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Chen

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(54) **HIGH POWER DIRECTIONAL COUPLER**

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(51) **Int. Cl.**
H01P 3/08 (2006.01)
H01P 5/18 (2006.01)

(52) **U.S. Cl.** **333/116**; 333/246

(58) **Field of Classification Search** 333/109, 333/116, 246

See application file for complete search history.

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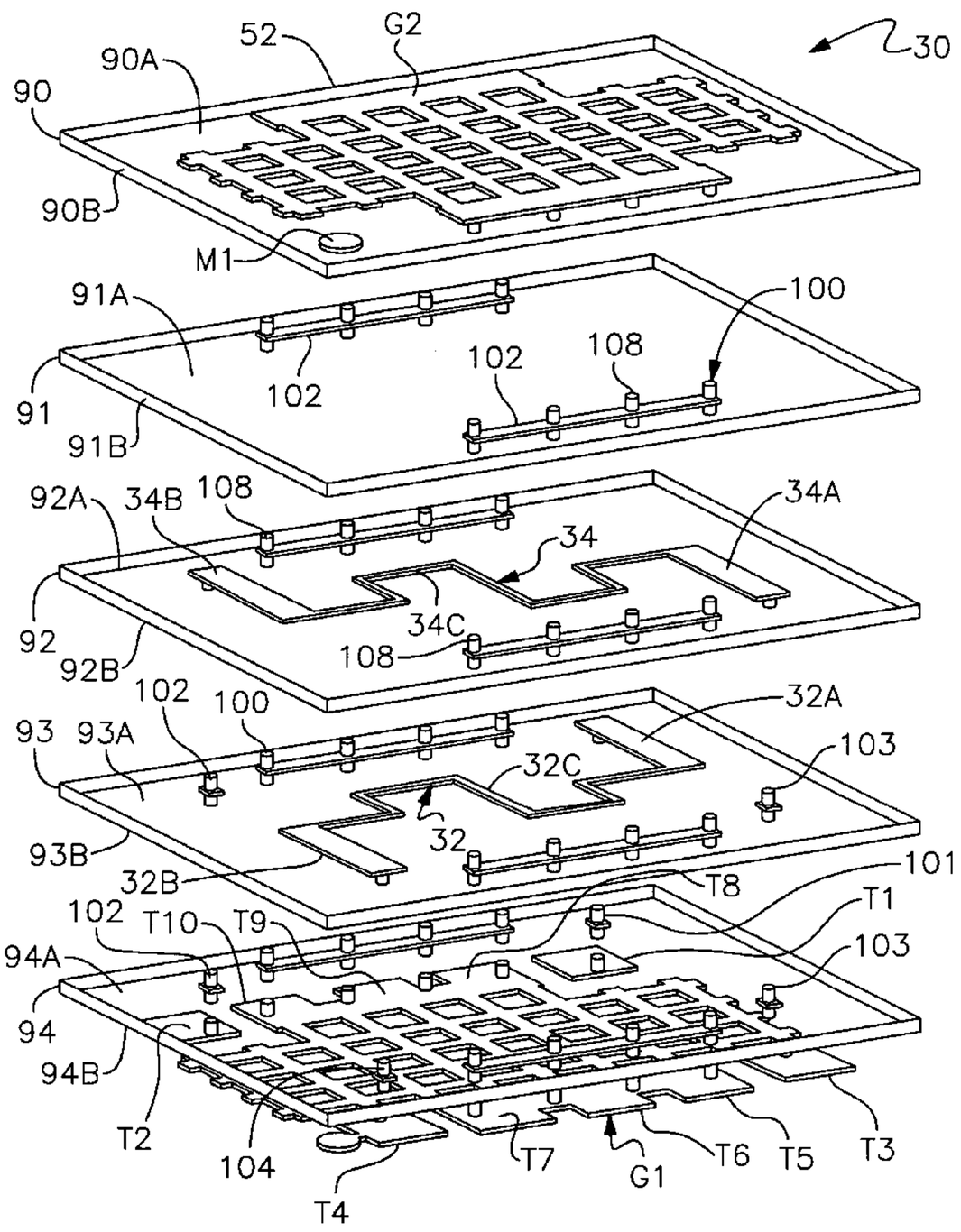
(57) **ABSTRACT**

A directional coupler has a multi-layered low temperature co-fired ceramic substrate. A circuit line is located on one of the layers and is connected to an input port and an output port. Another circuit line is located on a different layer and is connected to a forward coupled port and a reverse coupled port. The circuit lines are located close to each other such that they are electromagnetically coupled. Ground planes are located on the top and bottom surfaces of the substrate.

18 Claims, 7 Drawing Sheets



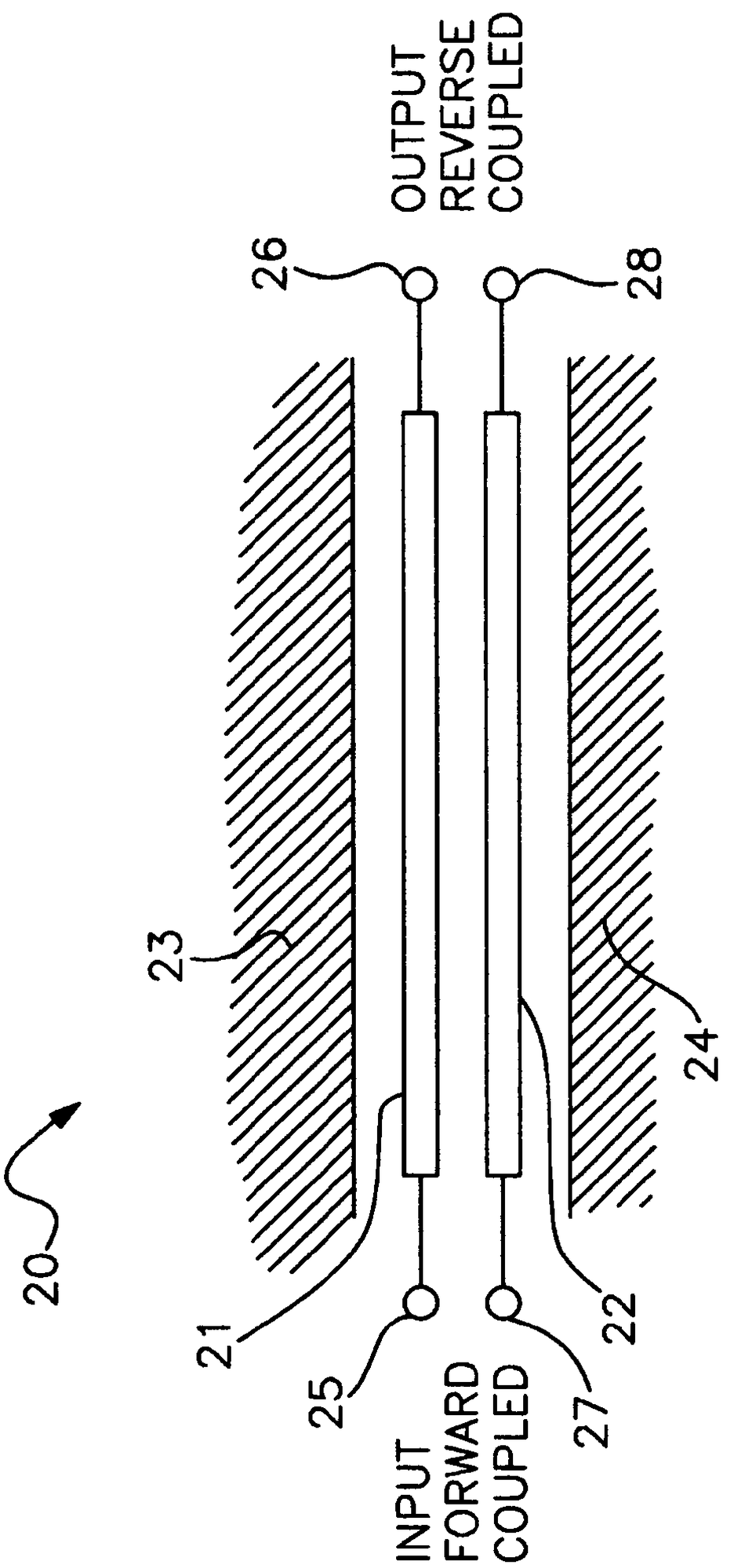


Fig. 1
(Prior Art)

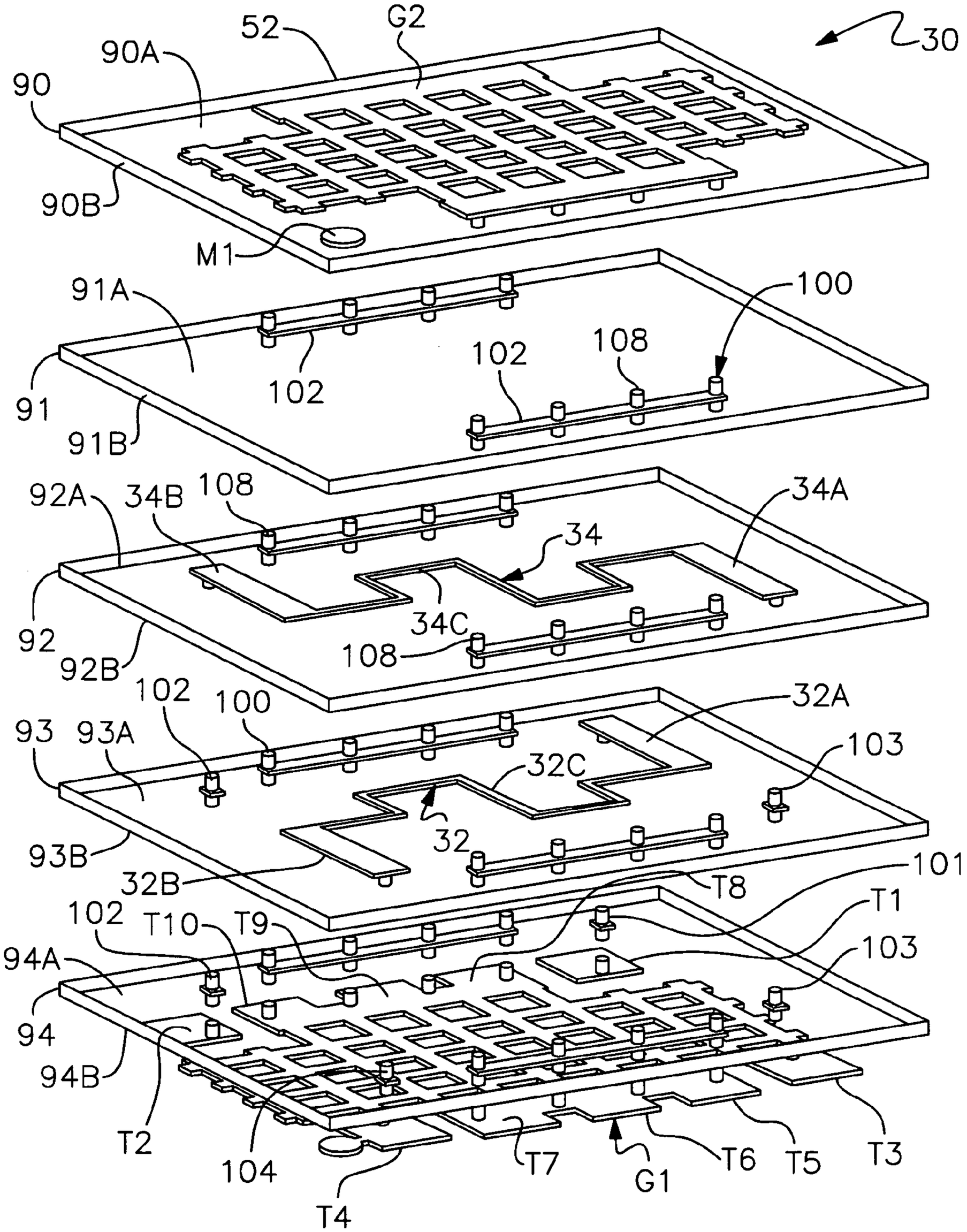

52
G2
30
90A
90
90B
M1
91A
100
102
108
91
91B
92A
34B
108
34A
34
34C
92
92B
108
102
100
32A
93
93A
103
32C
32
93B
32B
101
T8
T1
102
T10
T9
103
94A
94
94B
T2
104
T7
G1
T6
T5
T3
T4

Fig. 2

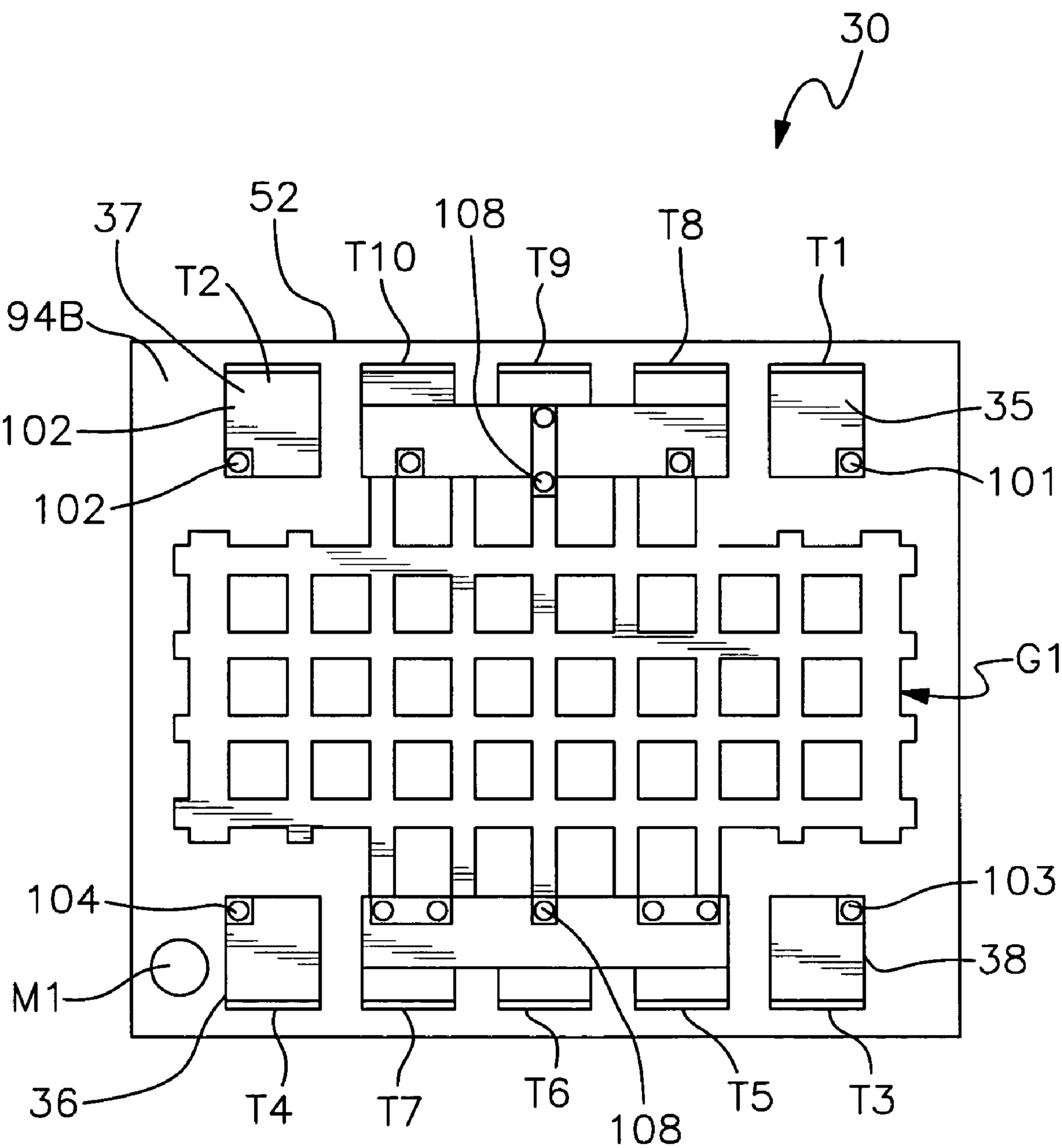

30
37
52
108
T8
T10
T9
T1
T2
94B
102
102
35
101
G1
104
103
38
M1
36
T4
T7
T6
T5
T3
108

Fig. 3

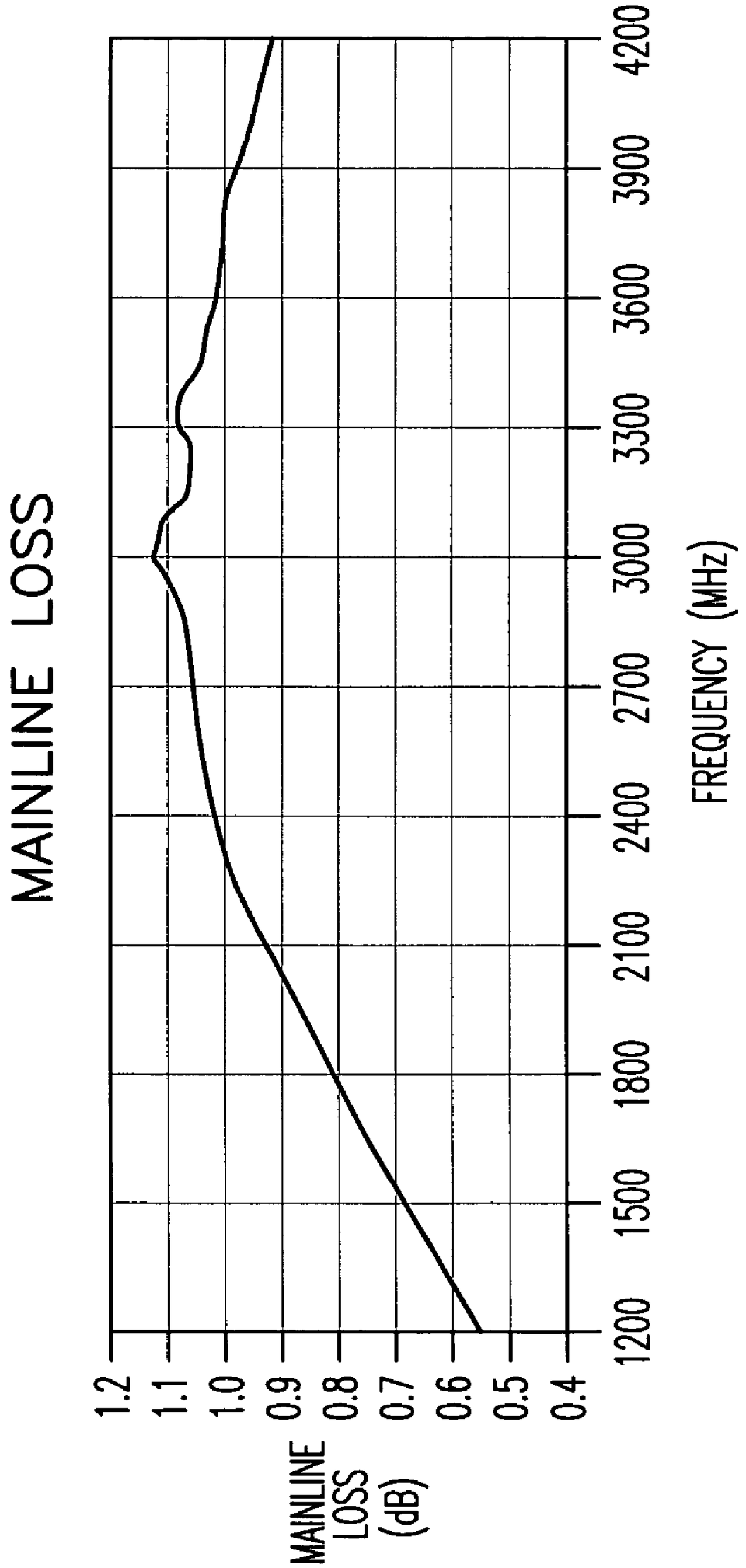

MAINLINE LOSS
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
MAINLINE LOSS (dB)
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
FREQUENCY (MHz)

Fig. 4

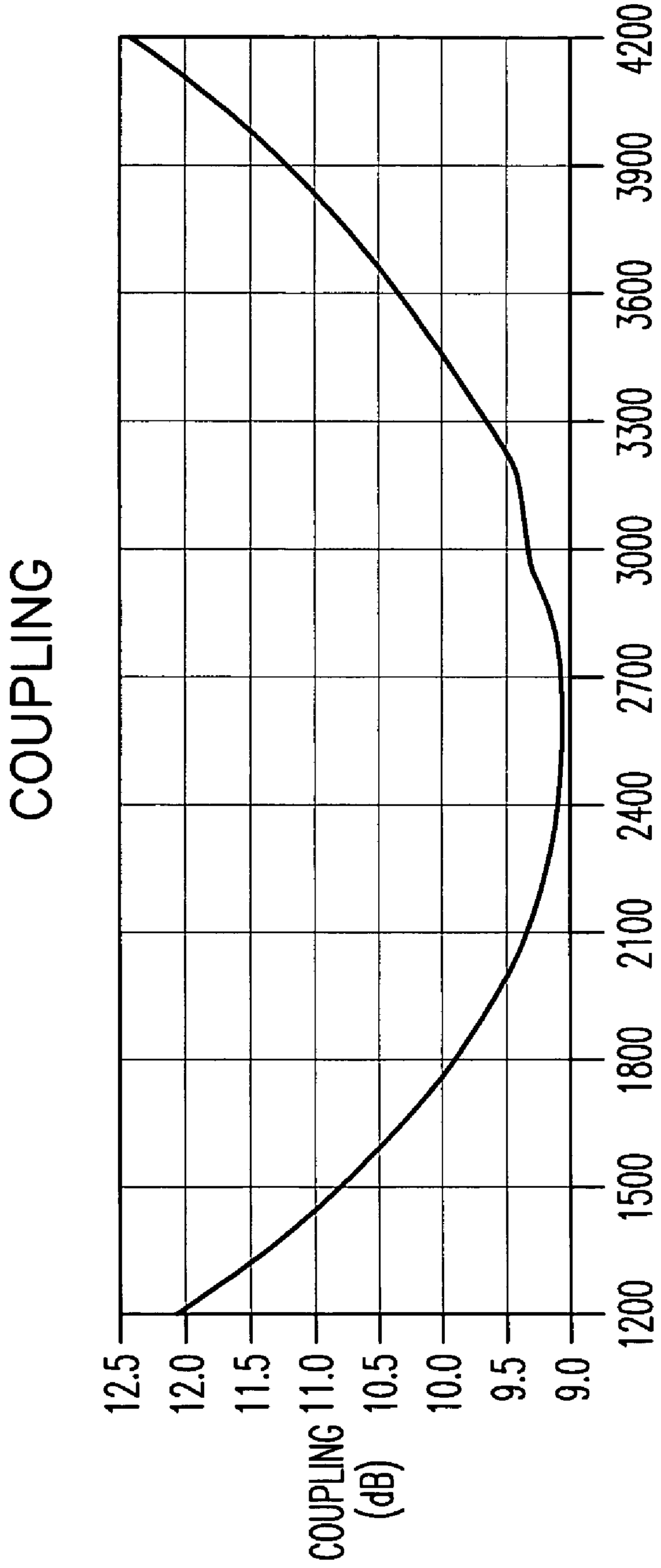

COUPLING (dB)
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
FREQUENCY (MHz)

Fig. 5

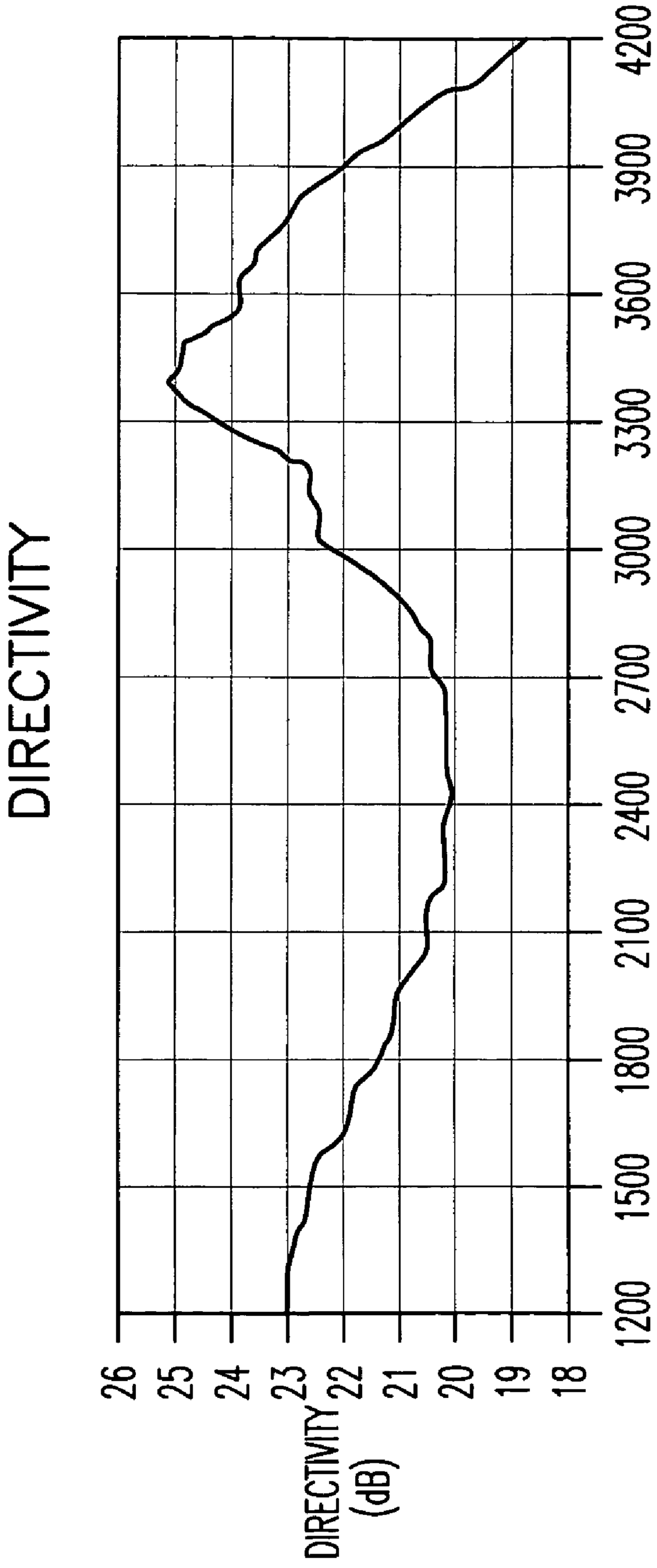

DIRECTIVITY
DIRECTIVITY (dB)
26
25
24
23
22
21
20
19
18
FREQUENCY (MHz)
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200

Fig. 6

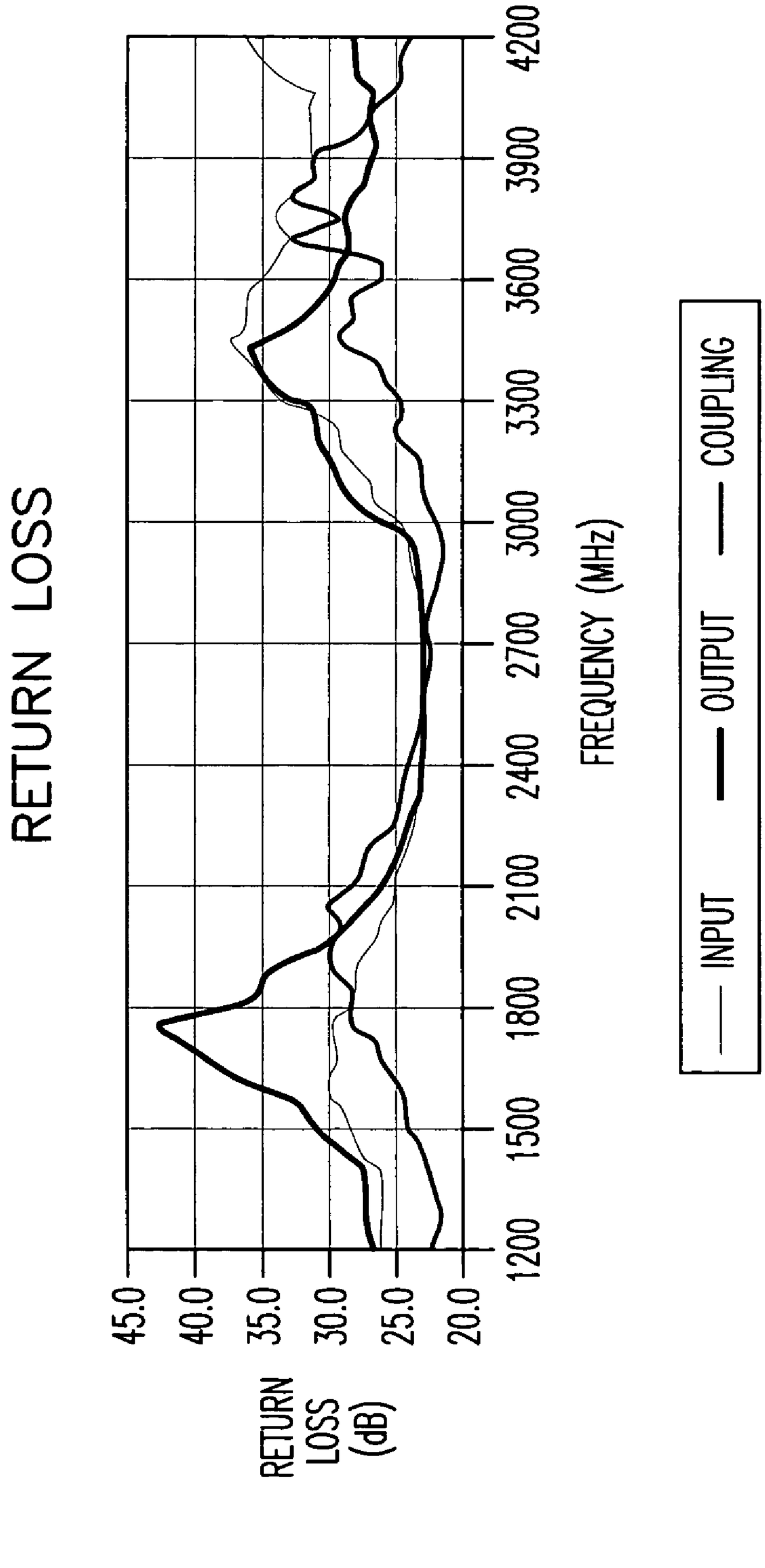

RETURN LOSS
45.0
40.0
35.0
30.0
25.0
20.0
RETURN LOSS (dB)
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
FREQUENCY (MHz)
INPUT
OUTPUT
COUPLING

Fig. 7

HIGH POWER DIRECTIONAL COUPLER

This application claims the benefit of Provisional Application No. 60/533,797, filed Jan. 2, 2004.

BACKGROUND

1. Field of Invention

This invention relate to directional couplers in general and more particularly to directional couplers that have a small overall size.

2. Description of Related Art

Directional couplers are used in a variety of applications in the RF and microwave frequency range. FIG. **1** shows a schematic diagram of a prior art directional coupler **20** including a pair of coupled circuit lines **21** and **22** located between ground planes **23** and **24**. This configuration is referred to as stripline. The circuit lines **23** and **24** are buried within a dielectric material, which commonly is a printed circuit board. The ground planes are one factor that determines the impedance and coupling of the circuit lines. The directional coupler **20** has four ports, an input port **25**, an output port **26**, a forward coupled port **27** and a reverse coupled port **28**. An input signal or power applied to the input port **25** will go mainly to the output port **26**. A portion of the input signal will be electromagnetically coupled to circuit line **22** and appear mostly at forward coupled port **27**. A very small portion of the signal will go to the coupled reverse port **28**.

The electrical signal coupled to the forward and reverse ports depends upon the coupled circuit line characteristic impedance and the coupling between the lines. Directivity is a measure of the directional coupler differentiation between ports.

Printed circuit boards have a dielectric material constant around 2.5. The low dielectric constant causes the overall size of the device to be large when designed for a given circuit line impedance.

A current unmet need exists for a directional coupler that is smaller with good electrical performance and that is low in cost to manufacture.

SUMMARY

It is a feature of the invention to provide a directional coupler that has a small size with good electrical performance.

It is a feature of the invention to provide a directional coupler that can be built in high volumes at low cost.

Another feature of the invention is to provide a directional coupler that includes a substrate having a top surface, a bottom surface and several layers. A first circuit line has a first end and a second end. The first circuit line is located on one of the layers. An input port is connected to the first end and an output port is connected to the second end. A second circuit line has a third end and a fourth end. The second circuit line is located on another layer. The first and second circuit lines are located proximate to each other such that they are electromagnetically coupled. A forward coupled port is connected to the third end and a reverse coupled port is connected to the fourth end. A first ground plane is located on the top surface and a second ground plane is located on the bottom surface.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic drawing of a conventional directional coupler.

FIG. **2** is an exploded perspective view of the present invention.

FIG. **3** is a bottom view of FIG. **2**.

FIG. **4** is a graph of main line loss versus frequency for the directional coupler of FIG. **2**.

FIG. **5** is a graph of coupling versus frequency for the directional coupler of FIG. **2**.

FIG. **6** is a graph of directivity versus frequency for the directional coupler of FIG. **2**.

FIG. **7** is a graph of return loss versus frequency for the directional coupler of FIG. **2**.

It is noted that the drawings of the invention are not to scale. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION

Referring now to FIGS. **2** and **3**, a directional coupler **30** is shown. Directional coupler **30** has a substrate **52**. Substrate **52** is a multi-layered dielectric substrate **52** formed from layers of low temperature co-fired ceramic (LTCC) material. Substrate **52** is comprised of multiple layers **90**, **91**, **92**, **93** and **94** of LTCC material. There are **5** LTCC layers in total. Substrate **52** has a top surface **90**A and bottom surface **94**B. Various circuit features are patterned on the layers.

Several conductive terminals are located on bottom surface **94**B. The terminals are formed from a solderable metal. Terminals T**1**, T**2**, T**3** and T**4** are located on bottom surface **94**B. Ground shield or plane G**1** is located on bottom surface **94**B and has ground terminals T**5**, T**6**, T**7**, T**8**, T**9** and T**10**. Ground shield or plane G**2** is located on top surface **90**A. The ground terminals would be soldered to a source of ground potential.

Terminal T**1** corresponds to the output port **35**. Terminal T**2** is the forward coupled port **37**. Terminal T**3** is the reverse coupled port **38**. Terminal T**4** is the input port **36**.

The terminals are used to electrically connect substrate **52** to a printed circuit board (not shown). The terminals would typically be soldered to the printed circuit board. An orientation mark M**1** is placed on top surface **90**A in order to prevent incorrect installation on the printed circuit board.

Planar layers **90**, **91**, **92**, **93**, and **94** are all stacked on top of each other and form a unitary structure **52** after firing in an oven. Layer **90** is the top layer, layer **94** is the bottom layer and layers **91**, **92** and **93** form inner layers. The layers are commercially available in the form of an unfired tape. Each of the layers has a top surface **90**A, **91**A, **92**A, **93**A and **94**A. Similarly, each of the layers has a bottom surface **90**B, **91**B, **92**B, **93**B and **94**B. The layers have several circuit features that are patterned on the surfaces. Multiple vias **100** extend through each of the layers. Vias **100** are formed from an electrically conductive material and electrically connect the circuit features on one layer to the circuit features on another layer.

Coupled circuit line **32** is formed on surface **93**A. Coupled circuit line **34** is formed on surface **92**A. Coupled circuit line **32** has wide ends **32**A and **32**B and a thin center section **32**C. Coupled circuit line **34** has wide ends **34**A and **34**B and a thin center section **34**C. Circuit lines **32** and **34** have a snake like, winding or sinuous shape and are located directly above each other on different planes. Circuit lines **32** and **34** are separated by layer **92**. Circuit lines **32** and **34** are

electromagnetically coupled through the dielectric medium of layer **92**. The circuit lines are formed from a conductive metal material. Circuit lines **32** and **34** are referred to as striplines because they are sandwiched between ground or reference planes G**1** and G**2**.

Via **101** connects terminal T**1** to circuit line end **32**A. Via **102** connects terminal T**2** to circuit line end **34**B. Via **103** connects terminal T**3** to circuit line end **34**A. Via **104** connects terminal T**4** to circuit line end **32**B.

A mesh ground shield or plane G**2** is formed on surface **90**A. Another mesh ground shield or plane G**1** is formed on surface **94**B. Ground buss **102** connects several of the grounded vias **108** together on layers **91**, **92** and **93**.

The circuit features such as the vias, circuit lines, terminals and ground planes are formed by screening a thick film paste material and firing in an oven. This process is well known in the art. First, layers of low temperature co-fired ceramic have via holes punched, the vias are then filled with a conductive material. Next, the circuit features are screened onto the layers. The terminals, lines and ground planes are formed with a conductive material. The layers are then aligned and stacked on top of each other to form substrate **52**. The substrate **52** is then fired in an oven at approximately 900 degrees centigrade to form a single unitary piece.

A directional coupler **30** in the form of substrate **52** was designed, fabricated and tested for electrical performance over the frequency range of 1200 to 4200 MHz. Substrate **52** as built and tested had an overall substrate size of 0.3 inches by 0.25 inches by 0.27 inches. The circuit lines **32** and **34** were designed for an impedance of 50 ohms. Circuit lines **32** and **34** have a line width of 0.005 inches and a line thickness of 0.0003 inches. The vias had a diameter of 0.008 inches. The dielectric constant of the low temperature co-fired ceramic layers was 7.8.

FIGS. **4**–**7** show the electrical performance of directional coupler **30**. Turning now to FIGS. **4**–**7**, a graph of mainline loss versus frequency for directional coupler **30** is shown in FIG. **4**. FIG. **5** shows a graph of coupling versus frequency. FIG. **6** is a graph of directivity versus frequency. FIG. **7** is a graph of return loss versus frequency at the ports. Directional coupler **30** maintains good electrical performance while being considerably smaller than the prior art devices.

The present invention has several advantages.

Directional coupler **30** is smaller than previous devices and therefore takes up less room when mounted on a printed circuit board.

Fabricating the substrate **52** using a low temperature co-fired ceramic process results in more uniform electrical characteristics.

Because directional coupler **30** is small, more individual couplers can be fabricated from the same sheet of ceramic tape resulting in a lower unit cost.

While the invention has been taught with specific reference to these embodiments, someone skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and the scope of the invention. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A directional coupler comprising:

a) a substrate having a top surface, a bottom surface and a plurality of layers;

b) a first circuit line having a first end and a second end, the first circuit line located on one of the layers;

c) an input port connected to the first end and an output port connected to the second end;

d) a second circuit line having a third end and a fourth end, the second circuit line located on another layer, the first and second circuit lines located proximate to each other such that they are electromagnetically coupled;

e) a forward coupled port connected to the third end and a reverse coupled port connected to the fourth end;

f) a first ground plane located on the top surface;

g) a second ground plane located on the bottom surface; and

h) a plurality of ground vias connected between the first and second ground planes.

2. The directional coupler according to claim **1**, wherein the substrate is low temperature co-fired ceramic.

3. The directional coupler according to claim **1**, wherein the first and second circuit lines have a winding shape.

4. The directional coupler according to claim **1**, wherein the first and second circuit lines are opposed to each other with one of the layers located therebetween.

5. The directional coupler according to claim **1**, wherein a plurality of vias connect the circuit lines to the ports.

6. The directional coupler according to claim **1**, wherein a first, second, third and fourth terminal are located on the bottom surface.

7. The directional coupler according to claim **6**, wherein the first terminal is connected to the third end, the second terminal is connected to the first end, the third terminal is connected to the second end and the fourth terminal is connected to the fourth end.

8. A directional coupler comprising:

a) a substrate having first, second, third, fourth and fifth layers,

b) a first circuit line located on the third layer and having a winding shape, the first circuit line having a first and second end;

c) a second circuit line located on the fourth layer and having a winding shape, the second circuit line having a third and fourth end;

d) the first and second circuit lines being coupled to each other;

e) a first ground plane located on the first layer;

f) a second ground plane located on the fourth layer;

g) a first, second, third, and fourth terminal located on the fourth layer;

h) a first via extending between the first terminal and the third end;

i) a second via extending between the second terminal and the first end;

j) a third via extending between the third terminal and the second end; and

k) a fourth via extending between the fourth terminal and the fourth end.

9. The directional coupler according to claim **8**, wherein the substrate is fabricated from a low temperature co-fired ceramic.

10. The directional coupler according to claim **8**, wherein the substrate is less than or equal to 0.3 inches in length by 0.25 inches in width by 0.27 inches in height.

11. The directional coupler according to claim **8**, wherein the first and second ground planes are connected together.

12. A directional coupler comprising:

a) a multi-layered substrate, the substrate having an upper surface and a lower surface, a first ground plane located on the upper surface and a second ground plane located on the lower surface;

b) a first circuit line located within the substrate on a first layer and having a first and second end;

c) a second circuit line located within the substrate on a second layer and having a third and fourth end;

d) a first, second, third and fourth terminal located on the lower surface;

e) a first via extending between the first terminal and the first end;

f) a second via extending between the second terminal and the second end;

g) a third via extending between the third terminal and the third end;

h) a fourth via extending between the fourth terminal and the second end; and

i) a plurality of ground vias connected between the first and second around planes.

13. The directional coupler according to claim 12, wherein the substrate is low temperature co-fired ceramic.

14. The directional coupler according to claim 12, wherein the first and second circuit lines have a winding shape.

15. The directional coupler according to claim 12, wherein the first and second circuit lines are opposed to each other with one of the layers located therebetween.

16. The directional coupler according to claim 12, wherein the circuit lines have a thin center portion and wide ends.

17. The directional coupler according to claim 12, wherein a plurality of ground terminals are located on the lower surface.

18. The directional coupler according to claim 12, wherein a ground bus is connected between the ground vias.

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