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(54) **BROADBAND MICROSTRIP TO PARALLEL-PLATE-WAVEGUIDE TRANSITION**

BREITBANDIGER ÜBERGANG VON MIKROSTREIFENLEITUNG AUF PARALLELPLATTEN-
HOHLLEITER

TRANSITION DE MICRORUBAN A LARGE BANDE EN GUIDE D'ONDES A PLAQUES PARALLELES

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Description

BACKGROUND

[0001] The present invention relates generally to waveguide transitions, and, more particularly, to a broadband microstrip to parallel-plate-waveguide transition.

[0002] Conventional microwave transitions related to the present invention involve the use of a waveguide operating in a fundamental mode rather than a parallel-plate or overmoded waveguide. Therefore, the prior art waveguide transition designs cannot achieve a broadband and low-VSWR capability as is provided by the present invention.

[0003] A transition between a coplanar line and a waveguide is, for example, disclosed in Patent Abstracts of Japan, Vol. 10, No. 340 (JP 61142802) and the paper "A NEW INTEGRATED WAVEGUIDE-MICROSTRIP TRANSITION", J.H.C. van Heuven, 4th European Microwave Conference-Proceedings, September 10-13, 1974, pages 541-545.

[0004] It would be advantageous to have a broadband microstrip to parallel-plate-waveguide transition that improves upon conventional waveguide transition.

SUMMARY OF THE INVENTION

[0005] The present invention comprises a broadband transition for use between a shielded microstrip and a parallel-plate waveguide. The broadband transition comprises a metallic taper that is electrically connected to a conductive strip of the microstrip at one end and to a wall of the waveguide at the other end. The metallic taper may be optimized to tune out, over a broad operating frequency band, reflections caused by the discontinuity between the two largely disparate transmission media comprising the microstrip and parallel-plate waveguide.

[0006] The broadband transition provides for a low VSWR transition with wide operating bandwidth and wide-angle scanning capability between a linear array of shielded microstrip circuits (e.g., phase shifters) and a parallel-plate waveguide structure (e.g., a continuous transverse stub array antenna). The shielded microstrip lines minimize cross-coupling between adjacent circuits, thereby allowing their individual amplitude and phase excitations to be imposed on a line source along the parallel-plate waveguide interface. The metallic taper is also suitable for construction of a planar, in-line transition between microstrip and rectangular waveguide with full-band coverage of the fundamental waveguide mode. No description of this particular type of transition has been found in the technical literature.

[0007] The present invention may be used in applications that require a low-VSWR, broadband, planar, inline transition between microstrip and parallel-plate or rectangular waveguide structures. In particular, the present invention provides a capability to transition between a linear array of microstrip circuits (e.g., RF feed networks,

ferrite or PIN-diode phase shifters, microwave amplifiers or mixers, etc.) and the line feed for parallel-plate or overmoded waveguide. The present invention may be used to provide low-cost, two-dimensional scanning capability by combining this type electronic scanning line feed in one plane with mechanical rotation in an orthogonal plane.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawing, wherein like reference numerals designate like structural elements, and in which:

Fig. 1 illustrates an exemplary broadband microstrip to parallel-plate waveguide transition in accordance with the principles of the present invention;

Fig. 2 shows a solid-dielectric continuous transverse stub array antenna as an example of the planar antenna;

Fig. 3 shows a section of the transition for three adjacent elements;

Fig. 4 is a graph showing computed VSWR for an exemplary 32-element continuous transverse stub array antenna

Fig. 5 illustrates an exemplary broadband transition that may be used as a low-VSWR transition between microstrip and rectangular waveguide; and

Fig. 6 shows the profile defined by points illustrated in Table 1.

DETAILED DESCRIPTION

[0009] Referring to the drawing figures, Fig. 1 illustrates the use of a broadband microstrip to parallel-plate waveguide transition 20 in accordance with the principles of the present invention in an antenna system 10. Fig. 1 illustrates a simplified block diagram of the antenna system 10 showing a typical application of the broadband transition 20.

[0010] The antenna system 10 comprises a planar antenna 30 with which the transition 20 is used. The planar antenna 30 has a line feed input including a parallel-plate or overmoded waveguide section. The planar antenna 30 also comprises a linear array of phase shifters 13 that each have a microstrip RF port 13a. The broadband transition 20 provides an RF interface between the phase shifters 13 and the antenna 30. A combiner/divider 12 for receiving input signals at an RF input 11 establishes an amplitude distribution along a line-feed input 30a of the antenna, and the linear array of phase shifters 13 may be adjusted to produce the appropriate phase front to scan the beam output by the antenna 30 at its radiating aperture at a desired angle.

[0011] Fig. 2 shows a solid-dielectric continuous trans-

verse stub array antenna 30 as a representative example of the planar antenna 30. The continuous transverse stub array antenna 30 has a parallel-plate waveguide horizontal line feed 31. An eight-way vertical corporate feed 32, located behind an aperture plate 33, feeds eight continuous transverse stub radiators 34. The horizontal aperture distribution, which is provided by the n-way combiner/divider 12 and phase shifters 13 shown in Fig. 1, is imposed onto the parallel-plate line feed 30a along the rear of the antenna 30.

[0012] A section of the present broadband transition 20 used for three adjacent elements is shown in Fig. 3. A 0.140 inch high, dielectric-filled, parallel-plate waveguide 21 (shown on the left-hand side of Fig. 3) corresponds to the parallel-plate line feed 30a of the continuous transverse stub array antenna 30. A plurality of microstrip circuits 22 each comprising a shielded microstrip feed line 24 (shown on the right-hand side of Fig. 3), comprise output circuits for three phase shifters 13, and are the same height as the parallel-plate waveguide 12 in order to minimize the physical discontinuity at the interface. The plurality of microstrip circuits 22 are fabricated on a substrate 23, such as a 0.025 inch thick Rexolite® substrate 23, which is preferably the same dielectric material from which both the parallel-plate waveguide 21 and continuous transverse stub array antenna 30 are made.

[0013] A section of the top wall of the broadband transition 20 is cut away in Fig. 3 so that one of a plurality of metallic tapers 26 can be seen. The tapers 26 may be fabricated either as a separate part, or fabricated as part of the parallel-plate region by forming the required shape in the dielectric material and subsequently metalizing the cavity walls. The metallic taper 26 is electrically connected to the microstrip feed line 24 of the microstrip circuit 22 at one end and to a wall (shown as the upper or top wall) of the waveguide 21 at the other end.

[0014] While the broadband transition 20 has the capability of low VSWR performance over multi-octave bandwidths, a design tradeoff may be imposed by the requirement to avoid grating lobes appearing in real space at the upper band edge for large scan angles. This relationship is given by the formula:

$$\frac{s}{\lambda_h} - \frac{1 - 1/n}{1 + |\sin \theta_{\max}|} \quad \text{Equation (1)}$$

where:

s = spacing between adjacent elements;
 λ_h = wavelength at the highest operating frequency;
 n = number of elements; and
 $\theta_{\max}$ = maximum scan angle from broadside.

[0015] As an example of the present invention, a broadband transition 20 for a 32-element continuous

transverse stub array antenna 30 was modeled using a Hewlett-Packard High Frequency Structures Simulator (HFSS) computer program. The array antenna 30 was designed to operate over the 6 to 18 GHz frequency band and scan to ± 60 degrees without grating lobes. Equation (1) gives the maximum allowable element spacing as 0.340 inch, and thus a spacing of 0.325 inch was chosen to provide some margin for fabrication tolerances.

[0016] Fig. 4 shows the computed magnitude of reflection $|S_{11}|$ and transmission $|S_{21}|$ coefficients versus frequency. The computed VSWR, shown in Fig 4, is below 1.50:1 from 7 to above 24 GHz. However, grating lobes occur above 22.7 GHz if the array is scanned to ± 60 degrees. At 24 GHz, the array may be scanned only to ± 27.8 degrees without grating lobes. The element spacing may be increased slightly (e.g., 0.350 inch) to give the desired low-VSWR performance down to 6 GHz, but then ± 60 degrees scan coverage without grating lobes would be achievable only up to 17.5 GHz. At higher frequencies, the usable scan sector would become progressively smaller, as expressed by Equation (1).

[0017] The broadband transition 20 of the present invention may also be used as a low-VSWR transition between microstrip circuits 22 and rectangular waveguide 21, as is shown in Fig. 5. The wideband capability of this particular broadband transition 20, however, is limited by cutoff of the fundamental mode at the low frequency end and the propagation of higher-order modes at the high end.

[0018] The methodology used to the design the metallic taper 26 includes the following steps. The width (Y direction) of the taper 26 is chosen to be equal to the line width of the microstrip circuit 22. This avoids the necessity of matching in the Y direction, and this option is available for special design requirements.

[0019] The length of each taper 26 is determined by the operational bandwidth, desired VSWR and space limitations. Tapers 26 are typically several wavelengths long at the lowest frequency for the respective medium. In the example design, tapers 26 less than a wavelength long were dictated by physical constraints.

[0020] The curves of the tapers 26, which are initially parabolic, are optimized numerically to minimize reflection coefficient across the desired band. Alternately, optimization routines may be used to compute the curves.

[0021] Table 1 gives the X and Z coordinates for the lower and upper surfaces of the metallic taper 26, while Fig. 6 shows the profile defined by these points.

Table 1

Lower Surface Upper Surface

X (inch)	Z (inch)	X (inch)	Z (inch)
-0.660	0.140	-0.660	0.140
-0.600	0.132	-0.600	0.140
-0.540	0.118	-0.540	0.140
-0.480	0.100	-0.480	0.140

(continued)

Lower Surface		Upper Surface	
X (inch)	Z (inch)	X (inch)	Z (inch)
-0.420	0.084	-0.420	0.140
-0.360	0.070	-0.360	0.140
-0.300	0.058	-0.300	0.140
-0.240	0.048	-0.240	0.140
-0.180	0.040	-0.180	0.140
-0.120	0.033	-0.120	0.140
-0.060	0.028	-0.060	0.140
0	0.025	0	0.140
0.100	0.025	0.100	0.140
0.200	0.025	0.200	0.140
0.300	0.025	0.300	0.140
0.400	0.025	0.400	0.140
0.500	0.025	0.500	0.140
0.580	0.025	0.580	0.118
0.660	0.025	0.660	0.100
0.740	0.025	0.740	0.084
0.820	0.025	0.820	0.070
0.900	0.025	0.900	0.058
0.980	0.025	0.980	0.048
1.060	0.025	1.060	0.040
1.140	0.025	1.140	0.033
1.220	0.025	1.220	0.028
1.300	0.025	1.300	0.025

[0022] Thus, a broadband microstrip to parallel-plate-waveguide transition has been disclosed. It is to be understood that the above-described embodiment is merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention. Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.

Claims

1. A broadband microstrip to parallel-plate-waveguide transition (20) for coupling RF energy to a planar antenna (30), comprising:

a parallel-plate waveguide (21);
a plurality of microstrip circuits (22) that each comprise a shielded microstrip feed line (24) disposed on a substrate (23); and
a plurality of metallic curved tapers (26) that each have a first end that is coupled to one of the plurality of microstrip feed lines and that each have a second end disposed adjacent to the waveguide, wherein the width (Y direction) of each metallic taper (26) is equal to the line width of the microstrip circuit (22), the length of each

taper is determined by the operational bandwidth, desired VSWR and space limitations, and curves of the tapers are optimized to minimize the reflection coefficient across the desired band.

2. An antenna system (10) comprising:

an RF input (11);
a combiner/divider (12) coupled to the RF input (11);
a linear array of phase shifters (13) that each have a microstrip RF port (13a) coupled to the combiner/divider (12);
a planar antenna (30) having a line feed input (30a) and a waveguide section; and
a broadband microstrip to parallel-plate-waveguide transition (20) coupled between the linear array of phase shifters (13) and the planar antenna (30) that comprises:

a parallel-plate waveguide (21);
a plurality of microstrip circuits (22) that each comprise a shielded microstrip feed line (24) disposed on a substrate (23); and
a plurality of metallic curved tapers (26) that each have a first end that is coupled to one of the plurality of microstrip feed lines and that each have a second end disposed adjacent to the waveguide, wherein the width (Y direction) of each metallic taper (26) is equal to the line width of the microstrip circuit (22), the length of each taper is determined by the operational bandwidth, desired VSWR and space limitations, and curves of the tapers are optimized to minimize the reflection coefficient across the desired band.

3. The antenna system (10) of claim 2, **characterized in that** the planar antenna (30) has a parallel-plate waveguide section.

4. The antenna system (10) of claim 2, **characterized in that** the planar antenna (30) has an overmoded waveguide section.

5. The antenna system (10) of claim 2, **characterized in that** the planar antenna (30) comprises a solid-dielectric continuous transverse stub array antenna (30).

6. The antenna system (10) of claim 5, **characterized in that** the continuous transverse stub array antenna (30) comprises a parallel-plate waveguide horizontal line feed (31).

7. The antenna system (10) of claim 2, **characterized**

in that the broadband transition (20) comprises a dielectric-filled, parallel-plate waveguide (21).

8. The transition of claim 1 or the system (10) of claim 2, **characterized in that** the parallel-plate waveguide (21) comprises a dielectric-filled parallel-plate waveguide (21). 5
9. The transition of claim 1 or the system (10) of claim 2, **characterized in that** the metallic tapers (26) 10 comprise separate metal parts.
10. The transition of claim 1 or the system (10) of claim 2, **characterized in that** the metallic tapers (26) 15 comprise metallized tapered dielectric material.

Patentansprüche

1. Breitbandiger Übergang von einer Mikrostreifenleitung auf einen Parallelplatten-Hohlleiter (20) zum Koppeln von HF-Energie in eine planare Antenne (30), mit: 20

einem Parallelplatten-Hohlleiter (21); 25
einer Vielzahl von Mikrostreifenschaltungen (22), die jeweils eine abgeschirmte Mikrostreifeneinspeiseleitung (24) auf einem Substrat (23) angeordnet aufweisen; und
einer Vielzahl von metallenen gebogenen Abschrägungen (26), die jeweils ein erstes Ende aufweisen, das mit einem der Vielzahl der Mikrostreifeneinspeiseleitungen gekoppelt ist, und die jeweils ein zweites Ende aufweisen, das benachbart dem Hohlleiter angeordnet ist, wobei die Breite (Y-Richtung) jeder metallenen Abschrägung (26) gleich der Leitungsbreite der Mikrostreifenschaltung (22) ist, die Länge jeder Abschrägung bestimmt wird durch die Betriebsbandbreite, die gewünschte VSWR und die Raumgrenzen, und die Krümmungen der Abschrägungen sind optimiert, um den Reflexionskoeffizienten über das gewünschte Band zu minimieren. 30 35 40

2. Antennensystem (10) mit: 45

einem HF-Eingang (11);
einem Kombinerer/Teiler (12), der mit dem HF-Eingang (11) gekoppelt ist; 50
einer linearen Anordnung von Phasenverschiebern (13), die jeweils einen Mikrostreifen HF-Anschluss (13a) aufweisen, der mit dem Kombinerer/Teiler (12) gekoppelt ist;
einer planaren Antenne (30) mit einem Leitungseinspeiseeingang (30a) und einem Hohlleiterabschnitt; und 55
einem breitbandigen Übergang (20) von einer

Mikrostreifenleitung zu einem Parallelplatten-Hohlleiter, der zwischen der linearen Anordnung von Phasenverschiebern (13) und der planaren Antenne (30) gekoppelt ist, der aufweist:

einen Parallelplatten-Hohlleiter (21);
eine Vielzahl von Mikrostreifenschaltungen (22), die jeweils eine abgeschirmte Mikrostreifeneinspeiseleitung (24) auf einem Substrat (23) angeordnet aufweisen; und
eine Vielzahl von metallenen gebogenen Abschrägungen (26), die jeweils ein erstes Ende aufweisen, das mit einem der Vielzahl der Mikrostreifeneinspeiseleitungen gekoppelt ist, und die jeweils ein zweites Ende aufweisen, das benachbart dem Hohlleiter angeordnet ist, wobei die Breite (Y-Richtung) jeder metallenen Abschrägung (26) gleich der Leitungsbreite der Mikrostreifenschaltung (22) ist, die Länge jeder Abschrägung bestimmt wird durch die Betriebsbandbreite, die gewünschte VSWR und die Raumgrenzen, und die Krümmungen der Abschrägungen sind optimiert, um den Reflexionskoeffizienten über das gewünschte Band zu minimieren.

3. Antennensystem (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die planare Antenne (30) einen Parallelplatten-Hohlleiterabschnitt besitzt.
4. Antennensystem (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die planare Antenne (30) einen übermodierten Hohlleiterabschnitt besitzt.
5. Antennensystem (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die planare Antenne (30) eine Gruppenantenne mit Festkörperdielektrikum und kontinuierlichen quer verlaufenden Stichleitungen (30) aufweist.
6. Antennensystem (10) nach Anspruch 5, **dadurch gekennzeichnet, dass** die Gruppenantenne mit kontinuierlicher quer verlaufenden Stichleitung (30) eine Parallelplatten-Hohlleiter-Horizontalleitungseinspeisung (31) aufweist.
7. Antennensystem (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** der breitbandige Übergang (20) einen Parallelplatten-Hohlleiter (21) mit Dielektrikumfüllung aufweist.
8. Übergang nach Anspruch 1 oder System (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** der Parallelplatten-Hohlleiter (21) einen mit Dielektrikum gefüllten Parallelplatten-Hohlleiter (21) aufweist.
9. Übergang nach Anspruch 1 oder System (10) nach

Anspruch 2, **dadurch gekennzeichnet, dass** die metallenen Abschrägungen (26) getrennte Metallteile aufweisen.

10. Übergang nach Anspruch 1 oder System (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die metallenen Abschrägungen (26) ein metallisiertes abgeschrägtes Dielektrikumaterial aufweisen.

Revendications

1. Transition (20) à large bande de micro-ruban à guide d'onde à lames parallèles pour le couplage d'énergie RF à une antenne plane (30), comportant :

un guide d'onde (21) à plaques parallèles
une pluralité de circuits à micro-ruban (22) qui comprennent chacun une ligne d'alimentation à micro-ruban blindé (24) disposée sur un substrat (23) ; et
une pluralité de parties métalliques effilées et courbes (26) qui ont chacune une première extrémité qui est couplée à l'une de la pluralité de lignes d'alimentation à micro-ruban et qui ont chacune une seconde extrémité disposée de façon à être adjacente au guide d'onde, la largeur (direction Y) de chaque partie effilée métallique (26) étant égale à la largeur de trait du circuit (22) à micro-ruban, la longueur de chaque partie effilée étant déterminée par la bande passante de fonctionnement, la valeur SWR souhaitée et des limitations d'espace, et les courbes des parties effilées étant optimisées afin de minimiser le coefficient de réflexion sur la bande souhaitée.

2. Système d'antenne (10) comportant :

une entrée RF (11) ;
un dispositif (12) de combinaison/division couplé à l'entrée RF (11) ;
un groupement linéaire de déphaseurs (13) ayant chacun un accès RF (13a) à micro-ruban couplé au dispositif (12) de combinaison/division ;
une antenne plane (30) ayant une entrée (30a) d'alimentation de ligne et une section de guide d'onde ; et
une transition (20) à large bande de micro-ruban à guide d'onde à plaques parallèles couplée entre le groupement linéaire de déphaseurs (13) et l'antenne plane (30), qui comporte :

un guide d'onde (21) à plaques parallèles ;
une pluralité de circuits (22) à micro-ruban qui comprennent chacun une ligne d'alimentation à micro-ruban blindé (24) dispo-

sée sur un substrat (23) ; et
une pluralité de parties effilées métalliques et courbes (26) qui ont chacune une première extrémité qui couplée à l'une de la pluralité de lignes d'alimentation à micro-ruban et qui ont chacune une seconde extrémité disposée de façon à être adjacente au guide d'onde, la largeur (direction Y) de chaque partie effilée métallique (26) étant égale à la largeur de trait du circuit (22) à micro-ruban, la longueur de chaque partie effilée étant déterminée par la bande passante de fonctionnement, une valeur SWR souhaitée et des limitations d'espace, et les courbes des parties effilées étant optimisées afin de minimiser le coefficient de réflexion sur la bande souhaitée.

3. Système d'antenne (10) selon la revendication 2, **caractérisé en ce que** l'antenne plane (30) a une section de guide d'onde à plaques parallèles.

4. Système d'antenne (10) selon la revendication 2, **caractérisé en ce que** l'antenne plane (30) a une section de guide d'onde à dépassement de mode.

5. Système d'antenne (10) selon la revendication 2, **caractérisé en ce que** l'antenne plane (30) comprend une antenne réseau (30) à adaptateur d'impédance transversale continue solide-diélectrique.

6. Système d'antenne (10) selon la revendication 5, **caractérisé en ce que** l'antenne réseau (30) à adaptateur d'impédance transversale continue comprend une alimentation (31) par ligne horizontale à guide d'onde à plaques parallèles.

7. Système d'antenne (10) selon la revendication 2, **caractérisé en ce que** la transition à large bande (20) comporte un guide d'onde (21) à plaques parallèles, rempli d'un diélectrique.

8. Transition selon la revendication 1 ou système (10) selon la revendication 2, **caractérisé en ce que** le guide d'onde (21) à plaques parallèles comporte un guide d'onde (21) à plaques parallèles rempli d'un diélectrique.

9. Transition selon la revendication 1 ou système (10) selon la revendication 2, **caractérisé en ce que** les parties effilées métalliques (26) comprennent des pièces métalliques séparées.

10. Transition selon la revendication 1 ou système (10) selon la revendication 2, **caractérisé en ce que** les parties effilées métalliques (26) comprennent une matière diélectrique effilée métallisée.

Fig. 1

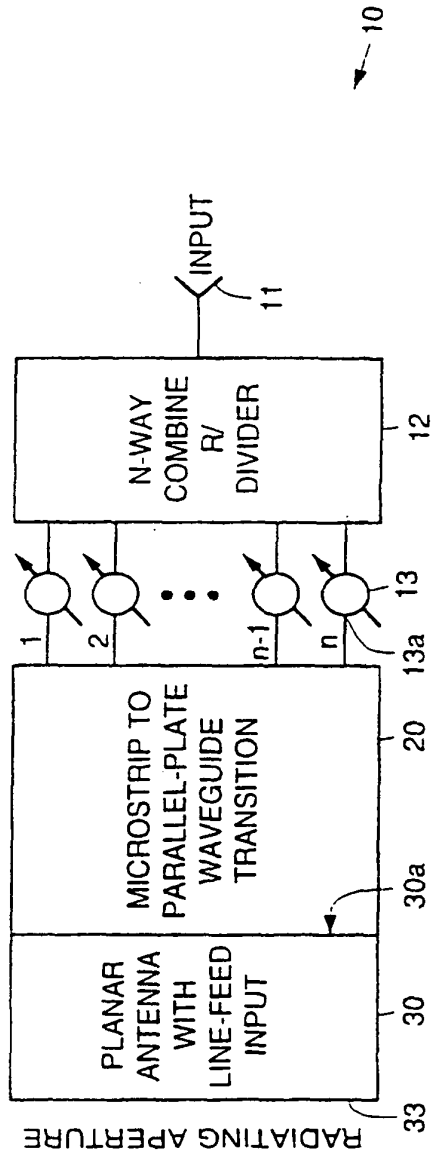
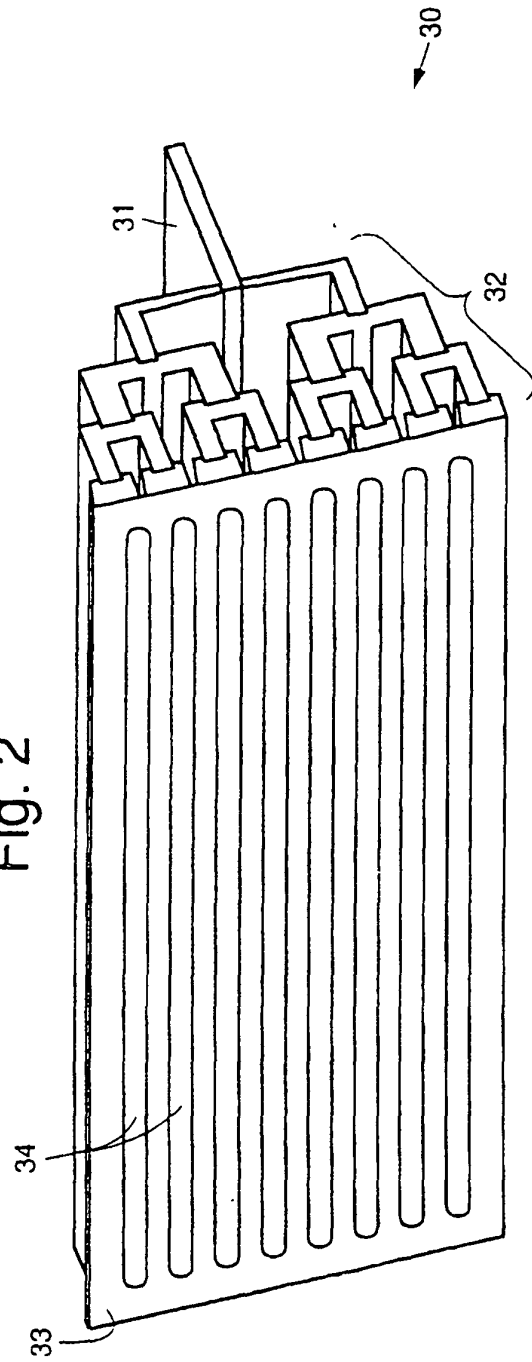


Fig. 2



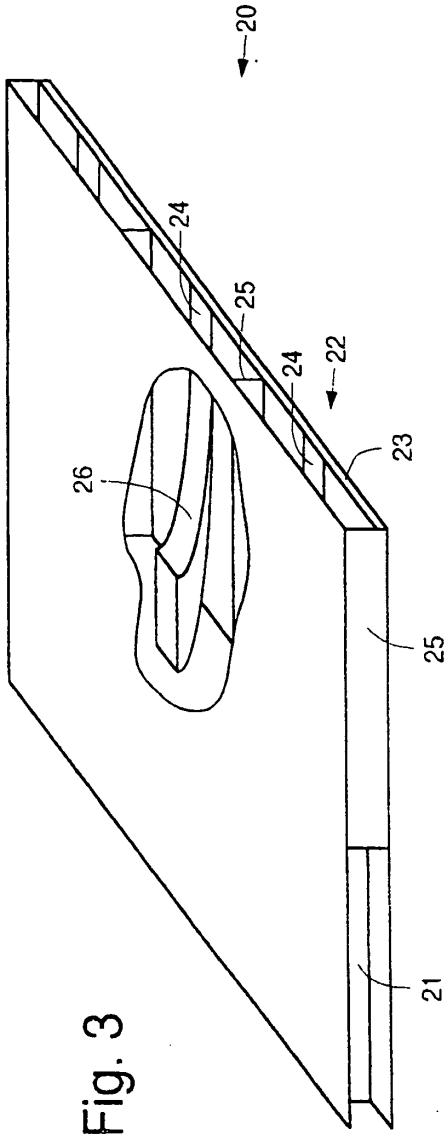
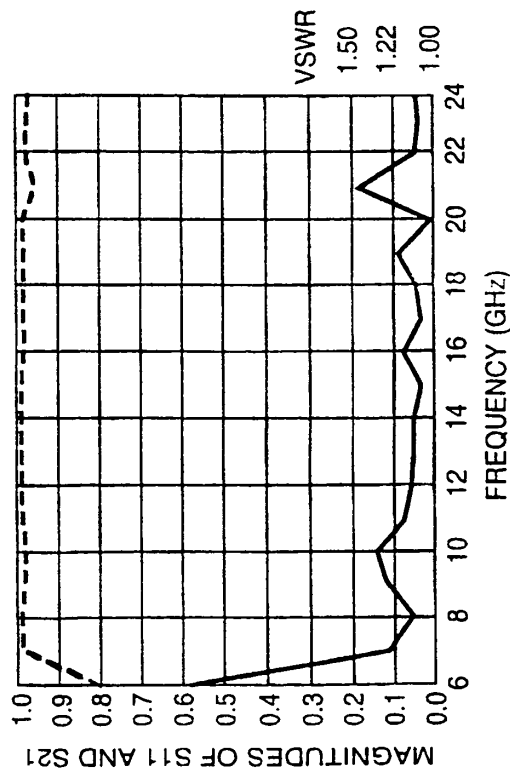


Fig. 4



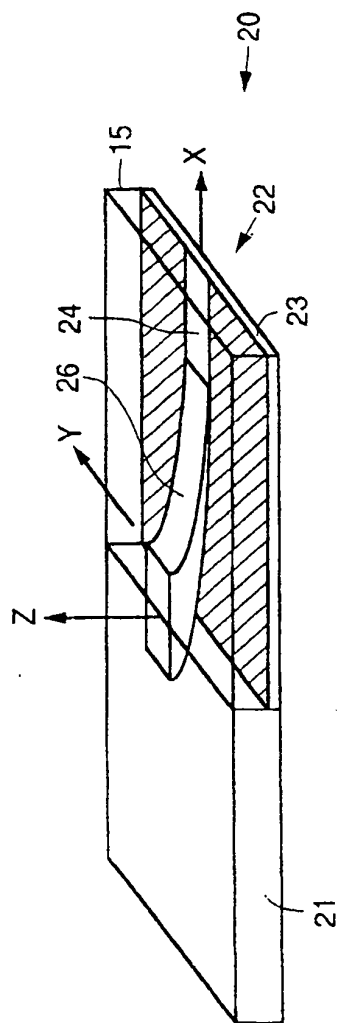


Fig. 5

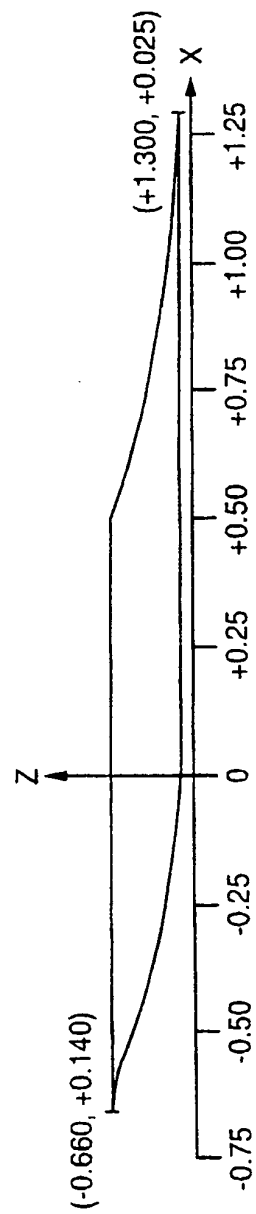


Fig. 6