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(54) **TRANSMISSION LINE STRUCTURE WITH PROTRUDING SUB-LINES AND DIELECTRIC ZONES FOR RF SIGNAL**

(71) Applicant: **Taiwan Semiconductor Manufacturing Company, Ltd.**, Hsinchu (TW)

(72) Inventor: **Hsiu-Ying Cho**, Hsin Chu (TW)

(73) Assignee: **TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY, LTD.**, Hsinchu (TW)

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H01P 3/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 23/66*** (2013.01); ***H01P 3/08*** (2013.01); *H01L 2223/6627* (2013.01)

(58) **Field of Classification Search**
CPC H01L 23/66; H01L 2223/6627; H01P 3/08; H01P 3/003
See application file for complete search history.

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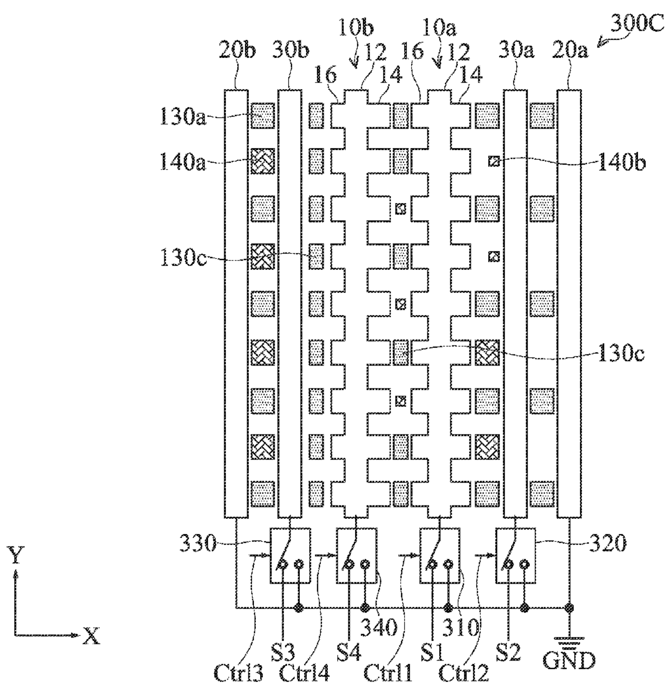
Primary Examiner — Matthew C Landau
Assistant Examiner — Ethan Edward Cutler
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

Transmission line structures are provided. The first and second conductive lines are formed in a metal layer over the semiconductor substrate and extend in a first direction. The first transmission line includes a first sub-line extending in the first direction, a plurality of second sub-lines extending toward the first conductive line, and a plurality of third sub-lines extending toward the second conductive line. The first dielectric material zones are formed between the second sub-lines and the first conductive line. The second dielectric material zones are formed between the third sub-lines and the second conductive line. The first and second dielectric material zones are separated from the first and second conductive lines and the first transmission line by an insulation material. Dielectric constant of the insulation material is less than that of the first and second dielectric material zones.

20 Claims, 12 Drawing Sheets



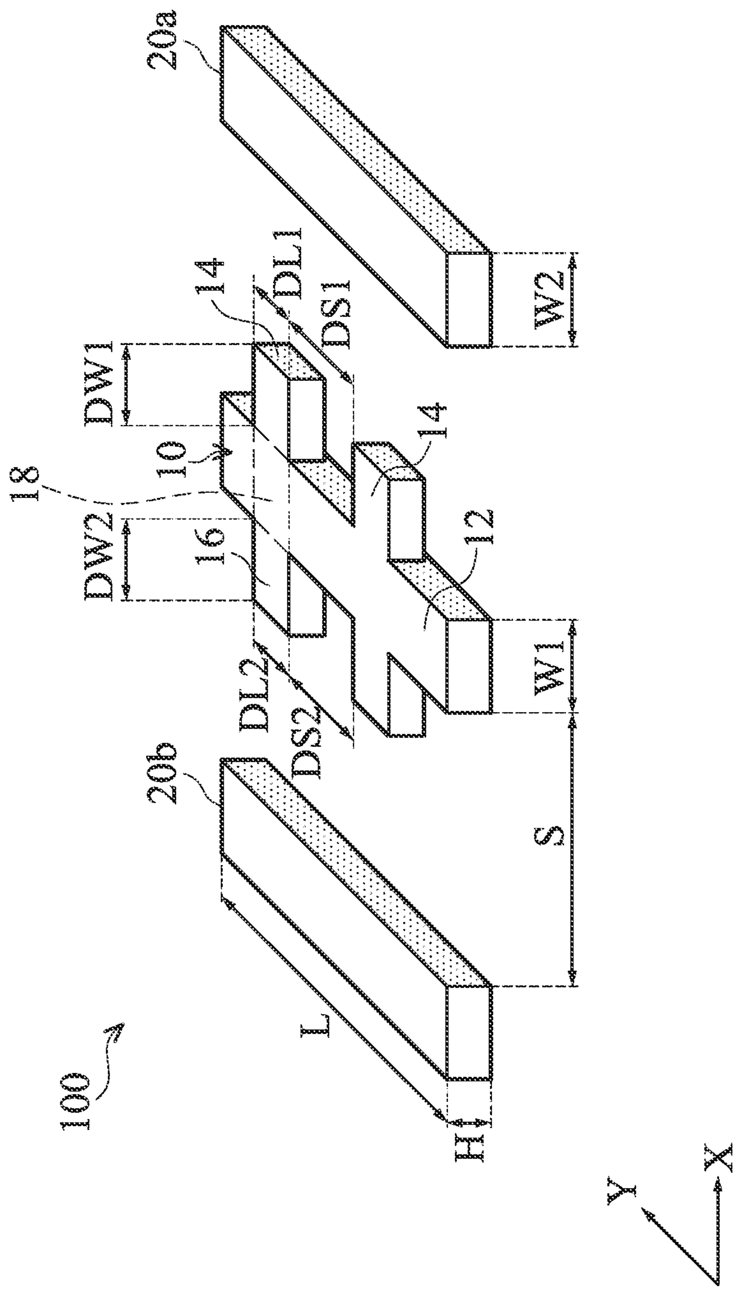


FIG. 1A

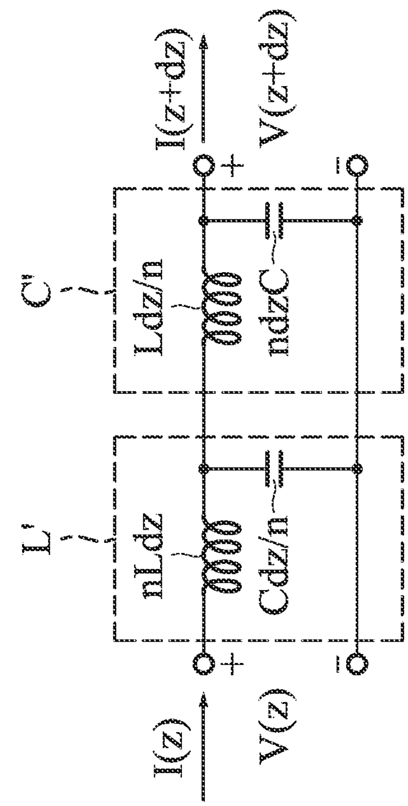

I(z+dz)
V(z+dz)
C'
Ldz/n
ndzC
L'
nLdz
Cdz/n
I(z)
V(z)
+
-

FIG. 1C

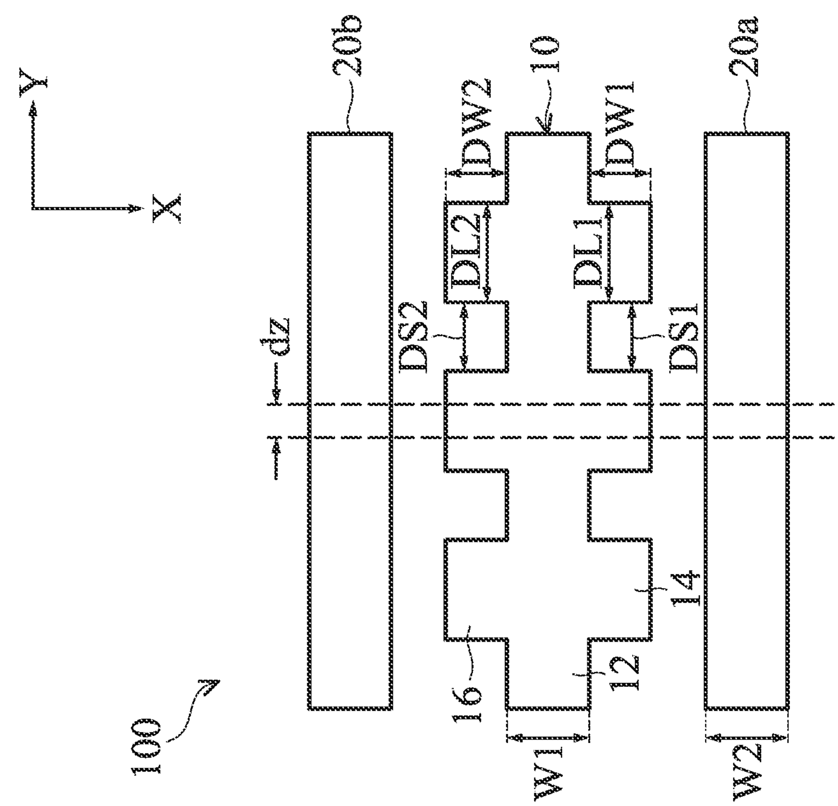

Y
X
20b
10
DW2
DW1
20a
DL2
DL1
DS2
DS1
dz
14
16
12
100
W1
W2

FIG. 1B

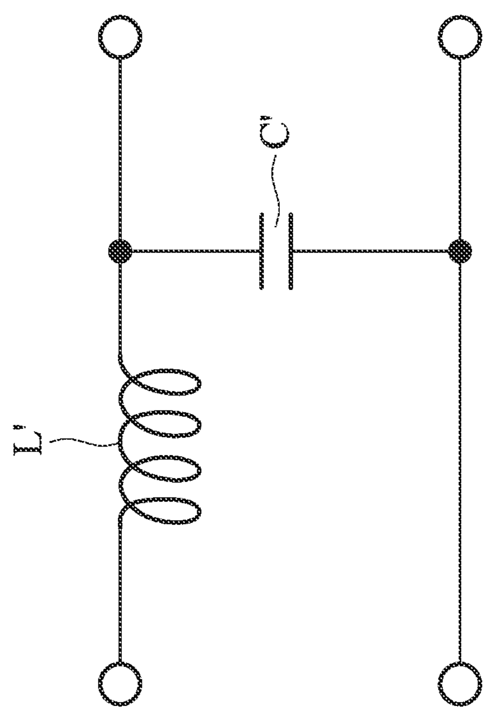


FIG. 1D

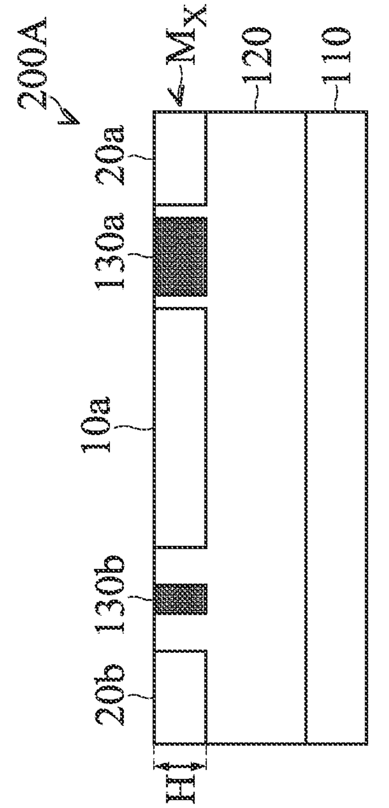

200A
20a
130a
10a
130b
20b
H1
120
110

FIG. 2B

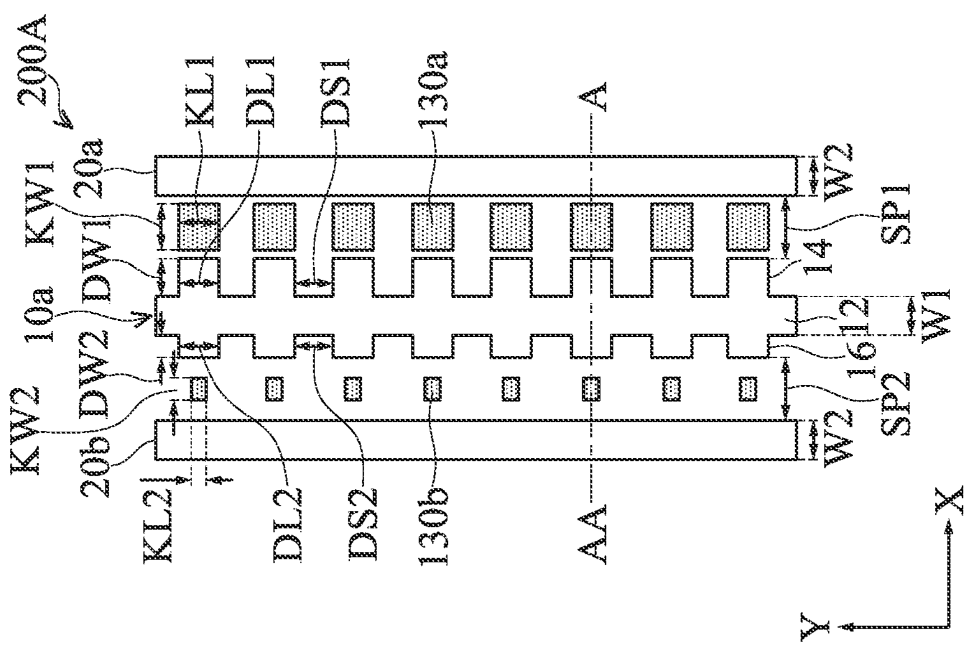

200A
20a
KW1
KL1
DL1
DS1
130a
DW1
10a
DW2
KW2
20b
KL2
DL2
DS2
130b
A
AA
W2
SP1
14
12
W1
16
SP2
X
Y

FIG. 2A

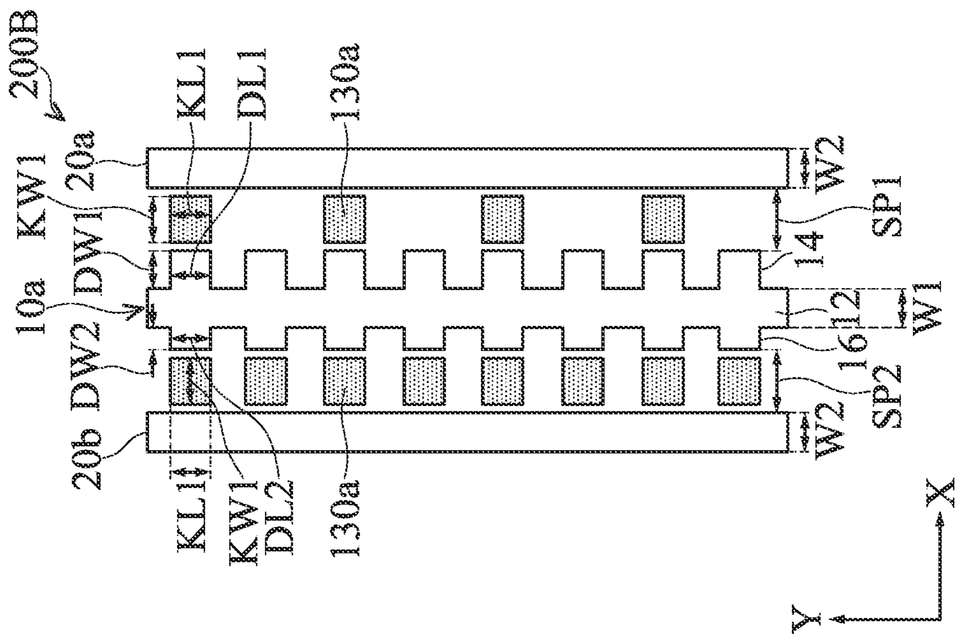

200B
KL1
DL1
130a
KW1
20a
DW1
10a
DW2
20b
W2
SP1
14
12
W1
16
SP2
W2
KL1
KW1
DL2
130a
X
Y

FIG. 3

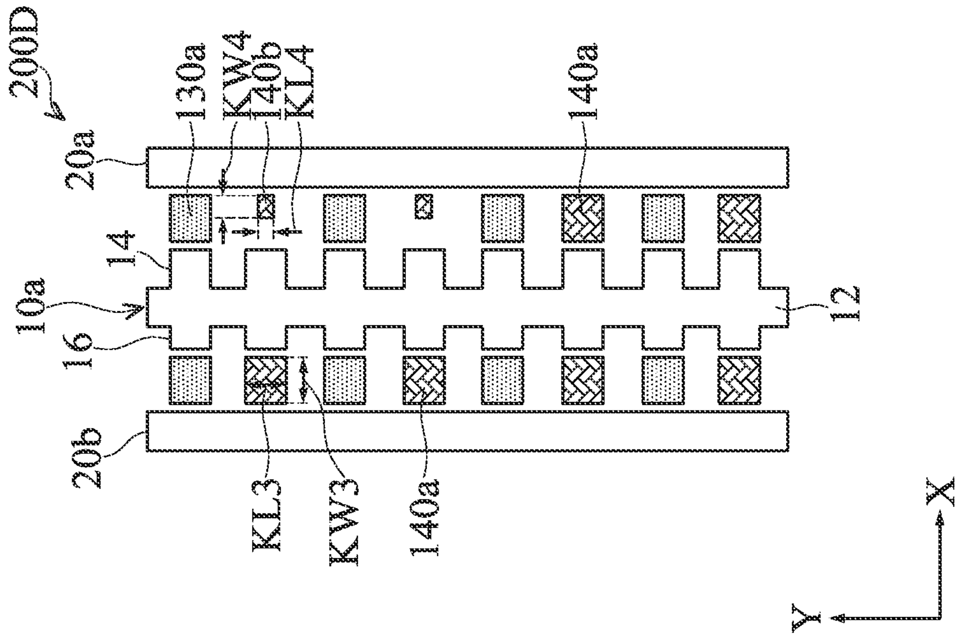

200D
20a
130a
KW4
140b
KL4
140a
14
10a
12
16
20b
KL3
KW3
140a
X
Y

FIG. 5

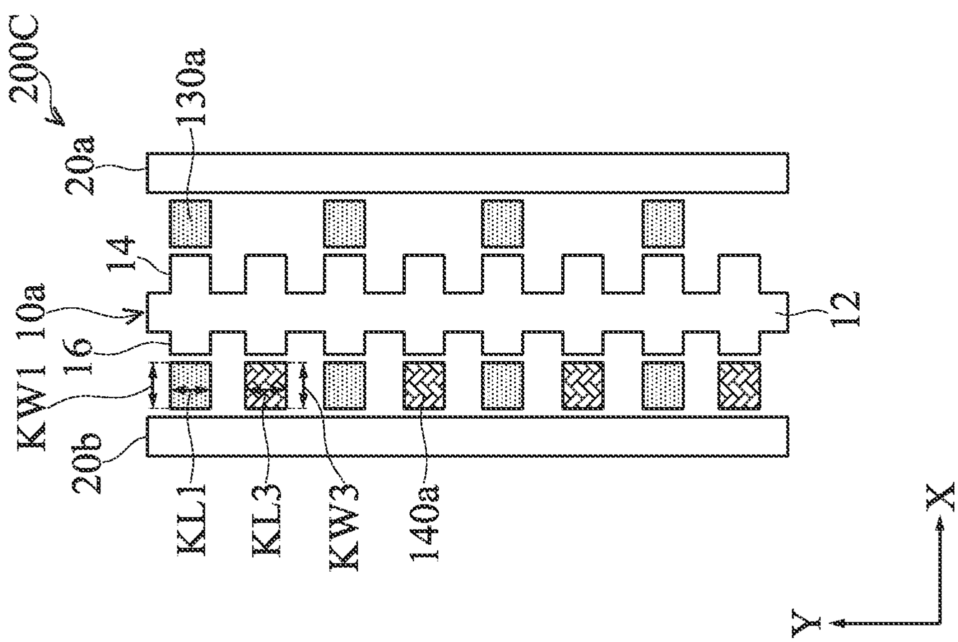

200C
20a
130a
14
10a
12
KW1
16
20b
KL1
KL3
KW3
140a
X
Y

FIG. 4

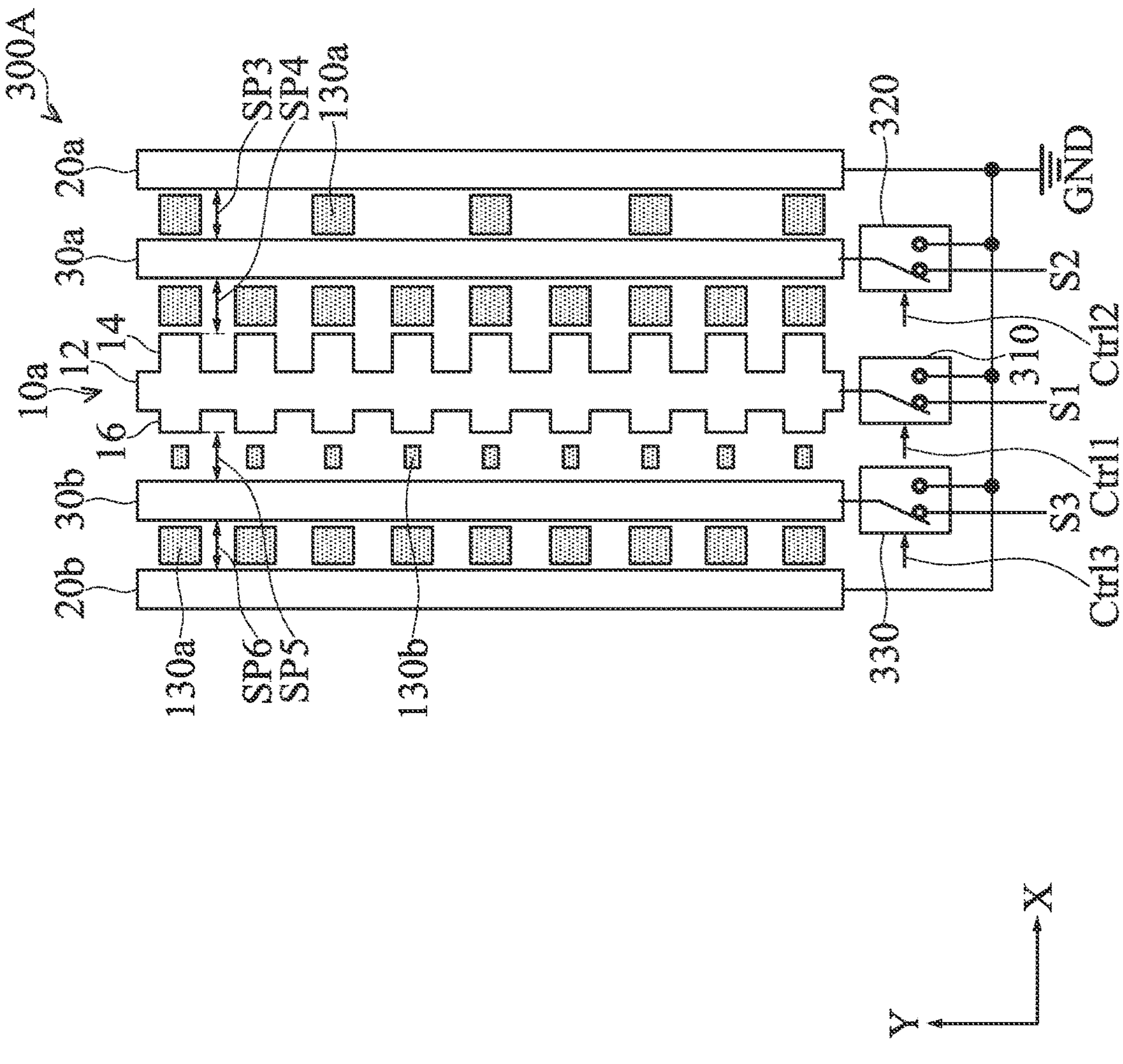

300A
20a
30a
10a
12
14
16
30b
20b
SP3
SP4
130a
130a
SP6
SP5
130b
320
310
330
GND
S2
S1
S3
Ctrl2
Ctrl1
Ctrl3
X
Y

FIG. 6A

	Ground line 20b	Transmission line 30b (switch 330)	Transmission line 10a (switch 310)	Transmission line 30a (switch 320)	Ground line 20a
λ_a_1	ground	ON	ON	ON	ground
λ_a_2	ground	ON	ON	ground	ground
λ_a_3	ground	ON	ground	ON	ground
λ_a_4	ground	ground	ON	ON	ground
λ_a_5	ground	ON	ground	ground	ground
λ_a_6	ground	ground	ground	ON	ground
λ_a_7	ground	ground	ON	ground	ground

FIG. 6B

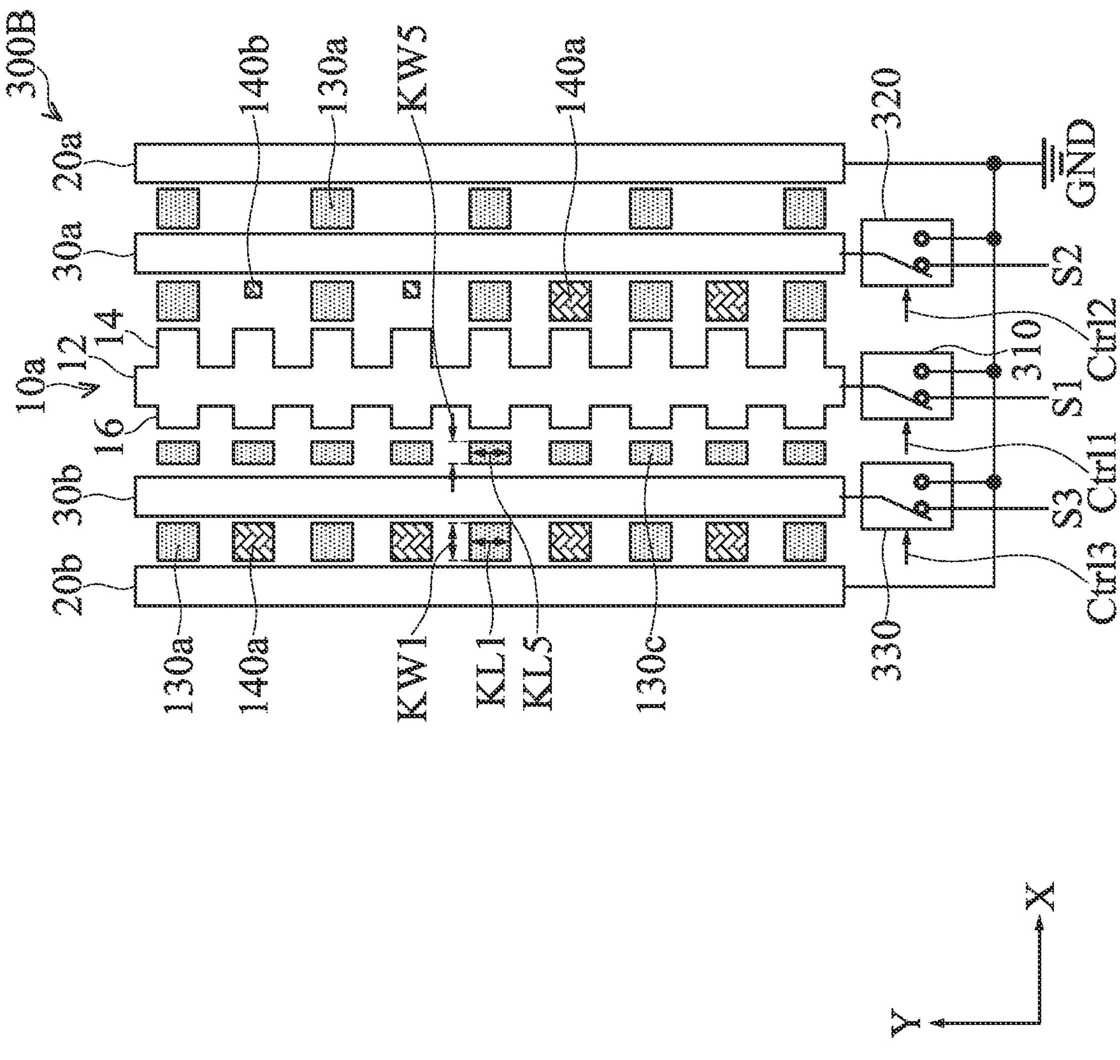

300B
20a
30a
14
12
10a
16
30b
20b
140b
130a
KW5
140a
320
GND
S2
Ctrl2
310
S1
Ctrl1
S3
Ctrl3
330
130a
140a
KW1
KL1
KL5
130c
X
Y

FIG. 7A

	Ground line 20b	Transmission line 30b (switch 330)	Transmission line 10a (switch 310)	Transmission line 30a (switch 320)	Ground line 20a
λ_b_1	ground	ON	ON	ON	ground
λ_b_2	ground	ON	ON	ground	ground
λ_b_3	ground	ON	ground	ON	ground
λ_b_4	ground	ground	ON	ON	ground
λ_b_5	ground	ON	ground	ground	ground
λ_b_6	ground	ground	ground	ON	ground
λ_b_7	ground	ground	ON	ground	ground

FIG. 7B

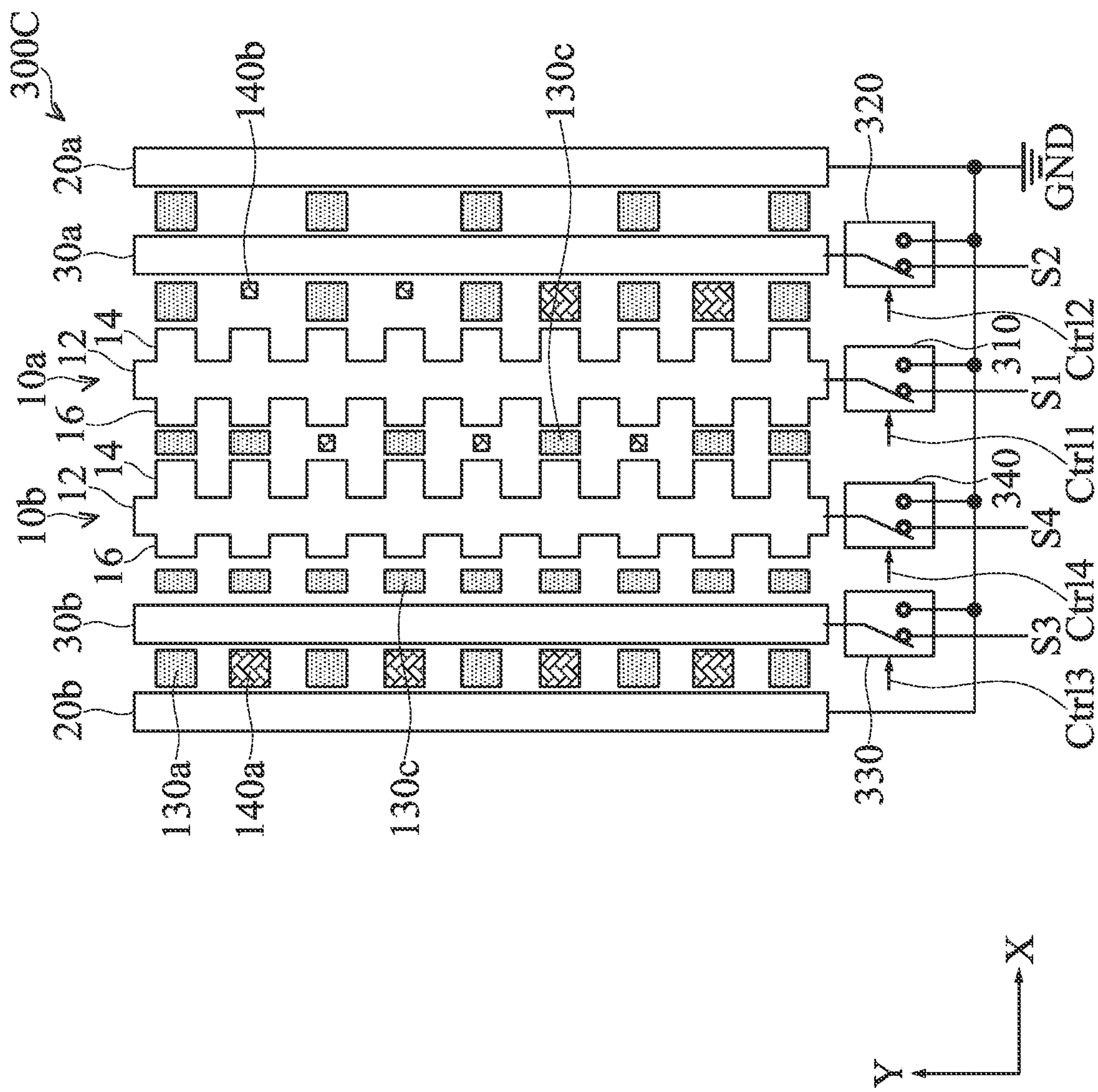

300C
20a
30a
10a
12
14
16
10b
30b
20b
140b
130c
130a
140a
320
310
340
330
GND
S1
S2
S3
S4
Ctrl1
Ctrl2
Ctrl3
Ctrl4
X
Y

FIG. 8A

	Ground line 20b	Transmission line 30b (switch 330)	Transmission line 10b (switch 340)	Transmission line 10a (switch 310)	Transmission line 30a (switch 320)	Ground line 20a
λ_c_1	ground	ON	ON	ON	ON	ground
λ_c_2	ground	ON	ON	ground	ON	ground
λ_c_3	ground	ON	ground	ON	ON	ground
λ_c_4	ground	ground	ON	ON	ON	ground
λ_c_5	ground	ON	ground	ground	ON	ground
λ_c_6	ground	ground	ground	ON	ON	ground
λ_c_7	ground	ground	ON	ground	ON	ground
λ_c_8	ground	ON	ON	ON	ground	ground
λ_c_9	ground	ON	ON	ground	ground	ground
λ_c_{10}	ground	ON	ground	ON	ground	ground
λ_c_{11}	ground	ground	ON	ON	ground	ground
λ_c_{12}	ground	ON	ground	ground	ground	ground
λ_c_{13}	ground	ground	ground	ON	ground	ground
λ_c_{14}	ground	ground	ON	ground	ground	ground
λ_c_{15}	ground	ground	ground	ground	ON	ground

FIG. 8B

TRANSMISSION LINE STRUCTURE WITH PROTRUDING SUB-LINES AND DIELECTRIC ZONES FOR RF SIGNAL

BACKGROUND

The semiconductor integrated circuit (IC) industry has experienced rapid growth. Technological advances in IC materials and design have produced generations of ICs where each generation has smaller and more complex circuits than the previous generation. In the course of IC evolution, functional density (i.e., the number of interconnected devices per chip area) has generally increased while geometry size (i.e., the smallest component (or line) that can be created using a fabrication process) has decreased. This scaling down process generally provides benefits by increasing production efficiency and lowering associated costs. Such scaling-down has also emphasized the importance of managing the transmission of radio frequency signals within such ICs. Coplanar waveguide (CPW) structures are often utilized for such transmission.

The parasitic of radio frequency (RF) on-chip passive components cannot be scaled as readily as the parasitic that accompanies active devices, such as transistors. In most circuit designs, the direct application of conventional transmission lines is not realistic as the electromigration (EM) wavelength is too long. For example, the electromagnetic wavelength in a SiO_2 dielectric material is 3000 μm at 50 GHz, which is area-consuming for the application of impedance matching networks of quarter-wavelength long transmission lines.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It should be noted that, in accordance with the standard practice in the industry, various nodes are not drawn to scale. In fact, the dimensions of the various nodes may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1**A shows a perspective view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **1**B shows a top view of the transmission line structure of FIG. **1**A, in accordance with some embodiments of the disclosure.

FIGS. **1**C and **1**D show the equivalent circuit of the transmission line structure of FIG. **1**A, in accordance with some embodiments of the disclosure.

FIG. **2**A shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **2**B shows a cross-sectional view of the transmission line structure along line A-AA in FIG. **2**A, in accordance with some embodiments of the disclosure.

FIG. **3** shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **4** shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **5** shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **6**A shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **6**B shows a wavelength table of the transmission line structure of FIG. **6**A, in accordance with some embodiments of the disclosure.

FIG. **7**A shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **7**B shows a wavelength table of the transmission line structure of FIG. **7**A, in accordance with some embodiments of the disclosure.

FIG. **8**A shows a top view of a transmission line structure, in accordance with some embodiments of the disclosure.

FIG. **8**B shows a wavelength table of the transmission line structure of FIG. **8**A, in accordance with some embodiments of the disclosure.

DETAILED DESCRIPTION

The following disclosure provides many different embodiments, or examples, for implementing different nodes of the subject matter provided. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In some embodiments, the formation of a first node over or on a second node in the description that follows may include embodiments in which the first and the second nodes are formed in direct contact, and may also include embodiments in which additional nodes may be formed between the first and the second nodes, such that the first and the second nodes may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

Some variations of the embodiments are described. Throughout the various views and illustrative embodiments, like reference numbers are used to designate like elements. It should be understood that additional operations can be provided before, during, and/or after a disclosed method, and some of the operations described can be replaced or eliminated for other embodiments of the method.

Furthermore, spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element or feature as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

FIG. **1**A shows a perspective view of a transmission line structure **100**, in accordance with some embodiments of the disclosure. The transmission line structure **100** is a coplanar waveguide structure in semiconductor device, and the transmission line structure **100** includes the transmission line **10** and the conductive lines **20***a* and **20***b*. In such embodiment, the transmission line **10** is a signal line disposed between the conductive lines **20***a* and **20***b*. Furthermore, the transmission line **10** is coupled to a wave source. The wave source may be any suitable frequency. For example, the wave source may include a radio frequency radio frequency signal Source, a transmitter, a transceiver, or an antenna. In some embodiments, the transmission line **10** carries a radio frequency signal along its length. In some embodiments, the transmission line **10** may be designed to carry a radio frequency signal in the microwave and/or millimeter range (for example, frequencies between about 300 MHz and about 300 GHz).

The conductive lines **20**a and **20**b are relatively static lines. In such embodiment, the conductive lines **20**a and **20**b are electrically coupled to ground, and thus, the conductive lines **20**a and **20**b may also be referred to as the ground lines. In some embodiments, the conductive lines **20**a and **20**b may be coupled to a fixed voltage source. In some embodiments, the conductive lines **20**a and **20**b may be coupled to an AC or DC voltage source, including a reference voltage source. In other words, a reference voltage (or a fixed voltage) is applied to the conductive lines **20**a and **20**b.

The transmission line **10** is composed of any material capable of propagating a radio frequency signal. The conductive lines **20**a and **20**b are composed of any material capable of shielding. For example, the transmission line **10** and/or the conductive lines **20**a and **20**b may include metal, such as aluminum, copper, tungsten, titanium, tantalum, titanium nitride, tantalum nitride, nickel silicide, cobalt silicide, silver, TaC, TaSiN, TaCN, TiAl, TiAlN, metal alloys, other suitable materials, or a combination thereof. It should be understood that the transmission line **10** may include the same or different material as the conductive lines **20**a and **20**b. Moreover, the conductive line **20**a may include the same or different material as the conductive line **20**b. In such embodiment, the transmission line **10** is separated from the conductive lines **20**a and **20**b by an insulation material, a dielectric material or other suitable material.

The conductive lines **20**a and **20**b are oriented parallel to one another in the Y direction. In such embodiment, the conductive lines **20**a and **20**b extend a distance L in the Y direction, and the conductive lines **20**a and **20**b have a height H. In some embodiments, the conductive lines **20**a and **20**b may extend longitudinally varying distances L, and the conductive lines **20**a and **20**b may have varying heights H. Similarly, the height H of the conductive lines **20**a and **20**b may be the same or different. In such embodiment, the conductive lines **20**a and **20**b has the same width W2 in the X-direction. In some embodiments, the conductive lines **20**a and **20**b have different widths W2. In some embodiments, the width W2 of the conductive lines **20**a and **20**b is wider than the height H of the conductive lines **20**a and **20**b. In some embodiments, the height H of the conductive lines **20**a and **20**b is larger than or equal to the width W2 of the conductive lines **20**a and **20**b.

In the transmission line structure **100**, the dimension of the transmission line **10** varies along the Y-direction. The transmission line **10** includes a sub-line (or a main segment) **12** extending in the Y-direction and multiple sub-lines **14** and **16** extending in the X-direction. The sub-line **12** has a width W1 in the X-direction. The width W1 of the sub-line **12** may be equal to or different from the width W2 of the conductive lines **20**a and **20**b. Each sub-line **14** extends from the sub-line **12** toward the conductive line **20**a in the X-direction. The sub-lines **14** have a width DW1 in the X-direction and a length DL1 in the Y-direction. Moreover, the sub-lines **14** are periodically arranged on and contact the sub-line **12** along the Y direction at intervals of space DS1. Each sub-line **16** extends from the sub-line **12** toward the conductive line **20**b in the X-direction. The sub-lines **16** have a width DW2 in the X-direction and a length DL2 in the Y-direction. Moreover, the sub-lines **16** are periodically arranged on and contact the sub-line **12** along the Y direction at intervals of space DS2. In some embodiments, if the length DL1 of the sub-line **14** is equal to the length DL2 of the sub-line **16** and the space DS1 is equal to the space DS2, the sub-lines **14** and **16** combined with the segment **18** can be regarded as a sub-line intersecting the sub-line **12**.

In FIG. **1**A, the sub-lines **14** and **16** have rectangular shape. In other embodiments, the sub-lines **14** and **16** may form an elliptical shape, a semi-circular shape, a triangular shape, other suitable shape, or a combination thereof. It should be understood that the sub-lines **14** may have different dimensions, and the sub-lines **16** may have different dimensions. In some embodiments, some sub-lines **14** and/or **16** are omitted. In other words, the number of the sub-lines **14** is different from the number of the sub-lines **16**.

The dimensions of the transmission line structure **100** may be selected to provide the desired signal characteristics, e.g., the desired phase velocity as described below. The electrical and radio frequency characteristics of the transmission line structure **100** in FIG. **1**A will be described by making reference to FIGS. **1**B, **1**C and **1**D. Using distributed circuit theory, the transmission line structure **100** may be modeled using a series of equivalent circuits. For each differential unit length dz, the transmission line structure **100** may be treated as if it included an equivalent circuit, such as the equivalent circuit illustrated in FIGS. **1**C and **1**D. The equivalent circuit has an inductance per unit length L' and a capacitance per unit length C'. Thus, the transmission line structure **100** may be described using line parameters based on electric circuit concepts.

The values of inductance per unit length L' and capacitance per unit length C' may be determined from the physical characteristics of the transmission line structure **100**, including its physical dimensions and material composition. The phase velocity Vp of a wave traveling along the signal line **10** may be expressed as:

$$V_p = \frac{c}{\sqrt{\varepsilon'_r \mu_r}} = \frac{1}{n/2\sqrt{L'C'}} = f\lambda,$$

where c is the velocity of light, ε'_r is the relative permittivity, and μdr is the relative permeability. Thus, to design a coplanar waveguide structure to have the desired phase velocity, the materials for the coplanar waveguide may be chosen to provide the desired relative permittivity and permeability. Alternately, the coplanar waveguide structure may be dimensioned to provide the desired inductance and capacitance using the structures disclosed herein.

In such embodiments, the periodic structure formed by the sub-lines **12**, **14** and **16**, provides alternating respective high and low impedance sections as illustrated in the equivalent circuit shown in FIG. **1**C and FIG. **1**D. If the alternating high and low impedance sections are short in length compared to the wavelength, and the alternating segments are cascaded together, the inductance is dominated by the high impedance section, and the capacitance is dominated by the low impedance section. The periodical structure within the transmission line **10** essentially provides the ability to have a higher permittivity epsilon ε_r and adjust the wavelength λ. Accordingly, the permittivity epsilon ε_r can be varied by different transmission line structures, such as the various embodiments presented herein. In some embodiments, the higher epsilon coplanar waveguide structures may be incorporated into microwave and millimeter wave integrated circuits (ICs), such as circuit impedance matching circuits of the quarter wavelength long transmission line, GPS satellite systems and wireless communication.

The following discussion provides various transmission line structures that may provide a higher permittivity epsilon Cr and result in an adjusting wavelength λ.

FIG. 2A shows a top view of a transmission line structure 200A, in accordance with some embodiments of the disclosure. The configuration of the transmission line structure 200A in FIG. 2A is similar with the configuration of the transmission line structure 100 in FIG. 1A. The difference between the transmission line structure 200A in FIG. 2A and the transmission line structure 100 in FIG. 1A is that the transmission line structure 200A further includes the dielectric material zones 130. The dielectric material zones 130 are divided into the dielectric material zones 130*a* with larger area and the dielectric material zones 130*b* with smaller area. In such embodiment, the dielectric material zones 130*a* and 130*b* are formed by the same high-k dielectric material, e.g., k>15 or 7≤k≤15. In some embodiments, the high-k dielectric material, may include metal oxides, metal nitrides, metal silicates, transition metal-oxides, transition metal-nitrides, transition metal-silicates, oxynitrides of metals, metal aluminates, zirconium silicate, zirconium aluminate, HfO_2, HfSiO, HfSiON, HfTaO, HfTaTiO, HfTiO, HfZrO, HfAlON, other suitable high-k dielectric materials, or a combination thereof.

In the transmission line structure 200A, the transmission line 10*a* includes the sub-line 12, the sub-lines 14 closed to the conductive line 20*a*, and the sub-lines 16 closed to the conductive line 20*b*. The length DL1 of the sub-line 14 is equal to the length DL2 of the sub-line 16 (i.e., DL1=DL2), and the width DW1 of the sub-line 14 is larger than the width DW2 of the sub-line 16 (i.e., DW1>DW2). Thus, the area of the sub-line 14 is greater than the area of the sub-line 16. Furthermore, the space between the sub-line 14 and the conductive line 20*a* is SP1, and the space between the sub-line 16 and the conductive line 20*b* is SP2. In some embodiments, the space SP1 is equal to the space SP2 (i.e., SP1=SP2). In some embodiments, the space SP1 is different from to the space SP2 (i.e., SP1>SP2 or SP1<SP2). If the space SP1 is equal to the space SP2, a distance between the conductive line 20*a* and the sub-line 12 is greater than a distance between the conductive line 20*b* and the sub-line 12 because the width DW1 of the sub-line 14 is greater than the width DW2 of the sub-line 16.

In FIG. 2A, the dielectric material zones 130*a* have a width KW1 in the X-direction and a length KL1 in the Y-direction, and the dielectric material zones 130*b* have a width KW2 in the X-direction and a length KL2 in the Y-direction. In such embodiment, the width KW1 is greater than the width KW2 (i.e., KW1>KW2), and the length KL1 is greater than the length KL2 (i.e., KL1>KL2). Thus, the area of the dielectric material zones 130*a* is greater than the area of the dielectric material zones 130*b*.

In FIG. 2A, the dielectric material zones 130*a* are disposed between the sub-lines 14 of the transmission line 10*a* and the conductive line 20*a*, and the dielectric material zones 130*b* are disposed between the sub-lines 16 of the transmission line 10*a* and the conductive line 20*b*. In the transmission line structure 200A, the dielectric material zones 130*a* disposed between the sub-lines 14 and the conductive line 20*a* have the same area, and the dielectric material zones 130*b* disposed between the sub-lines 16 and the conductive line 20*b* have the same area. In such embodiments, the sub-lines 14 and 16 and the dielectric material zones 130*a* and 130*b* have the same number.

FIG. 2B shows a cross-sectional view of the transmission line structure 200A along line A-AA in FIG. 2A, in accordance with some embodiments of the disclosure. In FIG. 2B, an insulation material layer 120 is formed over a semiconductor substrate 110. In some embodiments, the semiconductor substrate 110 is a Si substrate. In some embodiments, the material of the semiconductor substrate 15 is selected from a group consisting of bulk-Si, SiP, SiGe, SiC, SiPC, Ge, SOI—Si, SOI—SiGe, III-VI material, or a combination thereof. In some embodiments, the insulation material layer 120 may be an inter-layer dielectric (ILD) layer or an inter-metal dielectric (IMD) layer. Furthermore, the insulation material layer 120 may include any suitable material and any suitable thickness. In some embodiments, the insulation material layer 120 includes a dielectric material, such as TEOS oxide, silicon oxide, silicon nitride, silicon oxynitride, hafnium oxide, zirconium oxide, titanium oxide, aluminum oxide, hafnium dioxide-alumina (HfO_2—Al_2O_3) alloy, PSG, BPSG, other suitable dielectric materials, or a combination thereof.

The transmission line 10*a* and the conductive lines 20*a* and 20*b* are formed in a metal layer Mx. Furthermore, the metal layer Mx may be a top metal layer, an intermediate metal layer or a lower metal layer. The transmission line 10*a* and the conductive lines 20*a* and 20*b* are separated from each other by the insulation material layer 120. The dielectric material zone 130*a* is formed in the insulation material layer 120 and between the transmission line 10*a* and the conductive line 20*a*, and the dielectric material zone 130*b* is formed in the insulation material layer 120 and between the transmission line 10*a* and the conductive line 20*b*. In other words, the dielectric material zones 130*a* and 130*b* are separated from the transmission line 10*a* and the conductive lines 20*a* and 20*b* by the insulation material layer 120. In such embodiment, the transmission line 10*a*, the conductive lines 20*a* and 20*b* and the dielectric material zones 130*a* and 130*b* have the height H and are formed in the save level. In some embodiments, the height of the dielectric material zones 130*a* and 130*b* is different from the height H of the transmission line 10*a* and the conductive lines 20*a* and 20*b*.

As described above, the dielectric material zones 130*a* and 130*b* are formed by the same high-k dielectric material. Furthermore, the dielectric constant of the dielectric material zones 130*a* and 130*b* is greater than the dielectric constant of insulation material layer 120.

FIG. 3 shows a top view of a transmission line structure 200B, in accordance with some embodiments of the disclosure. The transmission line structure 200B includes the dielectric material zones 130*a*. In other words, no dielectric material zone 130*b* is formed in the transmission line structure 200B.

In the transmission line structure 200B, the number of dielectric material zones 130*a* between the transmission line 10*a* and the conductive line 20*a* is less than the number of dielectric material zones 130*a* between the transmission line 10*a* and the conductive line 20*b*. For example, the number of dielectric material zones 130*a* between the transmission line 10*a* and the conductive line 20*a* is half the number of dielectric material zones 130*a* between the transmission line 10*a* and the conductive line 20*b*. In other words, the dielectric material zones 130*a* are only configured between a portion of the sub-lines 14 and the conductive line 20*a*.

FIG. 4 shows a top view of a transmission line structure 200C, in accordance with some embodiments of the disclosure. The configuration of the transmission line structure 200C in FIG. 4 is similar with the configuration of the transmission line structure 200B in FIG. 3. The difference between the transmission line structure 200B in FIG. 3 and the transmission line structure 200C in FIG. 4 is that the transmission line structure 200C further includes the dielectric material zones 140*a*.

In FIG. 4, the dielectric material zones 130*a* have the width KW1 in the X-direction and the length KL1 in the

Y-direction, and the dielectric material zones **140***a* have a width KW3 in the X-direction and a length KL3 in the Y-direction. In such embodiment, the width KW1 is equal to the width KW3 (i.e., KW1=KW3), and the length KL1 is equal to the length KL3 (i.e., KL1=KL3). Thus, the area of the dielectric material zones **130***a* is equal to the area of the dielectric material zones **140***a*.

The dielectric material zones **130***a* and **140***a* are formed by different high-k dielectric materials. For example, the dielectric material zones **130***a* are formed by a first high-k dielectric material, and the dielectric material zones **140***a* are formed by a second high-k dielectric material. In some embodiments, the dielectric constant of the first high-k dielectric material is less than the dielectric constant of the second high-k dielectric material. For example, the dielectric constant of the first high-k dielectric material is between 7 and 15, and the dielectric constant of the second high-k dielectric material is greater than 15. Moreover, the dielectric constant of the first/second high-k dielectric material is greater than the dielectric constant of insulation material layer **120** of FIG. **2**B. In some embodiments, the dielectric constant of the first high-k dielectric material is greater than the dielectric constant of the second high-k dielectric material. For example, the dielectric constant of the first high-k dielectric material is greater than 15, and the dielectric constant of the second high-k dielectric material is between 7 and 15.

In the transmission line structure **200**C, the dielectric material zones **130***a* and **140***a* with different dielectric constant are disposed between the transmission line **10***a* and the conductive line **20***b*, and the dielectric material zones **130***a* with same dielectric constant are disposed between the transmission line **10***a* and the conductive line **20***a*. In some embodiments, the dielectric material zones **130***a* and **140***a* are interleaved between the transmission line **10***a* and the conductive line **20***b* along the Y-direction. Furthermore, only the dielectric material zones **130***a* are disposed between the transmission line **10***a* and the conductive line **20***a* along the Y-direction. Moreover, no dielectric material zone is formed between the dielectric material zones **140***a* and the conductive line **20***a* in the X-direction.

FIG. **5** shows a top view of a transmission line structure **200**D, in accordance with some embodiments of the disclosure. The configuration of the transmission line structure **200**D in FIG. **5** is similar with the configuration of the transmission line structure **200**C in FIG. **4**. The difference between the transmission line structure **200**C in FIG. **4** and the transmission line structure **200**D in FIG. **5** is that the transmission line structure **200**D further includes the dielectric material zones **140***b*.

In FIG. **5**, the dielectric material zones **140***a* and **140***b* are formed by the same high-k dielectric materials. Furthermore, the dielectric material zones **140***b* have a width KW4 in the X-direction and a length KL4 in the Y-direction. In such embodiment, the width KW3 is greater than the width KW4 (i.e., KW3>KW4), and the length KL3 is greater than the length KL4 (i.e., KL3>KL4). Thus, the area of the dielectric material zones **140***a* is greater than the area of the dielectric material zones **140***b*.

In the transmission line structure **200**D, the dielectric material zones **130***a* and the dielectric material zones **140***a*/**140***b* are interleaved between the transmission line **10***a* and the conductive line **20***a* along the Y-direction. It should be noted that arrangement of the dielectric material zones **140***a* and **140***b* between the sub-line **14** and the conductive line **20***a* is merely an example and is not intended to limit the transmission line structures.

FIG. **6**A shows a top view of a transmission line structure **300**A, in accordance with some embodiments of the disclosure. Compared with the transmission line structures **200**A through **200**D, the transmission line structure **300**A further includes the transmission lines **30***a* and **30***b* and the switches (or selectors) **310** through **330**. The switches **310** through **330** are formed in the semiconductor substrate **110** of FIG. **2**B.

In transmission line structure **300**A, the transmission lines **30***a* and **30***b* and the conductive lines **20***a* and **20***b* have the same shape that is different from the shape of the transmission line **10***a*. In such embodiment, the transmission lines **30***a* and **30***b* are the linear lines and the transmission line **10***a* is the non-linear line. Furthermore, the conductive lines **20***a* and **20***b* are the linear lines. As described above, the conductive lines **20***a* and **20***b* are coupled to the ground GND, i.e., the conductive lines **20***a* and **20***b* are ground lines.

The transmission line **30***a* is disposed between the transmission line **10***a* and the conductive line **20***a*, and the transmission line **30***b* is disposed between the transmission line **10***a* and the conductive line **20***b*. The transmission line **10***a*, the conductive lines **20***a* and **20***b*, and the transmission lines **30***a* and **30***b* are separated by an insulation material layer (e.g., the insulation material layer **120** in FIG. **2**B). The space between the transmission line **30***a* and the conductive line **20***a* is SP3, the space between the sub-line **14** and the transmission line **30***a* is SP4, the space between the sub-line **16** and the transmission line **30***b* is SP5, and the space between the transmission line **30***b* and the conductive line **20***b* is SP6. In some embodiments, the spaces SP3 through SP6 are the same. In some embodiments, the spaces SP3 through SP6 are different.

The dielectric material zones **130***a* with the larger area are disposed between the transmission line **30***b* and the conductive line **20***b*, between the transmission line **10***a* and the transmission line **30***a*, and between the transmission line **30***a* and the conductive line **20***a*. The dielectric material zones **130***b* with the smaller area are disposed between the transmission lines **10***a* and **30***b*. In such embodiment, the number of dielectric material zones **130***a* between the transmission line **30***a* and the conductive line **20***a* is less than the number of dielectric material zones **130***a* between the transmission lines **30***a* and **10***a* or between the transmission line **30***b* and the conductive line **20***b*. Moreover, the number of dielectric material zones **130***b* between the transmission lines **30***b* and **10***a* is equal to the number of dielectric material zones **130***a* between the transmission lines **30***a* and **10***a* or between the transmission lines **30***b* and **20***b*.

The switch **310** is coupled to the transmission line **10***a*, and the switch **310** is controlled by a control signal Ctrl1. In response to the control signal Ctrl1, the switch **310** is configured to selectively connect the transmission line **10***a* to the wave source (not shown) for receiving the radio frequency (RF) signal S1 or to the ground GND for grounding. The switch **320** is coupled to the transmission line **30***a*, and the switch **320** is controlled by a control signal Ctrl2. In response to the control signal Ctrl2, the switch **320** is configured to selectively connect the transmission line **30***a* to the wave source (not shown) for receiving the RF signal S2 or to the ground GND for grounding. The switch **330** is coupled to the transmission line **30***b*, and the switch **330** is controlled by a control signal Ctrl3. In response to the control signal Ctrl3, the switch **330** is configured to selectively connect the transmission line **30***b* to the wave source (not shown) for receiving the RF signal S3 or to the ground GND for grounding.

The control signals Ctrl1, Ctrl2 and Ctrl3 are provided by a controller (not shown), and the controller and the transmission line structure are implemented in the same semiconductor device. In some embodiments, the RF signals S1, S2 and S3 are different. In some embodiments, the RF signals S1, S2 and S3 are the same or signals are correlated.

FIG. **6**B shows a wavelength table of the transmission line structure **300**A of FIG. **6**A, in accordance with some embodiments of the disclosure. In the table of FIG. **6**B, by controlling the connection configurations of the switches **310**, **320** and **330**, seven wavelengths λ_a_1 through λ_a_7 are obtained.

Referring to FIG. **6**A and FIG. **6**B together, each of the switches **310**, **320** and **330** is configured to operate in an "ON" state or a "ground" state according to the corresponding control signal (e.g., the control signal Ctrl1, Ctrl2 or Ctrl3). Taking the switch **310** as an example, in the "ON" state, the switch **310** is configured to connect the transmission line **10***a* to the wave source (not shown), thus the RF signal S1 is provided to the transmission line **10***a*. Conversely, in the "ground" state, the switch **310** is configured to connect the transmission line **10***a* to the ground GND, thus the transmission line **10***a* is grounded.

When the switches **310**, **320** and **330** are operated in the "ON" state, the RF signals S1, S2 and S3 are respectively provided to the transmission lines **10***a*, **30***a* and **30***b*, thus the wavelength λ is adjusted to λ_a_1.

When the switches **310** and **330** are operated in the "ON" state and the switch **320** is operated in the "ground" state, the RF signals S1 and S3 are respectively provided to the transmission lines **10***a* and **30***b* and the transmission line **30***a* is grounded, thus the wavelength λ is adjusted to λ_a_2. Furthermore, when the transmission line **30***a* is grounded through the switch **320**, the transmission line **30***a* may function as the ground line for the transmission line **10***a*.

When the switches **320** and **330** are operated in the "ON" state and the switch **310** is operated in the "ground" state, the RF signals S2 and S3 are respectively provided to the transmission lines **30***a* and **30***b* and the transmission line **10***a* is grounded, thus the wavelength λ is adjusted to λ_a_3.

When the switches **310** and **320** are operated in the "ON" state and the switch **330** is operated in the "ground" state, the RF signals S1 and S2 are respectively provided to the transmission lines **10***a* and **30***a* and the transmission line **30***b* is grounded, thus the wavelength λ is adjusted to λ_a_4. Furthermore, when the transmission line **30***b* is grounded through the switch **330**, the transmission line **30***b* may function as the ground line for the transmission line **10***a*.

When the switch **330** is operated in the "ON" state and the switches **310** and **320** are operated in the "ground" state, the RF signal S3 is provided to the transmission line **30***b* and the transmission lines **10***a* and **30***a* are grounding, thus the wavelength X is adjusted to λ_a_5.

When the switch **320** is operated in the "ON" state and the switches **310** and **330** are operated in the "ground" state, the RF signal S2 is provided to the transmission line **30***a* and the transmission lines **10***a* and **30***b* are grounding, thus the wavelength is adjusted to λ_a_6.

When the switch **310** is operated in the "ON" state and the switches **320** and **330** are operated in the "ground" state, the RF signal S1 is provided to the transmission line **10***a* and the transmission lines **30***a* and **30***b* are grounding, thus the wavelength is adjusted to λ_a_7.

Therefore, in the transmission line structure **300**A, the wavelength A can be adjusted from λ_a_7 to λ_a_1 by controlling the connection configurations of the switches **310**, **320** and **330** (i.e., the operation state of the witches **310**, **320** and **330**).

As shown in FIG. **6**B, by controlling the connection configurations of the switches (e.g., the selective on/off combination of the signal line) and different implant processes of the dielectric material zones, the tunable high-impedance section is obtained for the transmission line structure **300**A.

FIG. **7**A shows a top view of a transmission line structure **300**B, in accordance with some embodiments of the disclosure. The configuration of the transmission line structure **300**B in FIG. **7**A is similar with the configuration of the transmission line structure **300**A in FIG. **6**A. The difference between the transmission line structure **300**A in FIG. **6**A and the transmission line structure **300**B in FIG. **7**A is that the transmission line structure **300**B further includes the dielectric material zones **130***c* and the dielectric material zones **140***a* and **140***b*.

In FIG. **7**A, the dielectric material zones **130***a* and **130***c* are formed by a first high-k dielectric material, and the dielectric material zones **140***a* and **140***b* are formed by a second high-k dielectric material. In some embodiments, the dielectric constant of the first high-k dielectric material is less than the dielectric constant of the second high-k dielectric material. For example, the dielectric constant of the first high-k dielectric material is between 7 and 15, and the dielectric constant of the first high-k dielectric material is greater than 15. In some embodiments, the dielectric constant of the first high-k dielectric material is greater than the dielectric constant of the second high-k dielectric material. For example, the dielectric constant of the first high-k dielectric material is greater than 15, and the dielectric constant of the first high-k dielectric material is between 7 and 15.

The dielectric material zones **130***c* have a width KW5 in the X-direction and a length KL5 in the Y-direction. In such embodiment, the width KW1 is greater than the width KW5 (i.e., KW1>KW5), and the length KL1 is greater than or equal to the length KL3 (i.e., KL1>KL5). Thus, the area of the dielectric material zones **130***a* is greater than the area of the dielectric material zones **130***c*.

In FIG. **7**A, the dielectric material zones **130***a* and **140***a* are interleaved between the transmission line **30***b* and the conductive line **20***b* along the Y-direction. The dielectric material zones **130***c* are disposed between the transmission lines **30***b* and **10***a*. The dielectric material zones **130***a* and the dielectric material zones **140***a*/**140***b* are interleaved between the transmission lines **30***a* and **10***a* along the Y-direction. The dielectric material zones **130***a* are disposed between the transmission line **30***a* and the conductive line **20***a*.

In the transmission line structure **300**B, the wavelength λ can be adjusted by controlling the connection configurations of the switches **310**, **320** and **330**. Referring to FIG. **7**B, FIG. **7**B shows a wavelength table of the transmission line structure **300**B of FIG. **7**A, in accordance with some embodiments of the disclosure. In the table of FIG. **7**B, by controlling the connection configurations of the three switches **310**, **320** and **330**, seven wavelengths λ_b_1 through λ_b_7 are obtained.

FIG. **8**A shows a top view of a transmission line structure **300**C, in accordance with some embodiments of the disclosure. The configuration of the transmission line structure **300**C in FIG. **8**A is similar with the configuration of the transmission line structure **300**B in FIG. **7**A. The difference between the transmission line structure **300**B in FIG. **7**A and the transmission line structure **300**C in FIG. **8**A is that the transmission line structure **300**C further includes the transmission line **10***b* and the corresponding switch (or the selector) **340**.

Similar to the transmission line **10***a*, the transmission line **10***b* is the non-linear line. The transmission line **10***b* has a periodic structure formed by the sub-line **12**, the sub-lines **14** periodically arranged to the right of the sub-line **12**, and the sub-lines **16** periodically arranged to the left of the sub-line **12**. As described above, for the transmission line **10***b*, the sub-line **14** and the sub-line **16** may have the same area. In such embodiment, the sub-line **14** and the sub-line **16** have the different areas.

In FIG. **8**A, the dielectric material zones **130***c* and **140***b* are disposed between the transmission lines **10***a* and **10***b*. Moreover, the switch **340** is connected to the transmission line **10***b*. The switch **340** is configured to operate in an "ON" state or a "ground" state according to the control signal Ctrl4. In the "ON" state, the switch **340** is configured to connect the transmission line **10***b* to the wave source (not shown), thus the RF signal S4 is provided to the transmission line **10***b*. Conversely, in the "ground" state, the switch **340** is configured to connect the transmission line **10***b* to the ground GND, thus the transmission line **10***b* is grounded.

In the transmission line structure **300**C, the wavelength λ can be adjusted by controlling the connection configurations of the switches **310**, **320**, **330** and **340**. As shown in FIG. **8**, FIG. **8**B shows a wavelength table of the transmission line structure **300**C of FIG. **8**A, in accordance with some embodiments of the disclosure. In the table of FIG. **8**B, by controlling the connection configurations of the four switches **310**, **320**, **330** and **340**, fifteen wavelengths λ_c_1 through λ_c_{15} are obtained.

The transmission line structures disclosed herein may be formed using well-known semiconductor manufacturing processes. Moreover, the transmission line structures disclosed herein may be used in many products, including but not limited to items such as integrated circuits, monolithic microwave integrated circuits, radio frequency transmitters and receivers, radio frequency communication equipment, antennas, circuit boards, amplifiers, modulators, and demodulators.

Embodiments of the transmission line structures are provided. By using dielectric material zones with high-k dielectric materials between the transmissions and the ground lines in the transmission line structure, a higher permittivity epsilon Cr and lower phase velocity speed Vp of the transmission line structure as compared to conventional transmission line module. Furthermore, by switching the connection configurations of the switches connected to the respective transmission lines, the wavelength λ can be adjusted. Therefore, compared with conventional transmission line modules with constant dielectric material, the transmission line structures in the disclosure can fulfill small form factor package due to the variable dielectric material (e.g., the dielectric material zones **130***a* through **130***c* and **140***a* through **140***b*) inside.

In some embodiments, a device is provided. The device includes a semiconductor substrate, a first conductive line and a second conductive line, a first transmission line formed in the metal layer and between the first and second conductive lines, a plurality of first dielectric material zones and a plurality of second dielectric material zones. The first and second conductive lines are formed in a metal layer over the semiconductor substrate and extend in a first direction. The first transmission line includes a first sub-line extending in the first direction, a plurality of second sub-lines perpendicular to the first sub-line and extending toward the first conductive line, and a plurality of third sub-lines perpendicular to the first sub-line and extending toward the second conductive line. The first dielectric material zones are formed between the second sub-lines and the first conductive line. The second dielectric material zones are formed between the third sub-lines and the second conductive line. The first and second conductive lines and the first transmission line are separated from each other by an insulation material, and the first and second dielectric material zones are separated from the first and second conductive lines and the first transmission line by the insulation material. The dielectric constant of the insulation material is less than that of the first and second dielectric material zones.

In some embodiments, a device is provided. The device includes a semiconductor substrate, a first ground line and a second ground line, a first transmission line and a second transmission line formed in a metal layer, a first switch, a second switch, a plurality of first dielectric material zones, and a plurality of second dielectric material zones. The first and second ground lines are formed over the semiconductor substrate and extend in a first direction. The first transmission line is formed in the metal layer and between the first and second ground lines. The first transmission line is divided into a first sub-line extending in the first direction, a plurality of second sub-lines extending toward the first ground line along a second direction, and a plurality of third sub-lines extending toward the second ground line along the second direction, and the first direction is perpendicular to the second direction. The second transmission line is formed in the metal layer and between the second ground line and the first transmission line. The first switch is formed in the semiconductor substrate and connected to the first transmission line. The second switch is formed in the semiconductor substrate and connected to the second transmission line. The plurality of first dielectric material zones are formed between the second sub-lines and the first ground line or between the second ground line and the second transmission line. The plurality of second dielectric material zones are formed between the third sub-lines and the second transmission line. The first and second dielectric material zones are separated from the first and second ground lines and the first and second transmission lines by an insulation material. The dielectric constant of the insulation material is less than that of the first and second dielectric material zones.

In some embodiments, a device is provided. The device includes a semiconductor substrate, a first conductive line and a second conductive line, a plurality of transmission lines, a plurality of switches, an insulation material layer formed over the semiconductor substrate, and a plurality of first dielectric material zones. The first and second conductive lines are formed in a metal layer over the semiconductor substrate and extend in a first direction. The plurality of transmission lines are formed in the metal layer and between the first and second conductive lines. The transmission lines have different shapes. The plurality of switches are formed in the semiconductor substrate, wherein each of the switches is connected to a respective transmission line. The first and second conductive lines and the transmission lines are separated from each other by the insulation material layer. The plurality of first dielectric material zones are formed in the insulation material layer and between the first and second conductive lines and the transmission lines. The first dielectric material zones are separated from the first and second conductive lines and the transmission lines by the insulation materials. The dielectric constant of the insulation material layer is less than that of the first dielectric material zones.

The foregoing outlines nodes of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A device, comprising:

a semiconductor substrate;

a first conductive line and a second conductive line formed in a metal layer over the semiconductor substrate and extending in a first direction;

a first transmission line formed in the metal layer and between the first and second conductive lines, wherein the first transmission line comprises a first sub-line extending in the first direction, a plurality of second sub-lines perpendicular to the first sub-line and extending toward the first conductive line, and a plurality of third sub-lines perpendicular to the first sub-line and extending toward the second conductive line;

a plurality of first dielectric material zones formed between the first transmission line and the first conductive line, wherein the second sub-lines comprises a first group and a second group, and wherein the first dielectric material zones are disposed between the second sub-lines of the first group and the first conductive line, and spaces between the second sub-lines of the second group and the first conductive line are free of the first dielectric material zones; and

a plurality of second dielectric material zones and a plurality of third dielectric material zones formed between the first transmission line and the second conductive line, wherein the third sub-lines comprises a third group and a fourth group, and wherein the second dielectric material zones are disposed between the third sub-lines of the third group and the second conductive line, and the third dielectric material zones are disposed between the third sub-lines of the fourth group and the second conductive line, such that the second and third dielectric material zones are interleaved along the first direction,

wherein the second and third dielectric material zones have different dielectric materials,

wherein the first and second conductive lines and the first transmission line are separated from each other by an insulation material, and the first and second dielectric material zones are separated from the first and second conductive lines and the first transmission line by the insulation material.

2. The device as claimed in claim **1**, wherein the number of second sub-lines is greater than the number of first dielectric material zones, and the number of third sub-lines is greater than the number of second dielectric material zones.

3. The device as claimed in claim **1**, wherein a fixed voltage is applied to the first and second conductive lines.

4. The device as claimed in claim **1**, wherein a space between the second sub-lines and the first conductive line is equal to a space between the third sub-lines and the second conductive line.

5. The device as claimed in claim **1**, further comprising:

a second transmission line formed in the metal layer and between the first and second conductive lines and extending in the first direction;

a first switch formed in the semiconductor substrate and connected to the first transmission line; and

a second switch formed in the semiconductor substrate and connected to the second transmission line,

wherein the first and second conductive lines are ground lines,

wherein when the first switch is turned on, a first radio frequency (RF) signal is applied to the first transmission line, and when the second switch is turned on, a second RF signal is applied to the second transmission line.

6. The device as claimed in claim **1**, wherein area of the second sub-line is larger than or equal to area of the third sub-line.

7. The device as claimed in claim **1**, wherein the first and second dielectric material zones have the same dielectric constant, and area of the first dielectric material zone is equal to area of the second dielectric material zone.

8. A device, comprising:

a semiconductor substrate;

a first ground line and a second ground line formed in a metal layer over the semiconductor substrate and extending in a first direction;

a first transmission line formed in the metal layer and between the first and second ground lines, wherein the first transmission line is divided into a first sub-line extending in the first direction, a plurality of second sub-lines extending toward the first ground line along a second direction, and a plurality of third sub-lines extending toward the second ground line along the second direction, and the first direction is perpendicular to the second direction;

a second transmission line formed in the metal layer and between the second ground line and the first transmission line;

a first switch formed in the semiconductor substrate and connected to the first transmission line;

a second switch formed in the semiconductor substrate and connected to the second transmission line,

a plurality of first dielectric material zones formed between the second sub-lines and the first ground line;

a plurality of second dielectric material zones formed between the third sub-lines and the second transmission line; and

a plurality of third dielectric material zones and a plurality of fourth dielectric material zones formed between the second transmission line and the second ground line, wherein the third and fourth dielectric material zones are interleaved along the first direction and have different dielectric materials,

wherein the first and second dielectric material zones are separated from the first and second ground lines and the first and second transmission lines by an insulation material,

wherein dielectric constant of the insulation material is less than that of the first and second dielectric material zones.

9. The device as claimed in claim **8**, wherein a space between the second sub-lines and the first ground line is equal to a space between the third sub-lines and the second transmission line, and the space between the third sub-lines and the second transmission line is equal to a space between the second transmission line and the second ground line.

10. The device as claimed in claim **8**, wherein when the first switch is turned on, a first RF signal is applied to the first transmission line, and when the second switch is turned on, a second RF signal is applied to the second transmission line.

11. The device as claimed in claim **8**, wherein area of the second sub-line is larger than or equal to area of the third sub-line.

12. The device as claimed in claim **8**, wherein the first and second dielectric material zones have the same dielectric constant, and area of the first dielectric material zone is different from area of the second dielectric material zone.

13. The device as claimed in claim **8**, wherein dielectric constant of the fourth dielectric material zones is greater than that of the first dielectric material zones.

14. The device as claimed in claim **8**, further comprising:

a plurality of fifth dielectric material zones formed between the second sub-lines and the first ground line,

wherein the first and fifth dielectric material zones are interleaved along the first direction and have different dielectric materials.

15. A device, comprising:

a semiconductor substrate;

a first conductive line and a second conductive line formed in a metal layer over the semiconductor substrate and extending in a first direction;

a first non-linear transmission line formed in the metal layer and between the first and second conductive lines, wherein the first non-linear transmission line comprises a first sub-line extending in the first direction and a plurality of second sub-lines extending toward the second conductive line along a second direction, and wherein the first direction is perpendicular to the second direction;

a first linear transmission line formed in the metal layer and between the first non-linear transmission line and the second conductive lines;

a plurality of switches formed in the semiconductor substrate and connected to the first non-linear transmission line and the first linear transmission line;

an insulation material layer formed over the semiconductor substrate, wherein the first and second conductive lines, the first non-linear transmission line, and the first linear transmission line are separated from each other by the insulation material layer;

a plurality of first dielectric material zones formed in the insulation material layer and between the second sub-lines and the first linear transmission line; and

a plurality of second dielectric material zones and a plurality of third dielectric material zones formed in the insulation material layer and between the first linear transmission line and the second conductive lines, wherein the second and third dielectric material zones are interleaved along the first direction and have different dielectric materials,

wherein the number of the first dielectric material zones is greater than the number of the second dielectric material zones and the number of the third dielectric material zones,

wherein the first dielectric material zones are separated from the first and second conductive lines and the transmission lines by the insulation materials,

wherein dielectric constant of the insulation material layer is less than that of the first dielectric material zones.

16. The device as claimed in claim **15**, wherein the first and second conductive lines are ground lines, wherein when a first switch of the switches is switched to connect a wave source, a first RF signal from the wave source is applied to the first non-linear transmission line connected to the first switch.

17. The device as claimed in claim **16**, wherein when the first switch is switched to connect a ground terminal, the first non-linear transmission line connected to the first switch is grounded.

18. The device as claimed in claim **15**, wherein dielectric constant or area of the first dielectric material zone is different from that of the third dielectric material zone.

19. The device as claimed in claim **15**, wherein the first non-linear transmission line further comprises a third sub-lines extending toward the first conductive line along the second direction.

20. The device as claimed in claim **19**, further comprising:

a second non-linear transmission line formed in the metal layer and between the first non-linear transmission line and the first conductive line, wherein the second non-linear transmission line comprises a fourth sub-line extending in the first direction and a plurality of fifth sub-lines extending toward the first non-linear transmission line along the second direction; and

a plurality of the fourth dielectric material zones formed in the insulation material layer and between the third sub-lines and the fifth sub-lines, wherein the second and the fourth dielectric material zones have the same dielectric material.

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