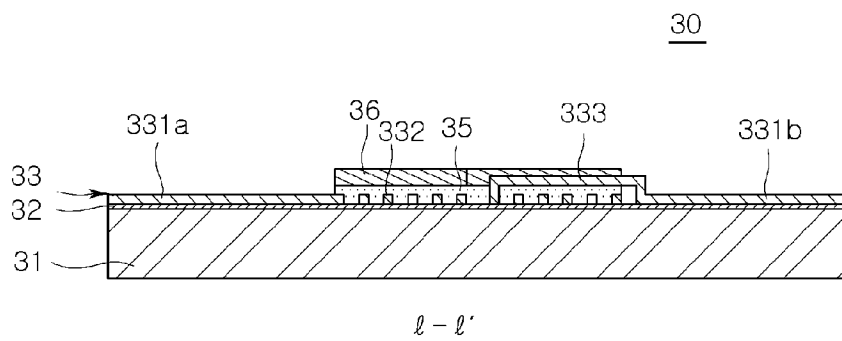
[Fig. 6]



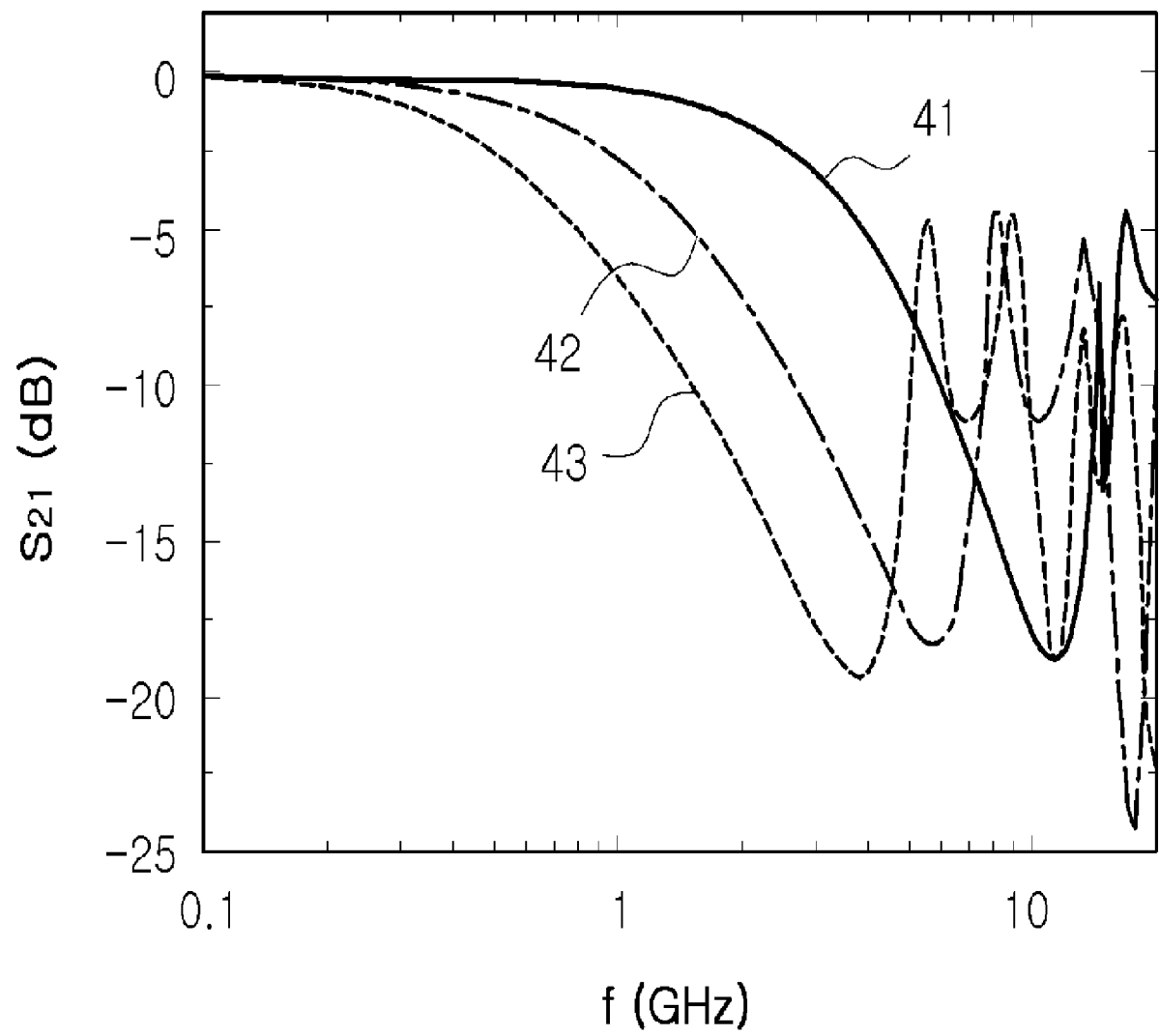
[Fig. 7]



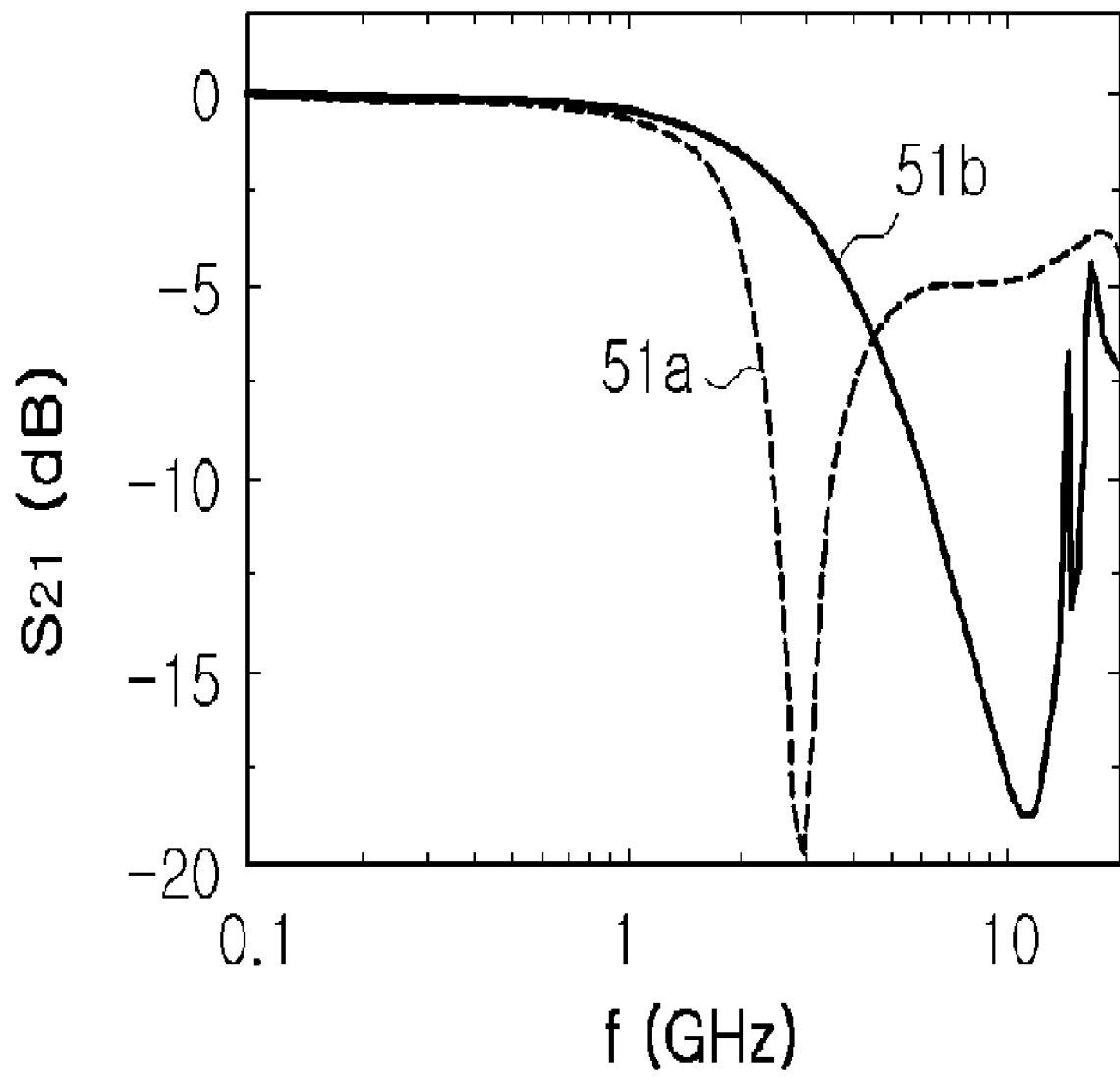
[Fig. 8]



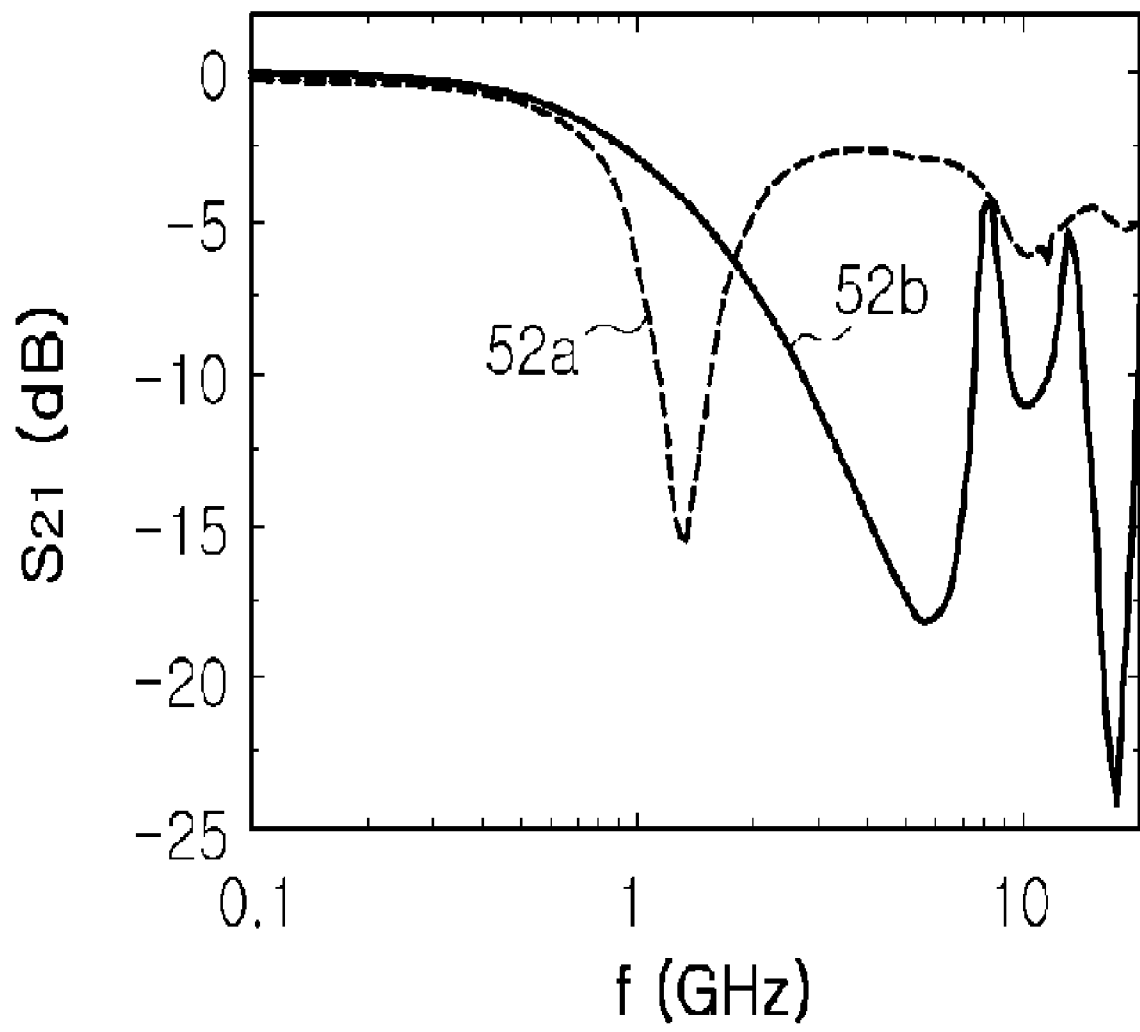
[Fig. 9]



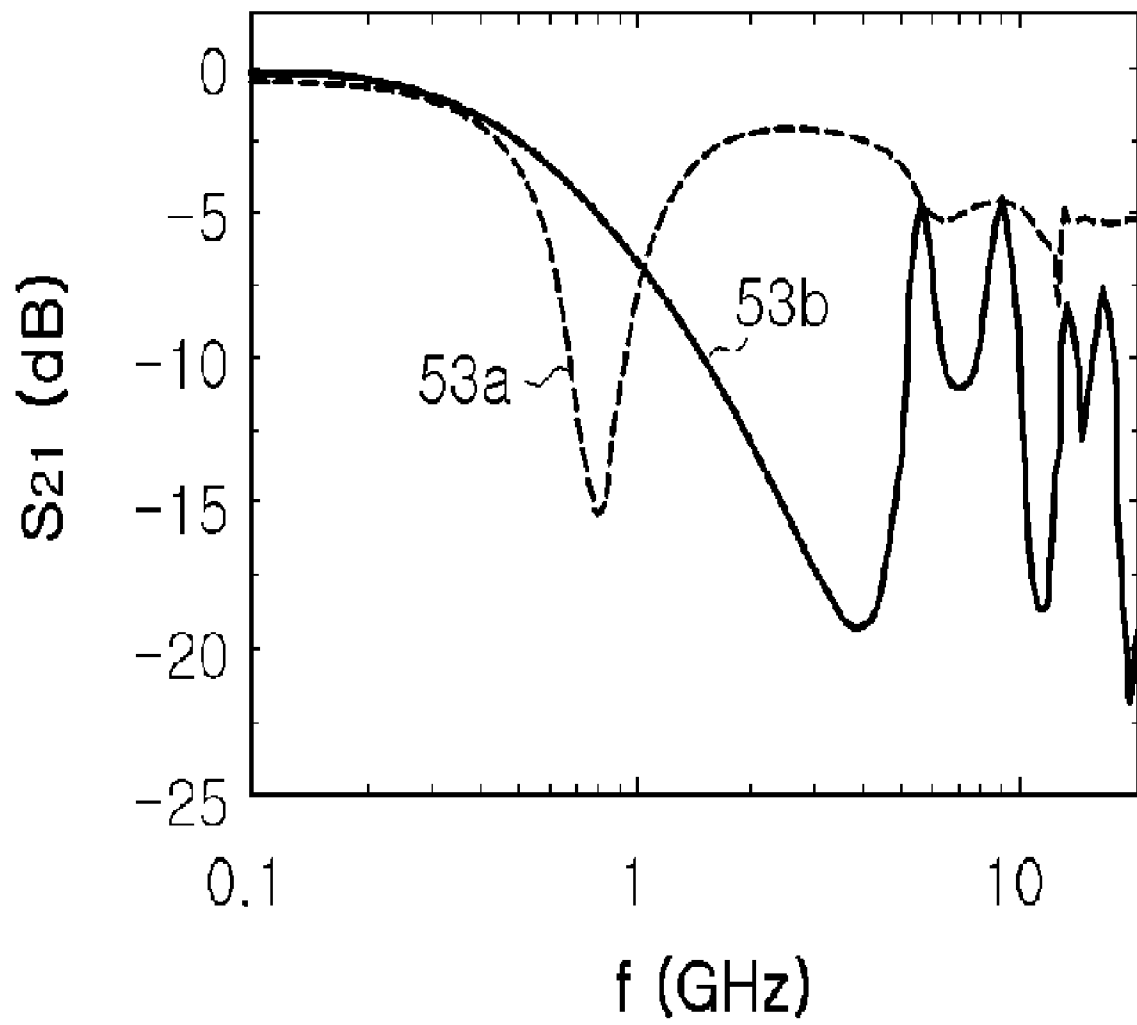
[Fig. 10]



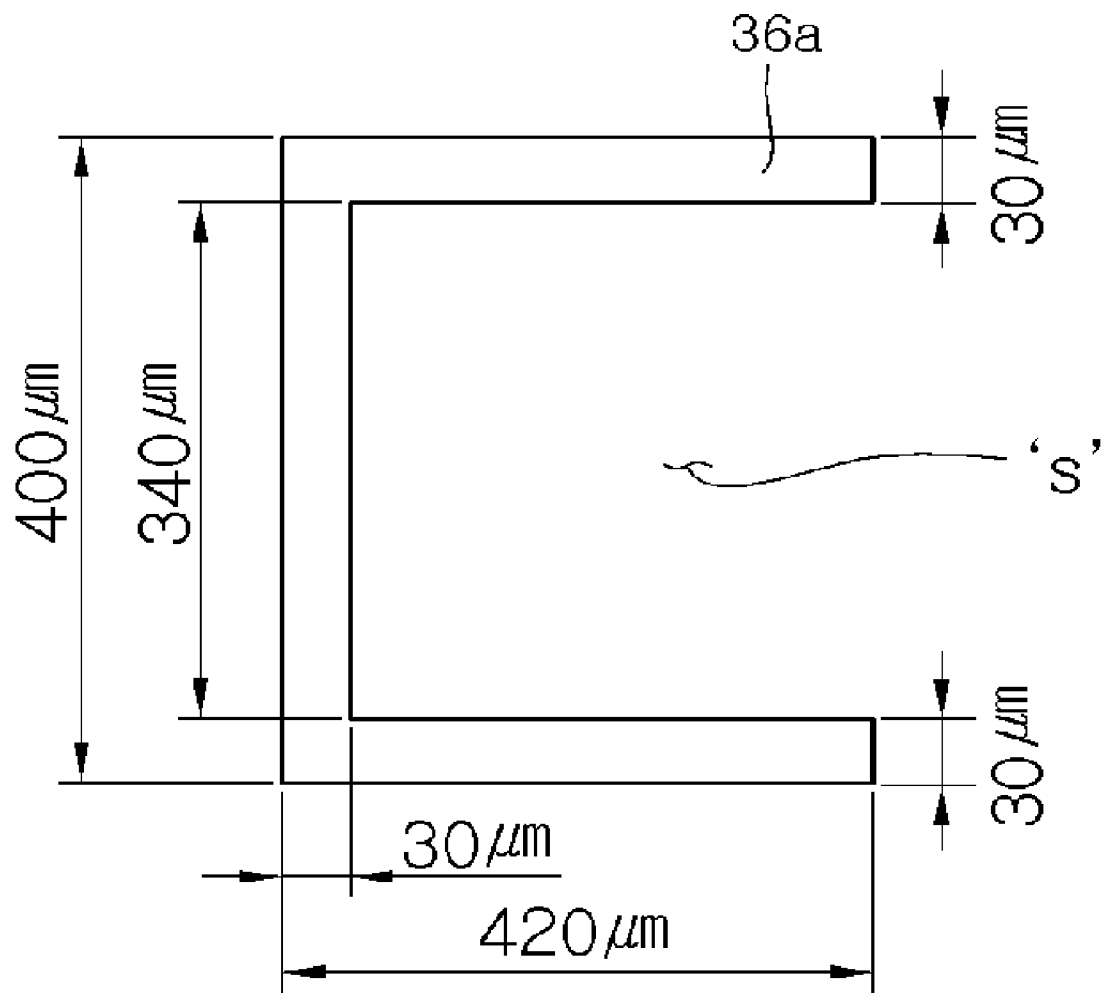
[Fig. 11]



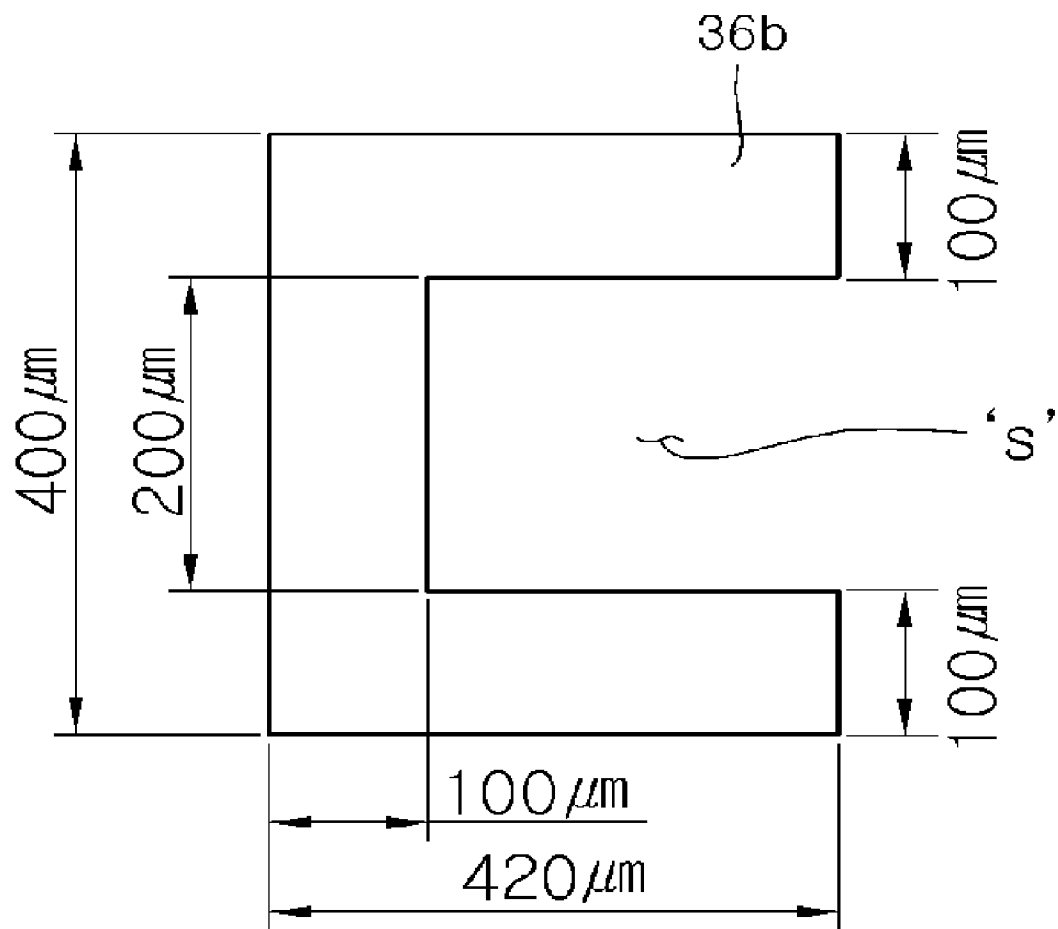
[Fig. 12]



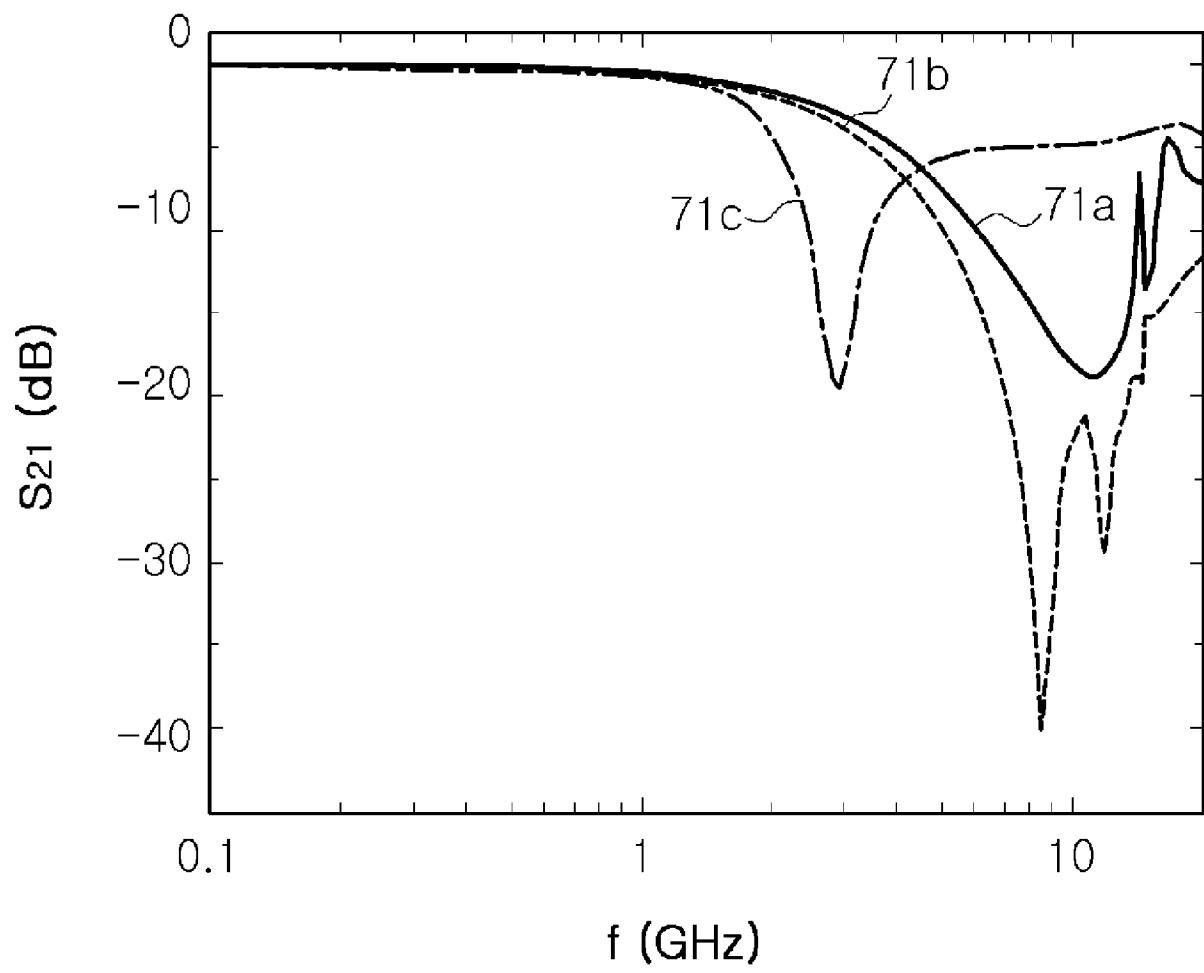
[Fig. 13]



[Fig. 14]



[Fig. 15]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/005491**A. CLASSIFICATION OF SUBJECT MATTER****H01P 1/20(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 : H01L 27/04, H01F 17/00, H01F 41/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) "semiconductor and spiral and inductor"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	M. Abdo-Tuko, et al., "Novel 18/36 GHz (M)MIC GaAs FET Frequency Doublers in CPW-Techniques Under the Consideration of the Effects of Coplanar Discontinuities", IEEE Transactions on Microwave Theory and Techniques, Vol.41, No.8, August 1993, pp.1307~1315. see the abstract ; introduction ; Fig.7.	1 ~ 18
A	JP 05-062836 A (MITSUBISHI ELECTRIC CO.) 12 March 1993. see the abstract ; page 2 <0002~0003> ; Fig.4~5.	1 ~ 18
A	Joachim N. Burghartz, et al., "Spiral Inductors and Transmission Lines in Silicon Technology Using Copper Damascene Interconnects and Low-Loss Substrates", IEEE Transactions on Microwave Theory and Techniques, Vol.45, No.10, October 1997, pp.1961~1968. see the abstract ; introduction ; Fig.1 ; Fig.2(c).	1 ~ 18



Further documents are listed in the continuation of Box C.



See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

03 MAY 2007 (03.05.2007)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2006/005491

Patent document
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date

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24.07.2000